SALT MARSH BIRD COMMUNITY RESPONSES TO OPEN MARSH WATER MANAGEMENT

by

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ABSTRACT

Salt marshes are productive ecosystems that provide critical breeding and foraging habitat for many bird species. Open marsh water management (OMWM), a method of mosquito abatement through habitat alteration, is a widely practiced management technique in Mid-Atlantic salt marshes. Although OMWM may alleviate the need for pesticide applications, the effect of these habitat modifications on obligate salt marsh breeding birds is not fully understood and remains an information priority for the United States Fish & Wildlife Service National Wildlife Refuge System. My objectives were to; 1) develop a method to quantify OMWM, 2) use an index of marsh bird community integrity to evaluate the effect of OMWM, and 3) determine the impacts of OMWM on Seaside Sparrow reproductive success and nesting ecology. I searched for and monitored nesting birds, performed callback and passive surveys, and estimated vegetation cover on 19 plots (1-3ha) within tidal marshes in Sussex County, Delaware in May-August 2006-2007. I categorized plots as limited (n = 10) or extensive OMWM (n = 9) based on the level of OMWM manipulations. I detected 29 species across all surveyed plots, but detected no difference in species richness between limited and extensive OMWM ($P = 0.145$). I defined four avian guilds: salt marsh obligates, wetland generalists, shorebirds, and gulls / terns to compare avian communities between limited and extensive OMWM. Only the relative abundance of the salt marsh obligate guild differed between limited and extensive OMWM and was more than 1.5 greater on limited OMWM sites than extensive sites ($P = 0.015$).

Relative abundance of Seaside Sparrows was 2.5 times greater on limited OMWM than on extensive OMWM ($P = 0.002$). Seaside Sparrow territory density ($P = 0.002$) and nesting density ($P = 0.031$) was also 2 times greater on limited OMWM plots than extensive OMWM plots. Nest survival rates were similar ($P = 0.584$). However, when comparing measures of productivity between limited and extensive OMWM, I found the number of Seaside Sparrow eggs/ha ($P = 0.026$) and fledglings/ha ($P = 0.053$) were greater on limited OMWM plots. Seaside Sparrow nest survival rates did not differ between levels of OMWM, but reproductive output was greater on areas with limited OMWM. OMWM does not appear to benefit most marsh bird species or guilds, but may negatively impact populations of salt marsh obligate species and Seaside Sparrows. OMWM may be used as an alternative means of mosquito control, but should not be considered a method of habitat enhancement for obligate salt marsh bird species. Refuges concerned with protecting populations of Seaside Sparrows or other salt marsh obligate birds should limit amounts OMWM in high breeding areas.

INTRODUCTION

Salt marshes are ecotonal habitats found between marine and terrestrial ecosystems (Greenberg and Maldonado 2006). Generally, salt marshes are common along the coasts of the mid-latitudes, but the actual area they occupy is small (Greenburg 2006). Globally, the Atlantic and Gulf coasts of North America contain the highest concentration of salt marshes (Greenberg and Maldonado 2006) which are dominated by grasses or small shrubs (Greenburg 2006). Despite having low plant and animal diversity, salt marshes are one of the most productive systems globally and are able to support high abundances of salt marsh species (Adam 1990, Mitsch and Gosselink 2000, Greenburg 2006).

Salt marshes provide a myriad of benefits to both humans and wildlife including filtering and improving water quality, supplying a buffer from storm surges and erosion, creating recreational opportunities, and providing nursery habitat for economically important fish and shellfish. Salt marsh ecosystems provide critical foraging, roosting, and breeding habitat for resident and migratory birds (Tiner 1985, Weller 1999). Many salt marsh bird species are completely dependent on salt marsh habitats for all phases of their annual cycle (e.g. breeding, migration, wintering) and some species' ranges occur entirely within the United States (Greenberg et al. 2006). Most obligate salt marsh birds are poorly studied and as a result of their tendency to be secretive and occupy dense vegetation, they are often overlooked during passive surveys (Glahn 1974, Manci and Rusch 1988, Gibbs and Melvin 1993, Legare et al. 1999, Lor and Malecki 2002, Allen et al. 2004). Salt marsh breeding bird populations in eastern North America are of high conservation concern because of incomplete information regarding their breeding ecology and reproductive success (Conway and Droege 2006).

Salt marshes have increased vulnerability to alterations and impacts from both terrestrial and marine stressors because of their coastal location (Adam 1990, Greenburg 2006). As a result of being relatively narrow strips of habitat along the coast, salt marshes are a linear landscape feature and more spatially limited relative to other habitat types (Mendelssohn and McKee 2000, Greenburg 2006). Consequently, small impacts can have profound affects on salt marsh structure and function. Due to their structure, salt marshes can be severely altered by even slight changes in hydrology or elevation relative to sea level rise.

Salt marshes in North America have often been considered wastelands of little value to humans and are thus among the most degraded of all habitats (Amezaga et al. 2002). Approximately 50% of salt marshes in the US have been completely destroyed through filling and dredging (Tiner 1984, Dahl 1990). Remaining salt marsh habitats have been altered for mosquito control or salt hay farming (Daiber 1986, Roman et al. 2000), degraded by pesticide use, natural and human induced alterations, invasive species, oil and chemical spills, and are threatened by sea level rise.

More recently, salt marsh management has focused on restoration or alterations to control mosquito populations. Historically, parallel grid ditching was a common method of draining salt marshes in order to reduce mosquito breeding habitat. However, this technique proved ineffective and often had ecologically damaging side effects. As a result, an alternative technique called open marsh water management (OMWM) was developed to reduce pesticide use and develop more ecologically sound mosquito control methods (Ferrigno and Jobbins 1968, Ferrigno et al. 1975, Wolfe 1996). OMWM may alleviate the need for pesticide applications, but the effects of these habitat alterations on obligate salt marsh breeding bird reproductive success is poorly understood. Information regarding potential impacts of salt marsh management on breeding bird species is an information priority for United States Fish & Wildlife Service (USFWS) and the National Wildlife Refuge System. The primary objectives of this project were 1) to develop a method to quantify OMWM, 2) to use an index of salt marsh bird community integrity (DeLuca et al. 2004) along with avian species richness and abundance to measure integrity of salt marshes altered by OMWM, and 3) to determine the effects of open marsh water management on habitat selection and the reproductive ecology of Seaside Sparrows.

Chapter 1

CHANGES IN MARSH BIRD COMMUNITY INTEGRITY ALONG A GRADIENT OF SALT MARSH CONDITION

Birds are considered good indicators of ecological integrity because of their strong relationship with ecosystem structure and function and are often easier to sample compared to other parameters (Bradford et al. 1998, O'Connell 1998, Canterbury et al. 2000, Bryce et al. 2002, DeLuca 2004). Many bird species are habitat specific, occupy higher trophic levels and are thus influenced by species at lower trophic levels (Pettersson et al. 1995, Deluca et al. 2004). If lower trophic level species, such as insects or plants, decline, it could result in predictable changes to the bird community (Pettersson et al. 1995). Because undisturbed systems are expected to support a different suite of species than highly degraded systems, predictions can be made regarding the avian community associated with habitats in different conditions (O'Connell et al. 1998). For example, species with specific life requirements should be found more often in unaltered areas whereas species with generalist traits should be most abundant in disturbed areas (DeLuca et al. 2004). Using these patterns in avian community assembly can provide a valuable indicator of ecosystem condition (Bradford et al. 1998, O'Connell 1998, Canterbury et al. 2000, Bryce et al. 2002).

Many salt marsh dependent bird species are listed as high conservation concern. Understanding how this unique bird community responds to different management actions is an information need throughout eastern North America. Some salt marsh bird species are completely dependent on salt marsh habitats for all phases of their annual cycle (e.g. breeding, migration, wintering) and some species' ranges occur entirely within the United States (Greenberg et al. 2006). As a result, changes in salt marsh habitat quality can have deleterious effects on salt marsh bird populations.

A common salt marsh alteration, open marsh water management (OMWM), is a technique that reduces mosquito populations. OMWM alters marsh habitat through the construction of ditches, ponds, and radials which provide habitat for mosquito larva eating fish (*Fundulus* spp.). OMWM is a regular practice in New Jersey and Delaware and is expanding to other states along the East Coast (Mitchell et al. 2006). Despite our poor understanding of how OMWM affects avian communities and salt marsh integrity, this technique remains a common management practice (Mitchell et al. 2006). Some studies have been conducted that compared bird use of OMWM to non-OMWM sites, and many concluded that OMWM does not have significant long-term impacts on waterbird species richness or abundance (Clarke et al. 1984, Meredith and Saveikis 1985, 1987, Brush et al. 1986, Wilson et al. 1987, Grant and Kirby-Smith 1998). Unfortunately most research has been limited to comparisons of species richness and abundance, and thus the integrity of the obligate marsh bird community has not been quantified. In the New England region, research has focused on the use and abundance of shorebirds, wading birds, and waterfowl between OMWM and non-OMWM sites (Clarke et al. 1984, Brush et al. 1986, Wilson et al. 1987, Mitchell et al. 2006). In Massachusetts, Brush et al. (1986) compared numerical responses of bird populations and concluded that OMWM had little affect on the abundance of avian groups. Meredith and Saveikis (1985, 1987) performed a similar study in Delaware and concluded that OMWM did not alter species composition or densities of bird guilds, including ducks and geese, herons and egrets, gulls and terns, and shorebirds. In North Carolina, Grant and Kirby-Smith (1998) compared summer bird populations in non-OMWM and OMWM sites and suggested that OMWM did not cause changes in avian populations (Grant and Kirby-Smith 1998). It is important to note that past studies were concerned with presence or absence of OMWM and, to date, no study has examined how the amount of OMWM manipulations may impact marsh bird community integrity. My objectives of this project were to 1) develop a method to quantify OMWM, 2) use an index of marsh bird community integrity (IMBCI) to estimate salt marsh integrity in OMWM manipulated marshes, and 3) use the IMBCI and other bird community measures to assess the impacts of OMWM on marsh birds during the breeding season.

Methods

Study Area and Site Selection

My research was conducted at Prime Hook National Wildlife Refuge and adjacent state and private owned lands in Sussex County, Delaware (Figure 1). Prime Hook is a 4,047 ha refuge established in 1963 under the Migratory Bird Conservation Act as a sanctuary for migratory birds (USFWS 2007). Before being designated as a refuge, most of the salt marsh within Prime Hook was ditched and/or farmed (USFWS 2007). The Refuge’s mission is to provide habitat and protection for migratory birds (especially waterfowl) and endangered species so that the people today and in future generations can enjoy these resources (USFWS 2007). All salt marsh areas in this study were grid ditched (early 1930s) as well as managed with varying levels of OMWM (Table 1).

I established and sampled 19 plots (1-2.25 ha) along salt marshes in Sussex County, Delaware in 2006 (n = 5 plots) and 2007 (n = 14 plots). Sixteen plots were located in Prime Hook National Wildlife Refuge, two on Delaware State Wildlife Areas, and one on Delaware Nature Society property. I selected plot locations using stratified random points generated in ArcMap (version 9.0; Environmental Systems Research Institute, Redlands, CA) using Hawth's tools (Beyer 2004). Sites were selected in salt marsh habitat in areas of extensive OMWM and limited OMWM. Plot boundaries were defined according to vegetation composition (sample of overall marsh) and accessibility. Four plots were within areas established by the US Fish & Wildlife Service (James-Pirri et al. 2005). All plots except for two were at least 100 m apart.

Study plots were located in *Spartina* sp. low and high marsh habitat. Plants associated with study sites included short and tall Smooth Cordgrass (*S. alterniflora*), Groundsel Tree (*Baccharis halimifolia),* Marsh Elder (*Iva frutescens),* Rose Mallow (*Hibiscus moscheutos*), Tidalmarsh Amaranth (*Amaranthus cannabinus*), Marsh Fleabane (*Pluchea odorata*), Glasswort (*Salicornia spp.*), Salt Hay (*S. patens*), Big Cordgrass (*S. cynosuroides*), Saltmarsh Rush (*Juncus gerardii*), Black Needle Rush (*J. roemerianus*), Saltgrass (*Distichlis spicata*), and Common Reed (*Phragmites australis*). Some common species in adjacent upland habitat consisted of Eastern

Redcedar (*Juniperus virginiana*), Northern Bayberry (*Myrica pensylvanica*), Southern Waxmyrtle (*M. cerifera*), and Loblolly Pine (*Pinus taeda*).

OMWM Score Development

I used 2002 aerial photography shapefiles provided by Delaware Mosquito Control that indicated where ditches and ponds were installed, ground observations, and measurements to quantify the amount of OMWM on each plot. I used ArcMap (version 9.0; Environmental Systems Research Institute, Redlands, CA) to calculate the extent of OMWM ditching and ponds within each plot and the extent of ditching in a 50 m buffer around each plot. I measured pond area and the width and length of all ditches to estimate the area of ditching on each plot. I used the following equation to develop an OMWM score for each plot:

$$[(\text{Ditch area} + \text{Ditch area within 50 m buffer of plot} + \text{Pond area}) * \text{Date score}] * 100 = \text{OMWM score}$$

I multiplied the total length of a ditch by the average ditch width for a plot and divided by plot size to estimate total ditch area per plot. I estimated the area of ditching within a 50 meter buffer around each plot to estimate affects of nearby OMWM. My comprehensive management score was developed by summing ditch area of a plot, the ditch area within a 50 meter buffer of a plot, and the OMWM pond area within a plot. To account for temporal variation in OMWM, I developed an age class score based on the time since management. Most OMWM systems will require re-excavations every

10 to 20 years (Meredith et al. 1985, Wolfe 1996). Therefore, new OMWM systems are more disturbed then those 10 years or older. To account for this temporal variation, I multiplied the OMWM score by 2 if the system was younger then 10 years. To normalize the scores, I multiplied the final values by 100. Based on these estimates of management extent, I separated plots into two management classifications: Extensive and limited using the 50th percentile in OMWM score as the defining cut point (Table 1).

Avian Measures

I conducted point counts to survey bird communities using the Standardized North American Marsh Bird Monitoring Protocols (Conway 2007) at all 19 plots at least eight times from May through August 2007. I counted all species within my study plots. Surveys were 11 minutes and included a 5 minute silent period followed by a play-back period with 30 second vocalizations of secretive marsh birds followed by 30 seconds of silence. I used compact disks with calls, in order of least to most disturbing, of Least (*Ixobrychus exilis*) and American Bitterns (*Botaurus lentiginosus*), Virginia (*Rallus limicola*), Clapper (*R. longirostris*), King (*R. elegans*) and Black rails (*Laterallus jamaicensis*) and Sora (*Porzana carolina*). I performed surveys before 1400 h and never conducted surveys during heavy rain, wind greater than 15mph, or temperatures greater than 90° F. Species that were only observed flying over the plot were not included. All observers were trained in salt marsh bird identification (by sight and sound) and were tested before conducting surveys.

I used an index of marsh bird community integrity (IMBCI) to estimate the bird community condition at each study plot (DeLuca et al. 2004). I developed integrity scores for each bird species detected based on life history attributes (foraging habitat, breeding ecology, and migration) and conservation status (Table 2). I calculated a conservation rank for each species using conservation status described by Partners in Flight (2004), Delaware Wildlife Action Plan (Delaware Wildlife Action Plan Draft Document 2005), Delaware Department of Natural Resources and Environmental Control State ranks, and US Fish and Wildlife shorebird conservation scores (USFWS 2004). Scores assigned from different organizations were converted to the 1 to 4 scale of the index. I averaged the converted scores to get a final conservation score between 1 and 4. To account for the variation in abundance, I adjusted scores for salt marsh obligate species on each plot based on relative abundance estimates. I multiplied the relative abundance for salt marsh obligates on a plot by the species IMBCI score and then added the product to the species score. I used the following equation to calculate IMBCI scores for each plot:

$$\left[\left(\sum \text{Species IMBCI scores} \,/\, \text{number of species detected} \right) + \text{number of obligates detected} \right] - 4$$

Vegetation Sampling

I estimated and compared the vegetation composition within each plot along the OMWM gradient using the line intercept method (Krebs 1999). Vegetation cover categories included: High marsh vegetation (consisting of *S. patens*, *Disticulus spicata,* and *Juncus gerardi*), *Spartina alterniflora* short, *S. alterniflora* tall, *S. alterniflora*/mud mix, *S. alterniflora*/high marsh vegetation (consisting of *S. alterniflora* mixed with *S. patens*, *D. spicata*, and *J. gerardi*), *Salicornia* species, live and dead marsh shrub (*Iva frutescens* and *Baccharis halimifolia*), live and dead *Phragmites australis,* decaying vegetation, mud, pond, ditch, water, thatch, and miscellaneous vegetation. I sampled vegetation along 5 – 7 line transects that were 100-150 m long and 25 m apart. I measured the distance of each vegetation type along each transect and calculated the percent cover of each type for the entire plot.

Statistical Analyses

I calculated species richness as the total number of different species detected / ha across all surveys for each plot (Krebs 1999). I used the maximum number of individuals detected across all eight surveys divided by the sum of all the individuals detected on a plot to estimate relative abundance per plot (Krebs 1999). I established four guilds: salt marsh obligates, wetland generalists, shorebirds, and gulls / terns to compare avian communities between limited and extensive OMWM plots. I used ANOVA to examine differences in species richness and abundance between limited and extensive OMWM based on species guilds and on individual species (Zar 1999). I used principal components analysis (PCA) to illustrate the relationship between vegetation cover and OMWM and IMBCI class (Dytham 2003). I used Varimax rotation and extracted all factors with eigen values > 1. Mean factor scores (± 1 SE) for each plot type (OMWM and IMBCI) on the first two factors were plotted.

Results

OMWM scores across the 19 plots ranged from 0 to 26.28 (Table 1). The mean score for limited OMWM (mean = 0.47, SE = 0.24) sites was 29 times less than extensive OMWM scores (mean = 13.53, SE = 2.8). I detected 29 species across all surveyed plots in 2007 (Table 3). Most of the species detected (52%) I categorized as wetland generalists (n = 15; Table 3). The number of species detected on extensive OMWM plots (24 species, mean = 4.04 species/ha, SE = 0.49) did not differ from the species richness on limited OMWM plots (23 species, mean = 5.47 species/ha, SE = 0.77, $F_{1,18} = 2.34$, $P = 0.145$). Relative abundance of Seaside Sparrows was 2.5 times greater on limited OMWM than on extensive OMWM and was the only species that differed in relative abundance between plots with limited and extensive OMWM (Table 4).

The relative abundance of the salt marsh obligate guild was more than 1.5 times greater on limited OMWM compared to extensive OMWM ($F_{1,18} = 7.41$, $P = 0.014$). Relative abundance for gulls / terns ($F_{1,18} = 1.65$, $P = 0.216$), shorebirds ($F_{1,18} = 0.73$, $P = 0.406$), and wetland generalist ($F_{1,18} = 1.20$, $P = 0.289$) guilds did not differ between limited and extensive OMWM.

Mean IMBCI scores across the 19 plots were 8.36 ± 0.47(SE) and ranged from 2.67 to 11.21. Species IMBCI scores ranged from four (Barn and Tree Swallow) to 15 (Saltmarsh Sharp-tailed Sparrow, Table 3). Nine plots were categorized as low IMBCI (mean = 6.83, SE = 0.66) and ten as high IMBCI (mean = 9.74, SE = 0.24; Table 5). I did not detected a difference between the IMBCI scores for limited

OMWM plots (mean = 9.04, SE = 0.41) and extensive OMWM sites (mean = 7.60, SE = 0.84, $F_{1,18}$ = 2.54, *P* = 0.129).

The dominate vegetation cover on limited OMWM plots consisted of *S. alterniflora* (41.1%), high marsh vegetation (19.1%), *S. alterniflora* tall (17.4%), *S. alterniflora*/high marsh vegetation (9.5%; Table 6, Figure 2). Extensive OMWM plots were dominated by high marsh vegetation (28.1%), *S. alterniflora* short (13.9%), decaying vegetation (12.0%) and *Salicornia* species (11.0%; Table 6, Figure 2). Limited OMWM plots had 3 times more *S. alterniflora* short and 2.9 times more *S. alterniflora* tall cover than extensive OMWM (Table 6). Extensive OMWM had 4 times more ditching, 15.6 times more *Salicornia spp.*, and 4 times more decaying vegetation (Table 6).

In the PCA, factor 1 explained 21.2% of the variaiton and was positively correlated with both live and dead shrubs and negatively with *Spartina alterniflora* short. Factor 2 described 17.3% of the variation and was positively correlated with *Salicornia spp.* and decaying vegetation and negatively correlated with *S. alterniflora* short (Figure 3). When I plotted the mean factor scores by management class and IMBCI score, limited OMWM plots and low IMBCI scores were associated with the *S. alterniflora* short and high OMWM and high IMBCI scores were associated with live and dead shrubs at the positive end of the axis (Figure 3). In factor 1 there was a significant difference between limited and extensive OMWM ($F_{1,18}$ = 7.77, *P* = 0.013) but high and low IMBCI did not differ ($F_{1,18}$ = 1.50, *P* = 0.237). Limited OMWM plots and high IMBCI scores were associated with *S. alterniflora* and extensive

OMWM and low IMBCI scores were with *Salicornia spp.* and decaying vegetation. There was a significant difference between limited and extensive OMWM ($F_{1,18}$ = 6.73, $P = 0.019$) and but not between high and low IMBCI in Factor 2 ($F_{1,18}$ = 2.16, $P = 0.160$) in factor 2 (Figure 3).

Discussion

My research supports the conclusion that OMWM does not appear to significantly impact species richness or the abundance of common salt marsh species. I found no difference in species richness between limited and extensive OMWM plots. I did not detect differences in the abundance of wetland generalist, shorebirds, or gulls/terns guilds between OMWM types. However, I did find differences in the abundance of the obligate salt marsh guild and Seaside Sparrows.

Most obligate salt marsh bird species are not found in high abundance. The Seaside Sparrow is one exception, making it a possible indicator species for less abundant species in the obligate salt marsh bird guild. Although more salt marsh obligates were found on limited OMWM plots, at the species level, only Seaside Sparrows were greater on limited OMWM plots. Low sample size of the other obligate salt marsh species may have made it difficult to detected differences in the distribution between limited and extensive OMWM plots.

Traditional calculations of species richness, diversity, or abundance may provide information regarding bird use of a site, but it may not be a good indication of salt marsh condition. Salt marsh obligate birds are sensitive to environmental changes and are of higher conservation concern than other species found in the marsh (Conway

2007). In traditional estimates of species richness, generalist species are weighted the same as salt marsh obligate species. Thus, sites with many generalists may be considered higher quality then those sites with no generalists but several specialists. Under this system, a salt marsh with rare species may be considered poor habitat compared to a highly disturbed area with a variety of common species. By using an IMBCI scoring system, I assigned numerical ranks to each species so that the number of obligate species, not merely species in general, dictated marsh integrity (DeLuca et al. 2004). By adding a measure of abundance into the IMBCI, I was able to better quantify specialist use of marsh habitat.

Spartina alterniflora short was more abundant on limited OMWM than in extensive OMWM plots. However, it was the second most abundant cover recorded in extensive OMWM plots, with high marsh vegetation being the most abundant. Reduction in *S. alterniflora* immediately after OMWM construction was noted by Ferringo (1970) and is possibly due to increased tidal circulation (Wolfe 1996). Ferringo (1970) reported no changes in *S. patens* or *D. spicata*, but amount of *S. alterniflora* tall increased (Ferringo 1970). In my research high marsh vegetation, which includes *S. patens* or *D. spicata*, was the most common cover recorded in extensive OMWM plots, but *S. alterniflora* tall was more abundant on limited OMWM sites**.**

I found significant differences in factor 1 and 2 of the PCA between limited and extensive OMWM, but not for high and low IMBCI. Significant differences in factors for OMWM indicated that a relationship existed between limited OMWM and

S. alterniflora short form. Reduction of *S. alterniflora* short form and *S. patens* may occur as a side effect of OMWM (Mitchell et al. 2006). Although this loss may help control breeding mosquitoes, it may also impact obligate salt marsh birds (Mitchell et al. 2006). In factor 2 there was also a relationship among extensive OMWM, *Salicornia* species, and decaying vegetation. *Salicornia* species and decaying vegetation may provide foraging benefits for some species, but most likely will not benefit obligate salt marsh nesting birds.

Similar to this study, some studies have reported a decline in Seaside Sparrows in response to OMWM. Grant and Kirby-Smith (1998) surveyed breeding and non-breeding birds in two salt marshes in North Carolina (2 summers before OMWM and 4 summers after). They found the number of Seaside Sparrows was significantly greater on control plots, but the number of willets and clapper rails did not differ (Grant and Kirby-Smith 1998). They did not report if salt marsh obligate guild abundance differed between controlled and managed sites and concluded that OMWM was not related to changes in breeding or non-breeding bird populations in North Carolina (Grant and Kirby-Smith 1998). Brush et al. (1986) also concluded that OMWM had little affect on the abundance of avian groups in Massachusetts. Brush et al. (1986) found that only marsh passerines declined after the initial installment of OMWM, but recovered a year later. Meredith and Saveikis (1987) also reported that Seaside and Sharp-tailed Sparrows numbers decreased the first spring after OMWM, but returned by the 2nd spring. My results did not support their observations and indicated that salt marsh obligate guild and Seaside Sparrow abundance was greater on limited OMWM sites.

Several studies in the New England region concluded that the use and abundance of shorebirds, wading birds, and waterfowl did not differ between OMWM and non-OMWM sites (Clarke et al. 1984, Brush et al. 1986, Wilson et al. 1987, Mitchell et al. 2006). Meredith and Saveikis (1987) concluded that OMWM did not alter species composition or densities of bird guilds, including ducks and geese, herons and egrets, gulls and terns, and shorebirds. Brush et al. (1986) reported that shorebirds increased initially after OMWM installation, but declined to pre-altered levels after 3 years. My results supported this observation as shorebird, wetland generalist, and gull / tern densities were similar between limited and extensive OMWM sites.

The available literature on the effects of OMWM does not quantify the amount of OMWM in a study area. Thus, these studies are comparing control sites to un-quantified amounts of OMWM. Additionally most studies only compared a few sites of each management type. In my study I quantified the amount OMWM based on the area of actual excavations and time since management on 19 plots.

Comparing my results to other studies was difficult because most studies focused on waterfowl or wader use of OMWM created ponds (Clarke et al. 1984, Brush et al. 1986, Wilson et al. 1987, Shisler and Ferrigno 1987, Erwin et al. 1994, Batzer and Resh 1992). My research plots did not have extensive, large ponds and I focused more on bird use of marsh habitat. In addition, most research compared sites with OMWM to control sites or they survey a site before and after OMWM. In the available literature, all bird surveys were conducted up to 4 years post OMWM (Grant and Kirby-Smith, Brush et al. 1986, Meredith and Saveikis 1985, 1987). My study examined bird communities on marshes 4 to 20 years after OMWM. Most of my study plots experienced OMWM manipulations 14 to 20 years ago (n = 16). According to the literature OMWM systems may need physical maintenance every 10-15 years to remain fully functional (Meredith and Saveikis 1985). Some of the OMWM sites in this study were considered non-functional OMWM systems and required excavation to restore function. Despite most of the plots having experienced OMWM greater than 14 yrs ago, I still detected differences in salt marsh obligate abundance and Seaside Sparrow relative abundance.

Management Implications

Refuges concerned with protecting salt marsh integrity should use limited amounts OMWM in areas with high concentrations of obligate marsh birds. Although OMWM may not impact species richness, as the extent of OMWM increases, the integrity of the marsh may decrease.

OMWM does not appear to benefit marsh bird species or guilds and may negatively impact populations of salt marsh obligate species. OMWM may be used as an alternative means of mosquito control, but should not be considered a method of habitat enhancement for obligate salt marsh bird species. Additionally, OMWM negatively affects Seaside Sparrow relative abundance which may indicate further negative impacts to other individual obligate salt marsh birds.

The development of an OMWM score and an IMBCI that accounts for abundance of obligate species is a critical tool in marsh condition assessment. Land managers can use both the OMWM score and IMBCI together to assess salt marshes and target areas appropriate for management or protection. These measures should be incorporated into other wetland assessments to give managers a better understanding of salt marsh habitat quality.

Table 1. Open marsh water management (OMWM) score development for salt marsh plots in Sussex County, Delaware. Only ditches that were altered for OMWM were measured.

OMWM Class	Plot ID	Plot area (ha)	Total ditch length	Ditch area (m^2)	Ditch area 50 meters (m^2)	Pond area (ha)	Date of last OMWM	Age score	OMWM Score
Limited	12	2.25	0.00	0.00	0.00	0.00	-	1	0.00
	15	1.00	0.00	0.00	0.00	0.00	-	-	0.00
	17	2.25	0.00	0.00	0.00	0.00	-	1	0.00
	18	2.25	0.00	0.00	0.00	0.00	-	-	0.00
	20	2.25	0.00	0.00	0.00	0.00	-	-	0.00
	19	1.00	0.00	0.00	0.00	0.01	1989	1	0.01
	2	2.25	50.83	0.00	0.00	0.00	1989	1	0.46
	3	1.50	0.00	0.00	0.01	0.00	1989	1	0.77
	1	2.25	171.08	0.01	0.01	0.00	1990	1	1.34
	5	1.00	0.00	0.00	0.02	0.00	1994	1	2.18
Extensive	16	1.88	389.07	0.02	0.01	0.00	1989	1	3.65
	11	1.50	412.41	0.02	0.02	0.00	1990	1	4.32
	13	2.25	922.53	0.04	0.01	0.02	1990	1	6.68
	14	2.00	1179.32	0.04	0.03	0.03	1988	1	9.42
	6	2.25	1025.16	0.05	0.04	0.02	1994	1	10.75
	9	2.25	533.36	0.04	0.04	0.10	1992	1	17.53
	8	2.25	682.30	0.03	0.02	0.04	2002	2	19.20
	4	2.25	900.96	0.04	0.04	0.04	2004	2	23.98
	7	2.25	675.00	0.04	0.04	0.06	2002	2	26.28

Table 2. Scoring criteria used to develop index of marsh bird community integrity (IMBCI) scores.

	Score				
	Generalist				Specialist
Species Attributes	1	2	2.5	3	4
Foraging habitat	habitat generalist		marsh facultative		marsh obligate
Nesting habitat	non marsh nesting		marsh vegetation		marsh ground nesting
Breeding range	North America	North America, east of Rockies		Coastal North America	North America, east coast only
Conservation Rank	low concern		moderate		high concern

Table 3. Species detected and scores used to develop the index of marsh bird community integrity (IMBCI) in salt marsh sites in Sussex County, Delaware in 2007.

Guild	Species	Foraging habitat	Nesting substrate	Breeding range	Conservation rank	Total IMBCI score
Salt Marsh Obligates						
	Clapper Rail (*Rallus longirostris*)	4	4	3	1	12
	Seaside Sparrow (*Ammodramus maritimus*)	4	2.5	4	3	13.5
	Saltmarsh Sharp-tail Sparrow (*Ammodramus caudacutus*)	4	4	4	3	15
	Willet (*Catoptrophorus semipalmatus*)	4	4	1	2	11
Wetland Generalists						
	Barn Swallow (*Hirundo rustica*)	1	1	1	1	4
	Boat-tailed Grackle (*Quiscalus major*)	1	2.5	4	1.5	9
	Common Yellowthroat (*Geothlypis trichas*)	2.5	2.5	1	1	7
	Eastern Kingbird (*Tyrannus tyrannus*)	2.5	1	1	1.5	6
	Eastern Meadow Lark (*Sturnella magna*)	1	1	1	2	5
	Gadwall (*Anas strepera*)	2	2	1	2	7
	Great Blue Heron (*Ardea herodias)*	2.5	1	1	2	6.5
	Great Egret (*Ardea alba*)	2.5	1	1	2	6.5
	Mallard (*Anas platyrhynchos*)	2	2	1	1.5	6.5
	Marsh Wren (*Cistothorus palustrius*)	4	2.5	1	2	9.5
	Red-winged Blackbird (*Agelaius phoeniceus*)	1	2.5	1	1	5.5
	Snowy Egret (*Egretta thula*)	2.5	1	1	2	6.5
	Swamp Sparrow (*Melospiza georgiana*)	4	2.5	4	2	12.5
	Tree Swallow (*Tachycineta bicolor*)	1	1	1	1	4
	Wood duck (*Aix sponsa*)	2	1	1	1	5
Shorebirds						
	Black -bellied Plover (*Pluvialis squatarola*)	2.5	1	2	2	7.5
	Black-necked Stilt (*Himantopus mexicanus*)	3	2	2.5	2	9.5
	Greater Yellowlegs (*Tringa melanoleuca*)	2.5	1	2	2	7.5
	Least Sandpiper (Calidris	2.5	1	2	2	7.5

minutilla)					
Short-billed Dowitcher (*Limnodromus griseus*)	2.5	1	2	1.5	7
Semipalmated Plover (*Charadrius semipalmatus*)	2.5	1	2	2	7.5
Semipalmated Sandpiper (*Calidris pusilla*)	2	1	2	2	7
Gulls / Terns					
Black Skimmer (*Rynchops niger*)	2.5	1	2	2.5	8
Forster's Tern (*Sterna fosteri*)	2.5	1	1	2.5	7
Laughing Gull (*Larus atricilla*)	2	1	3	1	7

Table 4. Results of ANOVA to determine differences in bird species abundance between limited and extensive open marsh water management (OMWM) plots. Listed are bird species, index of marsh bird community integrity (IMBCI) scores, and guilds detected during 2007 point count surveys in Sussex County, Delaware. Only Seaside Sparrows were more abundant on limited OMWM plots.

			Limited OMWM		Extensive OMWM			
Guild	Species	IMBCI score	Mean	SE	Mean	SE	F	*P*
Salt Marsh Obligates								
	Clapper Rail (*Rallus longirostris*)	12	0.025	0.010	0.009	0.006	1.885	0.188
	Seaside Sparrow (*Ammodramus maritimus*)	13.5	0.327	0.041	0.129	0.035	13.136	0.002
	Saltmarsh Sharp-tail Sparrow (*Ammodramus caudacutus*)	15	0.074	0.012	0.068	0.027	0.049	0.828
	Willet (*Catoptrophorus semipalmatus*)	11	0.049	0.017	0.066	0.020	0.433	0.520
Wetland Generalists								
	Barn Swallow (*Hirundo rustica*)	4	0.070	0.011	0.052	0.023	0.555	0.467
	Boat-tailed Grackle (*Quiscalus major*)	9	0.002	0.002	0.000	0.000	0.895	0.357
	Common Yellowthroat (*Geothlypis trichas*)	7	0.009	0.005	0.014	0.007	0.250	0.624
	Eastern Kingbird (*Tyrannus tyrannus*)	6	0.014	0.007	0.033	0.017	1.122	0.304
	Eastern Meadow Lark (*Sturnella magna*)	5	0.005	0.005	0.000	0.000	0.895	0.357
	Gadwall (*Anas strepera*)	7	0.000	0.000	0.005	0.005	1.118	0.305
	Great Blue Heron (*Ardea herodias)*	6.5	0.002	0.002	0.000	0.000	0.895	0.357
	Great Egret (*Ardea alba*)	6.5	0.000	0.000	0.008	0.008	1.118	0.305
	Mallard (*Anas platyrhynchos*)	6.5	0.005	0.005	0.000	0.000	0.895	0.357
	Marsh Wren (*Cistothorus palustrius*)	9.5	0.040	0.015	0.067	0.040	0.431	0.520
	Red-winged Blackbird (*Agelaius phoeniceus*)	5.5	0.128	0.036	0.199	0.036	1.892	0.187
	Snowy Egret (*Egretta thula*)	6.5	0.005	0.005	0.011	0.008	0.559	0.465
	Swamp Sparrow (*Melospiza georgiana*)	12.5	0.020	0.010	0.027	0.016	0.139	0.714
	Tree Swallow (*Tachycineta bicolor*)	4	0.102	0.065	0.091	0.091	0.010	0.920
	Wood duck (*Aix sponsa*)	5	0.000	0.000	0.001	0.001	1.118	0.305
Shorebirds								
	Black -bellied Plover (*Pluvialis squatarola*)	7.5	0.000	0.000	0.007	0.005	2.081	0.167
	Black-necked Stilt (*Himantopus mexicanus*)	9.5	0.030	0.020	0.007	0.005	1.128	0.303
	Greater Yellowlegs (*Tringa*	7.5	0.002	0.002	0.011	0.008	1.293	0.271

melanoleuca)							
Least Sandpiper (*Calidris minutilla*)	7.5	0.057	0.041	0.131	0.070	0.876	0.362
Short-billed Dowitcher (*Limnodromus griseus*)	7	0.014	0.014	0.000	0.000	0.895	0.357
Semipalmated Plover (*Charadrius semipalmatus*)	7.5	0.004	0.004	0.015	0.015	0.504	0.487
Semipalmated Sandpiper (*Calidris pusilla*)	7	0.009	0.009	0.031	0.020	0.982	0.336
Gulls / Terns							
Black Skimmer (*Rynchops niger*)	8	0.000	0.000	0.004	0.004	1.118	0.305
Forster's Tern (*Sterna fosteri*)	7	0.000	0.000	0.005	0.005	1.118	0.305
Laughing Gull (*Larus atricilla*)	7	0.005	0.005	0.009	0.009	0.232	0.636

Table 5. Index of marsh bird community integrity (IMBCI) scores and salt marsh management on study plots in Sussex County, Delaware.

IMBCI class	OMWM class	Plot ID	Area (ha)	IMBCI score	OMWM score	Species richness (species/ha)	Seaside Sparrow abundance
Low	Extensive	8	2.25	2.67	19.2	1.33	0.00
	Extensive	7	2.25	4.79	26.28	3.56	0.00
	Extensive	6	2.25	6.27	10.75	3.22	0.09
	Limited	5	1.00	6.96	2.18	10.00	0.36
	Limited	2	2.25	7.79	0.45	4.00	0.25
	Extensive	13	2.25	7.90	6.68	6.22	0.08
	Limited	15	1.00	8.26	0.00	9.00	0.13
	Extensive	9	2.25	8.34	17.53	4.89	0.33
	Limited	12	2.25	8.47	0.00	5.78	0.33
	Limited	20	2.25	8.93	0.00	3.56	0.43
High	Limited	19	1.00	9.07	0.00	7.00	0.43
	Limited	3	1.50	9.26	0.77	4.67	0.53
	Extensive	11	1.50	9.33	4.32	5.33	0.19
	Extensive	4	2.25	9.44	23.98	3.11	0.11
	Limited	17	2.25	9.59	0.00	3.56	0.13
	Extensive	14	2.00	9.75	9.41	4.00	0.15
	Extensive	16	1.88	9.89	3.65	4.79	0.21
	Limited	1	2.25	10.89	1.34	4.00	0.35
	Limited	18	2.25	11.21	0.00	3.11	0.33

Table 6. Vegetation cover (%) in limited open marsh water management (OMWM) plots (n = 10) and extensive OMWM plots (n = 9) in Sussex County, Delaware.

	Limited OMWM		Extensive OMWM			
Vegetation Type	Mean	SE	Mean	SE	$F_{1,18}$	*P*
S. alterniflora Short	0.41	0.06	0.14	0.06	10.97	0.004
S. alterniflora Tall	0.17	0.03	0.06	0.02	7.01	0.017
S. alterniflora/High Marsh Veg.	0.10	0.03	0.06	0.03	0.73	0.405
S. alterniflora/Mud	0.03	0.01	0.03	0.02	0.00	0.992
High Marsh Veg.	0.19	0.05	0.28	0.08	0.99	0.333
Live Shrub	0.01	0.01	0.03	0.01	2.53	0.130
Dead Shurb	0.01	0.00	0.04	0.01	4.60	0.047
Thatch	0.01	0.01	0.01	0.00	1.51	0.236
Salicornia species	0.01	0.05	0.11	0.05	2.33	0.145
Decaying Vegetation	0.03	0.01	0.12	0.03	8.54	0.010
Mud	0.01	0.00	0.01	0.00	0.09	0.767
Ditch	0.01	0.00	0.03	0.00	40.82	0.000
Pond	0.00	0.00	0.04	0.01	13.02	0.002

Figure 1. Study areas used to determine salt marsh bird community responses to open marsh water management in Sussex County, Delaware 2006-2007.

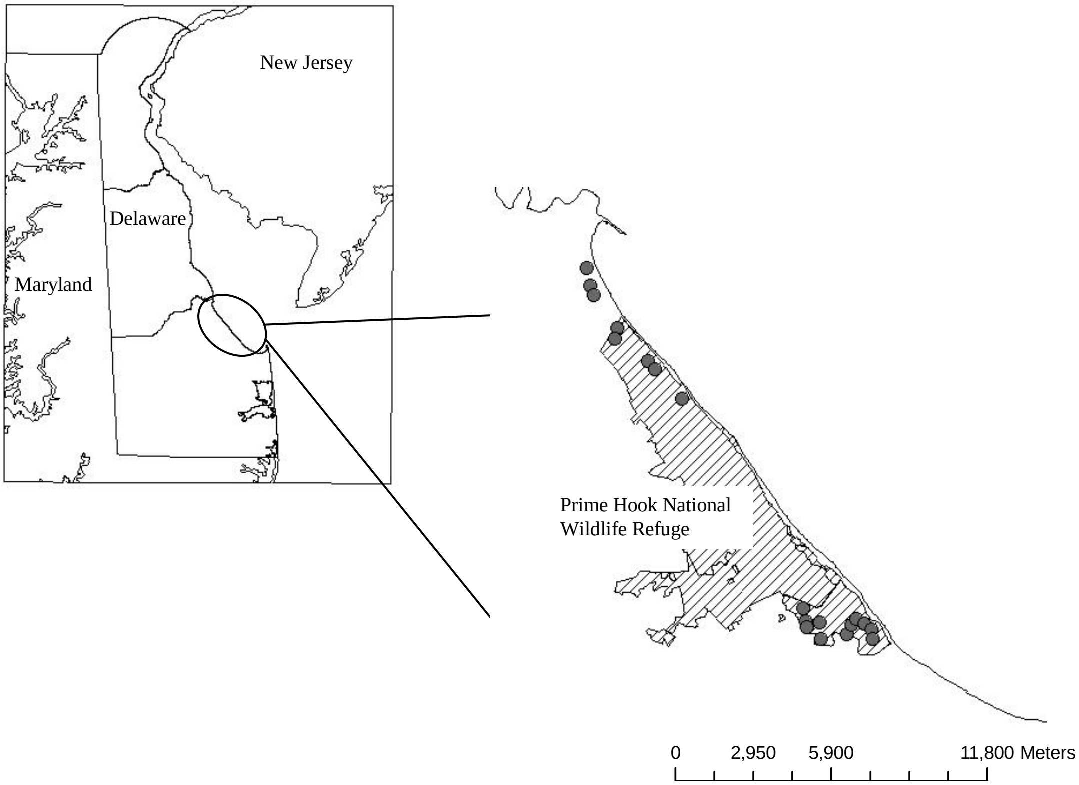


Figure 2. Comparison of vegetation/cover between plots with limited and extensive open marsh water management (OMWM) in Sussex County, Delaware.

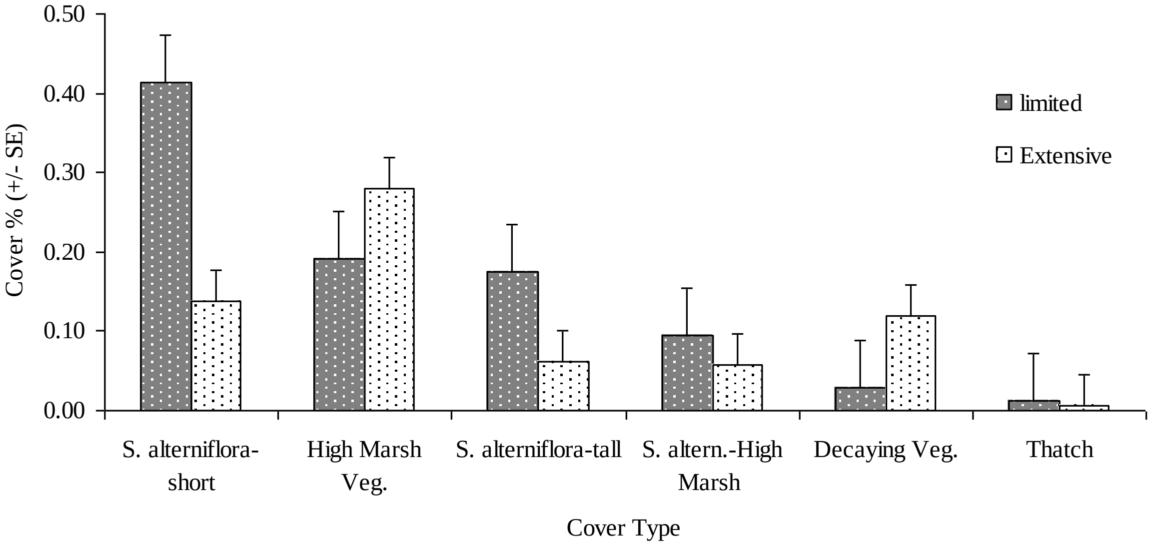
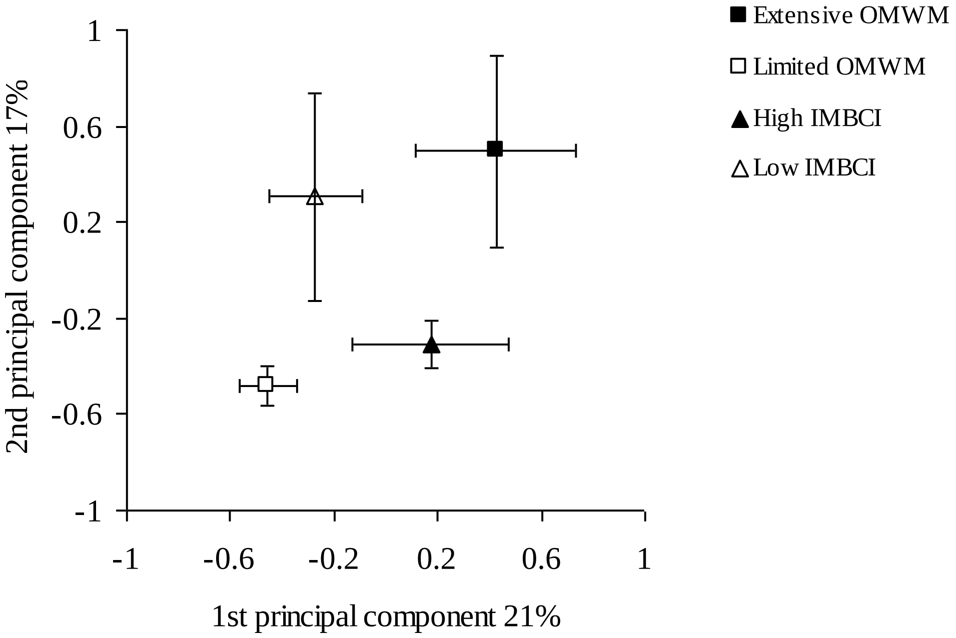


Figure 3. Mean vegetation factor scores (±SE) for each class of open marsh water management (OMWM) and index of marsh bird community integrity (IMBCI) score. In factor 1, limited OMWM and low IMBCI were clustered near the negative axis and extensive OMWM and high IMBCI near the positive. In factor 2 limited OMWM and high IMBCI were on the negative axis and extensive OMWM and low IMBCI were on the positive axis.



Chapter 2

EFFECTS OF OPEN MARSH WATER MANAGEMENT ON SEASIDE SPARROW REPRODUCTIVE SUCCESS AND ECOLOGY

Salt marsh ecosystems have been and are presently subjected to direct and indirect human alterations (e.g. ditching, draining, contamination, climate change). As part of a civil works program in the 1930s, salt marshes were drain, by constructing parallel grid ditches, in an attempt to control mosquitoes (Wolfe 1996). Bourn and Cottam (1938) estimated that 90% of the 227,433 ha of salt marsh from Maine to Virginia was ditched by 1938. From 1930-1960 more than 60% of Delaware’s 36,422 ha of salt marshes were parallel grid ditched (Lesser 2005).

Parallel grid ditching was not an effective method of mosquito control and documented impacts on salt marshes included lowered water table levels, drainage of marsh pools and pannes, vegetation changes, and associated impacts on habitat support functions for fish, birds, and other trophic components (Daiber 1986; Wolfe 1996). In the 1960s, open marsh water management (OMWM) was developed as an alternative management technique to parallel grid ditching. OMWM alters salt marshes by creating ponds and ditches, thereby providing favorable conditions for larvivorous fish which then in turn prey upon mosquito larva (Ferrigno and Jobbins 1968, Ferrigno et al. 1975, Meredith 1985). Spoil from ditch and pond construction is used to fill low elevation mosquito breeding habitats (Meredith 1985). In Delaware, approximately 2832.80 ha have been treated with OMWM since the 1960s (approximately 105.22 ha / year).

Although OMWM may alleviate the need for pesticide applications, there are concerns regarding the effect of these habitat modifications on wildlife, especially salt marsh obligate species. Salt marsh ecosystems provide habitat for a number of avian species of conservation concern, thus, understanding how OMWM may affect obligate salt marsh bird populations and reproduction is critical for refuge and other land managers.

Seaside Sparrows are an ideal species to evaluate impacts of marsh management because they are often restricted to large tidal marshes (Benoit and Askins 2002, Shriver et al. 2004, Gjerdrum et al. 2005), and are species of conservation concern throughout their range (Post and Greenlaw 1994, Rich et al. 2004, Gjerdrum et al. 2005). They are monogamous breeders and are sensitive to vegetation structure and hydrology (Post and Greenlaw 1994). Seaside Sparrows are completely dependant on salt marshes for all stages of their life cycle (breeding, foraging; Post and Greenlaw 1994). Because of their dependence on a particular ecosystem, their reproductive success and survivorship can be related to the quality of habitat. Compared to other obligate marsh nesting species, Seaside Sparrows are more abundant, allowing for adequate sample sizes among treatments. They are also found along the east and gulf coasts of North America, therefore, this research is applicable to a larger geographic area.

Most research conducted on the effects of OMWM on birds focused on bird species abundance or diversity (Mitchell at al. 2006, Erwin et al. 1994). There is limited information regarding the impacts of OMWM on the reproductive success of Seaside Sparrows. Some studies have reported a decline in Seaside Sparrows abundance in response to OMWM. In North Carolina, Grant and Kirby-Smith (1998) found the number of Seaside Sparrows were significantly greater on control plots compared to OMWM sites. Brush et al. (1986) found in Massachusetts that marsh passerines, including Seaside Sparrows, declined after the initial installment of OMWM, but recovered a year later. In Delaware, Meredith and Saveikis (1987) reported that Seaside and Sharp-tailed Sparrows numbers decreased the first spring after OMWM, but returned by the 2nd spring. No studies have examined the possible impact OMWM might have on nest density, survival, or success. My objectives were to determine the effects of OMWM on the reproductive ecology and success of Seaside Sparrows.

Methods

Study Area and Site Selection

See Chapter 1

OMWM Score Development

I assigned an OMWM score to each study plot based on the level of management (Table 1). I categorized each plot as either extensive or limited OMWM using OMWM scores (see chapter 1 for OMWM score calculation and category grouping criteria).

Vegetation Sampling

I sampled vegetation at two spatial scales; the plot (2007 only) and the nest in 2006 and 2007. Vegetation sampling was done at the end of the field season (July and August). I initially estimated and compared the vegetation composition within each plot along the OMWM gradient. Second, I estimated the vegetation composition at Seaside Sparrow nest sites and random locations within each plot (See Chapter 1 for details regarding plot sampling). For both these vegetation sampling procedures I used a line intercept method at the end of the field season (Krebs 1999) and measured the distance of each vegetation class along each transect. See Chapter 1 for description of vegetation cover categories. At the nest scale, I estimated vegetation species composition and percent cover within a 1 m^2 around each nest. Each 1 m^2 was evenly divided into six 1 m transect lines and I measured the vegetation (cm) along each line. I randomly located 15-20 1 m^2 points within each plot to estimate the percent cover of each vegetation that was available within the plot.

Territory Density

Seaside Sparrows are socially monogamous and defend territories (Post and Greenlaw 1994), therefore I used standard spot mapping techniques to estimate breeding territories on all study plots in 2006 and 2007 (International Bird Census Committee 1970, Bibby et al. 2000). I spot mapped each plot at least eight times between 1 May and 15 Aug 2006, 2007 and using techniques described by Bibby et al. (2000), I estimated the number of Seaside Sparrow territories/ ha on each plot.

Nest Survival and Productivity

I searched each plot for Seaside Sparrow nests at least eight times throughout the breeding season in 2006 and 2007 (May-Aug). I located nests by observing suspected breeding birds and by searching through breeding habitat. I recorded GPS coordinates and marked each with a flag placed 1 m from the nest for all nests. I checked nests to determine status every 3-4 days. I recorded several measures of productivity including the initial number of eggs, eggs in the complete clutch, eggs that hatched, and the number of chicks that fledged. Nests were monitored until all chicks fledged or it failed. I considered a nest successful if it fledged at least one chick.

Statistical Analyses

I used ANOVA with year as a random factor (Zar 1999) to compare vegetation cover at Seaside Sparrow nest sites to random locations and to determine if there were differences in Seaside Sparrow territory, nest density, and productivity between limited and extensive OMWM plots.

I estimated daily nest survival rates using Mayfield's (1975) method and calculated standard errors according to Johnson (1979). I tested for differences in nest survival between management types using Program CONTRAST (Sauer and Hines 1989). I chose the Mayfield method because of the short intervals between nest checks and because this method does not require the exact age, fate, or failure date of the nest to be known (Johnson 2007). The Mayfield estimate method was developed over a half century ago and it remains competitive against newer methods (Johnson 2006, Lloyd and Tewksbury 2006).

Results

Please see Chapter 1 for results regarding OMWM score development and classification and results for vegetation cover in limited and extensive OMWM.

Seaside Sparrow territory density was 2 times greater on limited OMWM plots than extensive OMWM plots (Table 7). I located and monitored 135 Seaside Sparrow nests on the 19 plots during the breeding seasons of 2006 and 2007. Limited OMWM plots had 2 times more Seaside Sparrows nests per ha than extensive OMWM plots (Tables 7). I did not detect Seaside Sparrow nests on four plots classified as extensive OMWM (mean OMWM score = 14.08, SE = 4.91; Table 8). *Spartina alterniflora* short was the dominant vegetation cover type within Seaside sparrow nest sites with *S. alterniflora* tall form, thatch, high marsh vegetation and *S. alterniflora*/high marsh vegetation mix the next most abundant vegetation types (Table 9, Figure 4). Nest sites on extensive OMWM plots had 2.3 times more *S. alterniflora* short and 2.6 times more *S. alterniflora* tall than random points (Table 9). Random points on extensive OMWM plots had 300 times more decaying vegetation than nest sites (Table 9). On limited OMWM sites, nests had 3 times more *S. alterniflora* tall than random points and decaying vegetation was 17 times greater at random sites compared to nests (Table 9).

Of the 135 Seaside Sparrow nests, 125 had sufficient data to estimate nest survival. I found 83 nests on limited OMWM plots and 42 nests on extensive OMWM plots. The estimated daily survival rates for nests showed no difference between limited (exposure days = 867, failed nests = 38, daily survival = 0.96, SE = 0.01) versus extensive OMWM plots (exposure days = 445, failed nests = 24, daily survival = 0.95, SE = 0.02). Nest survival rates did not differ between limited OMWM (nest survival = 0.31, SE = 0.05) and extensive OMWM (nest survival = 0.24, SE = 0.07; Chi-Square = 0.300, df = 1, *P* = 0.584).

Limited OMWM plots had 2 times the amount of eggs/ha and 2 times more fledglings/ha than extensive OMWM (Table 7). However, the number of chicks/ha did not differ between limited and extensive OMWM plots (Table 7).

Discussion

Spartina alterniflora short was the most common nesting cover used by Seaside Sparrows. When I compared nest sites to random points on extensive OMWM plots, the amount of *S. alterniflora* short was significantly greater at nests. However, it did not differ in limited OMWM plots. Based on the frequency of *S. alterniflora* short, limited OMWM sites may have more nesting opportunities for Seaside Sparrows. This conclusion supports concerns that OMWM may cause a loss of *S. alterniflora* short habitat for Seaside Sparrows (Mitchell et al. 2006).

Slight changes in elevation caused by OMWM may cause conversion of suitable Seaside Sparrow nesting vegetation to woody shrubs such as *Iva frutescens* and *Baccharis halimifolia* (Mitchell et al. 2006). Additionally, the threat of sea level rise to Seaside Sparrows may be augmented by the fragmentation of marsh with extensive ponds and ditches (Hayden et al. 1991, Erwin et al. 1994, Shriver and Gibbs 2004, Mitchell et al. 2006).

My results suggest that OMWM does effect Seaside Sparrow reproduction and ecology. The extent of OMWM had a negative effect on both Seaside Sparrow territory and nest density. Brush et al. (1986) recorded declines in marsh passerines, including Seaside Sparrows, after initial OMWM construction in Massachusetts but reported that populations recovered a year later. They attributed the decline to the removal of vegetation and to disturbance cause by machinery on marsh sites during the early breeding season (Brush et al. 1986). Additionally, in a six year survey of bird use of OMWM and non-OMWM marshes in North Carolina, Grant and Kirby-Smith (1998) found that the number of Seaside Sparrows was significantly greater on non-OMWM plots compared to treatment plots. In Delaware, Meredith and Saveikis (1985) reported that salt marsh sparrow species (combined Seaside and Saltmarsh Sharp-tailed) and red-winged blackbirds were the two most common species detected during early May (1981-1984) flushing surveys. However, during late May surveys, sparrows were not reported as the most abundant, possibly indicating that sparrows were not nesting on the sites. Throughout the four year study, only a few sparrow nests were found (Meredith and Saveikis 1985).

In my research nest survival rates did not differ between management types, however, productivity measures (territories, eggs, and fledglings / ha) were lower on extensive OMWM plots. Limited OMWM plots may have more available breeding habitat than extensive OMWM sites. For example, if a limited OMWM plot that supported 25 Seaside Sparrow territories was converted to extensive OMWM, then the number of territories would be reduced to 10. These results clearly show that Seaside Sparrow reproductive output was greater on areas with limited OMWM.

Management Implications

Land managers that want to support populations of Seaside Sparrows should use limited amounts OMWM in high breeding areas. Management that maintains or increases breeding densities of Seaside Sparrows may benefit other obligate marsh species. Based on my research, limiting the amount of OMWM will not affect nest survival but will increase Seaside Sparrow reproductive output.

The amount of OMWM a manager should allow depends on management goals and the organization's mission. The OMWM scoring system I developed can help managers target areas for management or protection. Scores for a particular location will change over time and so reassessment is needed. Given the dynamic nature of salt marshes, I suggest re-scoring sites every five years. Like other management tools, the OMWM score is designed to help with making management decisions and should be used with other tools in the overall assessment of an area. When used in conjunction with other measures, OMWM scores can help managers make decisions on how to control mosquito populations while maintaining a viable breeding population of obligate salt marsh breeding birds.

Table 7. ANOVA results for territory, nest, and productivity measures for limited open marsh water management (OMWM; 2006 n = 3, 2007 n = 10) and extensive OMWM (2006 n = 2, 2007 n = 9) plots in Sussex County, Delaware. Year was added as a random effect.

	Limited OMWM		Extensive OMWM			
Variable (per hectare)	Mean	SE	Mean	SE	$F_{1, 22}$	*P*
Territories	5.35	0.60	2.39	0.56	12.68	0.002
Nests	3.22	0.42	1.58	0.59	5.31	0.031
Eggs	11.68	1.54	5.68	2.04	5.71	0.026
Chicks	6.43	1.33	3.33	1.40	2.56	0.124
Fledged	5.36	1.10	2.30	0.97	4.17	0.053

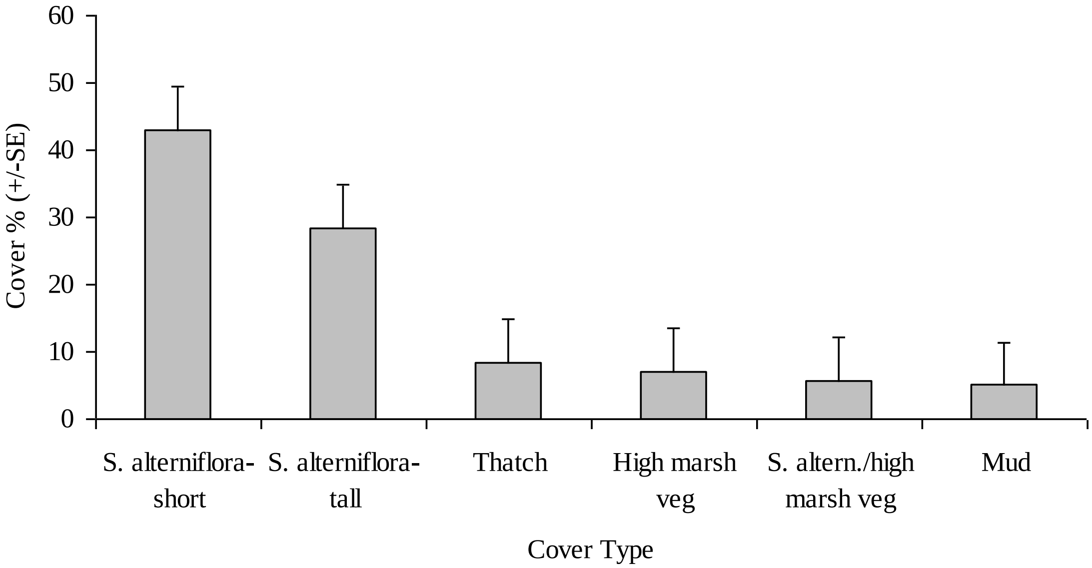
Table 8. Summary of salt marsh management in limited and extensive open marsh water management (OMWM) study plots in Sussex County, Delaware.

OMWM Class	Lat.	Long.	Plot ID	Plot area (ha)	OMWM score	Territory /ha	Nest /ha	Eggs/ ha	chicks/ ha	fledged/ ha
Limited	38.808	-75.221	12	2.25	0.00	5.78	4.00	11.11	4.89	1.78
	38.814	-75.206	15	1.00	0.00	5.00	3.00	0.00	0.00	0.00
	38.929	-75.318	17	2.25	0.00	6.67	5.33	14.22	8.44	8.00
	38.923	-75.317	18	2.25	0.00	4.44	7.56	22.22	15.11	13.33
	38.808	-75.199	19	1.00	0.00	10.00	8.00	23.00	15.00	8.00
	38.919	-75.316	20	2.25	0.00	3.11	2.22	7.11	5.33	4.44
	38.812	-75.227	2	2.25	0.46	3.33	3.78	12.22	6.44	6.44
	38.812	-75.227	3	1.50	0.77	4.00	3.00	9.33	4.33	4.00
	38.812	-75.208	1	2.25	1.34	4.89	1.78	7.11	5.33	5.33
	38.905	-75.306	5	1.00	2.18	7.50	3.00	9.50	3.50	3.50
Extensive	38.811	-75.200	16	1.88	3.65	4.26	4.79	12.23	9.04	7.98
	38.814	-75.222	11	1.50	4.32	1.33	0.00	0.00	0.00	0.00
	38.809	-75.209	13	2.25	6.68	2.67	2.22	8.89	4.89	2.67
	38.813	-75.202	14	2.00	9.42	2.00	0.00	0.00	0.00	0.00
	38.909	-75.306	6	2.25	10.75	5.11	4.89	15.78	10.67	6.67
	38.885	-75.279	9	2.25	17.53	3.11	2.67	8.44	1.33	1.33
	38.534	-75.172	8	2.25	19.20	0.00	0.00	0.00	0.00	0.00
	38.818	-75.228	4	2.25	23.98	1.33	0.22	0.67	0.00	0.00
	38.536	-75.175	7	2.25	26.28	0.00	0.00	0.00	0.00	0.00

Table 9. Vegetation cover and composition of Seaside Sparrow nests and random points on limited open marsh water management (OMWM; n = 91 and n = 258 respectively) and on extensive OMWM (n = 44, n = 170 respectively) plots in Sussex County, Delaware.

OMWM Class	Variable	Seaside Sparrow Nests		Random Points				
		Mean	SE	Mean	SE	df	F	*P*
Limited	*Spartina. alterniflora* short	42.69	4.22	35.92	2.65	1, 348	1.75	0.187
	S. alterniflora tall	29.02	4.07	10.43	1.57	1, 348	24.67	0.000
	Decaying vegetation	0.32	0.18	5.18	1.28	1, 348	5.07	0.025
	Ditch	0.35	0.22	1.01	0.39	1, 348	1.30	0.254
	Live Shrub	0.15	0.15	0.49	0.25	1, 348	0.65	0.421
	Dead shrub	0.46	0.33	0.56	0.25	1, 348	0.04	0.837
	Thatch	9.3	1.56	5.57	0.82	1, 348	5.40	0.021
	High marsh vegetation	8.1	1.84	30.84	2.57	1, 348	24.73	0.000
	S. alterniflora/high marsh veg.	6.31	1.85	5.12	1.08	1, 348	0.33	0.569
	Mud	4.38	0.76	4.21	0.64	1, 348	0.02	0.881
	Salicornia species	0.00	0.00	0.24	0.10	1, 348	1.97	0.161
Extensive	*S. alterniflora* short	43.44	6.59	18.54	2.61	1, 213	16.53	0.000
	S. alterniflora tall	27.36	5.59	9.96	2.13	1, 213	11.86	0.001
	Decaying vegetation	0.04	0.04	13.04	2.16	1, 213	9.32	0.003
	Ditch	5.74	2.19	2.35	0.93	1, 213	2.51	0.114
	Live Shrub	0.4	0.38	1.26	0.60	1, 213	0.52	0.474
	Dead shrub	0.47	0.28	0.63	0.21	1, 213	0.15	0.703
	Thatch	6.65	2.74	6.34	1.05	1, 213	0.02	0.902
	High marsh vegetation	4.84	1.98	34.25	3.04	1, 213	23.45	0.000
	S. alterniflora/high marsh veg.	4.37	2.35	1.04	0.47	1, 213	4.86	0.029
	Mud	6.33	1.52	7.20	1.19	1, 213	0.13	0.724
	Salicornia species	0.06	0.06	1.48	0.65	1, 213	1.25	0.265

Figure 4. Vegetation cover within 1 m² of 135 Seaside Sparrow nests located during the 2006 and 2007 breeding season (May-Aug) in Sussex County, Delaware.



REFERENCES

Adam, P. 1990. *Saltmarsh Ecology*. Cambridge University Press. New York, NY 10011. 461p.

Allen, T. S. L. Finkbeiner, D.H. Johnson. 2004. Comparison of detection rates of breeding marsh birds in passive and playback surveys at Lacreek National Wildlife Refuge, South Dakota. Waterbirds 27: 277-281.

Amezaga, J.M., L. Santamaría, and A.J. Green. 2002. Biotic wetland connectivit-supporting a new approach for wetland policy. *Acta Oecologica* 23:213–222.

Batzer, D. and V. Resh. 1992. Wetland management strategies that enhance waterfowl habitats can also control mosquitoes. American Mosquito Control Association Journal 8:117-125.

Benoit, L. K. and R. A. Askins. 1999. Impact of the spread of *Phragmites* on the distribution of birds in Connecticut tidal marshes. Wetlands 19:194–208.

Beyer, H. L. 2004. Hawth's Analysis Tools for ArcGIS. Available at http://www.spatialecology.com/htools.

Bibby, C.J., N.D. Burgess, D.A. Hill, and S.H. Mustoe. 2000. Bird Census Techniques, 2nd edn. Academic Press, New York.

Bourn, W. S. and C. Cottam. 1950. Some biological effects of ditching tidewater marshes. Fish and Wildlife Service, U.S. Department of Interior, Washington, DC, USA. Research Report 19.

Bradford, D. F., S. E. Franson, G. R. Miller, A. C. Neale, G. E. Canterbury, and D. T. Heggem. 1998. Bird species assemblages as indicators of biotic integrity in Great Basin rangeland. Environmental Monitoring and Assessment 49:1–22.

Brush, T., R. A. Lent, T. Hruby, B. A. Harrington, R. M. Marshall, and W. G. Montgomery. 1986. Habitat use by salt marsh birds and response to open marsh water management. Colonial Waterbirds 9: 189-195.

Bryce, S. A., R. M. Hughes, and P. R. Kaufmann. 2002. Development of a bird integrity index: using bird assemblages as indicators of riparian condition. Environmental Management 30:294–310.

Burger, J., J. Shisler, and F. H. Lesser. 1982. Avian utilization of six salt marshes in New Jersey. Biological Conservation 23:187–212.

Canterbury, G. E., T. E. Martin, D. R. Petit, L. J. Petit, and D. F. Bradford. 2000. Bird communities and habitat as ecological indicators of forest condition in regional monitoring. Conservation Biology 14:544–558.

Clarke, J., B. A. Harrington, T. Hruby, and F.E. Wasserman. 1984. The effect of ditching for mosquito control on salt marsh use by birds in Rowley, Massachusetts. Journal of Field Ornithology 55:160-180.

Conway, C.J. 2007. Standardized North American Marsh Bird Monitoring Protocols. USGS, Arizona Coop. Fish & Wildlife Research Unit. University of Arizona, Tucson, Arizona.

Conway, C.J. and S. Droege. 2006. A unified strategy for monitoring changes in abundance of birds associated with North American tidal marshes. Studies in Avian Biology 32:282–297.

Daiber, F.C. 1986. Conservation of Tidal Marshes. Van Nostrand Reinhold Co., New York.

Dahl, T. E. 1990. Wetland losses in the United States 1780's to 1980's. United States Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA.

Delaware Wildlife Action Plan 2005-2015. 2005. Accessed online on 9 May 2006 (http://www.dnrec.state.de.us/nhp/information/DEWAPTOC.shtml).

DeLuca, W.V., C.E. Studds, L.L. Rockwood, and P.P. Marra. 2004. Influence of land use on the integrity of marsh bird communities of Chesapeake Bay, USA. Wetlands 24: 837-847.

Dytham, C. 1999. Choosing and Using Statistics: A Biologist Guide. Blackwell Scientific Publications, Oxford.

Erwin, R.M., J.S. Hatfield, M.A. Howe, and S.S. Klugman. 1994. Waterbird use of saltmarsh ponds created for open marsh water management. Journal of Wildlife Management 58:516-524.

Ferrigno, F. 1970. Marsh destruction. Ecology of salt marsh and coastal impoundments. State of New Jersey, Project no. W-34-R-15. 17 p.

Ferrigno, F. and D.M. Jobbins. 1968. Open Marsh Water Management. Proceeding from NJ Mosquito Exterminal Association 55: 104-115.

Ferrigno, F., P. Slavin, and D.M. Jobbins. 1975. Salt marsh water management for mosquito control. Proceeding from New Jersey Mosquito Control Association 62:30-38.

Gibbs J. P. and S. M. Melvin. 1993. Call–response surveys for monitoring breeding waterbirds. Journal of Wildlife Management 7:27-34.

Glahn J. F. 1974. Study of breeding birds with recorded calls in north-central Colorado. Wilson Bulletin 86:206–214.

Grant, G. S. and W. W. Kirby-Smith. 1998. The Effect of Open-Marsh Water Management on Summer Bird Populations on Topsail Island, North Carolina. Estuaries 21: 361–363.

Greenberg, R. 2006. Tidal marshes: home for the few and the highly selected. Studies in Avian Biology 32: 2-9.

Greenberg, R. and J. E. Maldanado. 2006. Diversity and endemism in tidal marsh vertebrates. R. Greenberg, S. Droege, J. Maldonado, and M. V. McDonald, editors. Vertebrates of Tidal Marshes: Ecology, Evolution, and Conservation. Studies in Avian Biology, Lawrence, Kansas.

Hayden, B.R., R. Dueser, J.T. Callahan, and H.H. Shugart. 1991. Long-term research at the Virginia Coast Reserve. BioScience 41:310-318.

International Bird Census Committee. 1970. An international standard for a mapping method in bird census work recommended by the International Bird Census Committee. Audubon Field Notes 24:722-726.

James-Pirri, M. J., R. M. Erwin, and D. J. Prosser. US Fish and Wildlife Service (Region 5) salt marsh study: year 4 study report (2001-2004). Unpublished report submitted to J. Taylor, November 2005.

Johnson, D. H. 1979. Estimating nest success: the Mayfield method and an alternative. The Auk 96:651-661.

Johnson, D.H. 2006. Methods of estimating nest success: an historical tour. Studies in Avian Biology 34:1-12.

Krebs, C.J. 1999. Ecological Methodology. Addison Wesley, Menlo Park, California

Legare, M. L., W. R. Eddleman, P. A. Buckley, and C. Kelly. 1999. The effectiveness of tape playback in estimating Black Rail density. Journal of Wildlife Management 63: 116–125.

Lloyd, J.D. and J.J. Tewksbury. 2006. Analyzing avian nest survival in forests and grasslands: A comparison of the Mayfield and logistic-exposure methods. Studies in Avian Biology 34: 96-104

Lor, S and R.A. Malecki. 2002. Call-response surveys to monitor marsh bird population trends. Wildlife Society Bulletin 30:1195-1201.

Lesser, C. R. 2005. Open water marsh management: a source reduction technique for mosquito control. Delaware Department of Natural Resources and Environmental Control. http://www.dnrec.state.de.us/fw/mosquito/Final%20Draft%202%20of%20omwmarticleapril.pdf) Accessed 27 January 2006.

Manci, K. M. and D. H. Rusch. 1988. Indices to distribution and abundance of some inconspicuous waterbirds on Horicon Marsh. Journal of Field Ornithology 59: 67–75.

Mayfield, H. 1975. Suggestions for calculating nest success. Wilson Bull. 87:456-466.

Mendelssohn, I. A. and K. L. Mckee. 2000. Saltmarshes and mangroves, p. 501–536. *In* M. Barbour and W. D. Billings [EDS.], North American terrestrial vegetation. 2nd ed. Cambridge University Press, Cambridge, UK.

Meredith, W. H. and D. E. Saveikis. 1987. Effects of open marsh water management (OMWM) on bird populations of a Delaware tidal marsh, and OMWM's use in waterbird habitat restoration and enhancement. Pages 298-321 in W.R. Whitman and W.H. Meredith, eds. Waterfowl and wetlands symposium: proceedings of a symposium on waterfowl and wetlands management in the coastal zone of the Atlantic Flyway. Delaware Department of Natural Resources and Environmental Control, Dover.

Mitchell, L.R., S. Gabrey, P.P. Marra, and R.M Erwin. 2006. Impacts of marsh management on coastal-marsh bird habitat. Studies in Avian Biology 32: 155-175.

Mitsch, W.J. and J.G. Gosselink. 2000. Wetlands. John Wiley, New York, NY

O'Connell, T. J., L. E. Jackson, and R. P. Brooks. 1998. A bird community index of biotic integrity for the Mid-Atlantic Highlands. Environmental Monitoring Assessment 51:145–156.

Pettersson, R. P., J. P. Ball, K. Renhorn, P. Esseen, and K. Sjoberg. 1995. Invertebrate communities in boreal forest canopies as influenced by forestry and lichens with implications for passerine birds. Biological Conservation 74:57–63.

Post, W. and J.S. Greenlaw. 1994. Seaside Sparrow (*Ammodramus maritimus*). A. Poole and F. Gill. The birds of North America, No. 127. The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, DC.

Rich, T. D., C. J. Beardmore, H. Berlanga, P. J. Blancher, M. S. W. Bradstreet, G. S. Butcher, D. W. Demarest, E. H. Dunn, W. C. Hunter, E. E. In˜ Igo-Elias, J. A. Kennedy, A. M. Martell, A. O. Panjabi, D. N. Pashley, K. V. Rosenberg, C. M. Rustay, J. S. Wendt, and T. C. Will. 2004. Partners in Flight North American landbird conservation plan. Cornell Laboratory of Ornithology, Ithaca, NY.

Roman C. T., N. Jaworski, F. T. Short, S. Findlay, and R. S. Warren. 2000. Estuaries of the northeastern United States: habitat and land use signatures. Estuaries. 23:743–764.

Sauer, J. R. and J. E. Hines. 1989. Testing for differences among survival or recovery rates using program CONTRAST. Wildlife Society Bulletin 17:549-550.

Shisler, J., and T. Schulze. 1987. The impacts of water management for mosquito control on waterfowl populations in New Jersey. Pages 268-282 in W.R. Whitman and W.H. Meredith, eds. Waterfowl and wetlands symposium: proceedings of a symposium on waterfowl and wetlands management in the coastal zone of the Atlantic Flyway. Delaware Department of Natural Resources and Environmental Control, Dover.

Shriver W.G. and J.P. Gibbs. 2004. Seaside sparrows (Ammodramus maritimus) in Connecticut: projected effects of sea-level rise. In: Akc¸akaya HR, Burgman MA, Kindvall O, Wood CC, Sjögren-Gulve P, Hatfield JS, McCarthy MA (eds.), Species conservation and management: case studies. Oxford University Press, New York, pp 397–409.

Shriver, W.G., T.P. Hodgman, J.P. Gibbs, and P.D. Vickery. 2004. Landscape context influences salt marsh bird diversity and area requirements in New England. Biological Conservation 119: 545-553.

Tiner, R. W., Jr. 1984. Wetlands of the United States: current status and recent trends. U.S. Fish and Wildlife Service, National Wetlands Inventory, Washington, DC, USA.

United States Fish and Wildlife Service. 2004. U.S. Shorebird Conservation Plan. (http://www.fws.gov/shorebirdplan/USShorebird/downloads/ShorebirdPriorityPopulationsAug04.pdf) Accessed 16 January 2008.

United States Fish and Wildlife Service. 2008. Prime Hook National Wildlife Refuge (http://www.fws.gov/northeast/primehook/) Accessed 16 January 2008.

Weller, M.W. 1999. Wetland birds: habitat resources and conservation implications. Cambridge University Press, London, United Kingdom.

Wilson, W.H., T. Brush, R. Lent, and B. Harrington. 1987. The effects of grid-ditching and open marsh water management on avian utilization of Massachusetts salt marshes. Pp. 333-349 *in* W.R. Whitman and W.H. Meredith, eds. Waterfowl and wetlands symposium: proceedings of a symposium on waterfowl and wetlands management in the coastal zone of the Atlantic Flyway. Delaware Department of Natural Resources and Environmental Control, Dover.

Wolfe, R.J. 1996. Effects of open marsh water management on selected tidal marsh resources: a review. Journal American Mosquito Control Association 12:701-712.

Zar, J. H. 1999. Biostatistical analysis. Prentice Hall, Upper Saddle River, New Jersey.