Staying Alive on the Edge of the Earth: Response of Seaside Sparrows (Ammodramus maritimus) to Salt Marsh Inundation, with Implications for Storms, Spills, and Climate Change

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ABSTRACT

Seaside Sparrows (Ammodramus maritimus) spend their entire lives in coastal marshes. This narrow habitat requirement puts them at great risk from storm surge, coastal contamination, and sea level rise associated with global climate change. Our research with Seaside Sparrows in Lower Barataria, Plaquemines Parish, a vast network of marshes to the west of the Mississippi River delta, gave us the opportunity to examine how these birds responded to storm surge associated with Hurricane Isaac, which made landfall in Plaquemines Parish on 28 August 2012. According to USGS tide gauges, the storm inundated the entire marsh system to a depth of 1-4 m for 2-3 days, displacing >400000 Seaside Sparrows. Birds from our study sites fleeing the storm could have found dry land along a narrow tendril of levee along the Mississippi River, some 5-15 km away. Finding more ample areas of marsh would have required movements of 50-100 km. Within six weeks, our first sample following the storm, Seaside Sparrows had recolonized our study sites; we captured 25 birds, including one individual who had bred at the same site before Isaac. In the breeding season of 2013, we recaptured five individuals who had bred on our sites before Isaac, and three individuals who were first detected in October 2012. Density of breeding Seaside Sparrows dropped by as much as 80% in 2013 based on point count samples, although sweep samples did not indicate such a dramatic reduction. These results demonstrate that major storms reduce Seaside Sparrow populations, but that many Seaside Sparrows are capable of movements to escape storms, as well as rapid recolonization following return to normal water levels. Although Seaside Sparrows are vulnerable to loss of coastal marshes, their movements following Isaac suggest the birds should be capable of colonizing suitable habitat as the configuration of the coast changes. At the same time, this capacity for movement puts Seaside Sparrows at risk of repeatedly using areas that have been contaminated, such as from the Deepwater Horizon Oil Spill.
INTRODUCTION

The most familiar birds in Louisiana coastal marshes are probably conspicuous species like ducks, herons, gulls, terns, and blackbirds. One of the birds most strongly associated with coastal marshes, however, is the Seaside Sparrow (*Ammodramus maritimus*). This ubiquitous, yet easily overlooked species is common in salt marshes along the Atlantic and Gulf coasts (Post and Greenlaw 1994). As its name implies, it seldom strays from saline and brackish marshes dominated by *Spartina* spp. or other coastal grasses and rushes (Post and Greenlaw 1994). In fact, only a small handful of bird species, particularly Clapper Rails (*Rallus longirostris*) and Mottled Ducks (*Anas fulvigula*), are as completely dependent on Louisiana’s coastal marshes.

Living on the interface of land and water presents unique risks to Seaside Sparrows. Even small storms can produce storm surge of 1 m or more at the coast, enough to completely inundate salt marsh vegetation, forcing Seaside Sparrows to seek refuge elsewhere. Unusually high tides can destroy nests across entire populations (Marshall and Reinert 1990). Tropical storms and hurricanes strike the Gulf coast almost every year, leading to deeper inundation for longer periods at larger geographic scales (Keim *et al.* 2007). The high winds and heavy rains that accompany these storms also pose risks to small songbirds. It seems obvious that Seaside Sparrows in the path of a storm must flee or perish, but little is known about the birds’ strategy, or their success, at evading storms.

Seaside Sparrows’ short-term response to storms could provide inferences about their biogeographic history and their possible response to current risks. In the long term, changes in coastal configuration, especially in the dynamic deltaic lobes of the Mississippi River, have reshaped salt marsh geography (Roberts 1997; Mikhailov and Mikhailova 2010). If birds are relatively sedentary or generally unable to escape storms, we would expect a pattern of isolated populations in relatively stable marshes (Tomkins 1934). Alternatively, if birds chased by storms successfully move along the coast, we would expect less isolated populations. Based on morphological variation, Seaside Sparrows along the northern Gulf coast have been divided into four subspecies, suggesting a pattern of isolation at the eastern and western ends of the distribution in northern peninsular Florida and south Texas, with a more widely spread subspecies along the central coast (Post and Greenlaw 1994). Certainly some Seaside Sparrows became so sedentary that they diverged into distinct subspecies; two of these subspecies from Atlantic Florida (*A. m. pelonotus* and *A. m. nigrescens*) are now extinct, and a third, the Cape Sable Seaside Sparrow (*A. m. mirabilis*) of the Everglades, is endangered (Post and Greenlaw 1994). This sad fate seems directly related to these populations being unable to respond to changing conditions by expanding their distributions.

In current times, risks of coastal living include contamination from oil spills and the inevitable movement inward of the interface of land and water as relative sea level rises due to climate change and subsidence (Doyle *et al.* 2010). If Seaside Sparrows are relatively sedentary, we would expect their vulnerability to oil spills to be restricted to birds directly in the path of the oil, with possible heavy contamination. If birds are more mobile, the potential for contamination reaches more birds, including the possibility that individuals could repeatedly come into contact with oil, or that signs of contamination could be transported by birds that leave oiled marsh. On the time scale of the next several centuries, sea level rise will lead to overall
land loss, but encroachment of Gulf waters is expected to result in salt marsh replacing brackish marsh and other vegetation types less able to withstand increased salinity and inundation (Visser et al 2012, Visser et al 2013). Will Seaside Sparrows be able to track the changing distribution of their habitat as some areas lose salt marsh and other areas gain it?

Here we examine the response of Seaside Sparrows in southeastern Louisiana to the storm surge of Hurricane Isaac in August 2012. We began a study of Seaside Sparrows in March 2012 in an area that was heavily impacted by Isaac a few months later, giving us a chance to compare density before and after the storm, and to document the return of individual birds. First we reconstruct the timing, extent, and duration of the storm surge from publicly available data. Then we use land cover data and our estimates of Seaside Sparrow density to calculate how many birds were displaced. We track the return of Seaside Sparrows to the coast following the storm based on our own samples and citizen science information. Finally, we consider the overall effect of the storm on Seaside Sparrow populations by comparing abundance between 2012 and 2013.

METHODS

Our analysis focused on the Lower Barataria Region as defined by Visser et al (2012, 2013; Fig. 1a). Their analysis also provides vegetation classification for each region. About 77% of the Lower Barataria is open water. Vegetated land area is strongly dominated (94%) by vegetation classified into intermediate, brackish, and saline marsh. More specifically, about 82% of land area includes the Spartina-dominated marsh typically used by Seaside Sparrows.

Coastal Emergency Risks Assessment (CERA: http://coastalemergency.org/) at Louisiana State University provided data on the timing and extent of the Isaac storm surge. The CERA hindcast shows various measures of inundation accompanying Isaac, including water height above NADV88 (NADV88 is a standard measure of sea level), inundation depth above ground, and significant wave height above NADV88. The utility allows data to be viewed as a time series or as maxima. Here we report height above NADV88. The images we describe can all be seen at http://cera.cct.lsu.edu/cgi-cera-ng/cera-ng.cgi; terms of use of Google Maps restrict us from showing them directly. These data are also available from USGS (McCallum et al 2012).

We studied Seaside Sparrows extensively in six 2.5 ha plots in the central-east portion of the Lower Barataria region (Fig. 1b). We used standardized point counts (Hamel et al 1996) to generate estimates of bird density on the plots twice each year, once in late April (2012) or early May (2013) and once in early June. We conducted point counts from the bow of a boat parked at the edge of the marsh, sampling a semicircle with a 50 m radius from the observer. We totaled the number of individual birds detected within 50 m of the observer in each minute of a five minute point count. Each sample included two point counts/plot, with both points/plot surveyed on the same day. Here we use the maximum number detected within a single minute as our measurement. Based on the breeding phenology of Seaside Sparrows, the first sample included mostly breeding adults and a few recently fledged young. The second sample included proportionately more young birds. As an estimate of birds displaced by Isaac, we used the number of birds detected/point on the second survey to calculate the number of birds/ha
assuming perfect detection within 50 m of the observer. These estimates are certainly biased low due to birds that were present and not detected (Thompson 2002). Some individuals could have been counted on multiple points, but we were careful to omit birds that obviously moved between points. To examine whether densities of breeding birds were reduced as a result of Isaac, we compared the first samples between years.

Figure 1. a. Defined regions in central and eastern Louisiana from the Louisiana Comprehensive Master Plan for a Sustainable Coast (Appendix E, Figure 6). Our analysis is based on the Lower Barataria Region. b. Closeup of the Lower Barataria region. Our study sites are within the rectangle.
We also sampled sparrows with mist net roundups, called sweep samples. This technique is a less quantitative measure of bird abundance, but allows us to capture birds to be individually marked with USFWS bands. We set up a line of 4-5 12m mist nets perpendicular to the coastline, then used a line of 3-5 people to flush birds into the netline (Gordon 2000). On 10 October 2012 we sampled three of our plots with this technique. From March to June in 2012 and 2013 we sampled all plots repeatedly. For each year we used the maximum number of adult birds in a single sweep as a relative estimate of birds on each plot.

Citizen science data from Ebird (ebird.org), a platform for birders to enter georeferenced sightings, also provides information on the return of Seaside Sparrows to coastal marshes following Isaac. The Fourchon-Grand Isle area in the southwest corner of the Lower Barataria region is a popular birding destination, providing many checklists from September to December of 2012 (Fig. 1b). Unfortunately, almost all entries to Ebird are from walking or driving birders, so we have no useful Ebird data for the vast part of Lower Barataria accessible only by boat.

RESULTS

Extent of flooding

Hurricane Isaac made landfall near Port Fourchon as a category 1 hurricane on 29 August at about 0800 (all times UTC, which equals CDT + 5 hours), although flooding in coastal marshes, especially to the east of the Mississippi River channel, began earlier. The southern end of the Lower Barataria began to flood to a level of 1.5-2m (deep enough to completely inundate marsh vegetation) by about 0300 on 29 August. By this time all marsh in Lower and Middle Pontchartrain and the Birdfoot Delta (Fig. 1) were flooded, most to a depth of 2-4m. By 0900, about the southern half of the marshes in the Lower Barataria was flooded to >1.5m. By 1500, all marsh area in Lower Barataria was flooded, as was the Upper Barataria to at least Lake Salvador. At this point three areas in Lower Barataria were above water. One was an area of about 100 km2 in the northeastern corner of Lower Barataria, between Golden Meadow and Cutoff, which was continuous with non-inundated areas in Upper Barataria and Upper and Lower Terrebonne. The other two areas above water were narrow strips, generally much less than 1 km wide, one along the Mississippi River channel and one including Grand Isle and part of Fourchon. Six hours later, at 2100, all marsh in Lower Barataria remained flooded, as did marsh in Upper Barataria around Lake Salvador, marsh to the east of the Mississippi, and swamp and marsh around Lakes Bourne, Pontchartrain, and Maurepas. Clearly at this point all Seaside Sparrows had perished or been forced out of the marsh in Lower Barataria.

By about 0300 on 30 August peak levels had passed through Lower Barataria, although only in the far southern end of the region had levels dropped to <1 m. This condition persisted through the rest of 30 August. Over 31 August water began to drop to <1 m over about the southern half of Lower Barataria. Over 1 and 2 September marsh began to reappear above water through scattered areas in the southern part of Lower Barataria. By 2300 on 3 September, the last CERA hindcast, most of Lower Barataria had water levels comparable to before the storm, although flooding persisted in southern Upper Barataria.
Displaced birds

From point counts in June 2012, when we detected both adults and newly-fledged birds, we estimated $9.7 \pm 2.3$ (mean ± sd) Seaside Sparrows combined on the two points in each of plot. Converting to birds/ha, we used the mean + 1 sd as a high estimate (12.0 birds/ha), the mean as a medium estimate (9.7 birds/ha), and the mean – 1 sd as a low estimate (7.3 birds/ha). We considered these estimates to be appropriate for land classified by Visser et al (2012) as Saline-oystergrass (dominated by *Spartina alterniflora*; 307 km² in Lower Barataria), Brackish-wiregrass (dominated by *S. patens*; 247 km² in Lower Barataria), and Brackish-Brackish mixture (dominated by *S. patens*, *Distichlis spicata*, and *S. alterniflora*; 44 km² in Lower Barataria). Certainly there is variation in density of birds among habitats, and spatially within habitats. Seaside Sparrows might also avoid small patches of suitable habitat (Benoit and Askins 2002). Nevertheless, given the overwhelming dominance of habitat appropriate for Seaside Sparrows in Lower Barataria, we think the three levels of estimates provide likely bounds for Seaside Sparrow numbers at the end of the breeding season in Lower Barataria. Based on the available area in Lower Barataria in Visser et al (2013), our low, medium, and high estimates for Seaside Sparrows displaced by Isaac are 438834, 578266, and 718198 individuals.

Citizen science data give no clues about where displaced Seaside Sparrows might have gone during the storm and subsequent flooding. Ebird checklists from the time of the storm show expected storm waifs, such as Magnificent Frigatebirds (*Fregata magnificens*) as far north as Alexandria, LA, but no records of Seaside Sparrows away from the coast.

Return of displaced birds

One Ebird checklist reported a single Seaside Sparrow in central Lower Barataria on 7 September. Checklists from Grand Isle and Fourchon began to appear on 8 September 2012, with the first Seaside Sparrow reported on 16 September. Although their absence from three Grand Isle lists from 8 September until 16 September could reflect actual absence, it seems likely from the other species on those lists that the birders were mostly interested in birds in chenier forest or on the beach. Between 16 September and the end of 2012, Seaside Sparrows were reported on 20 checklists from Grand Isle and Fourchon. There were about 50 checklists submitted during that period, again with many that probably reflect little effort in salt marsh. A better gauge of birder effort in salt marsh is the number of lists reporting Clapper Rail (*Rallus longirostris*), another salt marsh specialist. Between September and December 24 checklists reported Clapper Rails, barely more than the lists reporting Seaside Sparrows, although the rails are considerably more vocal and easier to detect.

We sampled three of our plots on 10 October 2012, capturing a total of 25 Seaside Sparrows. Remarkably, one of the birds was a recapture of a male that had been captured in breeding condition on the same plot in April 2012. All other birds captured that day were new captures. In 2013 we recaptured another five birds that had been banded as adults during the 2012 breeding season. All five were on the same plots in 2013 where they had been banded in 2012.
Point count and sweep surveys provide somewhat different results for bird densities differences in 2012 and 2013 (Fig. 2). Sweep surveys showed slightly more adult birds/plot in 2012 ($6.9 \pm 4.7$ sd) than in 2013 ($4.5 \pm 2.6$ sd), but the difference was not significant with a Wilcoxon signed-rank test for paired data ($w = 1.5, p > 0.05, n = 6$ plots). Point counts from the first sample period showed a much more pronounced result, with $2.75 \pm 1.36$ birds/point in 2012 compared to $0.5 \pm 0.5$ in 2013 ($w = 0, p < 0.01, n = 12$ points). Although additional analysis may be required to rectify the differences between the two methods, collectively they suggest that Seaside Sparrow density was reduced following in 2013 after Isaac.

Figure 2. Abundance estimates from sweep samples (a) and point counts (b) for Seaside Sparrows on our sample plots in Lower Barataria before (2012) and after (2013) Hurricane Isaac.
DISCUSSION

The well-documented history of Hurricane Isaac makes it clear that vast areas of coastal marshes were inundated by the storm. Indeed, almost all salt marsh in southeastern Louisiana, on both sides of the Mississippi River, was simultaneously inundated. Our estimates indicate that in the Lower Barataria alone the flooding forced evacuation by at least 400,000 Seaside Sparrows.

Our comparative results between 2012 and 2013 suggest that Seaside Sparrow populations in Lower Barataria were reduced after the storm. Our point count estimates show a reduction of over 80%, although sweep samples show a much less dramatic difference of about 30%, with considerable error around the estimates. Despite this reduction following Isaac, it is also clear that many Seaside Sparrows found their way to Lower Barataria by late 2012. We also know that some of these birds were displaced individuals that returned to the exact same piece of marsh following the storm. From this result, we can’t interpret the degree of direct mortality from the storm, but we can infer that Seaside Sparrows did not suffer catastrophic mortality to the level that could threaten the persistence of local populations, and that displaced birds did not necessarily emigrate permanently from the area. An additional complication for interpreting the difference between years is that the storm appeared to have redistributed oil from the Deepwater Horizon spill, possibly contaminating (or recontaminating) our plots. Our results between years might be due both to general reduction of bird abundance and avoidance of oiled marsh along the southern tier of Lower Barataria, where oiling was most extreme (Emergency Response Management Application 2013).

Although we can safely surmise that many birds were able to flee the storm (see also Semple 1936 and discussion in Post and Greenlaw 1994), we can offer nothing more than speculation about where they went. Given that flooding to the east of the Mississippi River preceded flooding in our study area, it seems unlikely that our birds could have gone to marshes to the east. Rather, many thousands of birds were displaced from there as well. Flooding intensity decreased to the west beyond Lower Terrebonne, possibly allowing birds to remain in coastal habitats by moving that direction, into the Atchafalaya-Vermillion Bay Region or beyond. From our study sites, this would represent movements of >100 km. The delta of the Atchafalaya has relatively little salt marsh compared to the Lower Barataria and Lower Terrebonne (Visser et al 2012); birds moving to the west would have needed to move some 250 km to reach the vast, and unflooded, salt marshes of southwestern Louisiana. Birds may have moved inland to the north, perhaps just far enough to take refuge in vegetation that remained above water, some 80-100 km from our sites. We doubt that birds moved very far inland, or they would have appeared in Ebird data. We also doubt that large numbers of birds crowded into the narrow spits of dry land along the Mississippi River, although we cannot rule out the possibility that at least some birds weathered the storm there. At <10 km away from our sites, this would be the closest opportunity (other than the man-made structures on the marsh) for birds to find refuge above water, although birds there would have been buffeted by wind and rain.

Observations following Isaac support the idea that Seaside Sparrow populations in southeastern Louisiana are able to find and use suitable habitat in the region and probably beyond. Anticipating the altered coastal configuration resulting from climate change, we suggest that Seaside Sparrows should be able to track the changing availability of coastal marshes.
Increased frequency of major storms as a result of climate change could also limit the potential of Seaside Sparrow populations to recover, especially if our point count estimates reflect the actual extent of mortality from the storm (Webster et al. 2005, Bender et al. 2010). Of course, this highly specialized species will always be vulnerable to reductions in the overall availability of salt marsh. With warming temperatures, mangroves may sometimes replace Spartina-dominated marsh, to the detriment of Seaside Sparrows (Doyle et al. 2003, Visser et al. 2013). Proposed freshwater diversions in the Lower Terrebonne could also lead to overall loss of salt marsh in the region (Coastal Protection and Restoration Authority of Louisiana 2012; Visser et al. 2012, 2013). More subtle abundance changes between two salt-tolerant species dominant in marshes, Spartina alterniflora, which is preferred by Seaside Sparrows, and Juncus roemerianus, which is less favored, may also influence abundance of the birds as landscapes change (Rush et al. 2009, Woodrey et al. 2012).

This study was possible because of a research project to examine the effects of the Deepwater Horizon oil spill on marsh ecosystems, including Seaside Sparrow condition and population processes. The same movements that enable Seaside Sparrows to evade storms and use available salt marsh habitat probably also put them at risk of repeated exposure to oiled marshes, and allows effects of the oil to move beyond the local interface of oiled marsh (Henkel et al. 2012). At the same time, we know that Seaside Sparrows can be relatively sedentary, especially during the breeding season (unpublished data); in the absence of storms, contamination during the breeding season would strongly affect resident sparrows in the contaminated area.

Although we focused on a single species, the broader question of how terrestrial species living in marsh respond to major storms remains poorly studied. Herons in coastal Louisiana may be able to evade storms and switch breeding colonies in response to hurricane damage (Leberg et al. 2007). What happens to Clapper Rails and Mottled Ducks? Ebird data suggest that these species returned to the marsh following Isaac. Another fascinating case is the Marsh Rice Rat (Oryzomys palustris). We found this species on all of our plots in 2013; did these animals somehow weather the storm? This species swims well (Esher et al. 1978). They can move between islands or upslope through an ecotone to escape flooding (Wolfe 1982, Forys and Dueser 1993, Abuzeinneh et al. 2007), but these options seem inadequate to survive the extreme flooding resulting from Isaac in Lower Barataria. Life is necessarily precarious for land animals at the marsh-water interface; we can only hope that the combined onslaughts of climate change, oil spills and hurricanes are not too much for these populations to endure.

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