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Avian Communities of Created and Natural Wetlands: Saltmarshes of Southeast Virginia

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AVIAN COMMUNITIES OF CREATED AND NATURAL WETLANDS: SALTMARSHES OF SOUTHEAST VIRGINIA

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In Partial Fulfillment

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Master of Arts

by

David William DesRochers

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APPROVAL SHEET

This thesis is submitted in partial fulfillment of

the requirements for the degree of

Master of Arts

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ABSTRACT

In the United States, dramatic loss of wetland habitat due to development has led to the construction of artificial habitats to mitigate the loss. Under jurisdictional control of the U.S. Army Corps of Engineers, this destruction-creation dynamic attempts to replace ecological functions of lost wetlands. The success of avian communities may serve as a proxy for demonstrating successful wetland creation and may lead to a greater understanding of those conditions that drive a created wetland to success or failure. However, few comprehensive investigations of avian use of created wetlands exist. From May, 2001 to December, 2002, I investigated bird communities during the breeding season, migration, and winter on 11 created tidal marshes paired with 11 natural references of similar marsh type, size, and surrounding land use. Most of the sites were in developed areas, so in 2002 a new type of reference was added - small sections of larger, undisturbed marshes. Created sites supported fewer species of marsh birds, as well as fewer individuals and a lower diversity, than the paired, small references. Additionally, fewer species were observed on the created sites that were highly dependent upon wetlands, exhibited a narrow preference for habitat type, fed high on the food web, or migrated long distances. Red-winged Blackbird productivity also differed between these two treatments, as nests on created sites were less likely to survive through incubation. In contrast, only, two differences were found between the birds of the created sites and those of the larger, undisturbed reference marshes. Red-winged Blackbird nests were more likely to fledge on the large references than on the created sites, and there was also a difference in use of microhabitats by wintering sparrows. Despite the many differences observed during the breeding season, no differences were detected during the winter surveys between created sites and either reference treatment for the total number of species, total abundance, or abundance of sparrows. My findings suggest that created wetlands can partially replace the breeding and wintering bird communities of destroyed natural wetlands. However, created saltmarshes do not completely replace the breeding bird community lost when a natural saltmarsh is developed. Since wetland mitigation is likely to continue in the future, I recommend a direct comparison between created and restored wetlands to ascertain which method is the most effective for replacing wetland bird communities. This will help to ensure the persistence of wetland birds - a valuable component of coastal wetland habitats.

INTRODUCTION

Wetlands and Mitigation Policy

Salt marshes make up approximately 5% of the 20 million hectares of wetlands in the United States (Mitsch and Gosselink 2000). These tidal wetlands provide critical ecosystem services such as flood attenuation, wildlife habitat, and water quality improvement. They are also of great economic importance, having been valued at $22,832 per hectare per year for ecosystem services – the highest ranking out of 21 terrestrial and aquatic habitats studied (Costanza *et al.* 1997).

Currently, 75% of the human population of the United States lives within 100 km of a coast, and as a result, human activities such as residential and commercial development threaten coastal wetlands. For instance, proximity to residential development has been shown to drastically alter nutrient availability and interspecific competition in salt marsh plant communities in New England (e.g. Bertness *et al.* 2002). Wetlands disturbed by human activity are also prone to invasion by *Phragmites australis* (hereafter "Phragmites"), an aggressive wetland plant that can restrict tidal flow and outcompete other plant species, severely altering the marsh landscape and reducing biodiversity (Chambers *et al.* 1999). Phragmites is now very common, having invaded most types of wetlands throughout North America (e.g. Galatowitsch *et al.* 1999; Magee *et al.* 1999).

This alteration, combined with excessive loss of coastal wetland habitat due to development, has resulted in a growing jurisdictional movement to preserve, restore, and create these wetlands, so that there is no net loss (National Wetlands Policy Forum 1988). Under Section 404 of the Clean Water Act, the Army Corps of Engineers requires that developers mitigate for any wetland destruction by creation, restoration, or preservation of at least the same acreage as was destroyed (Army Corps of Engineers 999). The Corps' program also requires subsequent monitoring of created sites for at least five years to determine if the project was successful, and whether any supplementary activities are required, such as planting additional vegetation or removing excess sediments.

Despite legal protection of natural wetlands and a requirement for compensation for those lost to development, many past mitigation projects have not compensated sufficiently for the destroyed wetlands they were intended to replace. Most recently, The

National Academy of Science (2001) released a comprehensive review of mitigation efforts, briefings from outside experts, and a large body of scientific literature. The report's primary conclusion states that "the goal of no net loss for wetlands is not being met for wetland *functions* by the mitigation program, despite progress in the last 20 years". Other reviews have found similar results: mitigation projects were incomplete, never started, or were smaller than planned. Successful sites were often evaluated based on a limited number of visits or the measurement of simple structural indicators such as a few species of plants (e.g. Brown and Veneman 1998; Erwin 1991; Kentula *et al.* 1992a; McKinstry and Anderson 1994; Sifneos *et al.* 1992).

Monitoring the Success of Mitigation Wetlands

Short-term monitoring of only a few characteristics of wetlands, such as the presence of a plant species or adequate water level, is insufficient to determine if a mitigated site is a biologically viable and sustainable wetland ecosystem (Mitsch and Wilson 1996). Additionally, it is not currently known how long it takes artificial wetland systems to reach a stable, mature state of ecosystem development. Some estimate that it may take up to 200 years for saltmarshes to reach maturity (DiQuinzio *et al.* 2002; Mitsch and Wilson 1996; Thom *et al.* 2002). Therefore, long-term monitoring of the various communities supported on these artificial wetlands is essential to evaluate their degree of success.

In addition to long-term monitoring, comparison with a natural wetland is essential to determining the success of a mitigation wetland (Brinson and Rheinhardt 1996). Investigations into whether artificial wetlands are similar to natural reference wetlands have typically explored biomass of primary producers, aquatic invertebrate communities, and a limited number of vertebrate communities, usually fish.

Plant Communities:

Early investigations of created wetlands typically focused on vegetation communities and often revealed that mitigation failed to replace natural levels of productivity. For instance, several created *Spartina* marshes failed to produce as much above ground biomass as natural reference marshes (e.g. Broome *et al.* 1988; Gibson *et al.* 1994; Haltiner *et al.* 1997; Moy and Levin 1991). Limitations to growth were typically caused by acidic and/or nitrogen-poor soils, high rates of nutrient loss, and erosion.

Another factor that can cause mitigation wetlands to support different vegetation than that on natural wetlands is an unusual hydrological regime. Hydrology drives a wetland system, and improper hydrology can have severe detrimental effects on a developing wetland. For example, poor hydrology has drowned out plant communities, hindered seedling development, or prevented natural recruitment by propagules (Ashworth 1997; Budelsky and Galatowitsch 2000; Fraser and Kindscher 2001; Galatowitsch and van der Valk 1996). This can drive a mitigation wetland to failure if steps are not taken to return the hydrology to a more natural regimen.

Not all mitigation wetlands fail to support highly productive plant communities. Some created marshes support productive *Spartina* communities similar to those observed on natural marshes (e.g. Craft *et al.* 1999; Odland 1997; Posey et al. 1997; Webb and Newling 1985). If it can be established exactly why those wetlands were successful, then steps could be taken to ensure that the conditions that led to success are incorporated into future mitigation projects.

Despite the failure of some mitigation wetlands to support healthy plant communities, there are a number of techniques to improve the chances that these wetlands more closely resemble natural wetlands. Understanding the functions in a natural wetland that impact the vegetation is paramount. Surveying pre-impact wetland vegetation on sites that are to be developed provides a framework for what species should be established in the mitigation sites (Atkinson *et al.* 1993). Planted seedlings and seed banks in created wetlands have helped to establish plant communities, bolstering natural recruitment (e.g. Reinartz and Warne 1993; van der Valk 1999; Vivian-Smith and Handel 1996). Adding organic fertilizers to marsh sediments can also encourage developing plants (Stauffer and Brooks 1997). One of the most valuable techniques is supplemental mitigation – activities carried out after a site is created that increase the probability of success (e.g. planting of additional vegetation if original plantings die, removal of unwanted species or sediment, or exclusion of destructive wildlife such as beavers or wild pigs). Frequent monitoring is necessary, however, if supplemental mitigation is to be successful (Clewell 1999). Another useful tool to ensure successful development of the vegetation is modeling wetland development (Niswander and Mitsch 1995). If a site's development deviates from the modeled progression, for example, in terms of hydrology, then supplemental mitigation can alleviate the problem.

Animal Communities:

As with their ability to support plant communities, mitigated wetlands vary in their ability to support animals comparable to those found on natural wetlands. Some created wetlands support benthic and terrestrial invertebrate communities that are either comparable to or more abundant than those in natural references (Craft *et al.* 1999; Streever *et al.* 1996). Comparable fish densities have also been observed on other mitigated wetlands, but the same sites failed to replace crustacean communities (Minello and Zimmerman 1992). Other reported shortcomings have included failure to support 1) comparable levels of insects that disperse across large distances (Brown *et al.* 1997), 2) comparable abundances and densities of fish (Minello and Webb 1997; Moy and Levin 1991), 3) comparable richness and abundance of marine invertebrates (Cammen 1976, Scatolini and Zedler 1996; Talley and Levin 1999), and 4) stable invertebrate communities (Alphin and Posey 2000). Studies like these have provided some hypotheses to explain success or failure of created wetlands, e.g. low concentrations of organic matter leads to low density of invertebrates, or, the presence of sub-aquatic plants increases fish density by providing habitat. More work is needed, however, to determine why wildlife in created wetlands sometimes approximates those in natural references but sometimes fails to do so. Determining what specifically influences animals is problematic however, since wildlife is typically quite mobile, and many community-level interactions with other animals and abiotic factors are involved.

Wetland restoration has also been beneficial to animal communities. Marine invertebrate abundance increased in wetlands where tidal activity had been restored (e.g. Roman *et al.* 2002; Vose and Bell 1994). Fish use also increased dramatically once tidal dams were removed from coastal wetlands (e.g. Brockmeyer *et al.* 1997; Burdick *et al.* 1997). While recreating natural functions such as tidal activity can be successful, restoration may not always be possible for biological or political considerations. Therefore, it is important to study how animal communities respond to creation efforts in an attempt to manage successfully for their replacement.

Bird Communities:

There is currently a gap in our understanding of how marsh creation affects terrestrial vertebrate groups – particularly, bird communities. Birds, as valuable bioindicators, are essential in predicting the health of an ecosystem and are often sensitive to disruptions of normal ecological processes (e.g. Casalena 1998; Reinert and Mello 1995).

Some studies of created wetlands have revealed that they are relatively successful at supporting bird communities that are comparable to those on natural wetlands (Table 1). In an early study, man-made wetlands were surveyed for use by waterfowl as part of a larger wetland study over a two-year period. They were found to support more pairs of Mallard (*Anas platyrhynchos*) and American Wigeon (*Anas americana*) than other wetlands surveyed (Ruwaldt et al. 1979; Table 1). Unfortunately, neither the number of years since wetland creation nor the sample size was provided in this study. In a later study, foraging behavior by shorebirds in created wetlands did not differ significantly from that of the same species in natural reference wetlands (Brusati *et al.* 2001). This likely indicated similar food availability between created and natural sites.

There is stronger evidence, however, that created wetlands are not supporting bird communities comparable to those on natural wetlands. It was shown that created wetlands in Texas supported fewer species and fewer individuals than the natural reference wetlands to which they were compared (Melvin and Webb 1998). Created sites lacked suitable habitat for nesting and foraging and this likely explains the lower use by such birds as rails, shorebirds, and waterfowl. Interestingly, created sites did exhibit higher use by gull and tern species due to a single nesting colony that was established. However, supporting a colony of gulls may not be a priority of wetland mitigation since gulls are common, and there are other wetland birds of greater conservation concern such as rails and passerines. A created wetland in California failed to meet one of its key mitigation goals – the support of breeding Light-footed Clapper Rails (*Rallus longirostris levipes*) – a federally endangered species. The failure was due to a lack of appropriate habitat (Zedler and Calloway 2000). Breeding Wood Storks (*Mycteria americana*)

Table 1: Major studies of bird communities on created wetlands

Source	Year(s) Studied	# of sites:years since creation	Location
<u>Tidal Wetlands</u>:			
Rodgers *et al.* (1987)	**1981-85**	**?:?**	**Florida**
The created sites supported - Fewer breeding Wood Storks than natural references			
Melvin and Webb (1998)	**1990-1991**	**7:5-13**	**southwest Texas**
The created sites supported - lower species richness and abundance than natural references - Six species that were not detected on the natural sites (compared to 13 species detected on natural sites that were not seen on the created wetlands) - Higher gull and tern abundance than natural references			
Zedler and Calloway (2000)	**1999**	**1:12**	**western California**
The created site provided - A sufficient amount of open water for foraging Least Terns (*Sterna antillarum*) - Insufficient nesting substrate suitable for the endangered Light-footed Clapper Rail			
Brusati *et al.* (2001)	**1997-1999**	**4:4-12**	**southwest Texas**
The created sites supported - Five shorebird species whose foraging behavior was similar to that observed on natural references			
<u>Non-tidal Wetlands</u>:			
Ruwaldt *et al.* (1979)	**1973-74**	**?:?**	**South Dakota**
The created sites supported - More Mallard and American Wigeon pairs than other wetlands surveyed			

in Florida, another federally endangered species, have also been observed in lower numbers on created wetlands than on artificial sites typified by more upland vegetation (Rodgers *et al.* 1987). However, the quality of the natural sites decreased after the original study and comparable numbers of storks were later observed on both created and natural wetlands (Ogden 1991).

Several characteristics of created wetlands have been determined to affect the bird communities present on them. A study of waterfowl on created wetlands in Minnesota showed that pair density was positively correlated with certain attributes of the sites. For example, Blue-winged Teal (*Anas discors*) numbers were positively correlated with wetland age and surface area and Northern Shovelors (*Anas clypeata*) with mean depth and distance to the closest pond (Leschisin *et al.* 1992). Even though use of the created wetlands by waterfowl was documented, there was again no comparison made with natural reference wetlands. However, if the more successful sites can be used as templates for future wetland creation projects in waterfowl management, it will likely improve wetland mitigation. More work is needed to determine how successfully created wetlands support bird communties.

Avian use of restored wetlands has also been variably successful. In New England saltmarshes, the abundance of wetland dependent birds increased after restoration and was comparable to that of reference wetlands after 10-16 years (Brawley *et al.* 1998). Abundance of breeding birds also increased with age of restored wetlands in North and South Dakota (Ratti *et al.* 2001), Iowa (LaGrange and Dinsmore 1989), the Netherlands (Eertman *et al.* 2002), and Spain (Comín *et al.* 2001). However, natural references were only used for the Iowa study, where no differences were detected for avian richness, abundance, or diversity. Additionally, only incidental surveying was done on the restored sites in the Netherlands and Spain. This makes it difficult to determine if the restored sites were truly successful in replacing the historic bird communities. Despite an increase in abundance observed on the previously mentioned restored sites, there was no change in bird communities observed on restored wetlands in Iowa (Hemesath and Dinsmore 1993). In a New York study, different species were found on restored marshes and natural reference marshes (Brown and Smith 1998). Lastly, restoration of tidal activity in a Rhode Island marsh led to increased nest failure in

Saltmarsh Sharp-tailed Sparrows (*Ammodramus caudacutus*), (DiQuinzio *et al.* 2002). Despite the apparent failure, successful establishment of a productive sparrow population is anticipated because this project closely resembles another wetland restoration where Sharp-tailed Sparrow abundance increased once sufficient nesting substrate had developed (Brawley *et al.*1998).

Birds.on Created Wetlands in Virginia:

In Virginia, only two studies have looked at bird communities on created wetlands. Breeding birds on six created, forested wetlands (2-4 ha in size, 7-11 years old) supported fewer species and individuals and lower diversity than natural forested wetlands of the same size and ecological age. The difference was primarily due to a dearth of breeding songbirds (Snell-Rood and Cristol, in press). Created sites also supported species with lower values for wetland dependency, degree of habitat specialization, height in the food web, or migration distance. It was predicted that it would take more than 40 years for development of the avian communities on the created sites to reach the state of mature wetlands in the area. Reference sites, in contrast, recovered their full avian communities in only 25 years following clearcutting. Despite the observed differences and retarded development of the created sites, abundance of wading birds, waterfowl, raptors, aerial feeders, and woodpeckers did not differ between natural and created sites.

A one-year study in Virginia examined birds of a single five-year old, 0.4 ha saltmarsh in winter, spring, and summer. This created site supported fewer breeding birds than two adjacent reference plots (Havens *et al.* 1995). Additionally, only 47% of the species observed in the reference sites were ever seen in the created marsh. Interestingly, use by herons and shorebirds was higher on the created site, but the number of observations was small (n = 15). Only five observations of birds were made on all sites during the winter, and only seven birds were observed at the created marsh during the spring – a significantly lower value than on the natural plots. These two studies suggest that wetland creation in Virginia may be less than successful. I am aware of no other studies that have investigated bird use of created wetlands in Virginia.

More investigations into success of bird communities on mitigation wetlands are needed; in particular, more long-term studies. Most studies have lasted only a single breeding season. However, birds use wetlands throughout the year, and year-to-year variation may occur, so there is a need for studies during other seasons and across years.

Justification for this study

Approximately 25% of the total wetland area in Virginia is classified as tidal wetlands (Mitsch and Gosselink 2000). These wetlands provide valuable roosting and foraging habitat for migrating shorebirds and wintering waterfowl, and nesting grounds for many wetland birds. They are also essential for the life cycle of several bird species of conservation concern: Bald Eagle (*Haliaeetus leucocephalis*) and Gull-billed Tern (*Sterna nilotica*) are listed as threatened on the state list; Great Egret (*Ardea alba*), Little Blue Heron (*Egretta caerulea*), Tri-colored Heron (*Egretta tricolor*), Glossy Ibis (*Plegadis falcinellus*), Yellow-crowned Night-heron (*Nyctanassa violacea*), Saltmarsh Sharp-tailed Sparrow, Forster's Tern (*Sterna fosteri*), and Least Tern are of "special concern" (http://vafwis.org/bova/lists/CAT04.htm). If these species are to persist in the face of continued wetland destruction, then created tidal wetlands must be properly constructed, so that they have sufficient nesting, foraging, and roosting habitats.

An additional concern over created wetlands is overgrowth by Phragmites. Extensive invasion of created wetlands has been carefully documented in the Virginia tidewater area (Havens *et al.* 1997; Pyke and Havens 1999), Connecticut (Moore *et al.* 1999), and elsewhere. While birds have been observed using this invasive plant (e.g. Brawley 1994; Holt and Buchsbaum 2000), it is not completely clear how Phragmites invasion affects bird communities. There is some evidence, though, of a shift in the types of bird species found on marshes invaded by Phragmites (Benoit and Askins 1999). It is also possible that as original nesting habitat disappears, some birds may switch to nesting in Phragmites (e.g. Maccarone 1993; Parsons 1996) which may lead to problems such as increased exposure to predators (DiQuinzio *et al.* 2002). However, there is surprisingly little data available on exactly how Phragmites impacts birds.

My project is the most comprehensive investigation to date of bird communities on created tidal wetlands. To determine if created tidal wetlands are successful in mitigating for losses of natural wetlands, I conducted a two-year study of the avian communities, both in and out of the breeding season, on 11 created marshes and 22 natural reference marshes on the coastal plain of Southeast Virginia.

My null hypothesis was that avian communities supported on created salt marshes would be comparable to those of natural marshes. I would reject this null hypothesis if avian community diversity, richness, and abundance differed significantly between created and natural marshes. A recent study comparing bird communities on developed versus undeveloped lakeside habitats detected differences only after comparing use of sites by birds within particular subsets of the community based on foraging guilds (Lindsay *et al.* 2002). Therefore, I also compared the following selected subsets of the avian communities on created and natural wetlands: piscivores, aerial insectivores, raptors, ground feeders, and edge species.

Additionally, I examined avian use of my sites based on mean values for ecological rankings that classify each species with respect to some variable of conservation concern (Croonquist and Brooks 1991). Separate ecological rankings were given to each species based on: 1) degree of dependence on wetlands, 2) narrowness of habitat preference, 3) height in the food web, 4) extent of migratory behavior, and 5) conservation status based on Partners In Flight Priority Score data from the Mid-Atlantic Coastal Plain physiographic region.

During the second year of my study I investigated Red-winged Blackbird (*Agelaius phoeniceus*) productivity on a smaller subset (n = 21) of the 33 created and reference sites. To my knowledge, this is the first investigation of avian productivity in created wetlands. Red-winged Blackbirds were chosen because they were the only species observed at all sites.

In addition to breeding bird communities, I investigated three other aspects of bird use on my study sites to determine if created saltmarshes could support comparable bird communities throughout the year. These other studies focused on foraging by migratory shorebirds (September – October), roosting by wintering blackbirds (January – March), and occupation by wintering sparrows (November – March).

Since the Clapper Rail (*Rallus longirostris*) is the signature species of saltmarsh habitat along the mid-Atlantic coast, and a species of moderate conservation concern (Partners in Flight data), I paid special attention to them. Clapper Rails were the most abundant obligate saltmarsh species breeding on the study sites, occurring on 65% of the sites both years.

Finally, to determine if any differences in bird communities resulted from differences in vegetation, I surveyed the plant communities at each site. I compared created and reference sites in terms of plant richness and diversity, the percent cover of different height classes of vegetation, including Phragmites.

CHAPTER 1

BREEDING BIRD SURVEY

Methods:

Study Area:

I censused the bird communities on 11 created salt marshes and 11 natural salt marshes (hereafter "small reference" sites) in the Virginia tidewater area. I chose created sites from a list of marshes from a previous study (Pyke and Havens 1999), eliminating those that were smaller than 0.4 ha, were non-tidal, or were not created to mitigate for the loss of natural wetlands. I also located three additional created marshes by contacting local landowners that were reported to own created wetlands. As a reference, I chose the closest appropriate natural marsh, so that each reference was paired with a created site. Created and small reference sites were matched for size within 0.1 ha (range: 0.40 – 4.04 ha, mean = 2.13 ± 1.15 ha), surrounding land use (perimeters matched to 15% for forested upland, field, residential, and industrial/commercial activity), geographic locale (mean separation: 12 ± 14.6 km) and shape (approximately rectangular or square). Equal-sized natural marshes were chosen as references to represent small, isolated wetlands that might have been like those destroyed and necessitating the creation of new, isolated small wetlands.

In the second year of the study, I added a new set of natural reference sites (hereafter "large reference" sites, n = 11). From within large natural marshes, I delineated sections that were nearly the same size and shape as a created site. The marshes in which these references were imbedded were at least three times the size of the largest created site (≥ 12 ha). I added these large sites because I had discovered after the 2001 season that the small reference sites did not differ in percent cover of Phragmites from the created sites, suggesting that they were highly disturbed. The rationale for adding the second set of references was that these sites, being imbedded in larger marshes, represent a different type of natural wetland being destroyed by developers. Sites were located an average of 18.05 ± 12.02 km from the point 76° 30' 28" W Long., 37° 6' 56" N Lat. in Newport News, York County, Virginia.

Breeding Birds Censuses:

In both 2001 and 2002, I carried out fixed-area (50-m diameter) circular plot point counts at each site three times during the breeding season (15 May - 15 July). The season was divided into 3 periods (1 = 15 May - 3 June, 2 = 4 June – 22 June, 3 = 23 June – 15 July). I censused each site once during each period, spreading them out such that there were 10 d between visits to the same location. Counts lasted 10 min and were done between 0600 - 0930 when birds are most active. Random placement of points was impractical due to the small size and variable shapes of these sites. Instead, count circles were positioned to maximize the number of counts possible for each site. In a few cases of narrow rectangular marshes I used semi-circles with 50-m radii and corrected for plot size in the analysis. Created wetlands had the same number of count circles (or semicircles) as their matched reference sites, so they were exactly matched for amount of time and area censused. Censuses were not taken when wind was ≥ 15 km per h or when rain was present, since these factors may reduce bird detectability. In addition to the visits when point count surveys were done, I returned to all sites to complete vegetation surveys and nest searching (see vegetation and productivity sections). During all visits I made general observations of birds using the sites. This increased the chances of detecting individuals of cryptic species, and while these data are unsuitable for rigorous analysis, they do provide additional information on bird use.

Analysis:

To characterize the avian community at each marsh, I combined the point count data for all count circles, and used the maximum number of breeding pairs per species per site out of all three visits for analysis. Only one member of a pair had to be present, and species not recognizable by sex were automatically split into pairs. For example, two Eastern Kingbirds (*Tyrannus tyrannus*) would be listed as one pair, and three Chimney Swifts (*Chaetura pelagica*) would be classified as two pairs. This provided a conservative estimate of the actual number of pairs present at a site. With these data, I calculated species richness (number of species), abundance (number of pairs), and the Shannon-Weiner diversity index (combines richness and evenness of species) for each marsh in 2001 and 2002. For the 22 sites studied in both years, I combined the two years.

For all sites, the bird community data were analyzed separately for two subgroups of species: “true marsh” species, which were observed using the wetland itself or the airspace above it for perching, foraging, nesting, or singing, and “edge” species, which were seen only in the immediately surrounding upland vegetation. To determine how similar the treatments were to one another based on the types of “true marsh” species that were present at each site, I used the Jaccard (1912) similarity index which considers only species presence and Euclidean distance which compares how abundant a specific species is on each treatment.

I further divided “true marsh” species into specific foraging guilds for additional analysis: piscivores, aerial insectivores, raptors, and ground foragers (Appendix II – “True Marsh” species). I calculated richness, abundance, and diversity values separately for each guild, but I did not analyze a guild category if the treatment with the most observations had values for less than half of the sites. Finally, I calculated Red-winged Blackbird abundance separately from the point count data because this was the most abundant species, by far, and the only one present at every site.

I also examined avian use of the sites based on “ecological rankings” (Croonquist and Brooks 1991) and population status to provide another index of comparison that would be useful for management considerations. To do this, each species was ranked with respect to different ecological criteria of interest to conservationists and managers. This provides an alternative way of assessing the ecological value of the sites by placing a conservation value on each species that used them. Ecological rankings for each species were based on degree of dependence on wetlands, narrowness of habitat preference, height in the food web, whether it is a long distance migrant, and whether its population is in peril (Appendix II). Conservation status of a population was classified as low, moderate, or of high concern using the Partners in Flight Priority Score data from the mid-Atlantic coastal region (The Partners in Flight Handbook on Species Assessment and Prioritization – Version 1.1). The ecological rankings for all species found at a site were then combined to provide an index of how much value that site had with respect to various conservation concerns, such as preventing declines of wetland dependent species or Neotropical migrants.

All values are reported as mean ± standard deviation. Two-tailed paired t-tests were used to compare matched marshes (see Study Area above). Results were considered significant at $P < 0.05$. Where data did not conform to a normal distribution I used exponential, common log, natural log, or square root transformations to achieve normality. Where analyses were performed on transformed data, I show the untransformed values in text and tables. If transformation failed to normalize data, I used the non-parametric (and statistically less powerful) Wilcoxon signed-rank test.

Power Analysis:

One important purpose of *a priori* power analysis is to determine the size of the sample needed to detect a given effect size between two populations. The effect size is the degree to which the null hypothesis is false, or more simply, the degree to which two populations differ (Cohen 1988). If the null hypothesis is true, then the effect size is zero. Effect size can be expressed in terms of a unitless index (d) calculated from the means and standard deviations of two samples. Cohen (1988) suggests that a small effect size is $d = 0.2$, a medium effect size is $d = 0.5$, and a large effect size is $d = 0.8$. The ability to detect the hypothesized effect size, or difference, is known as statistical power. The higher the power, the more likely a researcher is to detect a difference if one is present. A power level of 0.80 is the lowest value that is typically accepted (Cohen 1988). That is, one should utilize a sample size large enough that there is an 80% probability of detecting a difference (whether it be small, medium, or large) at a specified α-level.

In order to detect a small difference ($d = 0.2$) between some variable measured from the bird populations on the created and reference sites (with power = 0.80 and $\alpha = 0.05$), I would have needed 400 saltmarshes in each treatment. This is probably more created saltmarshes than exist in the world. For a medium difference ($d = 0.5$), I would have needed 64 sites. Probably more than has been built on the entire East Coast. For a large difference ($d = 0.8$), 26 sites would have sufficed. I included every suitable created saltmarsh in the region, but this amounted to only 11 sites. Thus, from the start, I was likely only to detect very large differences ($d > 0.8$) when they were present. Thus, all of my comparisons had weak statistical power and my choices were to abandon the study or continue with the knowledge that I had only a small chance of detecting small or moderate differences. I accepted the fact my comparisons would have weak statistical power and conducted the study in the hopes of interesting results. All negative results in this thesis should be viewed with caution because my sample size is such that I had very low probability of rejecting the null hypothesis for any comparison, even when it was false.

Multivariate Analysis:

My primary objective of this analysis was, as in the previous univariate analyses, to determine if created saltmarshes differed from natural saltmarshes. However, I used multivariate techniques to allow me to examine this question while holding other variables constant that may have affected bird use, specifically, marsh area, proportion of upland edge, amount of each vegetation cover type, and surrounding land uses. To reduce the number of land uses and types of vegetation cover I used principal component analysis. A principal component is a linear combination of variable weightings that explains a portion of the overall variation in a data set and subsequently reduces the number of variables necessary for a multivariate analysis. The first principal component explains the most variation and each successive component explains less and less additional variation until 100% is explained. I only used principal components with eigenvalues > 1. To create the principal components for land use I combined variables measured from these different land uses: disturbed marsh, disturbed upland, river, undisturbed marsh, and undisturbed upland. For vegetation cover principal components I included amount of tall (including shrub), medium, and short vegetation.

I compared the three land use and one vegetation principal components between created and small reference treatments to determine the direction of difference when considered alone. I then used a mixed stepwise multiple regression analysis to test the effect of each principal component, as well as the other independent variables; treatment type, marsh size, and proportion of upland edge, on "true marsh" species richness, abundance, or diversity (dependent variables). In a mixed stepwise regression, the independent variables are added individually in descending order of the amount of variation that they explain until no additional variation can be explained by adding more.

Results:

Community Data:

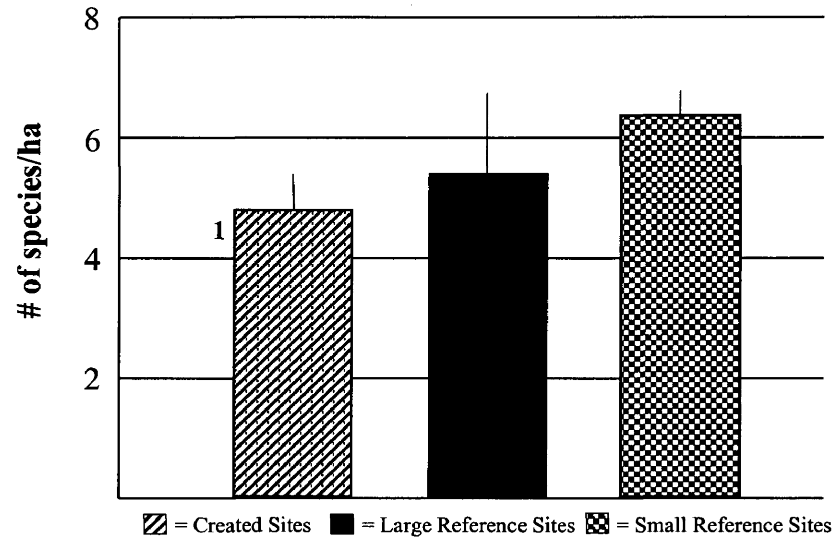
For the created and small reference sites, which were used in 2001 and 2002, I report results from both years separately and the two combined. Shannon-Weiner diversity, richness and abundance, combined for both years, were all significantly higher on the small reference sites (Table 2, Figures 1 – 3). Diversity, richness, and abundance did not differ significantly in 2001, although mean values tended to be higher for reference sites (Table 3). In 2002, diversity and richness were significantly higher on the small references 2002 (Table 3), but abundance did not differ. Of the 46 species detected on small references, 16 were never detected during point counts on created sites. This compares to seven out of 36 total species on created sites that were never detected during point counts on small references (Appendix I).

Created sites did not differ from large references in diversity, richness, or abundance (Table 4, Figures 1-3). Of the 34 species detected on large references, 16 were never detected during point counts on created sites. Similarly, created sites supported 16 species that were never detected on large sites during point counts. Interestingly, large reference sites had mean values that were intermediate to created and small reference sites in 17 of the 21 avian variables that I compared.

True Marsh versus Edge Species:

For 2001 and 2002 combined, created sites had significantly fewer "true marsh" species, and lower abundance and lower diversity of this group than small references (Table 5). In 2001, diversity of "true marsh" species did not differ significantly from small references, while richness and abundance were significantly lower on created sites (Table 6). Additionally, both diversity and richness were significantly lower on created sites in 2002. However, abundance

was not significantly different that year, despite a trend towards a lower mean on created sites (Table 6). Combining both years, nine "true marsh" species were absent from created sites: Turkey Vulture (*Cathartes aura*), Wood Duck (*Aix sponsa*), Osprey (*Pandion haliaetus*), Bald Eagle, Common Tern (*Sterna maxima*), Tree Swallow (*Hirundo bicolor*), Marsh Wren (*Cistothorus palustris*), Nelson's Sharp-tailed Sparrow (*Ammodramus nelsoni*), and Seaside



Avian Species Richness

Figure 1. Avian species richness for created sites, and their matched small (both years combined) and large references (2002 only). [1]Value is significantly lower than on small references. Bars represent standard errors.

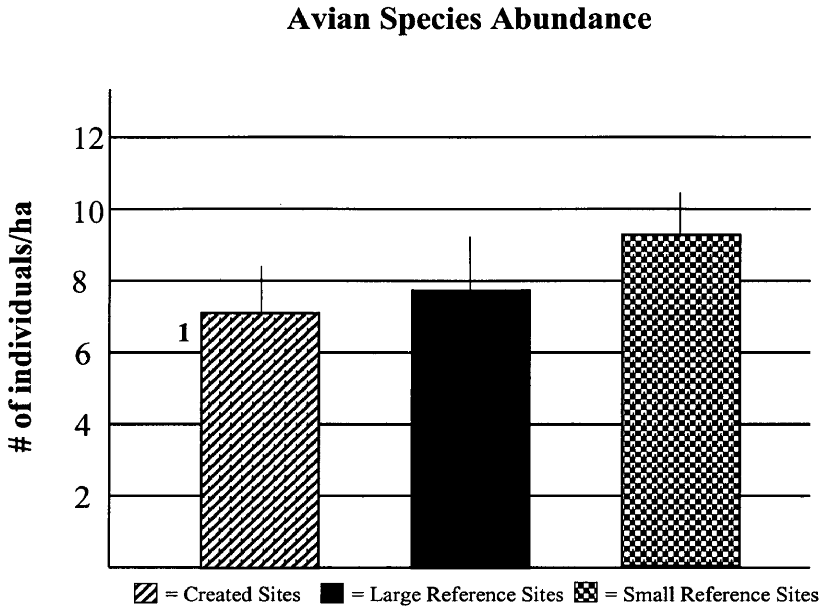


Figure 2. Avian abundance for created and their matched small (both years combined) and large references (2002 only). [1]Value is significantly lower than on small references. Bars represent standard errors.

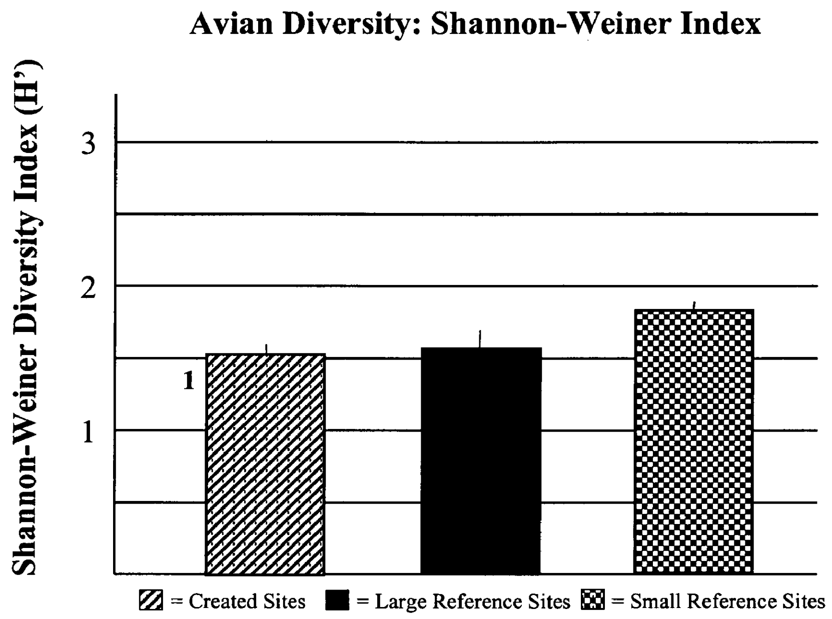


Figure 3. Shannon-Weiner Diversity (H') (Pielou 1975) of avian communities for created sites and their matched small (both years combined) and large references (2002 only). [1]Value is significantly lower than on small references. Bars represent standard errors.

Table 2. Comparison of mean avian diversity, richness, and abundance of the entire community for both 2001-2002 combined on created sites and their paired, small reference sites.

Category	Created	Sm. Ref.	P Value[1]
Diversity:			
Shannon-Weiner[2]	1.56 ± 0.32	1.83 ± 0.24	$P < 0.05$ ($t_{10} = -2.25$)
Species Richness[3] (# Species)	4.73 ± 2.38	6.24 ± 2.22	$P < 0.05$ ($t_{10} = -2.80$)
Abundance (# Individuals)	7.37 ± 3.10	9.26 ± 3.26	$P < 0.05$ ($t_{10} = -2.24$)

[1]Paired t-test, analysis done on [2]exponentially transformed and [3]common log transformed data

Table 3. Comparison of mean diversity, richness, and abundance of the entire community for 2001 and 2002 separately on created sites and their matched small references.

Category	Created	Sm. Ref.	P Value
Community Data - 2001			
Diversity:			
Shannon-Weiner	1.52 ± 0.51	1.80 ± 0.30	NS[1] ($Z = 1.18$)
Species Richness[3] (# Species)	4.84 ± 2.98	6.54 ± 2.52	NS[2] ($t_{10} = -1.91$)
Abundance[3] (# Individuals)	8.35 ± 3.46	10.80 ± 4.46	NS[2] ($t_{10} = -1.72$)
Community Data - 2002			
Diversity:			
Shannon-Weiner[3]	1.59 ± 0.24	1.87 ± 0.29	$P < 0.05$[2] ($t_{10} = -2.66$)
Species Richness[4] (# Species)	4.61 ± 2.31	5.94 ± 2.31	$P < 0.05$[2] ($t_{10} = -3.45$)
Abundance[4] (# Individuals)	6.39 ± 3.11	7.72 ± 2.79	NS[2] ($t_{10} = -2.01$)

[1]Wilcoxon signed-rank test, [2]Paired t-test, analysis done on [3]common log transformed and [4]natural log transformed data

Table 4: Comparison of mean avian diversity, richness, and abundance for created sites and large references.

Category	Created	Lg. Ref.	P Value[1]
<u>Diversity:</u>			
Shannon-Weiner[2]	1.56 ± 0.32	1.62 ± 0.60	NS ($t_{10} = -0.89$)
Species Richness[3] (# Species)	4.73 ± 2.38	5.58 ± 4.03	NS ($t_{10} = -0.18$)
Abundance (# Individuals)	7.37 ± 3.10	7.91 ± 4.81	NS ($t_{10} = -0.39$)

[1]Paired t-test, analysis done on [2]exponentially transformed and [3]common log transformed data

Table 5. Comparison of mean diversity, richness, and abundance of "true marsh" and "edge" species for both years combined on created sites and their matched small references.

Category	Created	Sm. Ref.	P Value[1]
<u>TRUE MARSH SPECIES</u>			
<u>Diversity</u>:			
Shannon-Weiner	1.06 ± 0.31	1.45 ± 0.50	$P < 0.05$ ($t_{10} = -2.28$)
Species Richness[2] (# Species)	2.78 ± 1.24	4.43 ± 2.23	$P < 0.05$ ($t_{10} = -2.68$)
Abundance[2] (# Individuals)	5.11 ± 2.31	7.45 ± 3.39	$P < 0.05$ ($t_{10} = -2.70$)
<u>EDGE SPECIES</u>			
<u>Diversity</u>:			
Shannon-Weiner[2]	0.65 ± 0.42	0.62 ± 0.56	NS ($t_{10} = -1.41$)
Species Richness[3] (# Species)	1.87 ± 1.51	1.74 ± 1.65	NS ($t_{10} = 0.31$)
Abundance[3] (# Individuals)	2.17 ± 1.60	1.79 ± 1.64	NS ($t_{10} = 1.20$)

[1]Paired t-test, analysis done on [2]common log transformed, and [3]natural log transformed data

Table 6. Comparison of 2001 and 2002 mean diversity, richness, and abundance of "true marsh" species on created sites and their matched small references.

Category	**Created**	**Sm. Ref.**	**P Value**
TRUE MARSH SPECIES - 2001			
Diversity:			
Shannon-Weiner	1.03 ± 0.46	1.47 ± 0.56	NS[1] (t_{10} = -1.74)
Species Richness (# Species)	2.78 ± 1.45	4.73 ± 2.20	NS[2] (Z = 1.62)
Abundance (# Individuals)	5.85 ± 2.46	8.91 ± 4.08	$P < 0.05$[1] (t_{10} = -2.45)
TRUE MARSH SPECIES - 2002			
Diversity:			
Shannon-Weiner	1.08 ± 0.39	1.42 ± 0.53	$P < 0.05$[1] (t_{10} = -2.82)
Species Richness (# Species)	2.78 ± 1.43	4.13 ± 2.53	$P < 0.05$[1] (t_{10} = -2.78)
Abundance (# Individuals)	4.38 ± 2.46	5.98 ± 3.25	NS[1] (t_{10} = -2.08)

[1]Paired t-test, [2]Wilcoxon signed-rank test

Sparrow (*Ammodramus maritimus*). Two "true marsh" species were detected only on created sites: Sharp-shinned Hawk (*Accipter striatus*) and Belted Kingfisher (*Ceryle alcyon*).

Abundance and Shannon-Weiner diversity of "true marsh" species were also significantly lower on created sites with both years combined. While the following species were observed during point counts on created sites, they were less abundant than on natural sites: Green Heron (*Butoroides virescens*), Mallard (*Anas platyrhynchos*), Chimney Swift (*Chaetura pelagica*), Purple Martin (*Progne subis*), Northern Rough-winged Swallow (*Stelgidopteryx serripennis*), and Red-winged Blackbird.

As with richness, abundance, and diversity of the entire avian community, no differences were found when only "true marsh" species were compared between created and large reference sites (Table 7). Despite the lack of significant differences, eight "true marsh" species were observed on large references that were not seen on created sites: Osprey, Red-tailed Hawk (*Buteo jamaicensis*), American Kestrel (*Falco sparverius*), Royal Tern (*Sterna maxima*), Tree Swallow, Marsh Wren, Nelson's Sharp-tailed Sparrow, and Seaside Sparrow. Interestingly, seven "true marsh" species were observed only created sites that were not seen on large references: Great Blue Heron (*Ardea herodias*), Green Heron, Yellow-crowned Night-heron (*Nyctanassa violacea*), Mallard, Sharp-shinned Hawk, Black Skimmer (*Rhynchops niger*), and Belted Kingfisher.

Table 7. Comparison of mean diversity, richness, and abundance of "true marsh" and "edge" species for created sites and large references.

Category	**Created**	**Lg. Ref.**	**P Value**[1]
TRUE MARSH SPECIES			
Diversity:			
Shannon-Weiner	1.06 ± 0.31	1.37 ± 0.46	NS (t_{10} = -0.18)
Species Richness[2] **(# Species)**	2.78 ± 1.24	3.82 ± 1.61	NS (t_{10} = 1.37)
Abundance[2] **(# Individuals)**	5.11 ± 2.31	5.98 ± 2.59	NS (t_{10} = -0.92)
EDGE SPECIES			
Diversity:			
Shannon-Weiner[2]	0.65 ± 0.42	0.50 ± 0.75	NS (t_{10} = -2.58)
Species Richness[3] **(# Species)**	1.87 ± 1.51	1.76 ± 3.11	NS (t_{10} = -2.39)
Abundance[3] **(# Individuals)**	2.17 ± 1.60	2.16 ± 3.70	NS (t_{10} = -0.92)

[1] Paired t-test, analysis done on [2] common log transformed and [3] natural log transformed data

The Jaccard similarity index indicated that, for the two years combined, created sites were only 59% similar to small references and only 42% similar to large references in terms of the types of "true marsh" species present. When small references were compared to the large references, they were 57% similar. Mean Euclidean distance between treatments was greater between created sites and large references than between created sites and small references while the distance between small references and large references was the smallest (Table 8). Created sites were more similar to the small references in 2002 than in than 2001 in terms of the types of species observed and their abundance (Table 9).

Table 8. Euclidean distance of "true marsh" species between treatments for both years combined.

Category	**Created**	**Sm. Ref.**	**Lg. Ref.**
Created	------------	3.89 ± 1.52	4.15 ± 2.81
Sm. Ref.	------------	------------	3.71 ± 3.09
Lg. Ref.	------------	------------	------------

Table 9: Euclidean distance of "true marsh" species between treatments: 2001/2002.

Category	**Sm. Ref. - 2001**	**Sm. Ref. – 2002**
Created - 2001	4.28 ± 12.50	------------
Created - 2002	------------	3.50 ± 10.23

"Edge" species did not differ significantly between created and small reference sites for richness, abundance, or diversity (Table 5). Interestingly, these were the only variables where created sites had mean values that were consistently higher than those detected on the small references, but the differences were only slight and not statistically significant. The same results were observed when I compared these variables between created and large reference sites (Table 7).

Guilds:

Among foraging guilds, aerial insectivore abundance was the only category to differ significantly between created and small reference sites, with higher values observed on the small references (Tables 7-9). Purple Martins (*Progne subis*) and

Northern Rough-winged Swallows (*Stelgidopteryx serripennis*) were much more abundant on the small reference sites. Mean richness and Shannon-Weiner diversity of insectivores also tended to be lower on the created sites, but these were not significant differences. Richness, abundance, and Shannon-Weiner diversity of ground foraging species and Red-winged Blackbird abundance did not differ detectably. Unfortunately, no two-year comparison was possible for piscivores or raptors since I saw them too infrequently for a useful analysis. No significant differences were detected for any guild category when created sites were compared to the large references (Tables 10-12), but all mean values tended to be slightly higher on the large sites, with the exception of Red-winged Blackbird abundance.

Table 10. Comparison of mean aerial insectivore diversity, richness, and abundance on created sites and their matched small references.

Category	Created	Sm. Ref.	P Value
Diversity: **Shannon-Weiner**	0.42 ± 0.35	0.75 ± 0.40	$P = 0.08^1$ ($t_{10} = -1.98$)
Species Richness (# Species)	1.23 ± 0.70	1.81 ± 0.86	$P = 0.07^2$ ($Z = 1.65$)
Abundance (# Individuals)	1.56 ± 0.79	2.32 ± 0.99	$P < 0.05^1$ ($t_{10} = -2.64$)

[1]Paired t-test, [2]Wilcoxon signed-rank test

Table 11. Comparison of mean ground forager diversity, richness, and abundance on created sites and their matched small references.

Category	Created	Sm. Ref.	P Value[1]
Diversity: **Shannon-Weiner**	0.45 ± 0.31	0.62 ± 0.54	NS ($t_{10} = -1.16$)
Species Richness[2] (# Species)	1.32 ± 0.70	1.96 ± 1.26	NS ($t_{10} = -1.78$)
Abundance[3] (# Individuals)	3.27 ± 1.96	4.48 ± 2.43	NS ($t_{10} = -1.58$)

[1]Paired t-test, analysis done on [2]exponentially transformed and [3]common log transformed data

Table 12: Comparison of mean Red-winged Blackbird abundance from point counts on created sites and their matched small references.

Category	Created	Sm. Ref.	P Value[1]
Abundance (# Individuals)	2.35 ± 1.46	2.63 ± 1.27	NS (t_{10} = -0.63)

[1]Paired t-test

Table 13. Comparison of mean aerial insectivore diversity, richness, and abundance for created sites and the large references.

Category	Created	Lg. Ref.	P Value
Diversity:			
Shannon-Weiner	0.42 ± 0.35	0.67 ± 0.58	NS[1] (t_{10} = -1.17)
Species Richness (# Species)	1.23 ± 0.70	1.80 ± 1.06	NS[2] (Z = 1.57)
Abundance (# Individuals)	1.56 ± 0.79	2.20 ± 1.41	NS[2] (Z = -0.87)

[1]Paired t-test, [2]Wilcoxon signed-rank test

Table 14. Comparison of mean ground forager diversity, richness, and abundance for created sites and large references.

Category	Created	Lg. Ref.	P Value[1]
Diversity:			
Shannon-Weiner[2]	0.45 ± 0.31	0.46 ± 0.60	NS (t_{10} = -0.63)
Species Richness[3] (# Species)	1.32 ± 0.70	1.66 ± 1.17	NS (t_{10} = -0.58)
Abundance[3] (# Individuals)	3.27 ± 1.96	3.42 ± 2.60	NS (t_{10} = -0.22)

[1]Paired t-test, analysis done on [2]exponentially transformed and [3]common log transformed data

Table 15. Comparison of mean Red-winged Blackbird abundance from point counts for created sites and large references.

Category	Created	Lg. Ref.	P Value[1]
Abundance (# Individuals)	2.35 ± 1.46	1.81 ± 0.67	NS ($t_{10} = 1.14$)

[1] Paired t-test

Ecological Ranks:

Comparison of mean ecological rankings of those species present on each site revealed that small references had significantly higher values than created sites for three of the four categories in 2001 and all four in 2002 and both years combined. The categories were degree of wetland dependency, narrowness of habitat preference, height in the food web, and migratory status (Table 16-18, Figure 4). Created sites supported only two of the six species that were classified as habitat specialists (and were wetland dependent in this case) and observed on small references. The four habitat specialists absent from created sites were Osprey, Bald Eagle, Common Tern (*Sterna hirundo*), and Seaside Sparrow. Created sites also supported fewer top-level predators such as Osprey and Bald Eagle that rank high for food web position as specialist carnivores. The created sites did support many "edge" species that feed low on the food web and are subsequently ranked much lower. Neotropical migrants such as Chimney Swift, Purple Martin, and Northern Rough-winged Swallow were also less abundant on created sites. Short-distance migrants such as Green Heron, Wood Duck, Mallard, and Osprey, which rank slightly lower than Neotropical migrants, were also rare on created sites.

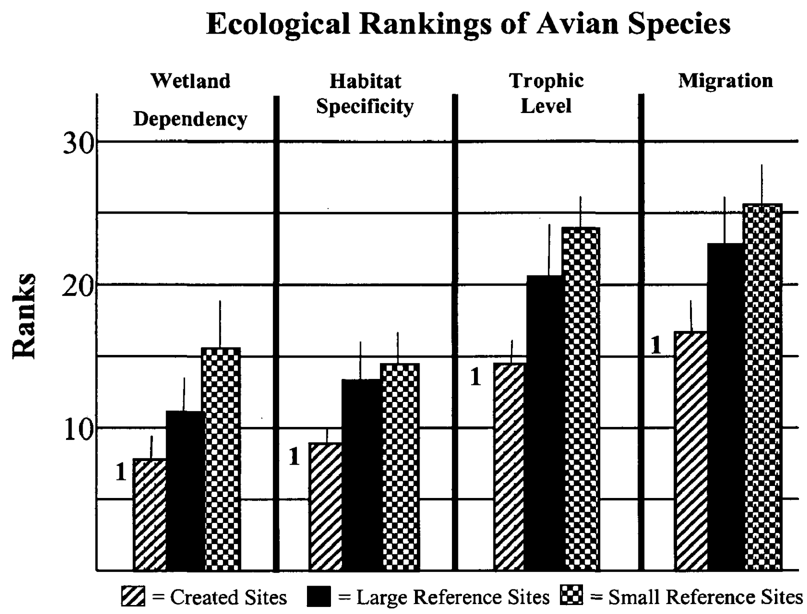


Figure 4. Ecological ranks of avian species on created sites and their matched small (both years combined) and large references (2002 only). [1]Value is significantly lower than on small references. Bars represent standard errors.

Table 16: Comparison of mean ecological rankings over two years on created sites and their matched small references.

Category	Created	Sm. Ref.	P Value[1]
Wetland Dependent Species[2]	7.95 ± 4.93	15.41 ± 10.21	$P < 0.05$ ($t_{10} = -2.97$)
Habitat Specificity	8.82 ± 3.03	14.73 ± 4.81	$P < 0.01$ ($t_{10} = -3.42$)
Trophic Level	14.91 ± 4.27	24.23 ± 6.98	$P < 0.05$ ($t_{10} = -2.84$)
Migratory Status	16.68 ± 6.06	25.45 ± 7.07	$P < 0.01$ ($t_{10} = -3.34$)
Conservation Status	15.15 ± 1.33	15.47 ± 1.77	NS ($t_{10} = -0.51$)

[1] Paired t-test, analysis done on [2] natural log transformed data

Table 17: Comparison of mean 2001 ecological rankings on created sites and their matched small references.

Category	Created	Sm. Ref.	P Value[1]
Wetland Dependent Species[2]	9.27 ± 7.16	17.27 ± 9.51	$P < 0.05$ ($t_{10} = -2.41$)
Habitat Specificity	9.27 ± 4.54	15.91 ± 6.36	$P < 0.05$ ($t_{10} = -2.38$)
Trophic Level	14.55 ± 6.84	25.36 ± 8.04	$P < 0.05$ ($t_{10} = -2.95$)
Migratory Status	16.91 ± 7.58	27.36 ± 6.85	$P < 0.01$ ($t_{10} = -3.36$)
Conservation Status	14.98 ± 1.49	15.73 ± 2.17	NS ($t_{10} = -0.83$)

[1] Paired t-test, analysis done on [2] natural log transformed data

Table 18. Comparison of mean 2002 ecological rankings on created sites and their matched small references.

Category	Created	Sm. Ref.	P Value[1]
Wetland Dependent Species[2]	6.64 ± 4.20	13.55 ± 11.48	$P = 0.05$ ($t_{10} = -2.25$)
Habitat Specificity	10.00 ± 3.49	16.36 ± 9.11	$P < 0.05$ ($t_{10} = -2.82$)
Trophic Level	15.27 ± 4.43	23.09 ± 8.32	$P < 0.05$ ($t_{10} = -3.37$)
Migratory Status	16.45 ± 5.85	23.55 ± 9.23	$P < 0.05$ ($t_{10} = -2.71$)
Conservation Status	15.32 ± 1.87	15.21 ± 1.67	NS ($t_{10} = 0.16$)

[1] Paired t-test, analysis done on [2] natural log transformed data

In terms of mean conservation status of populations, created sites did not differ from the small references in either year or for both years combined (Tables 16-18). Of the three “true marsh” species detected over the two years that are of highest conservation concern in the mid-Atlantic coastal region (Clapper Rail, Black Skimmer, and Seaside Sparrow), only Clapper Rail and Black Skimmer were observed on created sites versus all three on the small references. Between created and small reference sites, four species of high conservation concern were detected over the two years. Two of these were never detected on the created sites: Willet and Marsh Wren. The other two species, Chimney Swift and Eastern Kingbird, were detected on created sites, but were significantly less abundant than on the small references. Four species of moderate conservation concern were detected over the two years. Two of the species were absent from the created sites (Turkey Vulture and Osprey), one was significantly less abundant than on the small references (Purple Martin), and the fourth was detected on only one created site versus no small references (Least Tern).

None of the ecological rankings differed between the created and large reference sites

(Table 19, Figure 4), including conservation status. Mean values from the large references for degree of wetland dependency, preference for habitat, height in the food web, and degree of migratory behavior were intermediate between the values from the created sites and small references. The three species of highest conservation concern were present on the large references.

Table 19. Comparison of mean ecological rankings for created sites and large references.

Category	**Created**	**Lg. Ref.**	**P Value**
Wetland Dependent Species[3]	7.95 ± 4.93	10.55 ± 9.50	NS[1] (t_{10} = -0.29)
Habitat Specificity	8.82 ± 3.03	13.18 ± 8.99	NS[1] (t_{10} = -1.33)
Trophic Level	14.91 ± 4.27	20.55 ± 11.40	NS[2] (Z = -1.18)
Migratory Status	16.68 ± 6.06	23.00 ± 10.53	NS[1] (t_{10} = -1.41)
Conservation Status	15.15 ± 1.33	15.69 ± 1.80	NS[1] (t_{10} = -0.63)

[1] Paired t-test, [2] Wilcoxon signed-rank test, analysis done on [3] natural log transformed data

Multivariate analysis of factors:

High levels of disturbed upland habitat and river characterized the first land use principal component which was highest for created sites, moderate for small references, and lowest for the large reference sites (Table 20). The second land use component was characterized by high values for disturbed marsh and lack of river or undisturbed upland. Large reference sites had the highest mean value for this principal component, followed by small references, and then created sites. The third land use principal component was high on undisturbed upland forest and low on disturbed marsh. The mean value of this component was highest for created sites, slightly lower for the small references, and lowest for large references. The three land use principal components explained 36%, 29%, and 21%, respectively, of the variance in the land use variables.

Table 20. Principal components of surrounding land uses and vegetation of each treatment.

Component	Created	References	Eigen Value	Eigenvectors[1,2]				
				A	B	C	D	E
	Created	**Sm. Ref.**						
Land Use PC 1	0.72 ± 1.01	0.67 ± 0.92	1.82	0.30	0.50	0.38	-0.60	-0.40
Land Use PC 2	-0.14 ± 1.77	-0.03 ± 1.05	1.14	0.57	-0.61	-0.54	0.10	0.04
Land Use PC 3	0.34 ± 1.04	0.32 ± 0.97	1.03	-0.14	-0.05	0.14	-0.56	0.81
Vegetation PC 1	-0.83 ± 1.53	0.55 ± 0.86	1.51	0.38	-0.68	0.63	-----	-----
	Created	**Lg. Ref.**						
Land Use PC 1	0.72 ± 1.01	-1.38 ± 0.91						
Land Use PC 2	-0.14 ± 1.77	0.17 ± 0.64						
Land Use PC 3	0.34 ± 1.04	-0.66 ± 0.81						
Vegetation PC 1	-0.83 ± 1.53	0.28 ± 0.80						

[1] Eigenvectors for land use: A = Disturbed Marsh, B = Disturbed Upland, C = River, D = Undisturbed Marsh, E = Undisturbed Forest; [2] Eigenvectors for vegetation: A = Tall Vegetation, B = Medium Vegetation, C = Low Vegetation

The principal component for vegetation explained 50% of the variation in the three vegetation variables. It loaded heavily on low vegetation and lack of medium vegetation. Small references had the highest mean value for this component, followed by large references, and created sites (Table 20). The mean amount of upland edge was also highest for created sites, slightly lower for small references, and lowest for large references (Table 21).

Treatment (i.e. whether a site was created, a small reference, or a large reference) affected "true marsh" species richness, abundance, and diversity, and in each model, treatment explained the most variation. In addition to treatment, disturbed upland habitat, and upland edge affected "true marsh" species richness (regression: $r^2 = 0.14$) (Table 22). (In Table 22, the independent variables are listed in the order that they were selected in the model. The first variable explains the most variation, and each subsequently chosen variable explains less.) In addition to treatment, undisturbed forest affected abundance of "true marsh" species (regression: $r^2 = 0.13$) (Table 22). Marsh area also affected diversity of "true marsh" species (regression: $r^2 = 0.13$) (Table 22).

Table 21. Upland edge data used in multivariate analysis.

Component	Created	References	P Value[1]
	Created	**Sm. Ref.**	
Upland edge (m)	531.36 ± 219.38	429.07 ± 228.61	$P < 0.01$ ($t_{10} = 3.64$)
	Created	**Lg. Ref.**	
Upland edge (m)	531.36 ± 219.38	112.00 ± 65.30	$P < 0.01$ ($t_{10} = 6.02$)

[1] Paired t-test

Table 22. Results from the mixed stepwise multiple analysis of factors – effects on "true marsh" species richness, abundance, and diversity.

Independent Variables Included	Dependent Variables	r^2 (Cumulative)	P Value
Treatment	Richness	0.13	0.09
Land Use PC 1		0.17	0.13
Upland edge		0.22	0.22
Treatment	Abundance	0.11	0.03
Land Use PC 3		0.19	0.09
Treatment	Diversity	0.14	0.03
Area		0.19	0.18

CHAPTER 2

Productivity

Methods:

Nesting attempts of all species:

To determine the effects of wetland creation on avian productivity, I compared created and reference marshes for the number of unmated males defending territories, mated males that held territories, and active nesting territories that contained one or more nests. More detailed analysis was carried out for Red-winged Blackbirds (see below).

While visiting each site I recorded the number of territory-holding males present within the marsh and immediately adjacent to it (5 m into the surrounding edge habitat). I then compared the number of mated and unmated males among marsh types for each year and both years combined. To determine how many individuals attempted to breed, I searched for nests of birds at each site. With several assistants, I covered the entire area of each site for 150 person-min per ha (1 person-min is one person searching for one minute). I calculated the number of active nesting territories and compared these between treatments. Criteria for classifying male statues are reported in Table 23.

Table 23. Criteria for classifying unmated and mated males and active nesting territories.

Classification	Criteria
Unmated Male	Present at a site for more than one visit No evidence of a mate, a nest, or young in its territory
Mated Male	Present at a site for more than one visit plus Evidence of a mate
Active Nesting Territory	Female with nest material, food, or fecal sacs/eggshells, or a nest with eggs or nestlings or nearby fledglings

Red-winged Blackbirds:

To determine the affects of wetland creation on avian productivity, I compared nesting success of Red-winged Blackbirds between created sites and small and large references. To do this I used the well-established method of Mayfield (975). Nests were located with the help of assistants by observing adult females carrying nesting material or food. Intensive nest monitoring occurred on seven sites from each treatment, with each site re-visited approximately once every 10 days from 15 May until 6 August 2002. For each nest I recorded the number of days that eggs or young were known to be present in the nest (hereafter "exposure period"), the fate of all eggs or nestlings, and where possible, the number of young successfully fledged.

I categorized nest fate in one of three possible ways: successful, failed or abandoned, and uncertain. A nest was classified as successful if fledglings were seen, if feces from juveniles were observed on the rim of the nest, or if the nest was undisturbed and had held nestlings within several days of the predicted fledging date (10 d after hatching). When fledging date was unknown, the exposure period was determined using the "extrapolation method" (Manolis *et al.* 2000) in which I estimated day of fledging based on what developmental stage nestlings were at when last observed. For the nests that failed or were abandoned, I estimated that the exposure period had ended midway between the last two visits to that nest ("midpoint method", Manolis *et al.* 2000). For nests with completely uncertain fates, I used the "exclusion method" (Manolis *et al.* 2000) where all of the exposure days are excluded from analysis. However, if the nest survived through at least the incubation stage, then these data were included in the calculation of the Mayfield estimates for that stage. Monitoring ended on 6 August, when there were no more active nests.

For each site of a treatment I calculated the following Mayfield estimators: the probability that a population of nests on created and small reference sites would survive through incubation, the nestling period, and both periods combined. If a female had more than one nesting attempt, then I randomly selected one of her nests to include in the calculation of the estimators. In order to remain unbiased as to which nest was used, I randomly selected from those multiple nests 100 times, and along with the nests of single-nesting females, I calculated the estimators. I then averaged the 100 values to determine the final Mayfield values for each site. I compared the created sites to the small and large references for each of these Mayfield variables using Z-score analysis. These scores were calculated using the mean and variance of the daily survival rates from each period of each treatment population (see Hensler 1985; Hensler and Nichols 1981;

Johnson 1979; Manolis *et al.* 2000). Z-scores were considered significant if $Z < -1.96$ or $Z > 1.96$. All calculations used in productivity analysis are shown in Appendix V.

I also mapped out territories of each male and the females mated with it to determine the maximum number of young successfully fledged by each female, and the number of young successfully sired on each male's territory. Because extra-pair fertilization is common in Red-winged Blackbirds (Gibbs *et al.*1990), this is not an accurate estimate of actual paternity.

Finally, I developed an index of total breeding success of Red-winged Blackbirds for each created and small reference site used in the productivity study. The index considers all aspects of breeding for Red-winged Blackbirds from the time that a male establishes a territory until young fledge from a nest in that territory (see Appendix V for equation). Mean index values were then compared between the created site and both reference treatments.

Results:

Nesting attempts of all species:

For all species, including Red-winged Blackbirds, neither the number of territorial breeding males, nor unmated males, differed between created sites and small references (Table 24, Figure 5). Species for which breeding activity was observed (e.g. a completed nest with a nearby mate or young) are listed in Appendix I. Interestingly, created sites supported significantly more unmated males than the large reference sites (Table 25). However, the created sites did not differ from them in the number of territorial breeding males.

The number of active nesting territories did not differ significantly between created sites and small references (Table 26, Figure 5) or large references (Table 27). The two most common nesting species were Red-winged Blackbird and Clapper Rail. Red-winged Blackbirds made up 70% of all nesting territories in 2001 and 79% of all territories in 2002, and Clapper Rails made up 11% of all the territories in 2001 and 6% in 2002. Other species that were observed nesting in 2001 were Mallard and Marsh Wren (which also nested in 2002). White-eyed Vireo (*Vireo griseus*), Carolina Wren (*Thyrothorus ludovicianus*), and Blue Grosbeak (*Guiraca caerulea*) nests were found in 2002, but they were in shrubs along the immediate upland edge of the sites that they were detected on – all created sites except for the Carolina Wren. No nesting Mallards were detected in 2002, but the single Marsh Wren was observed nesting at one reference both years.

Table 24. Comparison of the number of territorial breeding and unmated males on created sites and their matched small reference sites.

Category	Created	Sm. Ref.	P Value[1]
Breeding Males[2]	6.18 ± 4.58	5.77 ± 2.35	NS ($t_{10} = 0.59$)
Unmated Males[2]	4.00 ± 2.45	4.95 ± 2.50	NS ($t_{10} = -0.89$)

[1] Paired t-test, analysis done on [2]natural log transformed data

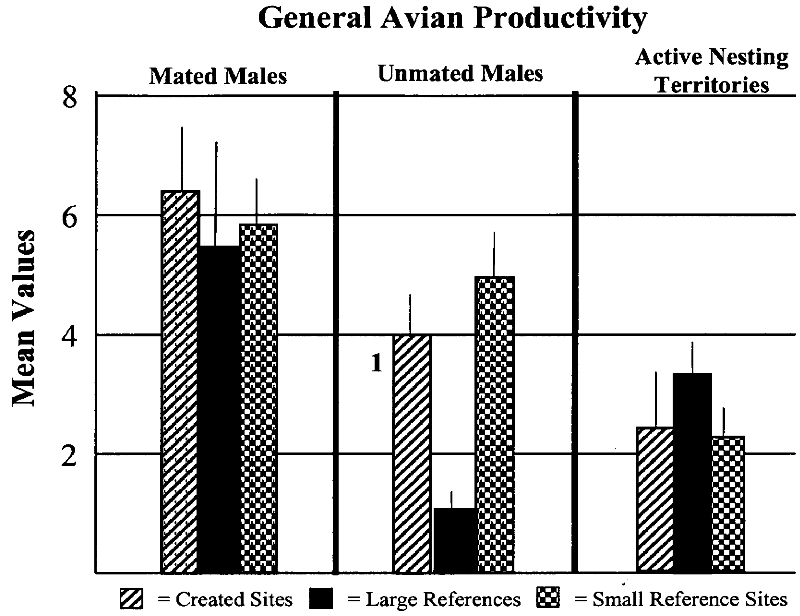


Figure 5. Comparison of general avian productivity for created sites and the matched small references. [1]Value is significantly lower than for large references. Bars represent standard errors.

Table 25: Comparison of the number of territorial breeding and unmated males between created sites and their matched large references.

Category	Created	Lg. Ref.	P Value
Breeding Males[3]	6.18 ± 4.58	5.55 ± 5.40	NS[1] ($t_{10} = 0.78$)
Unmated Males	4.00 ± 2.45	1.09 ± 0.83	P[2] < 0.05 ($Z = -3.10$)

[1]Paired t-test, [2]Wilcoxon signed-rank test, analysis done on [3]natural log transformed data

Table 26: Comparison of active nesting territories on created sites and their matched small reference sites.

Category	Created	Sm. Ref.	P Value[1]
Active Nesting Territories[2]	2.59 ± 2.91	2.18 ± 1.72	NS ($t_8 = 0.36$)

[1]Paired t-test, analysis done on [2]natural log transformed data

Table 27: Comparison of the number of active nesting territories between created sites and their matched large references.

Category	Created	Lg. Ref.	P Value[1]
Active Nesting Territories	2.59 ± 2.91	3.27 ± 2.73	NS ($Z = 0.86$)

[1]Wilcoxon signed-rank test

Red-winged Blackbirds:

The breeding success index of Red-winged Blackbirds was lower on created sites than on both types of references, but this difference was significant only between created and large references, despite a higher difference in means for created and small references (Tables 28a, b). This suggests that a given male arriving at a created site is less likely to succeed at some combination of finding mates, nesting, fledging young, and re-nesting. Productivity was low on all treatments, despite high daily survival rates (Table 29). The probabilities of surviving the incubation period, nestling period, or both combined did not differ significantly between created sites and either reference treatment (Tables 30a-30b). Despite the lack of differences, nests on created sites were twice as likely to fail during incubation than they were on the small references (Figure 6).

Table 28a. Comparison of Breeding Success Index (BSI) scores for Red-winged Blackbirds between created sites and their paired, small references.

Category	Created	Sm. Ref.	P Value[1]
BSI[2]	0.29 ± 0.53	1.70 ± 2.28	$P = 0.09$ ($t_6 = -2.04$)

[1]Paired t-test, analysis done on [2]square root transformed data

Table 28b. Comparison of Breeding Success Index (BSI) scores for Red-winged Blackbirds between created sites and their paired, large references.

Category	Created	Lg. Ref.	P Value[1]
BSI[2]	0.29 ± 0.53	1.27 ± 1.00	$P < 0.05$ ($t_6 = -2.56$)

[1]Paired t-test, analysis done on [2]square root transformed data

Despite small references having slightly higher mean values for the number of young fledged per female and per male territory, there were no differences when compared to the created sites (Table 31a). Created sites and large references also did not differ in terms of young fledged per female or per male territory (Table 31b).

Table 29. Red-winged Blackbird productivity data – created, small reference sites, and large reference sites.

Category	Created	Sm. Ref.	Lg. Ref.
Nests:			
Successful	13	15	14
Failed	17	16	22
Uncertain	18	13	16
Exposure Days:			
Incubation	108.31	114.6	160.1
Nestling	95.33	149.72	136.92
Both	203.64	264.32	297.02
Losses:			
Incubation	10	4.16	9.3
Nestling	3.16	3.9	6.5
Both	13.16	8.06	15.8
Probabilities of Surviving a Stage:			
Incubation	0.34	0.64	0.52
Nestling	0.71	0.77	0.61
Both	0.24	0.49	0.32
Daily Survival Rates (DSR):			
Incubation	0.91	0.96	0.94
Nestling	0.97	0.97	0.95
Both	0.94	0.97	0.95
Variance estimates (DSR):			
Incubation	7.74×10^{-4}	3.36×10^{-4}	3.42×10^{-4}
Nestling	3.36×10^{-4}	1.69×10^{-4}	3.32×10^{-4}
Both	2.97×10^{-4}	1.18×10^{-4}	1.70×10^{-4}

Table 30a. Z-Score results from comparison of Mayfield estimators between created sites and their paired small references.

Category	Z-Score
Incubation:	1.57
Nestling:	0.32
Both:	1.59

Table 30b. Z-Score results from comparison of Mayfield estimators between created sites and their paired large references.

Category	Z-Score
Incubation:	1.03
Nestling:	0.84
Both:	0.52

Table 31a. Comparison of the number of young fledged per female and per male territory between created sites and their matched small references.

Category	Created	Sm. Ref.	P Value[1]
Young Fledged:			
Per Female	1.50 ± 1.32	1.75 ± 1.77	NS ($t_{38} = -0.52$)
Per Male Territory	2.00 ± 1.76	2.26 ± 1.85	NS ($t_{36} = -0.45$)

[1] t-test

Table 31b. Comparison of the number of young fledged per female and per male territory between created sites and their matched large references.

Category	Created	Lg. Ref.	P Value[1]
Young Fledged:			
Per Female	1.50 ± 1.32	1.42 ± 1.54	NS (t_{43} = -0.19)
Per Male Territory	2.00 ± 1.76	1.92 ± 2.19	NS (t_{41} = -0.14)

[1] t-test

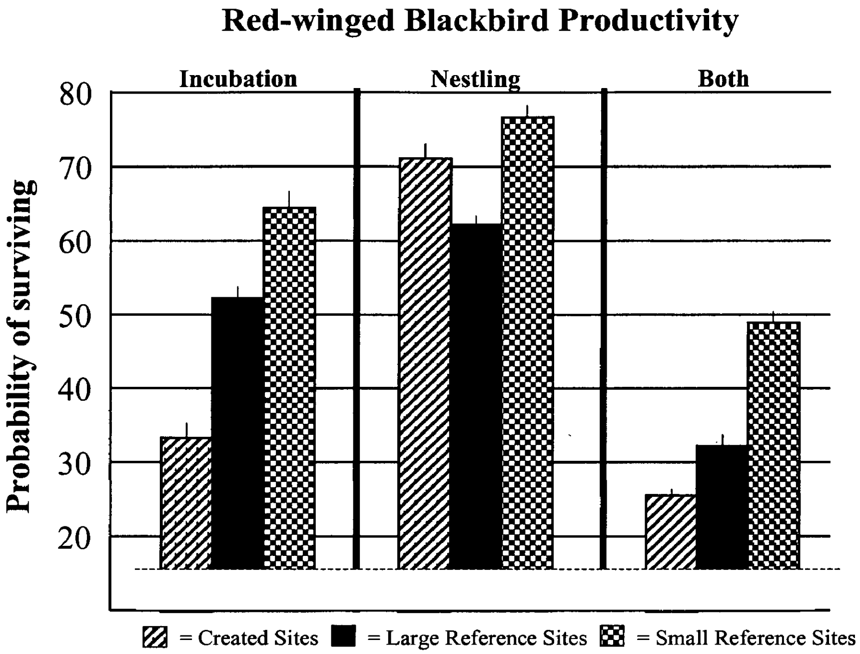


Figure 6. Nesting success of Red-winged Blackbirds on created sites and their paired small and large reference sites.
Bars represent standard errors.

CHAPTER 3

MIGRATION AND WINTER USE

Methods:

To assess bird use during the non-breeding season I conducted three types of surveys: (1) migratory shorebirds, (2) roosting blackbirds, and (3) wintering sparrows.

Migrating Shorebirds:

To determine if shorebirds were stopping over at the study sites during their southward migration, I intended to visit each site twice from September – October 2001. However, I completed only 19 surveys on 11 sites (six created, five small natural references) before the terrorist attacks of September 11, 2001, which caused me to lose access to the 11 sites on military installations. I visited eight sites twice (five created; three small natural) – once after high tide and once after low tide, and the three other sites (one created; two small natural) only once - after low tide. To survey for shorebirds, I systematically walked through a site, with several assistants, trying to flush birds. We walked five meters apart from one another and started along one upland edge, criss-crossing the site until it had been completely covered.

Roosting Blackbirds:

During late spring of 2001, blackbirds were observed leaving roosts just after dawn at two created sites dominated by Phragmites (Table 32). In January, 2002, I visited these sites, twice each, at dawn, to survey systematically for wintering blackbird roosts. Because there was one other site dominated by Phragmites, I surveyed it as well, despite the fact that blackbirds had not previously been observed roosting there.

Wintering Sparrows:

To determine if sparrows or other birds were using the sites as wintering habitat, I surveyed each one during each winter of the study (25 January – 27 March and 31 October – 20 December, 2002). All sites were surveyed twice each winter at least 14 days apart. All surveys were done using a 25 m rope with weights attached, harnessed between two assistants and dragged through the vegetation to flush birds. I used the flush-line because this survey method has proven successful for cryptic non-breeding season birds in open habitats (Fletcher *et al.* 2000). Many species other than sparrows were observed (e.g. snipe, rails, and other passerines), so they were included in the analysis as well. I surveyed an equal amount of area in both created and reference sites (total = 11.074 ha per treatment; mean = 1.01 ha per site), so that bird species richness and abundance, as well as sparrow species abundance could all be compared between the different treatments.

Table 32. Numbers of individuals of roosting blackbird species from two sites visited during the late spring in 2001.

Site	Species	Number observed
GC	European Starling (*Sturnus vulgaris*)	550
	Brown-headed Cowbird (*molothrus ater*)	40
	Red-winged Blackbird (*Agelaius phoeniceus*)	10
	Common Grackle (*Quiscalus quiscula*)	5100
MB	European Starling	288
	Common Grackle	146

Results:

Migrating waterbirds:

No shorebird species were ever detected using the sites during surveys. However, several shorebirds were observed near the sites: one Greater Yellowlegs (*Tringa melanoleuca*) was observed from a created site, and Killdeer (*Charadrius vociferus*) were seen flying over three other sites.

Wintering Blackbirds:

No blackbirds were observed roosting at the Phragmites dominated sites in 2001. Additionally, no roosts were observed at any of the other sites during the second breeding season in 2002, or the 2002 – 2003 winter survey. The two roosts that prompted this survey were apparently active during migration only.

Wintering Sparrows:

Sparrow abundance, or richness and abundance of all species did not differ significantly between created and small reference sites for both years combined (Table 33, Figure 7), or each year separately (Table 34-35). The same was true of the created and large reference sites, (which were surveyed only during the second winter of the study); (Table 36, Figure 8). Swamp Sparrow (*Melospiza georgiana*) was the most abundant species encountered during the two survey periods and it accounted for 60.3% of all observations (Appendix III).

Table 33. Comparison of wintertime avian richness and abundance of all species, as well as sparrow abundance for both years combined on created sites and their matched small reference sites. [1]Paired t-test

Category	Created	Sm. Ref.	P Value[1]
Species Richness (# All Species)	2.70 ± 1.47	2.78 ± 1.11	NS (t_{10} = -0.14)
Abundance (# All Individuals)	6.28 ± 4.14	5.78 ± 1.74	NS (t_{10} = 0.11)
Abundance (# Individual Sparrows)	4.34 ± 2.28	4.63 ± 1.75	NS (t_{10} = -0.33)

Table 34. Comparison of 2001 overall avian richness and abundance and sparrow abundance, on created sites and their matched small reference sites.

Category	Created	Sm. Ref.	P Value[1]
Species Richness[2] **(# All Species)**	2.89 ± 1.65	2.93 ± 1.31	NS (t_{10} = -0.35)
Abundance[2] **(# All Individuals)**	6.70 ± 3.63	7.25 ± 3.31	NS (t_{10} = -0.21)
Abundance[2] **(# Individual Sparrows)**	5.83 ± 3.70	5.64 ± 3.05	NS (t_{10} = 0.05)

[1] Paired t-test, analysis done on [2] square root transformed data

Table 35. Comparison of 2002 overall avian richness and abundance and sparrow abundance, on created sites and their matched small reference sites.

Category	Created	Sm. Ref.	P Value[1]
Species Richness[2] **(# All Species)**	2.53 ± 1.83	2.63 ± 1.12	NS (t_{10} = 0.21)
Abundance[2] **(# All Individuals)**	5.86 ± 6.96	4.31 ± 1.89	NS (t_{10} = 0.98)
Abundance[2] **(# Individual Sparrows)**	2.85 ± 2.80	3.61 ± 1.49	NS (t_{10} = -0.42)

[1] Paired t-test, analysis done on [2] normal log transformed data

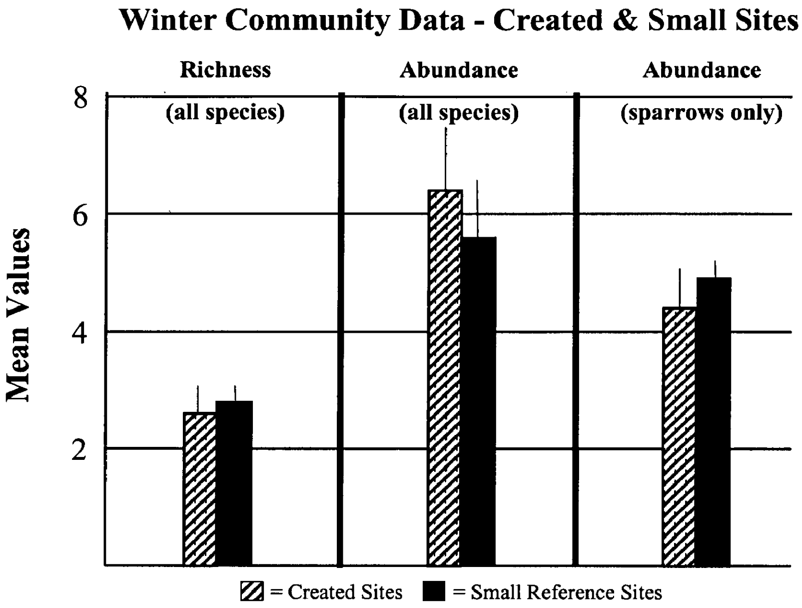


Figure 7. Winter avian community data for created sites and their matched small references. Bars represent standard errors.

Table 36. Comparison of overall avian richness and abundance and sparrow abundance, on created sites and their matched large reference sites.

Category	**Created**	**Lg. Ref.**	**P Value[1]**
Species Richness[2] (# All Species)	2.53 ± 1.83	1.70 ± 1.23	NS ($t_{10} = 1.00$)
Abundance[2] (# All Individuals)	5.86 ± 6.96	2.32 ± 1.61	NS ($t_{10} = 1.18$)
Abundance[2] (# Individual Sparrows)	2.85 ± 2.80	1.45 ± 1.71	NS ($t_{10} = -0.89$)

[1] Paired t-test, analysis done on [2] natural log transformed data

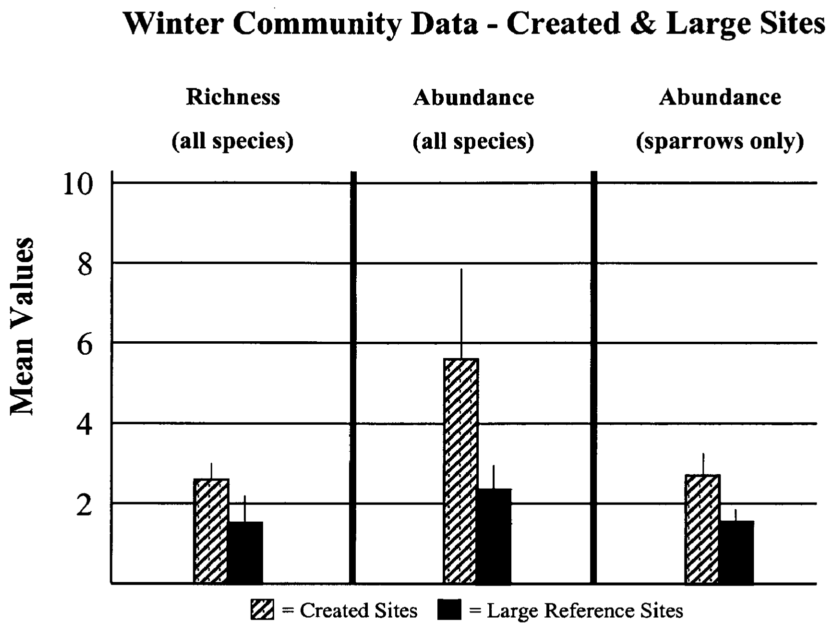


Figure 8. Winter avian community data for created sites and their matched large references. Bars represent standard errors.

CHAPTER 4

SITE USE BY RAILS

Methods:

Site Use by Rails:

I ranked each site with regard to how Clapper Rails used it. Sites were classified on a 5-point scale (Table 37), and were then compared across treatments.

Table 37. Ranking criteria for site suitability for rails.

Criterion	**Rank**
Nested and detected during a winter survey.	5
Nested but not detected in winter	4
No nesting attempt detected but present during both seasons	3
No nesting attempt detected; present only during summer	2
No nesting attempt detected; present only during winter	1
Never detected	0

Results:

Rail ranks were highest on large references, slightly lower on created sites, and lowest on small references. However, site suitability ranks did not differ significantly between created sites and either reference treatments (Table 38-39, Figure 9).

Table 38. Comparison of rail usage rankings on created sites and their matched small reference sites.

Category	Created	Sm. Ref.	P Value[1]
Site Usage Rank	1.77 ± 1.79	1.59 ± 1.43	NS (Z = -0.34)

[1] Wilcoxon signed-rank test

Table 39: Comparison of rail usage rankings between created sites and their matched large references.

Category	Created	Lg. Ref.	P Value[1]
Site Usage Rank	1.77 ± 1.79	1.91 ± 1.51	NS (Z = -0.03)

[1] Wilcoxon signed-rank test

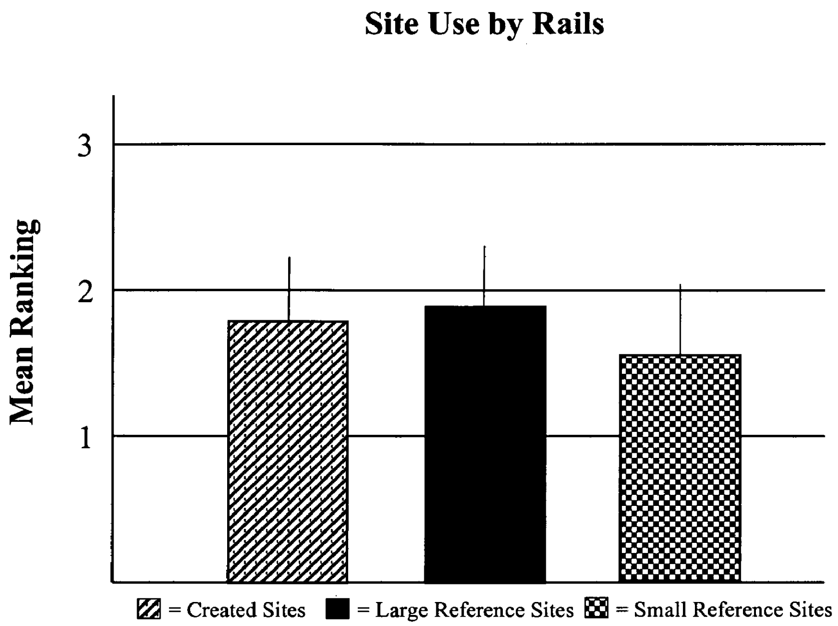


Figure 9. Rail use of created sites and their matched small and large references. Bars represent standard errors.

CHAPTER 5

PLANT COMMUNITIES

Methods:

Summer:

To determine which plant species were present at each site, so that I could potentially explain any differences detected in the avian communities, I used the line-intercept method to survey vegetation (Brower and Zar 1977). Two perpendicular 100-m transects were centered on each circular plot used for bird censusing. If transects extended beyond the marsh border, measurements ended at the marsh edge. I recorded the distances over which each species or combination of species occurred along each transect then calculated percent cover for several different groups of species classified by height: shrubs, tall, medium, and short (Appendix III). I then compared the mean percentage covered by each height class between created sites and both types of references. I also calculated and compared species richness, Shannon-Weiner diversity, percent cover of Phragmites, and percent unvegetated.

Red-winged Blackbird Nest Sites:

In order to determine what types of vegetation Red-winged Blackbirds were selecting for their nest sites, I surveyed nest site vegetation using the line-intercept method as mentioned above. However, the two perpendicular transects were 10-m long instead of 100-m. Vegetation cover was recorded as before, and total percent covers of each species were calculated to determine total percent cover for shrubs, tall, medium, and short vegetation. Total cover of Phragmites was also determined.

To determine if certain vegetation types were important to the Red-winged Blackbirds I performed a use-availability analysis. The average percent cover of each group of plants in which the birds nested (shrubs + tall vegetation, isolated shrubs, shrubs surrounded by tall vegetation, and medium vegetation) and the total percent cover of plants available from these categories in which the birds could potentially nest were used in this analysis (see Appendix V for equation). Positive results indicate that the birds were selecting vegetation more so than expected from its abundance, and negative values indicate that birds were avoiding that vegetation.

Winter:

During the 2002 (i.e., second) sparrow survey I also examined the vegetation from which sparrows were flushed in order to determine if there was a difference between created and references sites. To do this, I centered a 0.25 m^2 quadrat over the point where each bird was flushed during a survey. If a flock of individuals was flushed, then the quadrat was centered over the general area from which they were seen leaving and measurements were taken at one quadrat per 10 birds. I recorded the percent cover of the total vegetation within each quadrat as well as the percent unvegetated and the percent cover of each plant species. Initially, Smooth Cord Grass (*Spartina alterniflora*) appeared to comprise most of the vegetation observed in the quadrats. As a result, I decided to compare the percent cover of Smooth Cord Grass recorded in the quadrats between created sites and both references in addition to comparing the total percent cover of all vegetation. To determine mean height of the vegetation in the plot, I measured plant heights in 10 locations: two measurements in the center, four at the corners, and one between each of the corners going around the edge of the quadrat. Mean height of vegetation was then compared between created and reference treatments.

Results:

Summer:

The plant communities on created sites differed significantly from those on both the small and large reference sites in many ways. Plant diversity was lowest on the created sites, intermediate on the small references, and highest on large reference sites, with all differences being significant (Table 40-41). Richness was also significantly lower on created sites than on large references but did not differ between the created and small reference sites (Table 40-41, Figure 10). Percent cover of Phragmites also did not differ between created and small reference sites (Table 40), but this species, widely regarded as a nuisance (e.g. Chambers *et al.* 1999) covered a significantly lower percentage of the large reference marshes. Created sites had significantly more medium height plant cover than small and large references at the expense of low-growing species that were fairly common on the references such as Spike Grass (*Distichlis spicata)*, Salt Hay Grass (*Spartina patens*), and Olney Three-square (*Scirpus americana*) (Table 40-41, Figure 11). Created sites had significantly less cover of low vegetation than small and large references (Table 40-41, Figure 12). Smooth Cord Grass on created sites constituted approximately 95% of the vegetation cover of medium height plants at the expense of the four other plants detected in the category. The amount of shrub cover (isolated or surrounded by tall vegetation) or tall vegetation did not differ significantly between created and small references. Amount of tall vegetation did not differ significantly between created sites and the large references, but there was significantly more shrub cover in created sites (Table 41). Finally, the amount of unvegetated area did not differ between created sites and either reference (Table 40-41). All plant species observed on surveys are listed in Appendix V.

Red-winged Blackbird Nest Sites:

Vegetation data were recorded from 170 nests (created: n = 54, small references: n = 44, and large references: n = 72). Most nests (66%) were located directly in shrubs and these were disproportionately preferred (Table 42). An additional 19% of the nests were located in tall vegetation, which was also disproportionately preferred. Only 15% of the nests were in medium vegetation, and this cover type was actively avoided.

Table 40. Comparison of vegetation data on created sites and their matched small references.

Category	**Created**	**Sm. Ref.**	**P Value**
Diversity:			
Shannon-Weiner	0.71 ± 0.56	1.31 ± 0.50	$P < 0.05^1$ ($t_{10} = -2.42$)
Species Richness (Species/Site)	4.09 ± 1.97	5.73 ± 2.82	NS^1 ($t_{10} = -1.72$)
Percent Cover:			
Phragmites	7.18 ± 11.29	9.34 ± 19.56	NS^2 ($Z = -0.43$)
Height Classes:			
Shrub	1.77 ± 2.30	2.62 ± 4.28	NS^1 ($t_{10} = -0.19$)
Tall[3]	8.59 ± 13.72	12.59 ± 19.20	NS^1 ($t_{10} = -0.37$)
Medium	63.12 ± 24.52	35.38 ± 18.28	$P < 0.05^1$ ($t_{10} = 3.34$)
Short	8.97 ± 12.99	27.38 ± 18.75	$P < 0.05^2$ ($Z = 2.07$)
Unvegetated	17.25 ± 11.70	20.13 ± 12.62	NS^1 ($t_{10} = -0.86$)

[1] Paired t-test, [2] Wilcoxon signed-rank test, analysis done on [3] common log transformed data

Table 41. Comparison of vegetation data on created sites and their matched large references.

Category	**Created**	**Lg. Ref.**	**P Value**
Diversity:			
Shannon-Weiner	0.71 ± 0.56	1.40 ± 0.22	$P < 0.05^1$ ($t_{10} = -3.57$)
Species Richness (Species/Site)	4.09 ± 1.97	7.99 ± 2.34	$P < 0.0001^1$ ($t_{10} = -8.89$)
<u>Percent Cover</u> :			
Phragmites	7.18 ± 11.29	0.39 ± 0.72	$P < 0.005^2$ ($Z = 2.92$)
<u>Height Classes</u>:			
Shrub	1.77 ± 2.30	0.14 ± 0.20	$P < 0.01^1$ ($t_{10} = 3.94$)
Tall^3	8.59 ± 13.72	9.83 ± 12.77	NS^1 ($t_{10} = -0.15$)
Medium	63.12 ± 24.52	37.65 ± 15.25	$P < 0.01^1$ ($t_{10} = 3.35$)
Short	8.97 ± 12.99	17.60 ± 11.06	$P < 0.05^2$ ($Z = 2.37$)
Unvegetated	17.25 ± 11.70	22.52 ± 14.66	NS^1 ($t_{10} = -1.01$)

[1] Paired t-test, [2] Wilcoxon signed-rank test, analysis done on [3] common log transformed data

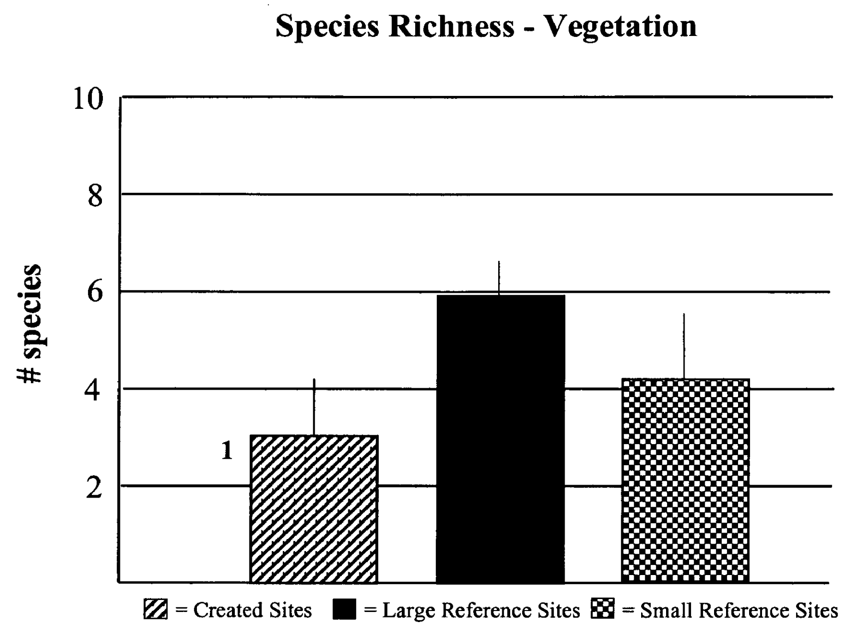


Figure 10. Species richness of vegetation on created sites and their matched small and large references. [1]Value is significantly lower than for large references. Bars represent

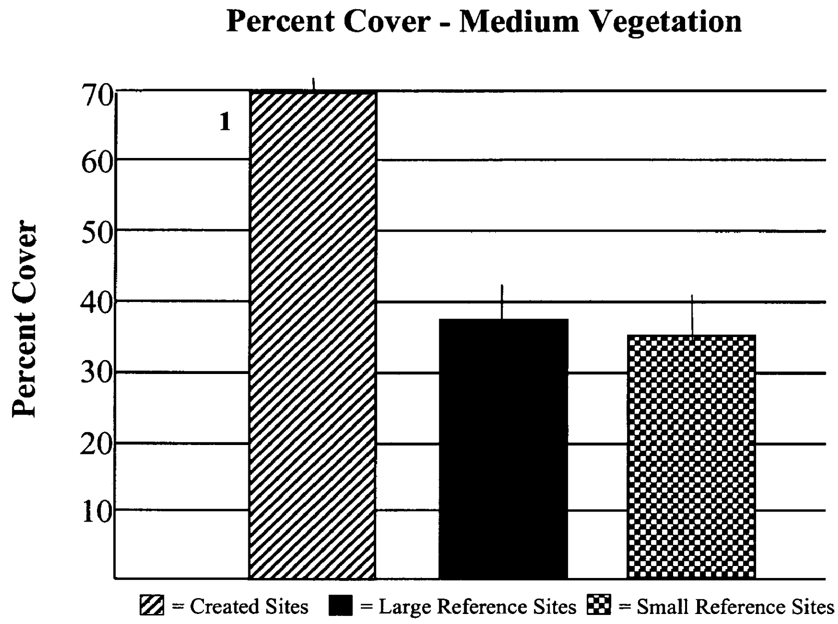


Figure 11. Percent cover of medium vegetation in created sites and their matched small and large references. Value is significantly higher than for both small and large references. Bars represent standard errors.

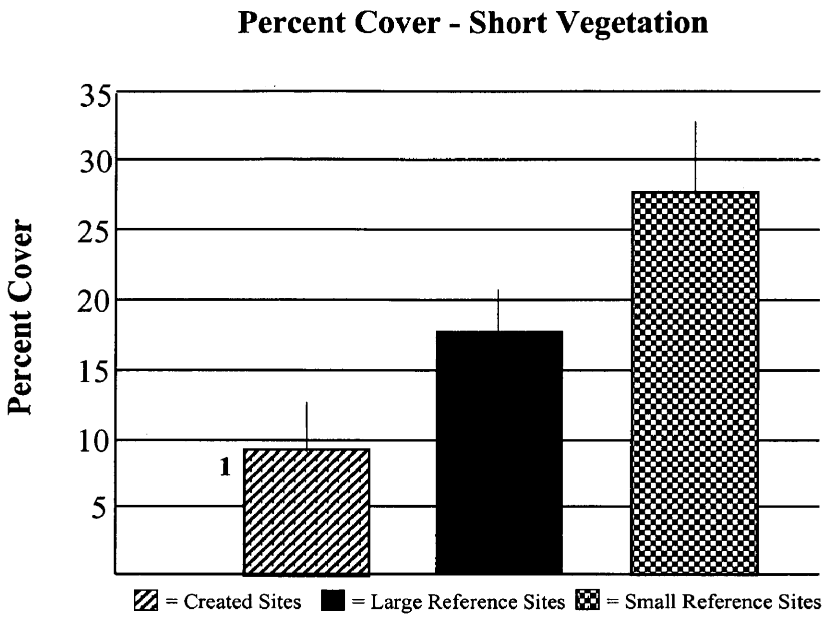


Figure 12. Percent cover of low vegetation in created sites and their matched small and large references. Value is significantly lower than for <u>both</u> small and large references. Bars represent standard errors.

Winter:

Vegetation from 110 quadrats was surveyed during the 2002 winter survey (Created: n = 38, small references: n = 51, large references: n = 21). Percent cover of *Spartina alterniflora* recorded from quadrats on created sites was almost twice the amount observed in the small references (Table 43). The percent cover of all vegetation and mean height of the vegetation did not differ significantly between these two treatments (Table 43). The same pattern was observed between created sites and the large references except that percent cover of Smooth Cord Grass was, on average, three times higher on the created sites than on the large references. Mean vegetation height was also significantly higher in the created sites than the large references (Table 44).

Table 42. Use-availability data for Red-winged Blackbird nests on created sites and their matched small and large references.

Nest	Created	Sm. Ref.	Lg. Ref.
Shrubs surrounded by tall vegetation	0.70[1]	0.56	0.62
Isolated shrubs	0.79	0.04	0.98
Medium Vegetation	-0.63	-0.14	-0.26
Tall Vegeation	0.67	0.40	0.51
Phragmites	0.60	0.45	0.92

[1] Positive numbers indicate preference, negative numbers indicate active avoidance

Table 43. Comparison of winter vegetation used by sparrows on created sites and their matched small references.

Category	**Created**	**Sm. Ref.**	**P Value**
Percent Cover ***Sp. alterniflora***	73.08 ± 41.60	44.67 ± 41.49	$P < 0.01$[1] ($Z = 3.21$)
Percent Cover Total Vegetation	74.21 ± 20.48	79.02 ± 20.40	NS[1] ($Z = -1.03$)
Mean Vegetation Height (m)	0.92 ± 0.32	0.92 ± 0.33	NS[2] ($t_{87} = 0.003$)

[1] Wilcoxon signed-rank test, [2] t-test

Table 44: Comparison of winter vegetation used by sparrows on created sites and their matched large references.

Category	**Created**	**Lg. Ref.**	**P Value**
Percent Cover ***Sp. alterniflora***	73.08 ± 41.60	25.71 ± 38.58	$P < 0.001$[1] ($Z = -4.17$
Percent Cover Total Vegetation	74.21 ± 20.48	69.05 ± 27.73	NS[1] ($Z = -0.38$)
Mean Vegetation Height (m)	0.92 ± 0.32	0.72 ± 0.35	$P < 0.05$[2] ($t_{57} = -2.21$

[1] Wilcoxon signed-rank test, [2] t-test

Discussion

I compared the bird communities of created and natural reference wetlands to determine how successful wetland mitigation is in replacing avian communities lost to development. I surveyed both breeding and wintering birds on 11 created and 22 natural wetlands. I also compared productivity of Red-winged Blackbirds and use by Clapper Rails.

Breeding Bird Surveys:

Created versus Small Reference Sites

During the summers of 2001 and 2002, I compared the breeding bird communities on 11 created tidal wetlands with those on 11 carefully matched, natural reference wetlands of the same size, shape, and surrounding land use to determine if mitigated wetlands successfully replaced breeding bird communities. Created sites supported fewer species, fewer individuals, and a less diverse community than the matched reference sites. The presence of a disproportionately large number of individuals of several species, notably Red-winged Blackbirds and Barn Swallows, contributed to the lower diversity on created sites.

Richness, abundance, and diversity of "true marsh" species, those seen using the marsh proper, were also lower on the created sites when compared with the matched references. These differences were also driving the overall community results because when the community was divided into "true marsh" and "edge" species there were no significant differences for "edge" species. The types of "true marsh" species on created sites differed from those on the small references. The Jaccard similarity index revealed that created sites were approximately 60% similar to the small references which indicates that created sites only support a fraction of the potential suite of bird species typical of a natural wetland.

I also compared how different foraging guilds were supported on the created and small reference sites. Abundance of aerial insectivores differed between created and small references, with more insectivores being observed on the reference sites. Greater numbers of Purple Martins and Northern Rough-winged Swallows on the small references contributed to this difference. Ground foragers did not differ between these treatments, nor did abundance of Red-winged Blackbirds.

It is unlikely that one factor could be driving all of these differences, so I present several possible explanations. A difference in plant diversity is an obvious place to look for an explanation, but I found only equivocal evidence supporting this conclusion. The low diversity and paucity of plant species on created sites would serve to reduce habitat heterogeneity, and since most tidal marsh plant species form large monocultures, this further reduces the number of microhabitats available for nesting, foraging, or roosting. Reduction in the number of niches available for insects could also impact the insectivorous birds such as Marsh Wrens and sparrows. The decrease in insect habitats, or suitable perches from which to hunt insects, could also drive the differences detected in aerial insectivore abundance. However, since there was no difference in the number of plant species between the created sites and small references niche availability may not differ between these treatments.

Multivariate analysis revealed that a site's treatment (whether it was created, a small reference, or a large reference) was the most important variable for explaining variation in the richness, abundance, and diversity of "true marsh" species. The amount of upland edge and disturbed upland habitat additionally affected "true marsh" species richness. Abundance was additionally affected by undisturbed forest. Diversity was affected by marsh area. While these additional variables are important to consider in designing better wetlands, the overwhelming importance of treatment indicates that created wetlands are fundamentally different than natural wetlands of two types, in particular, they do not support as many birds of as many species. This suggests that replacing birds of destroyed wetlands will require improved technology or disproportionately larger created wetlands.

While sites were matched for proportion of surrounding land uses, they were not matched for intensity of use. Six of the created sites were in areas of heavy human use and possessed little to no buffer habitat against the surrounding activity. Such a landscape position could hinder bird use of these created sites. Raccoons, cats, and crows – known avian predators – are common in areas with a lot of human activity. I observed predators quite regularly on my sites, and predation of Red-winged Blackbird nests during the incubation period was more common on created sites – 43% of all nests versus 23% loss on the small references. The nests of other species common in my study, such as Clapper Rail, were also frequently destroyed by predators, but smaller sample sizes prevented a formal comparison of productivity.

Age of the created sites is another possible explanation for the differences in the bird communities. The created sites are fairly young – less than 20 years in age. It is possible that the sites are not functionally mature enough to support bird or plant communities that are comparable to those on natural wetlands. At some mitigated wetlands species richness of breeding birds increased with the age (e.g. VanRees-Siewart and Dinsmore 1996), but evidence to the contrary has also been reported (Hemesath and Dinsmore 1993). Unfortunately, most of my sites are clustered around 15 years old, preventing any useful statistical analysis of age effects. Long-term monitoring could show that the created sites eventually reach equivalency with natural references, some of which have probably been around for many centuries.

Created and matched small reference marshes did not differ significantly in terms of diversity or richness of aerial insectivores, abundance, diversity, or richness of ground foragers, or abundance of Red-winged Blackbirds. However, it is important to note *that the created sites had lower mean values for every one of these comparisons*. This suggests that with a larger sample size, and concomitantly greater statistical power, I would have found differences for many other variables, rendering the apparent deficiency of created wetlands even more severe. In fact, the only variable for which created sites had higher (but still not statistically different) mean values were for those involving "edge" species that do not generally use saltmarshes. These results indicate that created wetlands are failing to replace the bird communities typical of natural wetlands. Simple 1:1 mitigation of destroyed wetlands with created wetlands is insufficient to replace lost ecological functions. Even if every acre destroyed is replaced with a created wetlands, it is likely that there will be a decline in saltmarsh bird populations in Southeast Virginia. In fact, most destroyed acres of tidal wetlands in Virginia are not compensated in any way (Duhring 2003).

Created versus Large Reference Sites

In 2002, I surveyed 11 demarcated sections of large, pristine marshes that were equal in size and shape to one of the created sites. I did this because I hypothesized they would better represent natural marshes that were typically destroyed. I had found that the small matched references exhibited the same high level of disturbance as the created sites, as was evident from the similar presence of Phragmites. Thus, small references were not truly representative of pristine saltmarshes. I compared the same avian community variables measured on the created sites with those on the equal-sized portions of larger, more pristine marshes. Created sites did not differ significantly from the large reference marshes for any of the avian variables compared. For 17 variables of the 21 compared, large marshes were intermediate between created marshes and small reference marshes. The large references had mean values that were slightly (but not statistically) higher than created sites for all 21 variables except "edge" species richness and diversity. The results were unexpected since I had predicted that the more pristine sites would support more species at higher abundance and with better nesting success. This resulting lack of difference between the created sites and large references is particularly surprising because the plant communities differed dramatically between created and large marshes, while they did not between created and small reference sites. Large references had more plant species and higher plant diversity, with virtually no invasion by Phragmites. This suggests that differences in plant communities that I measured do not fully explain the poor performance of created sites, because if they did, then the birds of larger references would have differed from those of created sites even more than the small reference sites. Despite the lack of significant differences between created sites and the large references in terms of diversity, richness, and abundance of the bird communities, created sites did differ from the large references in terms of the types of "true marsh" species being supported. This is evidenced by both the low value of the Jaccard similarity index (created sites were 42% similar to large references) and the greater Euclidean distance between these two treatments (4.15 ± 0.85) in contrast to that between the created and small reference sites (3.89 ± 0.49). As a result, created sites cannot be said to fully replace the breeding bird communities of large, pristine natural marshes, despite the lack of statistical differences in many of my comparisons.

Large reference sites, because they were demarcated out of much bigger saltmarshes (i.e. edge on one border instead of four) necessarily had less edge than created or small reference marshes. Created and small reference sites had five and four times more upland edge circumference, respectively, than the large references.

Counterintuitively, it is the difference in amount of edge habitat that may have caused the created and large reference sites to appear similar in terms of the birds that they support. Most of the species in this study nested in shrubs, which are most commonly found at the edges of saltmarshes. Because created sites had proportionately more edge than the portions of larger reference sites I demarcated, they may have supported more nesting pairs per sampling circle. Thus, even though large marshes may have offered better habitat on a per site basis, the sample I took probably underrepresented their diversity by including a high proportion of the shrubless interior. In addition, the created sites were typically surrounded by thin fragments of habitat such as woods or residential area and usually had a very narrow tidal connection with the surrounding estuary. The isolation of these sites may have concentrated birds during surveys, making them easier to detect. Thus, lack of significant differences between created and larger pristine marshes, while surprising and worthy of follow-up research, could be an artifact of differences in survey efficiency and proportion of edge, and thus is not as reliable a result as the comparison of created sites to closely matched small references.

Species of Conservation Concern:

If birds on created wetlands are less dependent upon wetland habitat, exhibit a wider range of habitat preferences, feed lower on the food web, have less of a migratory lifestyle, or have more stable populations along the mid-Atlantic coast, then created marshes have less value than natural marshes as part of wildlife conservation strategies. I found that mean rankings in these categories were significantly lower on the created sites than on small references, except for population status. There were no differences, in terms of these ecological rankings between created sites and large references. However, all mean rankings tended to be higher on the large sites, including population status. Thus, species that are most likely to be declining now and in the future (habitat specialists, predators, and Neotropical migrants) are less likely to inhabit created wetlands than natural wetlands of the same size, and there is a trend in the same direction when comparing created and large references.

For species officially listed in Virginia as being of conservation concern, such as the Bald Eagle, no statistical analysis was possible because I encountered so few during point counts. However, I did note if species were present at a site at any time during my visits. Using these less rigorous data I detected fewer species of conservation concern on created sites than on the small references. I observed Bald Eagles at two small references in 2001 and at three sites in 2002. No Bald Eagles were present at any created site either year. Interestingly, Bald Eagles were also absent from large marshes. Additionally, Yellow-crowned Night-Heron, another species of concern, was rare on created sites: two encounters in 2001 and three in 2002. In contrast, Yellow-crowned Night-Herons were present at four small reference sites both years and nested at one site in 2002. As with the Bald Eagle, the night-heron was entirely absent from the large reference sites. Least Terns were present on one created site and one small reference in 2001 and one large reference in 2002. A Gull-billed Tern was seen at one small reference in 2001, and a Little Blue Heron was seen flying by one small reference in 2002. Tri-colored Heron, and Glossy Ibis were not seen at any sites during the duration of the project. However, Great Egrets were equally common on both types of treatments in both years (Created: 2001 – 5 sites, 2002 – 6 sites; Small reference: 2001 – 8 sites, 2002 – 4 sites) and were seen on five of the 11 large references in 2002. This analysis suggests that created sites might provide suitable habitat for a few species of concern, but may support less of them than natural sites.

Productivity:

Created versus Small References Sites

I compared the number of active nesting territories and the number of both breeding and unmated territorial males in order to determine a general level of breeding success on created wetlands. Interestingly, created sites tended to have slightly more active nesting territories and breeding territorial males than the small references, but these differences were not significant. The number of unmated territorial males also did not differ between these two treatments.

Productivity of Red-winged Blackbirds was generally higher on small natural marshes where there was a 64% probability of a nest surviving through incubation (52% on large references), a 77% probability of surviving through the nestling stage (61 % on large references), and a 49% chance of fledging young (32% on large references). In contrast, eggs on created sites had a 34% chance of surviving incubation, a 71% chance of surviving the nestling stage, and a 25% chance of fledging young. These values are consistent with Dyer *et al.* (1977). Despite apparent differences during incubation, the probabilities of a nest surviving through each period on a small reference site were not significantly different from those on a created site. The high variance between nests may explain the failure to find statistical differences despite twice as much predation of eggs. No differences were detected between large references and created sites either. Predation was common on the created sites and is likely responsible for the low success rate of nests during incubation; however, exact cause of nest failure was often unknown. The lack of differences after hatching suggests that created sites provide sufficient resources to raise young such as food. A lack of significant difference between the created sites and small references in terms of young fledged per female or per male territory further supports this hypothesis.

I also compared total breeding success of Red-winged Blackbirds between created sites and both small and large references using a breeding success index that took into consideration whether a male found a mate, whether the mate nested, how many eggs she laid, whether any young were fledged, and whether the pair re-nested. The created sites had significantly lower breeding success index values than the large references but not the small references. This indicates that even for this common, adaptable species these sites do not support comparable levels of breeding success. I conclude that it is unlikely that the created sites adequately support more specialized and disturbance-sensitive wetland birds such as Clapper Rails and Marsh Wrens.

Red-winged Blackbird Nesting:

Red-winged Blackbirds nested in shrubs 66% of the time, and this type of vegetation is disproportionately favored for their breeding. Blackbirds also nested frequently in tall vegetation such as Rough Cord Grass (*Spartina cynusoroides*) and Phragmites. Additionally, they actively avoided nesting in medium vegetation such as Smooth Cord Grass and Black Needle Rush and only did so in the absence of more preferred nesting substrate. This was evident in several sites that were depauperate of shrubs.

Winter Bird Communities:

Created versus Small Reference Sites

In order to determine if created wetlands could support bird communities comparable to those on natural wetlands throughout the year, I conducted surveys of migrating shorebirds and waterfowl, winter blackbird roosts, and communities of birds that overwinter in coastal tidal marshes. There was no shorebird use or blackbird roosts detected. However, I was able to collect sufficient data for a comparison of the resident winter communities.

Created sites did not differ significantly from small references in terms of the number of species or individuals of all species or the number of sparrows. Typically, a site, regardless of treatment, would only support a few individuals of one or two species during a survey (mean = 0.61 ± 0.95 individuals per species). There were also no obvious differences in the types of species observed. In 2001, four species out of 14 total were detected on only one treatment, and in 2002, two species out of 11 were detected on only one treatment. Thus, similarity between created and small references was high. This suggests that created sites function as well as small, equal-sized sites in terms of supporting winter bird communities.

Created versus Large Reference Sites

Created sites also did not differ from the large sites for the three variables of the winter communities that I compared. The lack of statistical difference between these two treatments further suggests that created sites adequately replace wintering bird communities of natural wetlands, especially sparrow species since these were, by far, the most abundant type of bird present during the winter and made up 72% of all detections.

One reason for the lack of statistical differences may be that abundant winter birds such as Swamp and Song Sparrow, that are not saltmarsh obligate species, may lack a preferential response to saltmarsh conditions such as differences in the plant communities. Winter birds may also have less specific habitat requirements during the non-breeding season than they do during breeding. That is, habitat that may be unsuitable during the summer might become more suitable during the winter, and thus, the composition of the plant communities apparently does not affect the winter bird communities.

Vegetation Use by wintering sparrows:

In addition to surveying the winter communities of my study sites, I recorded data on the vegetation from which by wintering sparrows were flushed to determine if the birds were using different areas of created sites versus the references. I recorded information from 0.25 m^2 plots on vegetation height and vegetation cover and found that sparrows in created sites used microhabitat with significantly more Smooth Cord Grass cover than in microhabitat from either type of reference. This is likely an artifact of the created sites having significantly more medium-height vegetation cover, dominated by Smooth Cord Grass, than the small and large references. Additionally, when compared to large reference sites, sparrows in created sites used microhabitat that had significantly taller vegetation. This is likely a result from the greater abundance of medium height vegetation in the created sites and consequent lack of low vegetation. Since I did not find any statistical differences in terms of sparrow abundance, it is unlikely that the differing use of vegetation, although slight, visibly impacts this community in major ways. Further study with larger sample sizes would be needed to state this with confidence.

Site Use by Rails:

Since Clapper Rails were the most abundant obligate saltmarsh species detected during the two years, I scored each site based on the degree of rail use and compared these ranks between treatments. Sites where rails nested and also occurred during the winter ranked highest. Sites where rails were never detected ranked lowest. There was no difference between created sites and either small or large reference sites in degree of rail use. Despite the cryptic behavior of rails, I am confident in this comparison since I meticulously searched each site both years for rail nests, and the winter surveys with the flush line covered, on average, 55% of each site's area, including most of the non-shrubby vegetation that rails favor. All of this suggests that created sites are able to support rails just as well as natural tidal wetlands. This is encouraging because Clapper Rails are so highly dependent upon this type of habitat and are of moderate conservation concern.

Phragmites:

Phragmites was a significant component of the plant communities on most of the small sites. Since there was no significant difference in the amount of this species present between the created and small references, it most likely did not explain our results. Interestingly, the small references had a slightly higher mean coverage by this plant but still retained higher mean values for most avian variables. The amount of Phragmites was significantly higher on the created sites than the large references, but did not cause any detectable differences in bird communities. If Phragmites is affecting bird communities, then it is in a more subtle way than I was able to uncover. Anecdotally, I noted that when shrubs were not available, several species readily built nests in Phragmites, including Red-winged Blackbird and Marsh Wren.

Conclusions

Censusing birds on 11 created tidal wetlands over two years in southeastern Virginia allowed me to evaluate the success of wetland creation in terms of replacing one of the many functions of wetlands – supporting bird communities. While the mitigation sites attracted numerous birds, many aspects of the expected avian communities were not fully realized on these human-created wetlands – at last when compared to small natural wetlands of the same shape and size. Most notably, there were fewer individuals and fewer species, and this effect was limited to species that use the marsh vegetation rather than the edge. Created sites also had fewer species that were highly dependent on wetlands, highly specialized in terms of habitat, high on the food chain, or long distance migrants. Also, the means for total Red-winged Blackbird productivity were much lower on created sites than on small reference sites, although the differences were not significant.

Surprisingly, the birds of equal-sized portions of large, undisturbed natural marshes did not differ significantly from those on small, created sites, despite large differences in vegetation (particularly Phragmites abundance and the cover of medium and low growing plant species). Because of differences in proportion of edge, and possibly in bird detectability during censuses, data from the large marshes may have been biased.

The deficiencies I found in created marshes are probably due to a combination of factors, but further research is needed to determine what specific variables were responsible. Simple explanations such as lower vegetation diversity, more Phragmites, or differences in surrounding land use were not supported by my analysis. Therefore, I recommend exploring other aspects of wetlands such as where created sites are positioned in the landscape and their connectivity with an estuary, nest site limitations, or deficiencies in fish and insect prey bases. I also recommend a direct comparison between created and restored wetlands in order to determine which is the most effective method of mitigation. This has the potential to increase the success of future wetland mitigation in replacing one of the myriad important functions of wetlands – supporting healthy native bird communities.

APPENDIX I: Number of sites on which each species was detected

"True marsh" birds detected during the breeding season: 2001 & 2002

# of sites - detected during point counts
# of sites on which detected during all visits

Species	Created (2001/2002)	Sm Ref (2001/2002)	Lg Ref (2002)
Great Blue Heron (*Ardea herodias*)	0/1	1/0	0
	5/2	7/1	7
Great Egret (*Ardea alba*)	0/0	0/0	0
	5/6	8/4	5
Green Heron (*Butoroides virescens*)	1/1	1/3	0
	2/3(1)	4/6	0
Yellow-crowned Night-Heron (*Nyctanassa violacea*)	1/1	2/3	0
	2/3	4/4(2)	0
Turkey Vulture (*Carthartes aura*)	0/0	0/1	0
	0/4	0/2	2
Canada Goose (*Branta canadensis*)	0/0	0/0	0
	1/2(1)	2/2(1,2)	4
Wood Duck (*Aix sponsa*)	0/0	1/1	0
	0/0	1/1	1
Mallard (*Anas platyrhynchos*)	1/0	2/1	0
	3/4(1)	5/5	1
Osprey (*Pandion haliaetus*)	0/0	2/4	2
	2/3	3/7	6
Bald Eagle (*Haliaeetus leucocephalis*)	0/0	2/0	0
	0/0	2/3	0
Sharp-shinned Hawk (*Accipiter striatus*)	0/1	0/0	0
	1/1	0/0	0

Species	Created (2001/2002)	Sm Ref (2001/2002)	Lg Ref (2002)
Red-tailed Hawk (*Buteo jamaicensis*)	0/0	0/0	1
	0/3	1/1	5
American Kestrel (*Falco sparverius*)	0/0	0/0	1
	0/0	0/0	2
Clapper Rail (*Rallus longirostris*)	3/1	5/3	2
	5/6(1,2)	5/4(1,2)	7(2)
Willet (*Catoptrophorus semipalmatus*)	1/0	1/1	2
	1/0	1/1	2
Royal Tern (*Sterna maxima*)	0/0	0/0	1
	0/0	0/0	1
Common Tern (*Sterna hirundo*)	0/0	1/0	0
	0/2	1/0	0
Least Tern (*Sterna antillarum*)	1/0	1/0	1
	1/2	1/1	1
Black Skimmer (*Rhynchops niger*)	1/1	1/1	0
	2/1	1/2	1
Chimney Swift (*Chaetura pelagica*)	3/5	8/5	3
	5/5	8/5	3
Belted Kingfisher (*Ceryle alcyon*)	0/1	0/0	0
	0/2	1/1	1
Eastern Kingbird (*Tyrannus tyrannus*)	0/2	3/0	2
	2/3	4/2	2
Purple Martin (*Progne subis*)	3/2	5/3	6
	3/4	7/3	8
Tree Swallow (*Tachycineta bicolor*)	0/0	0/1	1
	0/0	1/1	1
Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)	0/3	4/4	2
	0/4	5/4(1,2)	2

Species	Created (2001/2002)	Sm Ref (2001/2002)	Lg Ref (2002)
Barn Swallow (*Hirundo rustica*)	8/8	9/7	8
	9/8	10/6	8
Marsh Wren (*Cistothorus palustris*)	0/0	2/1	1
	2/0	2/2(1,2)	2
Common Yellowthroat (*Geothylpis trichas*)	4/2	2/2	3
	8/7	5/4	7
Nelsons's Sharp-tailed Sparrow (*Ammodramus nelsoni*)	0/0	0/1	1
	0/1	0/1	1
Seaside Sparrow (*Ammodramus maritimus*)	0/0	1/1	2
	0/0	2/1	2(2)
Red-winged Blackbird (*Agelaius phoeniceus*)	11/8	11/11	11
	11/9(1,2)	11/11(1,2)	11(2)
Boat-tailed Grackle (*Quiscalus major*)	3/2	3/2	2
	4/3	3/2	2

(1) Nested in 2001

(2) Nested in 2002

"Edge" birds detected during the breeding season: 2001 & 2002

Species	**Created**	**Sm Ref**	**Lg Ref**
	(2001/2002)	(2001/2002)	(2002)
	# of sites detected on during point counts # of sites detected on during all visits		
Mourning Dove (*Zenaida macroura*)	0/0	0/0	0
	0/5	3/6	1
Yellow-billed Cuckoo (*Coccyzus americanus*)	0/0	0/1	0
	0/1	0/1	0
Red-bellied Woodpecker (*Melanerpes carolinus*)	0/1	0/2	1
	5/2	7/4	3
Downy Woodpecker (*Picoides pubescens*)	0/1	0/1	0
	5/6	5/6	1
Northern Flicker (*Colaptes auratus*)	0/0	0/0	1
	1/2	3/1	3$^{(2)}$
Eastern Wood-Pewee (*Contopus virens*)	0/0	1/0	2
	0/1	1/3	8
Acadian Flycatcher (*Empidonax virescens*)	0/0	1/0	1
	0/0	1/0	1
Great Crested Flycatcher (*Myiarchus crinitus*)	0/0	1/0	0
	4/2	6/0	3
White-eyed Vireo (*Vireo griseus*)	0/0	0/0	0
	2/4$^{(2)}$	1/3	2
Yellow-throated Vireo (*Vireo flavifrons*)	0/0	0/0	0
	0/0	1/0	0
Red-eyed Vireo (*Vireo olivaceus*)	0/0	0/0	0
	2/0	2/0	3
Blue Jay (*Cyanocitta cristata*)	0/1	0/0	0
	3/4	8/4	2

Species	Created	Sm Ref	Lg Ref
	(2001/2002)	(2001/2002)	(2002)
American Crow (*Corvus brachyrhynchos*)	0/0	0/0	0
	0/0	2/5	1
Fish Crow (*Corvus ossifragus*)	0/0	0/0	0
	0/1	1/3	2
Carolina Chickadee (*Poecile caronlinensis*)	1/2	1/3	0
	6/5	8/4	4
Tufted Titmouse (*Baeolophus bicolor*)	1/0	1/0	0
	2/1	6/4	3
White-breasted Nuthatch (*Sitta carolinensis*)	0/0	0/0	0
	2/0	1/0	2
Brown-headed Nuthatch (*Sitta pusilla*)	1/0	0/0	3
	1/1	1/3	6
Carolina Wren (*Thyrothorus ludovicianus*)	0/2	1/2	1
	8/5	7/8(2)	4(2)
Blue-gray Gnatcatcher (*Polioptila caerulea*)	0/0	0/1	1
	6/5	8/4	7
Eastern Bluebird (*Sialia sialas*)	1/1	0/0	1
	1/1	0/0	1
American Robin (*Turdus migratorius*)	2/1	2/1	0
	8/8	6/6	1
Gray Catbird (*Dumetella carolinensis*)	4/1	0/0	0
	4/2(2)	3/3	2
Northern Mockingbird (*Mimus polyglottus*)	1/0	2/1	0
	1/2	4/3(2)	0
Brown Thrasher (*Toxostoma rufum*)	0/1	2/1	0
	3/2	4/2	1
European Starling (*Sturnus vulgaris*)	0/1	0/0	0
	2/8	1/3	0

Species	**Created**	**Sm Ref**	**Lg Ref**
	(2001/2002)	(2001/2002)	(2002)
Pine Warbler (*Dendroica pinus*)	1/0	1/1	0
	3/4	4/4	5
Summer Tanager (*Piranga rubra*)	0/0	0/0	1
	0/2	0/0	5
Eastern Towhee (*Pipilo erythrophthalamus*)	0/1	1/0	0
	5/4	3/3	3
Song Sparrow (*Melospiza melodia*)	3/4	0/2	2
	3/4	2/4	2
Northern Cardinal (*Cardinalis cardinalis*)	4/4	3/3	1
	9/7	7/6⁽²⁾	6
Blue Grosbeak (*Guiraca caerulea*)	0/0	0/0	0
	1/2⁽²⁾	0/1	3
Indigo Bunting (*Passerina cyanea*)	2/2	1/0	1
	4/4	1/3	6
Common Grackle (*Quiscalus quiscula*)	2/1	1/2	1
	4/8	5/6	7
Brown-headed Cowbird (*Molothrus ater*)	0/0	1/1	2
	4/4	1/3	4
American Goldfinch (*Carduelis tristis*)	0/0	1/2	0
	0/3	1/5	5
House Sparrow (*Passer domesticus*)	0/0	0/0	0
	1/0	0/0	0

(1) Nested in 2001

(2) Nested in 2002

APPENDIX II: Ecological Ranks for species detected on point counts.

"True marsh" birds detected on point counts – 2001 & 2002

Ranks based on species' accounts from Farrand (1983) and Croonquist and Brooks (1991) – except Priority Scores.

A = **Wetland Dependency**: 0 = occurs in upland > 99% of the time or occasionally observed in wetlands, 1 = wetlands are not essential to the species, 3 = species is usually in or near wetlands, 5 = obligate wetland species

B = **Habitat Specificity**: 1 = occurs in three or more landscapes or one landscape, including urban (urban = 2 landscapes), 3 = occurs in ≥ three habitats in one landscape or two landscapes, 5 = occurs in 1 – 2 habitats in one landscape

C = **Trophic Level**: 1=omnivore, 2=generalist herbivore, 3=specialist herbivore, 4=generalist carnivore, 5=specialist carnivore

D = **Migratory Status**: 0 = sedentary, 2 = some populations migratory and some resident, 4 = medium distance migrant, 5 = Neotropical migrant

E = **Priority Scores (Partners in Flight Data: Mid-Atlantic Coastal Plain physiographic region)**

Assignment of **Foraging Guilds** based on personal experience of observer.

1 = Piscivores, 2 = Aerial Insectivore, 3 = Ground Forager, 4 = Raptor

Species	A	B	C	D	E	Guild
Great Blue Heron	5	3	4	2	15	1
Green Heron	5	1	4	4	17	1
Yellow-crowned Night-heron	5	3	4	5	17	3
Turkey Vulture	0	1	5	2	13	4
Wood Duck	5	3	3	4	16	3
Mallard	5	1	3	2	12	3
Osprey	5	5	5	5	16	1
Bald Eagle	3	5	5	2	16	1
Sharp-shinned Hawk	0	3	5	4	17	4
Red-tailed Hawk	0	1	5	2	12	4
American Kestrel	1	1	4	4	16	4
Clapper Rail	5	5	4	2	23	3
Willet	5	5	4	4	21	3
Royal Tern	5	5	4	4	17	1
Common Tern	5	5	4	5	17	1
Least Tern	5	1	4	5	18	
Black Skimmer	5	3	4	4	22	1
Chimney Swift	0	1	4	5	20	2
Belted Kingfisher	5	3	4	2	17	1
Eastern Kingbird	1	3	4	5	19	2
Purple Martin	0	1	4	5	16	2

Species	A	B	C	D	E	Guild
Tree Swallow	3	1	4	4	14	2
Northern Rough-winged Swallow	1	1	4	5	16	2
Barn Swallow	0	1	4	5	15	2
Marsh Wren	5	3	4	4	21	3
Common Yellowthroat	3	1	4	4	18	3
Nelsons's Sharp-tailed Sparrow		non-breeder				3
Seaside Sparrow	5	5	4	2	26	3
Red-winged Blackbird	3	1	1	2	10	3
Boat-tailed Grackle	3	2	1	2	17	3

"Edge" birds detected on point counts – 2001 & 2002

A = Wetland Dependency
B = Habitat Specificity
C = Trophic Level
D = Migratory Status
E = Priority Scores (Partners in Flight data)

Species	A	B	C	D	E
Red-bellied Woodpecker	1	1	1	0	17
Downy Woodpecker	0	1	4	0	17
Northern Flicker	0	1	1	2	16
Eastern Wood-Pewee	0	3	4	5	21
Acadian Flycatcher	3	5	4	5	21
Great Crested Flycatcher	0	1	4	5	18
Blue Jay	0	1	1	2	15
Carolina Chickadee	0	3	1	0	19
Tufted Titmouse	0	3	1	0	15
Brown-headed Nuthatch	1	5	4	0	23
Carolina Wren	0	3	4	0	16
Blue-gray Gnatcatcher	0	3	4	4	16
Eastern Bluebird	0	3	1	2	15
American Robin	0	1	1	2	11
Gray Catbird	0	1	1	4	20
Northern Mockingbird	0	1	1	0	12
Brown Thrasher	0	1	1	0	20
European Starling	0	1	1	0	12
Pine Warbler	0	3	4	4	19
Summer Tanager	0	3	4	5	17
Eastern Towhee	0	1	1	2	20
Song Sparrow	0	1	2	2	12
Northern Cardinal	0	1	2	0	13
Indigo Bunting	0	3	1	5	16
Common Grackle	1	1	1	1	13
Brown-headed Cowbird	0	1	1	2	11
American Goldfinch	0	1	2	2	12

APPENDIX III: Number of sites on which each species was detected

Species detected during winter surveys: 2001-2002 & 2002-2003

Species	Created	Sm Ref	Lg Ref
	(Year 1/Year 2)	(Year 1/Year 2)	(Year 2)
	# Ind. detected/year		
Yellow-crowned Night Heron (*Nyctanassa violacea*)	1/0	0/0	0
	1/0	0/0	0
Clapper Rail (*Rallus longirostris*)	1/2	3/2	1
	1/2	3/2	1
Virginia Rail (*Rallus limicola*)	1/0	0/0	0
	1/0	0/0	0
Killdeer (*Charadrius vociferus*)	1/0	0/0	0
	1/0	0/0	0
Wilson's Snipe (*Gallinago gallinago*)	3/0	1/1	1
	3/0	1/1	1
Carolina Chickadee (*Poecile caronlinensis*)	0/0	1/0	0
	0/0	1/0	0
Marsh Wren (*Cistothorus palustris*)	1/1	2/2	5
	1/1	2/2	5
Yellow-rumped Warbler (*Dendroica coronata*)	0/1	0/0	0
	0/1	0/0	0
Common Yellowthroat (*Geothylpis trichas*)	1/0	0/0	0
	1/0	0/0	0
Nelsons's Sharp-tailed Sparrow (*Ammodramus nelsoni*)	0/2	0/1	1
	0/2	0/1	1
Saltmarsh Sharp-tailed Sparrow (*Ammodramus caudacutus*)	1/2	0/1	3
	1/2	0/1	5
Seaside Sparrow (*Ammodramus maritimus*)	0/0	0/0	1
	0/0	0/0	1

Species	**Created**	**Sm Ref**	**Lg Ref**
	(Year 1/Year 2)	(Year 1/Year 2)	(Year 2)
	# Ind. detected/year		
Song Sparrow (*Melospiza melodia*)	3/4	6/6	0
	6/4	9/12	0
Swamp Sparrow (*Melospiza georgiana*)	11/8	10/9	5
	54/19	47/22	13
White-throated Sparrow (*Zonotrichia albicolis*)	0/0	1/0	0
	0/0	1/0	0
Red-winged Blackbird (*Agelaius phoeniceus*)	1/4	1/1	1
	1/34	4/3	1
Eastern Meadowlark (*Sturnella magna*)	0/1	0/1	0
	0/1	0/1	0
House Finch (*Carpodacus mexicanus*)	0/0	0/1	0
	0/0	0/1	0

APPENDIX IV: Number of sites on which plant species were detected

Height Class (Species)	# of sites detected on		
	Created	Sm. Ref.	Lg. Ref
Shrub			
Groundsel Tree (*Baccharis halimifolia*)	3	2	0
High-tide Bush (*Iva frutescens*)	8	7	5
Wax Myrtle (*Myrica cerifera*)	1	3	0
Tall			
Common Reed (*Phragmites australis*)	10	8	3
Rough Cord Grass (*Spartina cynusoroides*)	5	7	3
Medium			
Black Needlerush (*Juncus roemonarius*)	1	5	9
Narrow-leaved Cattail (*Typha angustifolia*)	1	1	0
Rose Mallow (*Hibiscus moscheutos*)	0	0	2
Salt Marsh Bulrush (*Scirpus robustus*)	2	5	1
Seashore Mallow (*Kosteletzkya virginica*)	0	0	1
Sedge spp. (*Fimbrystilis?*)	0	1	0
Smooth Cord Grass (*Spartina alterniflora*)	11	11	11
Switch Grass (*Panicum virgatum*)	1	0	0
Water Hemp (*Amaranthus cannabinus*)	0	3	0
Short			
Annual Salt Marsh Fleabane (*Pluchea purpurascens*)	0	0	3
Beaked Spike-rush (*Elocharis rostellata*)	0	2	3
Black Grass (*Juncus gerardii*)	0	0	3
Common Dodder (*Cuscuta gronovii*)	0	1	0
Common Glasswort (*Salicornia europaea*)	0	0	1
Dwarf Spike-rush (*Elocharis parvula*)	0	0	6
Hedge Bindweed (*Calystegia sepium*)	0	2	0
Marsh Orach (*Atriplex patula*)	1	1	0
Olney Three-square (*Scirpus americana*)	0	4	4
Perennial Glasswort (*Salicornia virginica*)	0	0	2
Perennial Salt Marsh Aster (*Aster tenuifolius*)	0	2	5
Pickerel Weed (*Pontederia cordata*)	0	0	1
Salt Hay Grass (*Spartina patens*)	5	9	9
Sea Lavender (*Limonium nashii*)	0	0	3
Seaside Gerardia (*Agalinis maritima*)	0	0	4
Seaside Ox-eye (*Borrichia frutescens*)	0	0	1
Soft-stemmed Bulrush (*Scirpus validus*)	0	0	1
Spike Grass (*Distichlis spicata*)	7	10	10
Swamp Dock (*Rumex verticillatus*)	0	0	1

APPENDIX V: Formulas Used for Productivity Analysis

Daily Survival Rates ($\hat{s}$):

(1) $\hat{s}_{\text{Incubation}} = 1-$ (losses/exposure days [during days 1 through 10])

(2) $\hat{s}_{\text{Nestling}} = 1-$ (losses/exposure days [during days 11 through 22])

Probabilities of Surviving a period:

(3) Probability of Surviving Incubation

$P = \hat{s}_{\text{Incubation}}{}^{n}$

n = length of period, in this case, 11 days for Red-winged Blackbirds.

(4) Probability of Surviving Nestling

$P = \hat{s}_{\text{Nestling}}{}^{n}$

n = length of period, in this case, 10 days.

(5) Probability of Surviving until Fledging (Incubation and nestling periods combined)

$P = [1 - (\text{total losses/total exposure days})]^{n}$

n = length of period, in this case, 21 days.

Z-Score Analysis following Johnson (1979) and Manolis *et al.* (2000).

(6) $| \hat{s}_1 - \hat{s}_2 | / \sqrt{[\text{Variance } (\hat{s}_1) + \text{Variance } (\hat{s}_2)]} > z_{\alpha/2}$

$\hat{s}_1$ = daily survival for period *j* – treatment 1

$\hat{s}_2$ = daily survival for period *j* – treatment 2

Variance ($\hat{s}_1$) = [(exposure days – losses) x losses]/(exposure days)^3 – treatment 1

Variance ($\hat{s}_2$) = [(exposure days – losses) x losses]/(exposure days)^3 – treatment 2

$z_{\alpha/2} = \pm 1.96$

Breeding Success Index (BSI) on a per site basis

(7) BSI = $(P_{\text{mating}})(P_{\text{nesting}})(\#\text{ eggs})(P_{\text{hatching}})(P_{\text{fledging}})(P_{\text{re-nesting}})$

(P_{mating}) = Probability that a male mates

(P_{nesting}) = Probability that the female constructs a nest

(# eggs) = The number of eggs laid

(P_{hatching}) = Probability of surviving incubation

(P_{fledging}) = Probability of fledging

$(P_{\text{re-nesting}})$ = Probability of attempting a second brood

Use-availability analysis equation

(8) I = (Used – Available) / (Used + Available)

I = Importance (negative values indicate that the birds are avoiding this vegetation, positive values indicate that the birds are showing a preference for it)

Used = Average percent cover of vegetation used for nesting

Available = Total percent cover available in which to nest

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David's love of birds began in the first grade when he first discovered the Scarborough Marsh Nature Center. He has returned there each summer to volunteer his time by leading canoe tours and bird walks. He is also a birder and aspires to continue doing avian studies combined with teaching at the collegiate level. His favorite species of bird is the Snowy Egret.