Created *versus* natural wetlands: Avian communities in Virginia salt marshes[1]

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Abstract: Permits to destroy wetlands often require the creation of the same type of wetland elsewhere. An assumption
underlying this practice is that such created wetlands will replace the ecological functions lost when the developed wetland
was destroyed. Part of this ecological function is providing habitat for wildlife, including, in coastal areas, a suite of bird species
tied to salt marshes for some portion of their life cycle. We tested the hypothesis that created wetlands provide habitat for
the avian communities lost when wetlands are destroyed by comparing the breeding and wintering birds on 11 small created
salt marshes with those on 11 natural reference salt marshes that were carefully matched for size and surrounding land cover.
We found that, during the breeding season, created salt marshes had lower avian abundance and richness than reference salt
marshes. In particular, wetland-dependent species were poorly represented on created wetlands. On the other hand, bird use
outside of the breeding season and use by an important salt marsh obligate species, the clapper rail (*Rallus longirostris*), did
not differ. Created wetlands that we surveyed failed to completely replicate the bird and plant communities that we observed
on nearby natural reference salt marshes, raising the question of whether current mitigation policies that encourage wetland
creation should continue without further investigation into the success of such wetlands at recreating wildlife habitat.
Keywords: *Agelaius phoeniceus*, created wetland, mitigation, *Rallus longirostris*, salt marsh.

Résumé : Les permis autorisant la destruction de milieux humides requièrent souvent la création en un autre lieu du même
type de milieu humide. La supposition qui sous-tend cette pratique est que le milieu humide créé remplacera les fonctions
écologiques perdues lors de la destruction d'un milieu humide pour le développement. Un de ces rôles écologiques est de
procurer des habitats à la faune incluant, dans les zones côtières, tout une suite d'espèces d'oiseaux inféodés aux marais salés
pour une partie de leur cycle vital. Nous avons testé l'hypothèse que les milieux humides créés procurent des habitats pour
les communautés aviaires perdues lors de la destruction de milieux humides en comparant les oiseaux nicheurs et en hivernage
dans 11 petits marais créés et 11 marais salés naturels de référence choisis soigneusement pour leur similarité de taille et de
couvert terrestre environnant. Nous avons trouvé que durant la saison de nidification, les marais salés créés supportaient
une moins grande abondance et richesse d'oiseaux que les marais de référence. En particulier, les espèces dépendantes des
milieux humides étaient peu représentées dans ceux créés. Cependant, il n'y avait pas de différence d'utilisation par les
oiseaux en dehors de la saison de nidification ni de fréquentation par le râle gris (*Rallus longirostris*), une espèce inféodée
aux marais salés. Les milieux humides créés ne répliquaient pas complètement les communautés d'oiseaux et de plantes
observées dans les marais salés naturels de référence ce qui soulève la question à savoir si les politiques courantes de mitigation
qui encouragent la création de milieux humides devraient être poursuivies sans une investigation approfondie du succès de
tels milieux humides à recréer des habitats pour la faune.
Mots-clés : *Agelaius phoeniceus*, marais salé, milieu humide créé, mitigation, *Rallus longirostris*.

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Introduction

Coastal wetland loss has long been recognized as a serious ecological problem (Tiner, 1984; Dahl, 1990). Loss of coastal wetland habitat is exacerbated by continuing coastal development (Kennish, 2001), which threatens remaining wetlands and the wildlife that use them, especially poorly studied species such as rails (Eddleman *et al.*, 1988). In the United States, when a permit is issued for wetland destruction, mitigation is often required in the form of creation, restoration, or preservation of a wetland with equal ecological value (US Army Corps of Engineers, 1999). Creation is sometimes favoured because it is the option that most clearly reverses the historical loss of wetland acreage. An assumption behind the requirement of such wetland mitigation is that a created wetland will provide the same ecological services that the destroyed wetland once did. This includes nutrient cycling, flood control and water filtration, and provision of wildlife habitat (Melvin & Webb, 1998). Birds are a visible component of wetland ecosystems that

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are often used as biomonitors because of their position relatively high in the trophic web (Burger *et al.,* 2004; Mallory, 2006). In this study we tested the hypothesis, and implicit assumption in wetland mitigation policy, that created wetlands replicate the avian communities of natural wetlands that they are designed to replace.

We examined the avian communities of 11 created salt marshes in southeastern Virginia, USA. Salt marshes provide foraging and nesting habitat for numerous birds, several of which are obligate species found in no other habitat, such as the seaside sparrow (Post & Greenlaw, 1994) and clapper rail (Eddleman & Conway, 1998; scientific names of birds appear in Appendix I).

In Virginia, where approximately 16% of the wetlands are classified as tidal (totalling 79 010 ha; Hershner *et al.,* 2003), salt marsh destruction and replacement continue to be permitted at a slow but steady rate (data available from http://www.vims.edu/rmap/wetlands/cgi-bin/index.htm). In addition, salt marsh is destroyed unintentionally or illegally without permit or subsequent mitigation. The global sea level rise predicted in coming years will further exacerbate the rate of tidal wetland loss through erosion (Erwin, Sanders & Prosser, 2004) and subsidence (Simas, Nunes & Ferreira, 2001). In the face of continued attrition of natural salt marshes, our objective was to determine if created salt marsh habitat supports the avian community expected for a comparable natural salt marsh.

Methods

STUDY SITES

We included in our study all of the created salt marshes of which we were aware in the portion of the Virginia coastal plain south of the city of Richmond. Breeding bird activity is limited on small sites so we excluded those < 0.4 ha. The created salt marshes were located, on average, 18.0 ± 12.0 km (all means in this paper are $\pm$ SD) from a point in Newport News, Virginia (37º 6' 56" N, 76º 30' 28" W). They had been created, on average, 15 ± 4 y prior to the study (range: 9–20 y) and averaged 2.1 ± 1.1 ha in size (range: 0.4–4.0 ha). Of the 10 salt marshes for which histories were available, all were created by grading and removing upland soil and creating a connection to a tidal creek to allow regular inundation. No soil amendments were used. Plantings consisted of *Spartina alterniflora* alone (*n* = 6 sites), this species plus *S. patens* and *Distichlis spicata* (*n* = 3 sites), or these 3 species plus *S. cynosuroides*, *Juncus roemerianus,* and 3 species of shrubs (*Iva frutescens*, *Baccharis halimfolia*, and *Myrica cerifera*) (*n* = 1 site). The smallest created salt marsh was the subject of a previous study on bird use of created and natural wetlands (Havens, Varnell & Bradshaw, 1995).

For each created salt marsh we pre-selected a carefully matched reference salt marsh because we wanted to determine what avian community would be expected at a wetland like the one it was meant to replace. Using ArcView 3.2, we selected reference salt marshes by choosing for each created salt marsh the closest available natural salt marsh that matched it in size (to 0.1 ha), shape (square or rectangular), and proportion of adjacent land cover types (to

within 15% for each of residential, industrial, forested, agricultural, and wetland). These reference salt marshes were separated from matched created salt marshes by an average of 12.0 ± 14.6 km. All data were obtained in 2001 and 2002.

BIRDS

To sample the breeding bird community of each salt marsh we used fixed-area (50-m radius) circular plot point counts (Bibby, Burgess & Hill, 1992). We visited each salt marsh 3 times during each breeding season: once each during 15 May–3 June, 4–22 June, and 23 June–15 July. This timing ensured that all counts were done after the peak of spring bird migration and before the decline in detectability that occurs at the end of the breeding season. Repeated counts at a salt marsh were separated by at least 10 d, lasted 10 min, and were initiated between 0600 and 0920, when birds are most active. Random placement of sampling circles was not practical because of their large size relative to the salt marshes; instead, we positioned them to allow the maximum number of points per salt marsh (median: 2, range: 1–3). At a few rectangular salt marshes we used semi-circles, but this layout was matched in the corresponding reference salt marshes, such that created salt marshes always had the same number of count circles (or semi-circles) as their reference salt marshes. In addition to point counts we kept a record of all species encountered during our breeding season visits to each salt marsh; these additional data appear in Appendix I but were not used in any of the analyses.

We also compared created salt marshes to paired reference salt marshes in terms of the degree of wetland dependence of the species detected in each type of marsh. Using classifications similar to Croonquist and Brooks (1991) and the species accounts in Ferrand (1983), we ranked each species in terms of degree of wetland dependency (1 = occasional use, 3 = usually in wetlands, 5 = obligate wetland species). For each wetland, we summed the ranks of each separate species detected during all of the bird surveys and then averaged these values for each treatment type.

In 2002 we examined reproductive success in 2 ways. First, using a team of experienced observers we searched for nests of all species for 150 person-min per ha (1 person-min is a person searching for 1 min). During these nest-searching visits we also recorded any breeding behaviour of the birds and classified each male as to whether it was paired (*i.e.,* female seen at least once), nesting (*i.e.,* part of a pair that built a nest), or incubating (*i.e.,* part of a pair that laid a complete clutch of eggs). The salt marshes were small enough that we are confident we found the majority of nests and detected most breeding attempts, even those of the secretive clapper rail. Second, we carried out a study of the breeding success of red-winged blackbirds, the only species that occurred at all sites and one that attempted to breed at the 14 largest marshes. We followed the fate of each nesting attempt through to fledging or failure.

We sampled bird use during the non-breeding season, when salt marsh birds are much harder to detect, by placing a single observer in a position to record all birds flushed by 2 assistants dragging a flush line (25-m-long weighted rope) over each salt marsh (Fletcher, Dhundale & Dean, 2000). We sampled in 2 consecutive non-breeding seasons,

25 January–27 March 2002 and 1 November–20 December 2002. A small portion of these periods overlapped the beginning of spring migration and the end of autumn migration for sparrows in our region, but all salt marshes were sampled at least once outside migration. Salt marshes were sampled twice, at least 11 d apart, during each non-breeding season period, and these samples were averaged. Because it is not possible to use this flush-line sampling technique in areas dominated by shrubs, we covered an average of only $50 \pm 18\%$ of each salt marsh. However, an equal area of emergent vegetation was surveyed in both created and reference salt marshes (mean = 1.0 ± 0.7 ha per salt marsh).

To determine if significant bird use was occurring at other times of year we visited 14 salt marshes opportunistically (25 visits) during autumn migration (15 August–15 November 2001) to detect any use by migratory shorebirds or waterfowl, or large roosts of blackbirds.

Vegetation

To characterize the vegetation present during the breeding season we used the line-intercept method to sample vegetation along 2 perpendicular 100-m lines centred on each bird sampling point (Brower & Zar, 1998). We recorded the distances along each line over which each plant species or combination of species occurred and converted these to percent coverages of 5 height classes: unvegetated (*i.e.,* mud at low tide), short (*e.g., S. patens*), medium (*e.g., S. alterniflora*), tall (*e.g., S. cynosuroides*), and shrub (*e.g., Iva frutescens*).

Analysis

We restricted all analyses of birds to species that we observed using the salt marsh vegetation or the airspace above it for perching, feeding, singing, or nesting. This excluded many species that occasionally flew across the salt marshes (*e.g.,* woodpeckers) and included some species that are not typically considered salt marsh birds (*e.g.,* hawks that pursued songbirds in the salt marsh; see Appendix I for the complete list). Detecting a single male, a single female, or a male with a female constituted 1 breeding unit. For all analyses we used the maximum number of breeding units recorded on any of the counts in that circle, averaged across all points at a salt marsh. Using paired *t*-tests to maximize statistical power, we compared the avian communities of created salt marshes to those of their matched reference salt marshes in terms of abundance (number of breeding units) and richness (number of species). Additionally, we estimated the similarity of species assemblages present (Jaccard, 1912).

We compared a single measure of breeding success for the entire avian community: the total number of males for all species in each salt marsh that acquired territories and then obtained a mate that completed a clutch of eggs. This measure of breeding success was then compared between created marshes and their matched reference marshes using a paired *t*-test.

In 2002 we also followed red-winged blackbird nests through to fledging, with the idea that blackbird productivity would provide an example of reproductive output that might apply to less abundant species. Although red-winged blackbirds are an adaptable species of no conservation concern at the present time, their body size, feeding habits, and nest site preference are similar to several other salt marsh species. Thus, their relative reproductive success in the 2 types of salt marshes might reflect the same pressures faced by less common species, particularly nest predation and food supply for offspring. To calculate the probability of a blackbird clutch surviving the entire incubation period or of any nestlings surviving the entire nestling period, we used the method described by Mayfield (1975). This method, which is a standard ornithological tool, estimates the probability of a clutch of eggs or brood of nestlings surviving each day in the nest and then averages these across all days the nest was known to be active, thereby correcting any bias introduced when nests are found at different stages of the breeding cycle. We also measured the height of blackbird nests to determine if nest site choice differed between created and reference marshes.

Data from non-breeding season surveys were in the form of number of individuals that were flushed from the vegetation as we dragged the weighted line through each salt marsh. From this we calculated abundance (of individuals) and richness (of species). The majority of birds detected in winter were sparrows, so we calculated separate abundances for sparrows and all other species combined.

Clapper rails were of particular interest because they are the only salt marsh obligate species that was found in any abundance on both types of salt marshes. They used salt marshes year-round but were hard to survey accurately due to their extremely secretive behaviour (*e.g.,* reluctance to fly, irregular vocalizations, and reliance on the densest vegetation; Eddleman & Conway, 1998; Taylor, 1998). Thus, we developed an index of rail use to allow a comparison across salt marsh types, as follows: 0 = absent, 1 = present only in winter, 2 = present only in summer but did not breed, 3 = present in both winter and summer but did not breed, 4 = not present in winter but nested in summer, 5 = present in winter and nested in summer. Because we used flush lines in winter and searched extensively for nests in summer we are confident that we had a high probability of detecting rail presence despite their secretive behaviour.

For the vegetation communities present we calculated plant species richness and percent cover of each height class and compared these between created and reference salt marshes. In addition, because the invasive common reed (*P. australis*) is of particular interest to wetland conservation and common in disturbed wetland habitats (*e.g.,* Havens, Priest & Berquist, 1997), we compared separately the percent cover of this species, though it was also included in the tall height class.

For all data (except breeding success) we averaged values across both years for created and reference salt marshes. In all cases we examined data for each year separately and in no case did the statistical conclusion change. For the sake of brevity we have omitted these redundant comparisons. All statistical analyses were 2-tailed with $\alpha = 0.05$. Data were tested for homogeneity of variances, and analyses were done on non-transformed data since paired *t*-tests are robust to data that are not normally distributed (Miller, 1986).

Results

AVIAN COMMUNITY

During the breeding season, created salt marshes had significantly lower avian abundance and richness than reference marshes (Table I). The Jaccard Similarity Index indicated that, in terms of species present, created and reference salt marshes overlapped by 44% (range: 24–67%). When each species present at a salt marsh was ranked with regard to wetland dependence, created salt marshes had a significantly lower mean ranking than reference salt marshes (Table I).

REPRODUCTIVE SUCCESS

We detected no statistically significant difference between control and reference salt marshes in the number of males, of all species combined, with mates that completed clutches (Table I). Species are shown separately in Appendix I, but low sample sizes preclude statistical analysis for those other than red-winged blackbirds. Fewer red-winged blackbirds completed clutches on created salt marshes than reference salt marshes (Table I). Using the Mayfield method we determined that the probability of an egg surviving the incubation period on a created salt marsh was 64%, while at least 1 nestling fledged in 57% of the nests. These rates compare unfavourably with those from reference salt marshes, where each egg had an 83% chance of hatching and 74% of nests fledged at least 1 young. Red-winged blackbirds nested higher in the vegetation at created salt marshes than at reference salt marshes (Table I).

NON-BREEDING BIRDS

We flushed 251 individuals of 17 species during the winter surveys. Of these, 142 (57%) were swamp sparrows (*Melospiza georgiana*) and 39 (16%) were of 4 additional sparrow species. Only 4 non-sparrow species comprised more than 1% of the total number of individuals detected (red-winged blackbird: 17%; clapper rail: 3%; marsh wren: 2%; and Wilson's snipe, *Gallinago delicata*: 2%). During the non-breeding season there were no differences in means between created and reference salt marshes for species richness (created: $x = 2.70 \pm 1.47$; reference: 2.78 ± 1.11, $t_{10} = 0.14$, NS), individual abundance (created: $x = 6.28 \pm 4.14$; reference: 5.78 ± 1.74, $t_{10} = 0.11$, NS), or sparrow abundance (created: $x = 4.34 \pm 2.28$; reference: 4.63 ± 1.75, $t_{10} = 0.33$, NS).

Created salt marshes did not differ from reference salt marshes in their mean index of clapper rail use (created: $x = 1.77 \pm 1.42$; reference: 1.59 ± 1.43, $t_{10} = 0.35$, NS). Rails nested on both types of salt marshes (created: $n = 2$ in 2001, $n = 4$ in 2002; reference: $n = 2$ in 2001, $n = 1$ in 2002) and were detected at some time of year on 8 created salt marshes and 7 reference salt marshes.

We detected no use during autumn migration by waterfowl or shorebirds at any of the subset of salt marshes sampled in 2001, so no further sampling was carried out. Nocturnal blackbird roosts were discovered during autumn migration in stands of *P. australis* at 2 created salt marshes in 2001, totalling 5700 and 434 individuals of 4 species. No other blackbird roosts were detected at any time during the study.

VEGETATION COVERAGE

In terms of species richness, the vegetation communities on created salt marshes did not differ from those on the natural reference salt marshes (Table II for all species combined and Table III for species, separately). However, created salt marshes had significantly less coverage by low-growing plant species (*e.g., S. patens*, *D. spicata*) and a higher percent coverage by medium-height species (almost exclusively *S. alterniflora*) than reference salt marshes (Table II). Furthermore, the percent cover of *S. alterniflora* was greater than or equal to 75% on 8 out of 11 of the created sites (data not shown). Percent cover of species on reference sites was more evenly distributed, with no plant species dominating the plant communities except for *P. australis*, which comprised 85% cover at one reference site. Created salt marshes did not differ from reference salt marshes in terms of coverage by *P. australis*, tall vegetation (*e.g., S. cynosuroides*), or shrubs (*Iva frutescens*, *Baccharis halimfolia*, and *Myrica cerifera*), and there were no differences between created and reference salt marshes in the percent of unvegetated substrate (Table II).

Discussion

Our primary goal in this study was to determine whether salt marshes created to replace those destroyed by development provide habitat for comparable avian communities. To estimate what avian community is lost when a salt marsh is destroyed we used natural reference salt marshes chosen to match the created salt marshes. Our comparison should be applicable to situations where a created wetland replaces an isolated marsh that has been completely destroyed. However, our results may not represent the situation in

TABLE I. Mean (± SD) avian community and reproductive success metrics on created salt marshes and size-matched natural reference salt marshes during the breeding season. Reproductive data are for males of all species (All) or red-winged blackbirds (RWBL).

	Created	Reference	t_{10}	P
Abundance	5.11 ± 2.31	7.45 ± 3.39	2.64	< 0.05
Richness	2.78 ± 1.24	4.43 ± 2.23	2.91	< 0.05
Wetland dependence	7.95 ± 4.93	15.41 ± 10.21	2.82	< 0.05
All; complete clutch[1]	1.91 ± 2.12	2.09 ± 1.91	0.4	NS
RWBL; complete clutch[1]	0.91 ± 1.58	1.91 ± 1.51	2.09[2]	< 0.05
RWBL nest height (m)[1]	1.81 ± 0.55	1.32 ± 0.42	2.53[3]	< 0.05

[1]Clutch and nest-height data were available only for 2002; other values are 2-y averages; [2]t_6, [3]t_{24}.

TABLE II. Mean (± SD) vegetation variables on created salt marshes and size-matched natural reference salt marshes.

	Created	Reference	t_{10}	P
Richness	4.09 ± 1.97	5.73 ± 2.82	1.72	NS
Unvegetated (%)	17.25 ± 11.70	20.13 ± 12.62	0.86	NS
Short (%)	8.97 ± 12.99	27.38 ± 18.75	2.36	< 0.05
Medium (%)	63.12 ± 24.52	35.38 ± 18.28	3.34	< 0.05
Tall (%)	8.59 ± 13.72	12.59 ± 19.20	0.95	NS
Shrub (%)	1.77 ± 2.30	2.62 ± 4.28	0.19	NS
P. australis (%)	7.18 ± 11.29	9.34 ± 19.56	0.56	NS

TABLE III. Plant species and the number of salt marshes on which they were observed.

Height class	Species	Created	Reference
Short	*Distichlis spicata*	7	10
	Spartina patens	5	9
	Schoenoplectus americanus	0	4
	Atriplex patula	1	1
	Eleocharis rostellata	0	2
	Symphyotrichum tenuifolium	0	2
	Calystegia sepium	0	2
	Cuscuta gronovii	0	1
Medium	*Spartina alterniflora*	11	11
	Bolboschoenus robustus	2	5
	Juncus roemerianus	1	5
	Amaranthus cannabinus	0	3
	Typha angustifolia	1	1
	Panicum virgatum	1	0
	Fimbrystilis spp.	0	1
Tall	*Phragmites australis*	10	8
	Spartina cynosuroides	5	7
Shrub	*Iva frutescens*	8	7
	Baccharis halimifolia	3	2
	Myrica cerifera	1	3

which only the edge of a large marsh is impacted and a small marsh is created elsewhere as mitigation.

Birds

Considering all species of birds that used salt marsh habitat during the breeding season (*i.e.,* excluding edge species that never entered the salt marsh or species that merely flew over), created salt marshes had fewer individual birds and fewer species than reference salt marshes. To gauge the conservation implications of the differences between avian communities we ranked each species based on its degree of dependence on wetland. The average species inhabiting a created salt marsh was less wetland dependent than the average for reference marshes. It is clear from these comparisons that the avian communities on created salt marshes are not the same as those on the salt marshes they were intended to replace, and the species present tend to be those less likely to be in jeopardy from wetland destruction.

However, our community metrics were all based on the mere presence of breeding birds, rather than their realized reproductive success. We also compared reproductive success for all nesting species combined and for the 1 breeding species that occurred on all salt marshes (red-winged blackbird). Considering all breeding species, there were no differences in number of males that obtained mates that completed clutches of eggs. This suggests that males on created salt marshes are just as capable of attracting mates and inducing them to nest, but most species were present at only a few salt marshes so little can be concluded. When we considered only red-winged blackbirds, which built approximately 75% of the nests in this study, we found lower reproductive success on created marshes, whether measuring the rate of clutch completion or relative Mayfield estimates of the daily survival of eggs or nestlings. Blackbird nests also were built in higher vegetation at created sites, probably reflecting the lower abundance of short vegetation. This difference in nest

height could be responsible for the lower egg and nestling period survival probabilities at created salt marshes. Of potential nest predators observed at our sites—snakes, small mammals, and predatory birds—the latter (specifically crows) were detected in abundance. We hypothesize that avian predators such as crows may be more likely to detect nests in tall vegetation, possibly explaining the difference in nest success between created and reference sites. However, a further study on sources of egg and nestling mortality will be necessary. Elsewhere, we have shown that the differences in reproductive success of these same red-winged blackbirds greatly increase the chance that these salt marshes act as population sinks in which adults attempt to breed but do not replace themselves over their lifetime (Keagy, Schreiber & Cristol, 2005). Red-winged blackbirds are not restricted to salt marshes and are not a species of conservation concern, but our rationale for studying them was that if red-winged blackbird reproductive success differs on created marshes, the same might be true of other species.

One of the most promising findings was that clapper rails, which are salt marsh obligates of some conservation concern, were present on most of the created salt marshes throughout the year. Further research on clapper rail reproductive success on created salt marshes is warranted, as we were able to locate nests but not determine productivity for this highly secretive species. We also detected no differences in use by non-breeding birds, primarily wintering sparrows, which suggests another way that these created marshes might contribute to conservation efforts.

Other comparisons of avian communities on natural and mitigation wetlands have produced results indicating that created wetlands do not fully replace the avian communities destroyed by development (Melvin & Webb, 1998; Snell-Rood & Cristol, 2003; Ma *et al.,* 2004), but most previous studies have focused on waterfowl in restored wetlands, so have little direct bearing on our findings. A recent comparison of natural and mitigation (both created and restored) emergent marshes in West Virginia, USA, found no differences in avian species richness or diversity and higher abundances for waterfowl on the mitigated sites, in apparent contrast to our results for salt marshes (Balcombe *et al.,* 2005). However, while passerine abundance did not differ significantly between mitigation and reference sites in the West Virginia study, there was nonetheless a drop in proportional representation by songbirds and thus a shift in the avian community towards waterfowl on the mitigated sites. Another study of 3 recently created salt marshes (< 4 y old) in Texas, USA, documented differences in the avian community of created *versus* reference sites based on differences in vegetation (Darnell & Smith, 2004). Most notably, in the created sites there was a shift from dominance by seaside sparrows to dominance by boat-tailed grackles. There is a need for more studies to determine whether created wetlands ever reproduce the avian communities of the wetlands they are intended to replace.

Vegetation coverage

As in other studies of created wetlands (Darnell & Smith, 2004; Balcombe *et al.,* 2005), the created salt marshes we studied supported vegetation communities that differed from natural reference salt marshes. This is not surprising,

because some of the created salt marshes had been planted with only one species, *S. alterniflora*, and thus had a disproportionate amount of this medium height vegetation at the expense of several low-growing species that were abundant on the natural salt marshes. The similarity of coverage by *P. australis* surprised us because we had anticipated that created salt marshes would have more of this invasive species than natural reference salt marshes (Havens, Priest & Berquist, 1997). However, in retrospect we should have expected this, because when we opted to match for size and surrounding land cover we were forced to select a set of reference salt marshes that were isolated and small, and thus perhaps more prone to invasion by this species than large salt marshes.

It is possible that the vegetation communities of created salt marshes could diversify over time (but see Morgan & Short, 2002; Balcombe *et al.,* 2005). Some aspects of created wetlands, such as the amount of organic matter in soil, may take up to 35 y post-construction to reach the levels observed in natural wetlands (Morgan & Short, 2002). Additionally, plant communities in natural wetlands can change dramatically over time, depending on both abiotic and biotic processes (Mitsch & Gosselink, 2000). Most of the wetlands in the present study were planted as monocultures and still had depauperate plant communities more than a decade later. These created salt marshes have yet to develop into habitats identical to those they were meant to replace. The question to be answered now is when and if they will serve as replacements. A similar study of 7- to 11-y-old created forested wetlands found that they differed from reference sites in both bird community and vegetation structure and were not on the same developmental trajectory as reference wetlands that had been logged 7–11 y earlier (Snell-Rood & Cristol, 2003). In that study, it appeared that excessively wet hydrology may have retarded the vegetation community. In the present study, the salt marsh vegetation community could be slowly diversifying, but future study is necessary because our sites lacked adequate variation in age.

MANAGEMENT IMPLICATIONS

Wetlands are created for many reasons, one of which is the replacement of lost wildlife habitat (Melvin & Webb, 1998). Because loss of wetland habitat due to development and changing climate is anticipated to continue (Kennish, 2001; Zedler, 2004), the issue is not whether to replace them, but how to replace them. Creation of wetlands is one of 3 mitigation options, the others being restoration and preservation of existing wetland. The preservation option has the drawback that it allows a decrease in wetland area and thus fails to meet the "no net loss" goal associated with the Clean Water Act (National Wetlands Policy Forum, 1988). The present study indicates that in southeastern Virginia, replacing natural salt marshes with created ones will not fully replicate the bird community that was present at the original site for at least a decade. In addition, the 1 species that nested abundantly at our study sites had lower reproductive success on created salt marshes. The reduced reproductive success could be compensated for, up to a point, by building multiple acres of wetland for each one destroyed (Keagy, Schreiber & Cristol, 2005), but no amount of mitigation will replace missing species if the

created habitat does not attract them. Further studies are needed to determine why created marshes attracted no nesting individuals of certain species (*e.g.,* marsh wren, seaside sparrow). This is particularly interesting in light of the fact that created marshes appeared to be attractive to nesting clapper rails, a strict salt marsh obligate. The success of wetland creation may improve if wetlands are designed with the specific goal of replacing key habitat features required by a species and the geological and hydrological conditions that create those features. For example, seaside sparrows in the southeastern United States require salt marsh habitat with a few specific plant species and water arranged in pools and creeks (Post & Greenlaw, 1994). Failure to create conditions similar to these will reduce the likelihood of attracting this species.

With few exceptions, created wetlands have failed to completely replace the avian communities present on natural wetlands (and see National Academy of Sciences, 2001 for other taxa). Further research is needed before it can be concluded that created wetlands adequately replace the wildlife habitat lost when wetlands are destroyed. Continuing to assume that created wetlands are adequate replacements for destroyed natural wetlands, or that they will develop into adequate replacements over time, is not warranted based on the present study.

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APPENDIX I. Species presence (2001 and 2002) and number of clutches completed (2002 only) for created and reference salt marshes. (Number of created and reference salt marshes on which each species was detected during the surveys but outside of the 10-min point counts is shown in parentheses).

Species		Presence		Clutch completion
		Created 2001/2002	Reference 2001/2002	Created/Reference 2002 only
Canada goose	(*Branta canadensis*)	0/0 (1/2)	0/0 (2/2)	1/0
Wood duck	(*Aix sponsa*)	0/0 (0/0)	1/1 (1/1)	0/0
Mallard	(*Anas platyrhynchos*)	1/0 (3/4)	2/1 (5/5)	0/0
Great blue heron	(*Ardea herodias*)	0/1 (5/2)	1/0 (7/1)	0/0
Great egret	(*Ardea alba*)	0/0 (5/6)	0/0 (8/4)	0/0
Green heron	(*Butorides virescens*)	1/1 (2/3)	1/3 (4/6)	1/0
Yellow-crowned night-heron	(*Nyctanassa violacea*)	1/1 (2/3)	2/3 (4/4)	0/1
Turkey vulture	(*Cathartes aura*)	0/0 (0/4)	0/1 (0/2)	0/0
Osprey	(*Pandion haliaetus*)	0/0 (2/3)	2/4 (3/7)	0/0
Bald eagle	(*Haliaeetus leucocephalus*)	0/0 (0/0)	2/0 (2/3)	0/0
Sharp-shinned hawk	(*Accipiter striatus*)	0/1 (1/1)	0/0 (0/0)	0/0
Red-tailed hawk	(*Buteo jamaicensis*)	0/0 (0/3)	0/0 (1/1)	0/0
Clapper rail	(*Rallus longirostris*)	3/1 (5/6)	5/3 (5/4)	3/0
Willet	(*Tringa semipalmata*)	1/0 (1/0)	1/1 (1/1)	0/0
Least tern	(*Sternula antillarum*)	1/0 (1/2)	1/0 (1/1)	0/0
Common tern	(*Sterna hirundo*)	0/0 (0/2)	1/0 (1/0)	0/0
Black skimmer	(*Rhynchops niger*)	1/1 (2/1)	1/1 (1/2)	0/0
Chimney swift	(*Chaetura pelagica*)	3/5 (5/5)	8/5 (8/5)	0/0
Belted kingfisher	(*Megaceryle alcyon*)	0/1 (0/2)	0/0 (1/1)	0/0
Eastern kingbird	(*Tyrannus tyrannus*)	0/2 (2/3)	3/0 (4/2)	0/0
White-eyed vireo	(*Vireo griseus*)	0/0 (0/1)	0/0 (0/0)	1/0
Purple martin	(*Progne subis*)	3/2 (3/4)	5/3 (7/3)	0/0
Tree swallow	(*Tachycineta bicolor*)	0/0 (0/0)	0/1 (1/1)	0/0
N. rough-winged swallow	(*Stelgidopteryx serripennis*)	0/3 (0/4)	4/4 (5/4)	0/1
Barn swallow	(*Hirundo rustica*)	8/8 (9/8)	9/7 (10/6)	0/0
Carolina chickadee	(*Poecile carolinensis*)	0/0 (0/1)	0/0 (0/0)	1/0
Carolina wren	(*Thryothorus ludovicianus*)	0/0 (0/0)	0/0 (0/1)	0/1
Marsh wren	(*Cistothorus palustris*)	0/0 (2/0)	2/1 (2/2)	0/0
Blue-gray gnatcatcher	(*Polioptila caerulea*)	0/0 (0/0)	0/0 (0/1)	0/1
Gray catbird	(*Dumetella carolinensis*)	0/0 (0/1)	0/0 (0/0)	2/0
Common yellowthroat	(*Geothlypis trichas*)	4/2 (8/7)	2/2 (5/4)	0/0
Nelson's sharp-tailed sparrow	(*Ammodramus nelsoni*)	0/0 (0/1)	0/1 (0/1)	0/0
Seaside sparrow	(*Ammodramus maritimus*)	0/0 (0/0)	1/1 (2/1)	0/0
Blue grosbeak	(*Passerina caerulea*)	0/0 (0/1)	0/0 (0/0)	1/0
Red-winged blackbird	(*Agelaius phoeniceus*)	11/8 (11/9)	11/11 (11/11)	8/10
Boat-tailed grackle	(*Quiscalus major*)	3/2 (4/3)	3/2 (3/2)	0/0