Factors Influencing Swamp Sparrow Reproductive Success at Restored and Natural Marshes

Final Report

April 2009

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EXECUTIVE SUMMARY

Despite a significant investment of time and resources through local, state, and federal partnerships to restore wetland habitats, relatively few studies have documented the wildlife response to restoration actions. In particular, there is a need to evaluate demographic rates and reproductive success to determine whether restored habitats are capable of sustaining healthy animal populations.

Our project goal was to begin to address this knowledge gap by evaluating how wetland characteristics influence marsh bird reproductive success at a set of restored and natural marshes using the Swamp Sparrow (*Melospiza georgiana*) as a representative wetland species. I monitored two restored marshes and two natural marshes in south-central Wisconsin across three breeding seasons: 2006 through 2008. A paired design was used, where a restored wetland was paired with a natural wetland located within 3 km and similar with respect to size, topographic setting, and regional land use. The use of a paired design was intended to help control for differences in some landscape level factors that may influence Swamp Sparrow reproductive success.

Restored marshes were selected from properties enrolled in the Wetlands Reserve Program and were at least three years of age post-restoration, 100 acres in size or larger, and restored using hydrologic improvements (e.g. ditch blocks, removal of drain tiles, recontouring of topography). Natural wetlands were located on state-owned lands.

We hypothesized that reproductive success would differ between restored and natural wetlands due to differences in hydrology and vegetative composition which might influence nest site attractiveness and accessibility to predators. Because a qualitative review of WRP sites in Wisconsin suggested that many restored sites had lower water levels and shorter hydroperiods, I hypothesized that restored marshes would have lower nest success than natural marshes and that habitat attributes would differ between these two wetland types. I measured wetland habitat attributes at the nest and territory scales. Habitat variables included nest attributes (e.g. concealment, height substrate), wetland water levels, and various measures of vegetative structure and composition.

We used the software program MARK to estimate daily nest survival rates and model relationships between daily nest survival rates and wetland attributes.

The best fit models of daily nest survival rates using data pooled across our three-year study period indicated that nest survival rates were a function of habitat type (restored versus natural), the percent cover by vegetation within 3 m of the nest, and the final water level measured on the day of nest failure or fledging. Successful nests were more likely to occur at a natural wetland, have a lower percent cover by vegetation within 3 m of the nest and a lower water level on the day of fledging. The pooled daily nest survival rates were 0.919 for the restored marshes and 0.938 for the natural marshes. These values equate to an overall nest success rate of 0.11 for the restored marshes and 0.19 for the natural marshes. The confidence limits for these parameters did not overlap, thus confirming a difference between the restored and natural sites.

Both mean clutch size and mean 6-day nestling mass were similar at restored and natural marshes, suggesting that food resources were not limiting in the restored wetland. Nest survival rates appeared to be driven by nest predation, with higher predation rates at the restored wetlands. Although the restored wetlands and natural wetlands were located within 10 km of one another in similar landscape settings, it is possible that habitat features at the site or local landscape scale (< 1 km) influenced the types and numbers of predators found at each site and contributed to the observed differences in Swamp Sparrow reproductive success. While our findings suggest the potential for differences in the ability of natural and restored wetlands to sustain healthy breeding bird populations, this work should be replicated in other areas and across a broader range of wetland conditions.

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1.0 INTRODUCTION

Many thousands of acres of wetlands have been restored in the United States through a variety of local, state, and federal initiatives. Restoration efforts include the U.S. Fish and Wildlife Partners for Fish and Wildlife Program, the Wetlands Reserve Program, and restoration activities by organizations such as Ducks Unlimited and The Nature Conservancy. To date, more than 2 million acres have been enrolled in the Wetlands Reserve Program (WRP) alone (USDA 2008). The WRP is a voluntary program which provides financial and technical assistance to landowners to restore, protect and enhance wetlands. Most of these sites are former wetland areas that have been converted to farmlands. Landowners enter into conservation easement agreements or a restoration cost-share agreement with the USDA. Under the restoration cost-share agreement, marginal farmland may be restored to back to wetlands through a variety of measures including removal of tile drains, the installation of ditch blocks or water control structures, and the enhancement of wetland topography and microtopography.

A review of the wildlife benefits of the Wetland Reserve Program concluded that the available data imply that restored wetlands have a habitat value that is similar to natural or reference wetlands (Rewa 2007). Wildlife use of restored wetlands has been shown to be similar for invertebrates, amphibians, and birds (Rewa 2007). However, for birds and other taxa, documentation of wildlife responses to restoration beyond simple observations of habitat use is lacking. Little demographic data are available and it is largely unknown whether restored wetlands are sustaining healthy wildlife populations.

For example, the presence of birds at restored wetlands does not necessarily indicate that such sites are functioning as high quality habitats. Although this point has been debated, reproductive success may be poorly correlated with measures of habitat use such as species density and abundance (Van Horne 1983, Vickery et al. 1992). Because reproductive success for wetland birds is known to be influenced by habitat characteristics such as water depth, vegetative composition, surrounding land use, and predator assemblages, differences between restored and natural wetlands have the potential to affect habitat quality for birds (Picman et al. 1993, Picman and Isabelle 1995, Jobin and Picman 1997, Larison et al. 2001, Horn et al. 2005). The lack of demographic comparison among restored and natural wetlands limits our ability to understand how wetland restoration may be influencing bird populations.

The goal of our study was to begin to address this knowledge gap by evaluating the demographic response of birds to wetland restoration at both restored and natural sites. I used the Swamp Sparrow as a model passerine species to compare reproductive success at restored and natural wetlands. I calculated daily nest survival rates and modeled the relationships between survival rates and habitat characteristics to gain an understanding of how habitat characteristics affect reproductive success. This report summarizes the results of our three-year study.

2.0 OBJECTIVES

The specific objectives of this project were to:

(1) Compare avian reproductive success at restored and natural wetlands using the Swamp Sparrow as a model passerine species.

(2) Evaluate how wetland habitat attributes measured at the nest site and territory spatial scales influence reproductive success.

(3) If feasible, determine whether each wetland functions as a demographic source or sink.

3.0 METHODS

3.1. Study sites

This project was conducted in Dodge, Columbia, and Marquette counties in south-central Wisconsin. This region, north and east of the City of Madison, is characterized by rolling topography, drumlins, and other post-glacial features. Land use is primarily agricultural with some small towns and low density residential development. Corn, soybeans, and dairy products are the principal agricultural commodities.

Our study sites were shallow emergent marshes. Eggers and Reed (1997) described these wetlands as "meadow-marsh-open water complexes." All wetland study sites met the following criteria: (1) area of 100 acres or greater, to minimize potential area effects, (2) located in an agricultural landscape, and (3) willing property owners with site access from a paved or an unpaved road. Restored wetlands also were required to be at least three years of age post-restoration and have been restored using one or more of the following hydrologic modifications: ditch plugs, installation of berms, excavation of "scrapes," or removal of drainage tiles, following by passive site management (i.e. no burning, invasive species control, etc.).

Potential restored wetlands were selected from properties enrolled in the Wetlands Reserve Program. Potential natural wetlands were selected from Waterfowl Production Areas and state-owned lands. Once potential sites were identified, field visits were made to confirm wetland habitat types and site characteristics. A paired design was used, where each restored wetland was paired with a natural wetland located within 3 km and similar with respect to size, topographic setting, and regional land use. The use of a paired design was intended to help control for differences in some landscape level factors that may influence Swamp Sparrow reproductive success.

During 2006, Swamp Sparrow reproductive success was evaluated at a single WRP site and a single natural marsh. During 2007 and 2008, the study was expanded to monitor reproductive success four sites consisting of two restored WRP sites and two natural marshes. A brief description of each site is provided below.

Slinger WRP Site. The Slinger marsh is a 364-acre site that was restored in 2001. The site is part of an active farm with corn fields, barns, and farm roads proximal to the site. The site is dominated by shallow marsh and deep marsh habitats with some shallow mud flats and deeper areas of open water. In addition to Swamp Sparrow, other nesting birds observed at this site included Marsh Wrens (*Cistothorus palustris*), Red-winged Blackbirds (*Agelaius phoeniceus*), Yellow-headed Blackbirds (*Xanthocephalus xanthocephalus*), Common Yellowthroats (*Geothlypis trichas*), Virginia Rails (*Rallus limicola*), and Song Sparrows (*Melospiza melodia*). Numerous species of waterfowl and shorebirds were observed in the open water and mud flat areas and Black Terns (*Chlidonias niger*) were frequently observed foraging overhead.

Westford Marsh. This natural wetland site was located 2.8 km from the Slinger WRP site. The study plot is part of the 1,341 acre Westford Wildlife Area, which includes about 525 acres of shallow marsh and fresh meadow habitat. The marsh contains a diverse plant mixture of cattails, sedges and rushes, several types of ferns, and many species of herbaceous plants. Other bird species observed nesting in the natural wetland included Red-winged Blackbirds, Common Yellowthroats, Virginia Rails, and Song Sparrows. Sedge Wrens (*Cistothorus platensis*) nested in the adjacent meadow and foraged within the study plot. Sandhill Cranes (*Grus canadensis*) were seen and heard frequently in the deeper areas and occasionally were observed within the study plot. The plot is bordered by a meadow hillside and a small patch of forested savanna. Railroad tracks form the western boundary. There are no farmed fields, roads, or buildings immediately adjacent to this wetland.

Verhage WRP Site.

The Verhage WRP site is a 204-acre wetland that was restored in 2002 and is also within 3 km of the Slinger and Westford sites. This site is no longer farmed but the adjacent properties consist of corn fields, and a private residence. The wetland habitat ranges from fresh meadow to shallow marsh and the vegetation consists predominantly of cattail (*Typha sp.*) and reed canary grass (*Phalaris arundinacea*).

Shaw Marsh

The second natural wetland study site was located in the Shaw Marsh Wildlife Area. Shaw Marsh is a 900-acre site consisting of sedge meadows, shallow and deep marsh with scattered areas of open water, and upland prairie. Other wetland birds observed at this site include Red-winged Blackbirds, Common Yellowthroats, Song Sparrows, Sedge Wrens, and Sandhill Cranes. The adjacent properties are farmed lands but there were no farm fields immediately adjacent to our study plot.

3.2. Study species

We used the Swamp Sparrow as a model passerine species to compare reproductive success at restored and natural wetlands. Although the Swamp Sparrow is not of conservation concern (PIF 2009), it is well-suited as a study species because it is wetland dependent, moderately site faithful, and its nests can be located using the female's nest departure call. The relatively high abundance of breeding Swamp Sparrows in Wisconsin enabled sufficient sample sizes to be obtained for statistical analysis. Swamp Sparrow habitat requirements overlap those of several species of conservation concern including the Marsh Wren, Sora (*Porzana carolina*), King Rail (*Rallus elegans*), and Virginia Rail, as well as generalist species such as Common Yellowthroat. Typical habitat requirements for breeding Swamp Sparrows include shallow standing water, low dense cover, and elevated song posts (Mowbray 1997).

3.3 Nest monitoring

We established a monitoring plot at each wetland. Plots were approximately 5 ha in area. Nest searching began during the first week of May and continued until the first week of August. We located nests by listening for female nest departure calls. Once a calling female was heard, we tried to observe her arrival and departure until an approximate nest location could be determined. We then searched the area and located the nest. Nests were marked 1 m to each side using flagging tape. Nests were checked every one to three days following Martin and Geupel (1993). The number of eggs or young, number of cowbird eggs and young, nest fate, and the cause of failure were recorded. We also recorded the date, time, minutes spent at the nest, and the location and activity of adults. To minimize human scent trails, we performed all nest checks prior to 1500 hrs and avoided creating dead-end trails to nest. Fledglings were aged based on plumage characteristics or known hatch dates and were banded and weighed at approximately six days of age.

Swamp Sparrows typically fledge between 8 and 11 days of age. To minimize the chance of premature fledging, we tried to avoid checking nest contents on days 7, 8, or 9. We examined each nest for evidence of fledging or failure on day 10 or day 11. A nest was presumed to have fledged if there was no indication of predation and one or more of the following were observed: (1) parents were actively defending the nest site, (2) the nest cup was flattened and fecal material was observed on the nest cup or on adjacent vegetation, or (3) fledglings were seen or heard within 3 m of the nest.

We determined causes of nest failure by examining nests and egg or nestling remains. During the incubation stage, predation was assumed if the eggs were removed but the nest remained intact. If the nest was toppled or destroyed, we checked the area around the nest to determine whether all of the eggs or eggshells were present, which might suggest that a nest was destroyed by weather, particularly if a storm had occurred on the preceding day. During the nestling stage, we assumed that predation occurred if the nestlings were younger than eight days old and were removed from the nest with the nest remaining intact. If the nest was toppled, we searched the area around the nest to determine whether nestlings may have fallen from the nest and drowned. In some instances, there were obvious signs of predation such as partial nestling remains or animal scat or tracks at the nest. If chicks were eight days of age or older, we checked for evidence of fledgling. If no evidence of fledgling was found, we checked to see if nests had been destroyed by predators or if nests had been toppled due to weather or had failed due to other causes.

3.4 Habitat variables

Wetland habitat variables were measured at the nest and territory spatial scales at all four study sites. Upon finding a nest, we measured the water level at the nest, estimated the percent concealment when the nest was viewed from 1 m above, and recorded the nest substrate (e.g. cattail, grass, or sedge) and height. We used a handheld GPS to record the latitude and longitude of each nest. Following fledging or failure, we again measured the water level at the nest.

We also performed detailed stem counts and estimated the vegetative cover at each nest using a 20 cm by 50 cm Daubenmire frame. We randomly selected a compass direction and placed the frame within 0.5 m of the nest. We identified stems to the species level if possible. Stem counts were aggregated to tabulate the total number of stems within the following groups: total cattail, total grasses, total sedges and rushes, total herbaceous stems, total monocot stems, total dicot stems, and total stems.

To examine nest site selection by Swamp Sparrows, we also measured vegetative composition at a randomly selected point within each territory. Territory boundaries were estimated based on the average inter-nest distance among all Swamp Sparrow nests, which was approximately 7 m. We used a randomly selected compass bearing and a randomly selected integer between 0 and 7 to locate a random point relative to each nest.

During late July and early August, we visually estimated the vegetative composition within a portion of each territory (3 m radius from each nest) and classified the cover type as either live vegetation, dead vegetation or non-vegetated (bare ground, mud, open water). We recorded the percent cover of the following plant groupings: cattail, reed canary grass, other grasses, sedges and rushes, and herbaceous plants.

3.5 Data analysis

3.5.1 Hypotheses

We hypothesized that reproductive success would differ between restored and natural wetlands due to differences in hydrology and vegetative composition that likely influence nest site attractiveness and accessibility to predators. A qualitative review of WRP sites in Wisconsin suggested that many restored sites had lower water levels and shorter hydroperiods than natural wetlands (Coates, *unpublished data*). Additionally, vegetative characteristics appeared to differ with restored marshes having lower plant diversity, a higher percent cover by cattail species and reed canary grass and a lower abundance of sedges and rushes. Because of these potential differences, I hypothesized that the restored marshes would have lower nest success than natural marshes and that habitat attributes would differ between these two wetland types.

3.5.2 Comparisons of habitat characteristics

I used graphical methods and t-tests explore whether habitat attributes differed between successful and failed nests or between restored and natural marshes. Based on these results, I selected a subset of candidate variables for inclusion in likelihood-based modeling of the relationships between wetland attributes and reproductive success.

3.5.3 Modeling of Daily Nest Survival Rates and Habitat Relationships

I used a likelihood–based modeling approach to estimate daily nest survival rates and evaluate relationships between survival rates and reproductive success. Likelihood-based approaches offer numerous advantages over the traditional Mayfield method (Dinsmore et al 2002, Rotella et al. 2004, Shaffer 2004). Daily survival rates (DSRs) can be modeled directly as a function of one or more nest, group, and time-specific covariates, thus overcoming the need to stratify data and lessening the sample size issues that often occur with the Mayfield method (Rotella et al. 2004). Additionally, likelihood-based methods enable one to compare a large number of competing models using information-theoretic techniques (Rotella et al. 2004).

I used the nest survival module in the software program MARK to build and evaluate competing models of the DSR. The program MARK uses a generalized linear modeling approach that is based on the binomial likelihood and models the DSRs as a function of one or more covariates. A link function is used to mathematically characterize the relationship between the DSR and the covariates. The logit link function is frequently used, where the DSR is modeled as follows (Rotella et al. 2004);

$$DSR = f\,\frac{(\exp(\beta_o + \sum \beta_i x_{ji})}{(1 + \exp(\beta_o + \sum_j \beta_j x_{ij})}$$

where x_{ij} (j = 1, 2,…J) are covariates and β_{ij}s are estimated slope coefficients. I used the logit link function in our analyses. Additional details regarding the mathematics and theory of likelihood-based nest survival models can be found in Cooch and White (2006), Dinsmore et al. (2002), Rotella et al. (2004), and Shaffter (2004).

I examined competing models of nest survival rates that included various combinations of one or more habitat covariates as well as variables for site, year, and date. As discussed previously, I selected habitat covariates based on the results of our exploratory data analysis. For nests where data were not recorded, I substituted the mean values for the missing data. The use of mean values will not affect the slope estimates but results in smaller sample sizes and decreases the variance of the slope estimates.

I evaluated competing models in MARK using an information-theoretic approach. I compared the Aikake's information criteria (AICc) values and ΔAIC values calculated by MARK and then selected the model with the lowest AICc to draw inferences regarding the influences of wetland habitat attributes on Swamp Sparrow nest success.

3.5.4 Source / sink status

I used the nest monitoring data and literature-based survival estimates to evaluate whether the study wetlands could be classified as demographic sources or sinks for Swamp Sparrow (Pulliam 1988). If mortality (1 – adult survivorship) is balanced by recruitment, then:

$$(1 - \text{adult survivorship}) = \frac{\text{mean number of female offspring}}{\text{adult female}} \times \text{juvenile survival}$$

Therefore, if the mean number of female fledglings produced per female is less than (1 – adult survivorship)/(juvenile survivorship), the wetland can potentially be classified as a demographic sink (Donovan et al. 1995).

4.0 RESULTS

4.1 Nests Monitored

We monitored a total of 175 nests across the three breeding seasons. Of this total, 81 nests were located at restored marshes and 94 nests were located at natural marshes. The apparent nest success rate for the pooled data was lower at restored marshes (0.27) than natural marshes (0.45). Predation was the largest cause of nest failure followed by flooding (2008 only). Other causes of nest failure included weather, drowning, abandonment following partial depredation, and in one case, trampling of the nest site by white-tailed deer (*Odocoileus virginianus*). I did not observe any failures due to starvation. The mean 6-day nestling mass was similar at restored (u = 11.7 gm) and natural marshes (ū = 11.6 gm) further suggesting that differences in food resources did not contribute to observed differences in nesting success.

4.2 Habitat Attributes

At the restored wetlands, Swamp Sparrows nested in areas dominated by cattails, with reed canary grass, other grasses and stinging nettles (*Urtica dioica*) occurring along the drier edges. At the natural marshes, Swamp Sparrows also nested predominantly in cattails but also used sedge meadows (absent at the restored sites) and open grassy areas. Hypothesis testing confirmed that vegetative composition differed between restored and natural marshes (Table 1). In general, natural marshes had a lower percent cover by cattails, reed canary grass, and other grasses and a higher number and percent cover of sedges and rushes.

However, no vegetative attributes differed between successful and failed nests. The only vegetation variable selected as candidate for the maximum likelihood modeling was the total percent cover of vegetation (alive and dead) within 3 m of the nest, which had a p-value of 0.06 for the t-test between successful and failed nests. Nor were there statistically significant differences in most nest characteristics (nest height, height above water, concealment) between successful and failed nests.

Water levels measured at the nest at the time of fledging or failure were lower at restored marshes than natural marshes. Water levels measured at the time of nest fledging or failure also differed between successful and failed nests but were higher at failed nests. This result is an artifact of the 2008 field season which experienced a 100-year rainfall event early in the season that flooded and destroyed all existing nests. Flooding was most severe at Shaw Marsh and high water levels prohibited Swamp Sparrow from nesting until early July. When only 2006 and 2007 data were used, final water levels differed slightly between successful ($\bar{u}$ = 0.0165) and failed ($\bar{u}$ = 0.0313) but this difference was not statistically significant (*p*-value = 0.12).

4.3 Maximum Likelihood Models

We modeled the DSR as a function of site, year, the date that the nest was found (DATE0), and three potential habitat covariates: HABITAT type (restored or natural wetland), water level at the nest on the day of nest fledging or failure (FH20), and the percent cover of vegetation (live plus dead) within 3 m of each nest (TVEG3M).

We examined a subset of models containing combinations of one or more of these four covariates. We examined models with a time-varying DSR and where the DSR was constant across the nesting season. Table 2 summarizes the results for the top ten models. The models with the strongest support were based on a constant DSR where:

(1) $DSR = \beta_0 + \beta_1 * HABITAT + \beta_2 * H_20$

(2) $DSR = \beta_0 + \beta_1 * HABITAT + \beta_2 * H_20 + \beta_3 * TVEG3M$

There was little difference in the AICc values between these models. These results suggest that nest success was a function of habitat type, the final water level measured on the date of nest fledging or failure, and the percent cover by vegetation within 3 m of the nest. The addition of variables for site, year, and the date that the nest was found did not improve the model. From this modeling, the DSR estimated for restored wetlands was 0.9186 while the DSR estimated for natural wetlands was 0.938. These values equated to an overall nest success rate of 0.11 in restored wetlands and 0.19 in natural marshes, based on a 26-day nesting cycle.

4.4 Source-sink status

I compared the mean number of female fledglings produced per female to (1 minus adult survivorship)/(juvenile survivorship) to evaluate whether the restored and natural wetlands in our study functioned as demographic sources or sinks.

Data regarding adult survivorship are limited. Apparent survivorship for Swamp Sparrows has been estimated using mark-recapture analysis as 0.411 for the north-central region of the United States (Institute for Bird Populations 2009). I could not find estimates of juvenile survival but a value of one-half of the adult survival rate is frequently used, which would give a value of 0.2055. Substituting these values into the equation above suggest that the threshold for source/sink status is 2.86 female young produced per female adult per year.

The calculation of the mean number of females produced per female requires knowledge of the mean number of broods attempted and the mean clutch size for successful nests in each habitat type. The mean clutch size for successful nests was 3.71 in restored marshes and 3.26 in natural marshes. Assuming a 50:50 sex ratio, this would yield 1.86 females produced per successful nest in restored wetlands and 1.63 females produced per successful nest in natural wetlands. I assumed that each female would renest up to two additional times if the first attempt was unsuccessful and that each female could produce up to two broods per year. Given the nest success rate of 0.11 for the restored marshes, a population of 100 females would be successful on 11 of their first attempts and produce 11 x 1.86 or 20.46 female fledglings. The 89 second nest attempts would produce and additional 18.2 fledglings; and the 79 third renest attempts would produce 16.16 fledglings for a subtotal of 54.82. The females that were successful (29 total) could generate a total of 16.19 fledglings from a second brood. Thus, 71.06 female fledglings were produced per 100 female adults or 0.71 female young per female adult per year. Comparing this value to the threshold of 2.86 would suggest that the restored wetlands in our study functioned as a demographic sink. Although the juvenile survival rate and number of nest attempts is uncertain, increasing the juvenile survival rate up to the adult survival rate does not change this conclusion.

Similar calculations for the natural marshes yielded a value of 1.12 female young produced per female per year, which suggested that the natural marshes also functioned as demographic sinks during the three-year study period. Based on the average clutch sizes and assumptions above, the nest success rate would have needed to be approximately 0.56 for these natural wetlands to function as a demographic source and 0.46 for these restored wetlands to function as a demographic source. These results should be interpreted with caution as the calculations are very sensitive to estimates of juvenile and adult survival, both of which have a high degree of uncertainty.

5.0 Discussion

Our intensive monitoring of breeding Swamp Sparrows indicated that reproductive success was lower at the restored WRP marshes compared to nearby natural marshes. The best fit model indicates that the daily nest survival rate is a function of habitat type (restored or natural), percent cover of vegetation within 3 m of the nest, and final water level measured at fledgling or failure. However, because predation was the dominant cause of nest failure, it is possible that the factors which influence nest predation vary between restored and natural marshes.

Our visual observations of animals and their sign during the three field seasons suggest that Swamp Sparrow nest predators include snakes, voles (*Microtus* spp.), raccoons (*Procyon lotor)*, mink (*Mustela vison*), least weasels (*Mustela nivalis*), and Marsh Wrens. Although each pair of restored wetland and the natural wetland was located within 3 km of one another in similar landscape settings, it is possible that habitat features at the site-scale (< 1 km) influenced the types and numbers of predators found at each site and contributed to the observed differences in Swamp Sparrow reproductive success.

For example, our restored wetland was proximal to several small corn fields. It is possible that waste corn provides a supplemental food source that supports larger densities of certain predators or their prey. While our findings suggest the potential for differences in the ability of natural and restored wetlands to sustain healthy breeding bird populations, this work should be replicated in other areas and across a broader range of wetland conditions.

6.0 ACKNOWLEDGEMENTS

The 2008 field season was funded by a grant from the USDA. The 2006 and 2007 field seasons were funded by the Wisconsin Department of Natural Resources and a fellowship from the National Science Foundation. I gratefully acknowledge their support of this research.

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Table 1. Summary of Wetland Habitat and Nest Attributes: 2006 – 2008.

						Comparisons of Group Means (*t*-tests)							
Variable	**Units**	**Count**	**Grand Mean (all groups)**	**Pooled Variance (all groups)**	**Overall Standard Deviation**	**Fail**	**Fledge**	**Sig. Diff?**	***p* value**	**Natural**	**Restored**	**Sig. Diff?**	***p* value**
Date nest found	date	175	37.87	-	-	35.22	42.47	Yes	<0.05	39.40	36.09	No	-
Site	-	175	-	-	-	-	-	-	-	-	-	-	-
Year	-	175	-	-	-	-	-	-	-	-	-	-	-
Habitat type (restored or natural)	-	175	-	-	-	-	-	Yes			-	-	-
Nest Characteristics													
Water level when nest found	m	168	0.05	0.01	0.09	0.06	0.05	No	-	0.04	0.06	No	-
Water level at fledging/failure	m	161	0.07	0.03	0.17	0.09	0.03	Yes	<0.05	0.11	0.03	Yes	
Nest height	m	160	0.41	0.02	0.15	0.42	0.41	No	-	0.41	0.42	No	-
Nest Ht above Initial Water Level	m	155	0.36	0.02	0.14	0.36	0.35	No	-	0.36	0.36	No	-
Nest concealment	% conceal	141	52.5	1167.86	34.17	51.37	54.27	No	-	48.77	56.29	No	-
Clutch size	# eggs	175	3.54	0.73	0.86	3.60	3.42	No	-	3.49	3.59	No	-
Daubenmire Square Quadrats													
% Live Vegetation in 0.1 m^2	%	302	47.0	918.45	30.31	47.96	42.47	No	-	47.60	42.89	No	-
% Dead Vegetation in 0.1 m^2	%	302	37.7	744.54	27.29	36.47	41.55	No	-	32.55	45.03	Yes	0.005
% Total Vegetation in 0.1 m^2	%	302	84.8	488.78	22.11	84.43	84.02	No	-	80.15	89.21	Yes	0.01
% Non-vegetated in 0.1 m^2	%	302	15.2	488.78	22.11	15.57	15.98	No	-	19.85	10.79	Yes	0.01
Stem Counts													
Cattail, Narrow-leaved	No./0.1 m^2	302	2.33	10.38	3.22	2.16	2.42	No	-	1.41	3.23	Yes	<0.001
Cattail, Broad-leaved	No./0.1 m^2	302	0.06	0.14	0.37	0.07	0.04	No	-	0.06	0.03	No	-
Cattail, Hybrid	No./0.1 m^2	302	0.79	2.70	1.64	0.58	0.76	No	-	0.56	0.61	No	-
Cattail, Total	No./0.1 m^2	302	3.18	10.61	3.26	2.82	3.07	No	-	2.04	3.87	Yes	<0.001
Broad-leaved Arrowhead	No./0.1 m^2	302	0.83	3.30	1.82	0.90	0.58	No	-	1.46	0.00	Yes	<0.001
Total Grasses	No./0.1 m^2	302	16.57	586.15	24.21	14.51	20.67	No	-	16.20	17.68	No	-
Total Monocots	No./0.1 m^2	302	24.64	1230.52	35.08	22.27	26.33	No	-	25.77	21.67	No	-
Total Herbaceous	No./0.1 m^2	302	1.51	15.79	3.97	1.19	1.51	No	-	1.16	0.96	No	-
Total Stems	No./0.1 m^2	302	28.58	1203.99	34.70	25.84	30.36	No	-	29.30	25.17	No	-

Table 1. Summary of Wetland Habitat and Nest Attributes: 2006 – 2008 (continued).

						Comparisons of Group Means (*t*-tests)							
Variable	**Units**	**Count**	**Grand Mean (all groups)**	**Pooled Variance (all groups)**	**Overall Standard Deviation**	**Fail**	**Fledge**	**Sig. Diff?**	***p* value**	**Natural**	**Restored**	**Sig. Diff?**	***p* value**
% Dead w/in 3 m of nest	%	155	24.05	284.05	16.85	23.25	25.44	No	-	25.03	22.93	No	-
% Vegetated (live+dead) w/in 3 m	%	155	87.26	186.75	13.74	86.07	89.30	No	0.06	86.39	88.26	No	-
% Open w/in 3 m of nest	%	155	12.74	186.75	13.67	13.93	10.70	No	0.06	13.61	11.74	No	-
Vegetative Composition (live)													
% *Typha* w/in 3 m of nest	%	155	30.96	545.52	23.36	30.22	32.51	No	-	23.31	39.78	Yes	<0.001
% RCG w/in 3 m of nest	%	155	24.39	674.42	25.97	24.70	23.76	No	-	17.39	32.45	Yes	<0.001
% OthGrass w/in m of nest	%	155	3.48	90.40	9.51	3.63	3.15	No	-	6.13	0.41	Yes	<0.001
% TotalGrss w/in 3 m of nest	%	155	27.86	611.50	24.73	28.33	26.91	No	-	23.53	32.86	Yes	0.02
% SedgeRush w/in 3 m of nest	%	155	13.86	520.13	22.81	11.89	17.03	No	-	24.65	1.41	Yes	<0.001
% Herbaceous w/in 3 m of nest	%	155	5.47	122.64	11.07	5.90	4.64	No	-	4.70	6.36	No	-

Table 2. MARK models of daily nest survival rate (DSR): 2006 – 2008.

Model	K	AICc	ΔAICc
DSR = $\beta_0 + \beta_1$*HABITAT + β_2*FH20	3	559.93	0.00
DSR = $\beta_0 + \beta_1$*HABITAT + β_2*FH20 + β_3*TVEG3M	4	560.62	0.59
DSR = $\beta_0 + \beta_1$*FH20	2	562.49	2.56
DSR = $\beta_0 + \beta_1$*HABITAT + β_2*FH20 + β_3*TVEG3M + β_4*YR1 + β_5*YR2	6	563.17	3.24
DSR = $\beta_0 + \beta_1$*HABITAT + β_2*FH20 + β_3* TVEG3M + β_4SITESL + β_5*SITEWF + β_5*SITEV	6	564.07	4.13
DSR = $\beta_0 + \beta_1$*HABITAT + β_2*TVEG3M	3	564.89	4.95
DSR = $\beta_0 + \beta_1$*TVEG3M	2	565.81	5.88
Time Varying DSR = $\beta_0 + \beta_1$*HABITAT + β_2*FH20	2	566.31	6.37
DSR = $\beta_0 + \beta_1$*DATE0	2	566.32	6.38
DSR = $\beta_0 + \beta_1$*HABITAT	2	567.34	7.40

DSR = daily nest survival rate; K = number of parameters; AICc = Akaike's information criteria; HABITAT = habitat type, either restored wetland (coded as a 1) or natural wetland (coded as 0); FH20 = final water level at nest at time of fledging or failure; TVEG3M = percent cover of vegetation (live and dead) within 3 m of the nest; YR1 = a dummy variable for year, coded as 1 for 2006 and 0 otherwise; YR2 = a dummy variable for year, coded as 1 for 2007 and 0 otherwise; SITESL = a dummy variable for site, coded as 1 for the Slinger WRP Marsh and 0 otherwise; SITEWF = a dummy variable for site, coded as 1 for the Westford Marsh and 0 otherwise; SITEV = a dummy variable for site, coded as 1 for the Vehage WRP site and 0 otherwise; DATE0 = the date that the nest was located.

Figure 1. Map of study area near Beaver Dam, Wisconsin.