Lower Shore Tidal Marsh Climate Adaptation Project

Final Technical Report

AUTHORS:
Anderson Shepard, Defenders of Wildlife (ashepard@defenders.org)
David Curson, Ph.D, Audubon Maryland-DC (dcurson@audubon.org)
Kate Patton, Lower Shore Land Trust (kpatton@lowershorelandtrust.org)
Natalie Dubois, Ph.D, Defenders of Wildlife (ndubois@defenders.org)

7/22/2014

This report, as well as a public, short-version, can be downloaded from:
www.defenders.org/climatechange/mdwildlife
The associated GIS models are also available at the above URL.

This project was made possible with assistance from the National Fish and Wildlife Foundation Chesapeake Bay Stewardship Fund and from the Doris Duke Charitable Foundation.

Table of Contents

List of Maps

List of Tables

List of Figures

PROJECT SUMMARY

The coastal wetlands of Maryland's Lower Eastern Shore are one of the most extensive tidal marsh landscapes along the entire Atlantic Coast. Not only do they provide essential habitat for unique plants and animals (including the Saltmarsh Sparrow, which lives only in this region), but they also perform economically valuable services such as storm surge protection, water filtration and serving as a nursery grounds for the Chesapeake Bay's commercial fisheries. However, these marshes are eminently threatened by sea level rise.

The Chesapeake Bay is the third most vulnerable region in the nation, behind only Louisiana and southern Florida, when it comes to sea level rise. In 2011, the Maryland Department of Natural Resources projected that a 3.4 foot rise in sea level (a conservative estimate for the end of the century) could inundate more than 95 percent of existing tidal marsh.

Defenders of Wildlife partnered with Audubon Maryland-DC and the Lower Shore Land Trust to establish priorities and strategies for the conservation of the region's tidal marsh ecosystem. We used computer modeling to identify areas that may support tidal marsh in the future as sea level rises, and to prioritize these locations according to their likely ecological value as future tidal marshes. We focused especially on marsh "migration corridors," or the regions that can serve as connectors between marsh habitat today and marsh habitat in the future. By combining spatial models of marsh ecological value, priority marsh bird habitat, marsh migration corridors and future development risk, we were able to produce a map for a two-county area of the Lower Eastern Shore that identifies the highest priority areas for tidal marsh conservation and facilitated adaptation in response to climate change.

Of course, simple identification of these conservation priorities is not enough. There are limited resources for preserving these lands, and protection of the highest priority areas is by no means assured. Our team also developed a set of conservation tools and targeted outreach and communications strategies to reach the audiences that must be engaged to successfully conserve, manage and maintain viable tidal marsh habitat. Commitment from public agencies, landowners and other conservation partners will be critical to the successful conservation of this exceptional ecosystem.

The decision-support tools and maps, combined with the conservation and outreach strategies from this study, can go a long way toward ensuring conservation of the Chesapeake Bay's iconic marsh landscapes. However, this region is not alone in facing the extreme challenges posed by climate change and rising sea level. It is our hope that other coastal areas will adapt this study's conceptual frameworks, methods, strategies and tools and use them to model marsh migration over time to better plan for the strategic conservation of saltmarsh ecosystems.

Introduction

Chesapeake Bay, the largest estuary in the continental United States, includes parts of six states and is home to more than 17 million people. Once the most productive estuary in the United States, the bay supports more than 3,400 species of plants and wildlife, including 500 species of fish and shellfish (Chesapeake Bay Foundation 2012). Today, the bay's health is threatened by nutrient and sediment pollution, land-use conversion and resource use (Chesapeake Bay Foundation 2012b). The bay is also particularly vulnerable to the effects of climate change, and sea level rise is recognized as an urgent priority. In the Chesapeake Bay, sea level rise is not simply a problem of the future—it is already impacting low-lying coastal lands at twice the global average rate.

Sea level rise is widely recognized as an urgent priority in the Chesapeake Bay and its predicted impacts in the region have been described in reports by the Maryland Commission on Climate Change (2008), the National Wildlife Federation (Glick et al. 2008) and the U.S. Climate Change Science Program (2008). The Chesapeake Bay region ranks third in the nation as the most vulnerable to sea level rise (SLR), behind Louisiana and southern Florida (Johnson 2011). Naturally occurring land subsidence exacerbates the region's vulnerability. Not simply a problem of the future, sea level rise is already impacting low-lying coastal lands at twice the global average rate. Over the past 100 years, a foot of relative sea level rise has resulted in the disappearance of 13 islands from the Chesapeake Bay, and additional sea level rise impacts, such as wetland erosion and saltwater intrusion, are already evident. New estimates suggest that Maryland should prepare for 1.4 feet of sea level rise by 2050 and 3.7 feet or more by 2100 (Boesch et al. 2013), with flooding from storm surge rising well above these levels.

The natural ecosystems most at risk from rising sea level in the Chesapeake Bay are coastal wetlands. These wetlands provide a range of natural benefits critical for improving water quality, providing flood and erosion control, and supporting fish and wildlife populations. They provide habitat for unique flora and fauna, including two birds, the Seaside Sparrow and the Saltmarsh Sparrow, which evolved in this tidal environment and are found only in saltmarsh habitats along the U.S. Atlantic Coast.

Somerset and Wicomico counties on Maryland's Lower Eastern Shore host some of the most intact and extensive saltmarsh ecosystems in the entire Bay region. Land tenure in these counties includes an interwoven network of natural areas, agricultural areas, transportation links and settlements (**Map 1, pg. 48**). Compared to the more urbanized counties in the mid-Atlantic region, much of the Lower Eastern Shore has remained sparsely populated and rural. These low lying areas are particularly vulnerable to the impacts from sea level rise. For example, nearly 60 percent of the land area in Somerset and Wicomico counties lies in the 100 year flood plain (Joyce and Scott 2005), with 24 percent occurring below an elevation of 3.7 feet. In these low-lying areas, more than 76,000 acres of coastal wetlands provide shoreline protection as well as critical habitat for numerous plants and animals.

In 2011, the Maryland Department of Natural Resources (DNR) used a tool called Sea Level Affecting Marshes Model (SLAMM) to look at the potential impacts of sea level rise on Maryland's coastal wetlands and determined that, in Somerset and Wicomico counties, a 3.4-foot rise could inundate more than 63,000 acres of existing saltmarsh (92 percent of current extent) and more than 5,000 acres of tidal swamp (78 percent of current extent). However, about the same amount of currently dry land could potentially convert to marshland under such a rise.

Tidal marshes can build, or accrete, in response to sea level rise by depositing peat, and indeed have been doing so for thousands of years in the Chesapeake Bay as the land slowly subsides due to long-term geological processes. However, with the more rapid rates of sea level rise resulting from climate change, marsh accretion will not keep pace with rising tides (Glick et al. 2008). In some coastal areas tidal wetlands will only persist if they can move upslope and inland as sea level rises. For adjacent uplands to function as "migration corridors" for these threatened habitats, they must remain free of barriers, such as development and hardened shoreline protection.

Over the past decade a number of reports have been published on the vulnerability of the Middle Atlantic coastal region to climate change, as well as strategy concepts for climate change adaptation (Glick et al. 2008, Boesch 2008, CCSP 2009, MCCC 2008). In Maryland, all of the counties in and adjacent to the Lower Eastern Shore have produced technical guidance or response strategies to sea level rise (Cole 2008, Worcester County 2008, Somerset County 2008). The neighboring counties within the Delmarva Peninsula—including those in Virginia and Delaware—have all developed their own guidance documents for adapting to climate change. These strategies recommend changes to land use planning policies, such as the creation of floodplain planning zones with reduced permitted building densities and the identification of areas for new wetlands in the future. Implementation of these land-use recommendations will require public support and partnerships.

An example of this type of partnership is the 2010 climate change adaptation strategy for the Eastern Shore of Virginia covering Accomack and Northampton counties (Parker and Crichton 2011). Led by The Nature Conservancy, this group has since convened a climate adaptation working group representing a broad array of local interests—from aquaculture, agriculture, local government and community organizations—to build a shared vision for enhancing resilience and facilitating adaptation of this globally important and productive coastal area.

Despite the regional interest in preparing for and understanding the impacts of sea level rise, spatially explicit climate adaptation strategies—those that can guide adaptation actions on the ground—are less common. One recent example is the Dorchester County Climate Adaptation Project, which produced a set of adaptation actions for tidal marshes in southern Dorchester County, Maryland (Lerner et al. 2013). These actions include land protection within spatially defined marsh migration corridors, habitat management recommendations for current tidal marshes and climate adaptation recommendations for agricultural and forestry sectors of the economy.

The Lower Shore Tidal Marsh Climate Adaptation Project described in this report extends this spatially explicit approach to Somerset and Wicomico counties (**Map 2, pg. 49**). Like the Dorchester County Project, this project uses saltmarsh birds to highlight the biological conservation values of the landscape, and focuses on land protection strategies in areas of marsh with high ecological value and connectivity across time. The objectives of the project are to:

1. Identify areas in Somerset and Wicomico counties with the greatest ecological value for current and future tidal marsh ecosystems, and delineate potential marsh migration corridors;
2. Identify the highest priority current and future tidal marsh habitat for saltmarsh birds;
3. Identify and prioritize opportunities at the parcel level for land protection in high ecological value marsh areas and marsh migration corridors;
4. Develop guidance for conservation easement language specific to sea level rise and the protection of future tidal habitats;
5. Develop outreach and communications strategies to promote sea level rise adaptation among landowners and local governments;
6. Identify funding opportunities for land protection and sea level rise adaptation stewardship on private lands.

This project brings together partners with shared interests in finding ways to better address the combined impacts of sea level rise on the natural resource values of the Lower Eastern Shore.

The Lower Shore Land Trust (LSLT) was established in 1990 with a mission to protect the natural heritage, rural character and historic landscapes of Somerset, Wicomico and Worcester counties. To date, LSLT has worked with interested landowners to secure permanent protection of nearly 18,000 acres of land throughout Maryland's most biologically diverse region, utilizing donated conservation easements and funding from the Rural Legacy Program, the federal Farm and Ranchlands Protection Program and the Conservation Reserve Enhancement Program.

Audubon Maryland-DC's conservation and science efforts extend state-wide, with a focus on restoring and protecting Maryland's most ecologically significant coastal wetlands and forests using education, science, community engagement and advocacy. Within the project area, Audubon has identified 85,665 acres as the Somerset-Wicomico Marshes Important Bird Area for saltmarsh obligate bird species, which are a focus of this project.

Defenders of Wildlife has worked with land trusts and other conservation partners in the Chesapeake Bay watershed to improve strategic conservation planning and enhance their capacity to protect biodiversity in the face of climate change.

In addition to these three partners, this project is intended to leverage additional partnerships to assist the state of Maryland in implementing its adaptation strategy along the Lower Eastern Shore.

In this report we describe new tools that were developed to identify land protection opportunities for coastal wetland migration corridors as well as the highest priorities for saltmarsh conservation. These tools are part of an outreach strategy aimed at increasing land protection opportunities to secure the critical areas that coastal wetlands will need in order to migrate inland over time. These tools will help ensure that ecologically significant coastal wetlands of the Chesapeake Bay can persist and remain viable in light of their primary threat, sea level rise, thereby maintaining the ecological services they provide.

TECHNICAL REPORT OUTLINE

The body of this report consists of three main sections:

Section I, *Tidal Marshes and Saltmarsh Birds*, provides a detailed assessment of the ecology of the region's tidal marshes and the conservation values of these habitats for the Lower Eastern Shore. This section also highlights saltmarsh birds as a group of species that are excellent indicators of healthy tidal marsh ecosystems, and thus of great value for modeling the ecological integrity of these lands. Specifically, we identify seven focal species of saltmarsh birds from our study area that are of conservation concern due to sea level rise-related habitat loss. This section describes the ecological data that was collected for these bird species and then incorporated into the analyses described in Section II.

Section II, *Climate Adaptation Analysis*, describes the technical methodology that was used to model the effects of sea level rise on the region's tidal marsh ecosystems and to identify the areas of current and future marsh of highest priority for direct land protection. Specifically, we describe (a) the analysis to identify remaining core saltmarsh bird habitat under sea level rise projections; (b) the analysis to identify marsh migration corridors and the regions of highest ecological value for saltmarsh persistence over time; and (c) the analysis which incorporates predicted development pressure along with modeled conservation value to identify the lands of highest priority for conservation.

Section III, *Outreach Strategies and Land Conservation Tools*, uses the Lower Shore Land Trust as an example to demonstrate the types of outreach and communications strategies, land conservation tools and funding opportunities that are key to promoting sea level rise adaptation among landowners and local governments.

Additionally, the following appendices provide further detail of this project's methods and results:

Appendix I, *Maps*

Appendix II, *Saltmarsh Bird Vulnerability and Survey Data*

Appendix III, *GIS Models*

Appendix IV, *Drafting Conservation Easements to Adapt to Climate Change*

SECTION I: TIDAL MARSHES AND SALTMARSH BIRDS

The goal of saltmarsh conservation is to protect the healthy ecosystem both on the current and on the future landscape. We need to understand the ecological and vegetation associations on the current landscape in order to project those relationships in the future. This section describes the ecology of tidal saltmarshes in the Lower Eastern Shore of Maryland, as well as the distribution biology and vegetative associations of a focal set of saltmarsh specialist birds.

TIDAL MARSH ECOLOGY

The tidal marshes of Somerset and Wicomico counties are part of a large marsh complex occupying the southeastern quadrant of the Chesapeake Bay from Dorchester County in Maryland to Accomack County, Virginia. This is one of the most extensive tidal marsh landscapes in the Northeast United States. Tidal marshes, (salt and brackish estuarine emergent wetlands) that are the focus of this project, cover 15 percent (approximately 69,000 acres) of the project area. The largest tidal marsh blocks are found on peninsulas at Ellis Bay (Nanticoke), Deal Island, Fairmount and Crisfield. These peninsulas are separated by the Wicomico River, Manokin River and Big Annemessex River, respectively (**Map 1, pg. 48**).

Owing to its geographical position in the middle section of the Chesapeake Bay the project area is a brackish (mesohaline) system with bay waters averaging 12-18 ppt salts (Chesapeake Bay Program 2008). The tidal range in the project area is narrow, 0.7 m, resulting in marshes with little variation in elevation.

Vegetation patterns in tidal marshes are determined principally by two factors, salinity and frequency of tidal inundation. The classic model of saltmarsh zonation describes a decrease in both tidal flooding and salinity upslope from the lower tidal limit, and distinct vegetation zones arranged along the elevation gradient. Regularly flooded "low" marsh is flooded twice daily by tides and irregularly flooded "high" marsh is flooded less often than daily.

LOW MARSH

In Somerset and Wicomico counties the SLAMM model identifies two extensive patches of low marsh, at Fairmount Wildlife Management Area (WMA) and Janes Island State Park. Elsewhere, low marsh is confined mostly to creekbanks and upper borders of tidal flats, from mean sea level to mean high water.

Due to the influence of the tidal regime, low saltmarsh is usually dominated by the tall form[1] of a single grass species, smooth cordgrass (*Spartina alterniflora*) (Tiner and Burke 1995). In addition to this grass species, the low marsh areas this region (as observed at Fairmount WMA and Janes Island) are also dominated by black needlerush (*Juncus roemerianus*)[2].

HIGH MARSH

High marsh constitutes the great majority of estuarine emergent marsh in the project area. High marsh supports a more diverse vegetative assembly than low marsh but it is still restricted to a handful of dominant plant species which often grow in monotypic stands in a mosaic pattern. These dominant species are described in Box 1.

---

[1] McCormick and Soames (1982) also consider the short form of smooth cordgrass to typify low marsh, although other authors (Tiner and Burke 1995) describe short form smooth cordgrass as a high marsh plant.
[2] Black needlerush is variably described as a high marsh plant (McCormick and Soames 1982, Tiner and Burke 1995) or a low marsh plant (Watts 1992, Maryland Department of Natural Resources 2005). In the brackish Chesapeake Bay marshes, black needlerush occupies a greater elevational range than in true (polyhaline) saltmarsh where it is confined to the high marsh.

Box 1: Saltmarsh Vegetation

Meadow cordgrass (*Spartina patens*) / spikegrass (*Distichlis spicata*)

A dominant association of saltmarshes, mixed stands of meadow cordgrass and spikegrass are also abundant in the more saline parts of brackish marshes, where they occupy the higher elevations of the high marsh (Tiner and Burke 1995, McCormick and Soames 1982).

Smooth cordgrass (*Spartina alterniflora* - short form)

Another dominant saltmarsh species, smooth cordgrass is also present often on the bayside fringe of high marsh in more saline parts of marshes, but is less common in the project area than meadow cordgrass. Its classification as a high marsh plant by Tiner and Burke (1995) but as a low marsh plant by McCormick and Soames (1982) likely reflects a position straddling the boundary of these two marsh zones.

Black needlerush (*Juncus roemerianus*)

Black needlerush dominates large areas of high marsh, as well as low marsh, in the brackish marshes of the Chesapeake Bay, whereas in polyhaline marshes it is often confined to the upper limits of the high marsh. In transplant experiments in Georgia, Pennings et al (2005) found that black needlerush cannot tolerate as much salinity or flooding as smooth cordgrass, but outcompetes smooth cordgrass in the flooding and salinity ranges that are suitable for both species. Black needlerush occupies a wide range of elevations within the marsh and has a high tolerance for anaerobic conditions (NRCS 2007). It is variably described as a high marsh plant (McCormick and Soames 1982, Tiner and Burke 1995) or a low marsh plant (Watts 1992, Maryland Department of Natural Resources 2005). Within our project area, needlerush generally occupies elevations slightly lower than meadow cordgrass. Black needlerush recovers more slowly from burning than do *Spartina* species and threesquare (NRCS 2007), and burning can be used to promote those species over needlerush (McCormick and Soames 1982).

Olney threesquare (*Schoenoplectus americanus*)

This species can dominate more upstream portions of brackish high marsh where it tolerates frequent flooding in marshes that are submerging. Olney threesquare is less common within our project area than in Dorchester County, where it forms some very extensive stands. Although described as a high marsh plant by McCormick and Soames (1982) and Tiner and Burke (1995), this species tolerates regular and even permanent flooding.

Marsh elder (*Iva frutescens*) / Groundsel-bush (B*accharis halimifolia*)

These two salt-tolerant shrub species are common in the upper portions of high marshes, where they generally occur over a sward of meadow cordgrass and spikegrass, and can form dense stands along the upland marsh border. They also occupy small hummocks and levees within the open marsh.

Common reed (*Phragmites australis*)

The common reed is one of the most successful invasive plants in coastal marshes in the United States. The native form of *Phragmites*, distributed in the northeast and Mid-Atlantic, is not invasive by nature, but a genetic form of this species introduced from Europe and Asia has spread aggressively throughout the country since the early twentieth century (Meyerson et al. 2009). Invasive *Phragmites* can form dense stands that dominate the upper boundary zone of tidal marshes, but are more scattered in open saltmarsh where more saline conditions reduce its competitive advantage. The vulnerability of tidal marshes to *Phragmites* depends largely on salinity and flooding (R. M. Chambers, pers. comm.), with increasing levels of these factors excluding *Phragmites*. Chambers et al (2008) conducted a boat-based shoreline survey of *Phragmites* throughout the Chesapeake Bay during 2001-2005. In Somerset and Wicomico counties *Phragmites* occurred on 4.8-4.9 percent of the shoreline, far less than in less saline portions of the upper Chesapeake Bay.

In Maryland the great majority of high marsh is made up of black needlerush (38.5 percent), meadow cordgrass/spikegrass (24.5 percent) and threesquare (15 percent) (McCormick and Soames 1982). Within the Somerset and Wicomico counties project area, threesquare is less common and most high marsh consists of a mosaic of black needlerush and cordgrass/spikegrass. Black needlerush is the predominant element of most marshes in the project area, although cordgrass marsh dominates extensive areas at Deal Island and on the Pocomoke Sound.

The Sea Level Affecting Marshes Model (SLAMM) used to project the location of future marshes is described in Section II. Table 1 summarizes the wetland and other land cover types used by the SLAMM model in our project area. Three of the SLAMM categories are of particular focus for this assessment: regularly flooded marsh (low marsh), irregularly flooded marsh (high marsh) and transitional saltmarsh. These wetland types are collectively referred to as "tidal marshes" throughout the document.

Table 1 - Current area of wetlands and other land cover types in the study area.

SLAMM category	Area (ac)	% Cover
Developed Land	8,263.5	1.8%
Undeveloped Dry Land	286,519.3	63.4%
Freshwater Swamp	66,088.0	14.6%
Cypress Swamp	45.6	<1%
Inland Freshwater Marsh	6,461.7	1.4%
Tidal Freshwater Marsh	641.2	0.1%
Transitional Saltmarsh	3,404.6	0.8%
Regularly Flooded Marsh	14,472.4	3.2%
Estuarine Beach	1,108.2	0.2%
Tidal Flat	3,238.3	0.7%
Inland Open Water	1,655.7	0.4%
Riverine Tidal Open Water	1,493.4	0.3%
Tidal Creek	7.1	<1%
Irregularly Flooded Marsh	51,188.0	11.3%
Tidal Swamp	7,412.6	1.6%
Total	451,999.9	100.0%

Saltmarsh Birds – Focal Species Conservation Status and Ecology

One of the objectives of this project was to identify and map areas of tidal marsh habitat of highest priority for saltmarsh birds within the project area. To do so we identified seven saltmarsh specialists as focal species:

- American Black Duck
- Black Rail
- Clapper Rail
- Coastal Plain Swamp Sparrow
- Saltmarsh Sparrow
- Seaside Sparrow
- Willet

These seven focal species were selected on the basis of their degree of ecological specialization on tidal marshes, and their conservation priority at the national, regional or state level (see Box 2). These species also each have significant populations in tidal marshes in the project area. Their ecological status as saltmarsh specialists makes them appropriate indicator species for this habitat and appropriate umbrella species for a range of other species that use tidal marshes. Additionally, each of these seven species was identified as either "moderately" or "highly" vulnerable to climate change at the statewide scale by the Maryland DNR, using the NatureServe Climate Change Vulnerability Index (Release 2.01; NatureServe 2010) – see Appendix II.

Box 2: Marsh Bird Conservation Priorities

The Partners in Flight Bird Conservation Plan for the Mid-Atlantic Coastal Plain (Watts 1999) identifies saltmarsh as one of the highest ranking habitats in conservation priority for birds in the region. The saltmarsh bird assemblage includes four species on the American Bird Conservancy / Audubon WatchList due to declining populations (Black Rail, Saltmarsh Sparrow and Seaside Sparrow in the highest "Red" category of concern, and Clapper Rail in the "Yellow" category of moderate concern). Two saltmarsh birds stand out as having conservation priority globally - Black Rail is listed by Birdlife International as globally Near-Threatened, and Saltmarsh Sparrow is listed as globally Vulnerable due to its breeding range being restricted to the northeast United States (the only bird species so restricted). The North Atlantic Landscape Conservation Cooperative (NALCC), a conservation science-management partnership led by the USFWS, has identified four of this plan's seven focal species (American Black Duck, Clapper Rail, Saltmarsh Sparrow, Willet) as representative species in the Mid-Atlantic sub-region of the NALCC. The NALCC defines a representative species "as a species whose habitat needs, ecosystem function, or management responses are similar to a group of other species. It is assumed that conservation planning and actions for a representative species will also address the needs of other species."

Table 2 - Avian conservation targets in Somerset and Wicomico counties

Species	Endemism category (breeding populations)[a]	Conservation priority		
		National [b]	Regional (BCR 30) [c]	State of Maryland [d]
American Black Duck	4		HH	GCN
Black Rail	3	WL Red, BCC	HH	E, GCN
Clapper Rail	2	WL Yellow	H	
Coastal Plain Swamp Sparrow	2		M	I, GCN
Saltmarsh Sparrow	1	WL Red, BCC	HH	GCN
Seaside Sparrow	1	WL Red, BCC	HH	GCN
Willet	2		H	GCN

[a] *Endemism:* Category: 1 = species endemic to tidal marsh; 2 = subspecies endemic to tidal marsh; 3 = species with majority of populations in North America restricted to tidal marsh; 4 = species with majority of populations in Mid-Atlantic region restricted to tidal marsh (adapted from Greenberg and Maldonado 2006)
[b] *National priority*: WL = Audubon/American Bird Conservancy WatchList; Red category = Highest national concern; Yellow category = Declining or rare. See http://birds.audubon.org/2007-audubon-watchlist; BCC = USFWS Birds of Conservation Concern (2008) http://www.fws.gov/migratorybirds/NewReportsPublications/SpecialTopics/BCC2008/BCC2008.pdf
[c] *Regional priority (BCR 30):* HH = Highest priority; H = High priority; M = Moderate priority. See http://www.northatlanticlcc.org/rep_species.html
[d] *State priority:* Listed in the Code of Maryland Regulations (COMAR 08.030.08) as E = Endangered, T = Threatened, I = In Need of Conservation. See website: http://www.dnr.Maryland.gov/wildlife/rteanimals.asp GCN = Listed in Maryland Wildlife Diversity Conservation Plan as a Species of Greatest Conservation Need. See http://www.dnr.state.md.us/wildlife/Plants_Wildlife/WLDP/divplan_about.asp

All of the focal species in the saltmarsh bird assemblage use tidal marsh as their principal breeding habitat in the Mid-Atlantic region. Most of the species require high marsh for nesting sites because this habitat escapes daily flooding, and within the high marsh zone they generally prefer extensive tracts of short-statured *Spartina* grasses. Most species in the group are short distance migrants, wintering in the Southeast and Mid-Atlantic. More information about each species' distribution and ecological associations can be found in Box 3.

Many other bird species of conservation priority also use the tidal marshes in Somerset and Wicomico counties and will likely benefit from conservation strategies for sea level rise adaptation arising from this plan. These species are listed in Appendix II. (Some of these species are of similar or higher conservation priority than the project's focal species, but they have a lesser degree of dependence on tidal marshes and the majority of their respective populations live in other habitats).

Box 3: Focal Bird Species Distribution and Ecology

American Black Duck *(Anas rubripes)*

American Black Duck has an extensive breeding range across eastern North America, including inland regions where it nests in wooded wetlands and bogs (Longcore et al 2000). In the Mid-Atlantic it is found breeding mostly in tidal marshes—the population around Tangier Sound in the Chesapeake Bay, including Somerset and Wicomico counties, used to be one of the largest southern breeding populations. Breeding Bird Atlas data show that Black Duck distribution contracted in Maryland as this species largely disappeared from the Patuxent and Potomac Rivers (Brewer 2010).

During the nesting season Black Ducks may prefer meadow cordgrass over other vegetation types. Watts (1992) detected Black Ducks more often in meadow cordgrass than in other vegetation types in a survey of tidal marshes on the western shore of Virginia.

Black Rail *(Laterallus jamaicensis)*

Black Rail has a wide geographic range across North and South America but its distribution is disjunct and localized. The eastern United States population is confined to saltmarshes where it is one of the rarer members of the saltmarsh species assemblage. Within the Mid-Atlantic region the main population inhabits the middle reaches of the eastern shore of the Chesapeake Bay from Dorchester County, MD, to Accomack County, VA (Wilson et al 2007). Night-time surveys undertaken for this nocturnal species revealed that the Maryland population had declined by more than 80 percent from 1991 to 2007 (Davidson 2010). The main conservation threats to this species in tidal marshes appear to be flood events from high tides which result in nest loss and increased predation (Davidson 2010).

In eastern North America Black Rails nest only in the high marsh zone of tidal marshes, and in Maryland they prefer marsh dominated by meadow cordgrass (*Spartina patens*), smooth cordgrass and spikegrass (*Distichlis spicata*), with scattered black needlerush, cat-tail and threesquare (Eddleman et al 1994, Davidson 2010).

Clapper Rail *(Rallus longirostris)*

The Clapper Rail is found on both the west and east coasts of North America. The east coast subspecies group inhabits tidal marshes from New England to Tamaulipas, Mexico (Eddleman and Conway 1998).

This species is found in high and low marsh zones. In New Jersey, it prefers smooth cordgrass marsh over meadow cordgrass (Eddleman and Conway 1998). In the Virginia portion of the Chesapeake Bay Clapper Rails were detected most often in black needlerush and tall cordgrass during daylight surveys, but abundant remains of fiddler crabs, their principal summer prey, indicated frequent use of high marsh meadow cordgrass at night (Watts 1992).

Coastal Plain Swamp Sparrow *(Melospiza georgiana nigrescens)*

Swamp Sparrow is a widespread species common in freshwater wetlands, and the Coastal Plain Swamp Sparrow is a subspecies endemic to tidal marsh habitats in the Mid-Atlantic region. This subspecies breeds only in Maryland, Delaware, New Jersey and New York (Greenberg and Droege 1990).

Within tidal marshes, Coastal Plain Swamp Sparrow occupies the saltbush shrub zone near the upland edge of the marsh, favoring marsh elder and groundsel-bush but also occupying stands of *Phragmites* and *Lythrum*. The zone of suitable shrub habitat typically extends 200-400 m from the edge of the marsh-upland transition but small patches of saltbush along roads and on isolated hummocks in the marsh interior can also provide habitat (Greenberg and Droege 1990, Beadell et al 2003).

Box 3 *continued*:

Saltmarsh Sparrow *(Ammodramus caudacutus)*

The Saltmarsh Sparrow's breeding population is endemic to the northeastern United States, breeding only from Maine to Virginia. It winters in tidal marshes from the Mid-Atlantic to Florida (Greenlaw and Rising 1994). Somerset and Wicomico counties are close to the southern limit of its breeding range.

This species nests only in the high marsh zone and is largely restricted to short grass meadows dominated by meadow cordgrass (*Spartina patens*), spikegrass (*Distichlis spicata*) and saltmeadow rush (*Juncus gerardi*) (Greenlaw and Rising 1994, Benoit and Askins 1999, Shriver et al 2004). In Maryland, its preferred habitat is described as interior tracts of high marsh dominated by smooth cordgrass and spikegrass, also in black needlerush marshes (Davidson 2010). This species has been best studied in Connecticut where research has identified habitat characteristics associated with sparrow presence and nest success. Saltmarsh Sparrows nest low, almost at ground level, in meadow cordgrass and smooth cordgrass and tidal flooding is the most frequent cause of nest failure (DiQuinzio et al 2002). Males play no role in rearing nestlings and marshes with the most birds are not necessarily those where the most females nest (Gjerdrum et al 2005). A recent study (Meiman 2011) found that models that best fit data for Saltmarsh Sparrow presence used different variables than for sparrow nesting. Although nesting habitat was best predicted by detailed delineation of plant communities, nesting areas were best predicted by a model with a variable derived from spectral reflectance values from remote sensing data (Meiman 2011).

Seaside Sparrow *(Ammodramus maritimus)*

The Seaside Sparrow is confined to the east coast of North America, but is more widespread than the closely related Saltmarsh Sparrow, being found in tidal marshes from southern New England to Texas near the Mexican border (Post and Greenlaw 1994).

Seaside Sparrow is more abundant than Saltmarsh Sparrow in Maryland and has a broader ecological niche, occupying black needlerush and smooth cordgrass habitat of the low marsh (where it is most abundant) as well meadow cordgrass habitat in the high marsh (Coskren 2010).

Willet *(Catoptrophorus semipalmatus)*

The Willet is distributed in two disjunct regions of North America, with a western subspecies occupying interior grasslands of the west and an eastern subspecies inhabiting tidal marshes on the east coast from New Brunswick in Canada to Tamaulipas in Mexico.

In Maryland, Willets preferred habitat is high marsh meadows of meadow cordgrass, sometimes interspersed with taller vegetation, and containing areas of open water such as tidal creeks or shallow, permanent ponds (Davidson 2010).

THE 2011-12 SHARP SALTMARSH BIRD SURVEY

In order to develop a more detailed picture of abundance patterns and habitat relationships of the focal saltmarsh bird species within the project area, bird data and vegetation data were collected in the breeding seasons of 2011 and 2012 by Audubon Maryland-DC at 207 survey points in tidal marsh in the four counties of Maryland's lower eastern shore. The survey was part of the northeast regional Saltmarsh Habitat Avian Research Project (SHARP, http://www.tidalmarshbirds.org/). Audubon Maryland-DC completed the surveys under contract from the Maryland Department of Natural Resources, with funds from a competitive State Wildlife Grant administered by the U.S. Fish and Wildlife Service.

The survey's sampling frame selected up to 10 survey points per hexagon-shaped primary sampling unit – the Somerset-Wicomico project area contained 8 hexagons and 63 survey points. Birds were measured by point counts using Standardized North American Marsh Bird Monitoring Protocol, which uses call broadcasts to solicit response from secretive marsh birds. The number of individuals detected was recorded during 3 replicate visits from May-July. Habitat data was collected during a brief vegetation survey at each point during a single visit in June. The percent cover of each stand-forming plant species was estimated by eye in the 50 m radius circle around each point.

Patterns of abundance and habitat-landscape relationships of focal bird species within the project area were assessed based on the following:

1. Survey results maps showing average numbers of birds detected at each survey point during 2011 and 2012.
2. Histograms of vegetation cover at points where focal bird species were detected, based on 2011 data.
3. Univariate analyses of the influence of vegetation and landscape variables on mean detection rate of focal bird species, based on 2011 data.
4. Multiple logistic regression models of the influence of vegetation and landscape characteristics on presence-absence of focal bird species, based on 2011 data. Only statistically significant variables in Wilcoxon Signed Ranks tests were included in the logistic regression procedure. Data from all Maryland survey points was included; County was included as a covariate.

See Appendix II for the complete SHARP survey results for each of the seven focal species, as well as detailed results from the univariate and multiple logistic regression analyses and Wilcoxon Signed Ranks tests.

COMPOSITE ABUNDANCE OF FOCAL BIRD SPECIES

Map 3 (pg. 50) shows the combined abundance of the seven focal bird species from the 2011-12 SHARP surveys. The map shows greater abundance of these avian saltmarsh specialists in the 5 primary sampling units (PSUs) at Deal Island, Fairmount and the Crisfield vicinity than in the 3 PSUs at the Nanticoke River, Wicomico River and Marumsco Creek. This likely reflects these species preference for more extensive marshes dominated by saltmarsh vegetation. Marshes sampled in the Nanticoke River PSU and Wicomico River PSU are of limited size and support vegetation reflecting less saline conditions.

VEGETATION ASSOCIATIONS OF FOCAL BIRD SPECIES

The vegetation associations of the seven focal saltmarsh specialists are summarized in Table 3. (Published literature used to determine relationships include works cited earlier in this section. This table should not be considered comprehensive but a summary of current knowledge). The most preferred vegetation type for saltmarsh focal birds is short-statured *Spartina* high marsh meadows, with five of the seven bird species showing a preference and none showing an overall avoidance of this vegetation. There is also a clear general preference for black needlerush among this bird assemblage. *Phragmites* is avoided by most members of this bird assemblage.

Table 3 - Vegetation associations of focal saltmarsh bird species

Bird species	Marsh vegetation type[1]											
	Phragmites		**Threesquare**		**Salt bush**		**Short Spartina**		**Needlerush**		**Tall Spartina**	
American Black Duck				+			+					
Black Rail			+				+		+			
Clapper Rail		-		-					+	+	+	
Coastal Plain Swamp Sparrow	+				+							+
Saltmarsh Sparrow	-	-					+	+	+	-	-	
Seaside Sparrow		-			+	-	+	+	+	+		
Willet		-		-			+	+		-		

[1]For each vegetation type the left column shows relationship indicated by published literature and the right column show relationship indicated by SHARP survey results.
"+" indicates positive relationship; "**-**" indicates negative relationship; a blank space indicates an uncertain or neutral relationship.

AREA SENSITIVITY IN FOCAL BIRD SPECIES

Analysis of the SHARP survey data revealed a general preference for the marsh interior and avoidance of the upland marsh edge in the majority of the focal bird species (see Appendix II for complete results and analysis). These data also demonstrate area sensitivity in two saltmarsh birds (Saltmarsh Sparrow and Seaside Sparrow) and thus highlight the importance of large interior marsh patches where these species can maintain high population densities. The nature of these relationships suggests that an appropriate distance threshold between interior marsh and edge marsh for bird conservation planning purposes in Maryland is 500 m.

PRIORITY AREAS FOR SALTMARSH BIRD CONSERVATION.

Results of the SHARP surveys indicate that all of the extensive tidal marshes on the three major peninsulas in Somerset County (Deal Island, Fairmount and Crisfield) are of high conservation importance for specialist birds, and that the Nanticoke River marshes and smaller marshes along creeks with less saline conditions, are of lesser importance for this bird assemblage. Saltmarsh Sparrow and Black Rail are the two bird species of highest conservation priority among the focal birds of this project. The distribution of these two species, based on SHARP surveys and other sources suggests two areas of highest bird conservation priority: Deal Island and Pocomoke Sound. All records of Saltmarsh Sparrow and Black Rail were located within these areas.

We can use these vegetation associations and area sensitivity data in conjunction with the future marsh occupancy outputs of the SLAMM model, described in Section II, to project how sea level rise might affect important saltmarsh bird habitat. Spatial modeling of priority future saltmarsh bird habitat based on these data is described in the next section.

Section II: Climate Adaptation Analysis

This section provides an explanation of the methods employed to model the future distribution of marshes, priority habitat for saltmarsh birds, marsh migration corridors and priority marsh conservation areas. See Appendix III for further detail on models and methods, including the GIS models used.

We used computer modeling to project the effects of sea level rise on the current and future distribution of saltmarsh ecosystems in Somerset and Wicomico counties, Maryland. Our objectives were to identify areas that may support tidal marsh in the future as sea level rises, and to prioritize these locations according to the likely ecological value of future tidal marshes.

Our analysis consisted of five principle steps:

1. Selection of an appropriate sea level rise model and identification of the subset of saltmarsh types on which to run the analyses.
2. Modeling a series of time steps with increasing levels of sea level rise and mapping the extent and distribution of saltmarsh habitat patches for each.
3. Identification of marsh "migration" corridors—chains of saltmarsh habitat that are spatially linked across time.
4. Identification of high-priority areas for marsh conservation based on saltmarsh ecological value, modeled core bird habitat, risk of future development, and land cover conversion suitability.
5. Application of prioritization results to land ownership units to identify priority parcels and areas for land conservation.

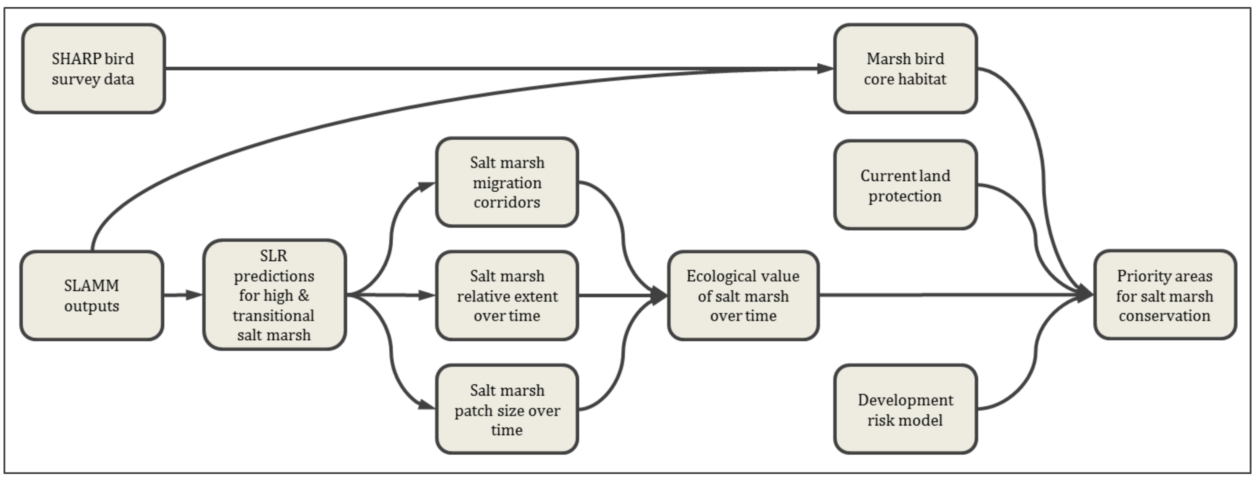


Figure 1 - Conceptual diagram showing the process for modeling priority areas for saltmarsh conservation.

SEA LEVEL AFFECTING MARSHES MODEL – SLAMM

There is a heightened interest in accurately modeling for sea level rise (SLR) as we begin to see the empirical effects of transgressing waters along our coastlines, and there are numerous sea level rise models—both physical and semi-empirical models—currently available. From a conservation perspective, tidal marsh ecosystems are hugely important as they are rare to begin with, they are highly susceptible to loss due to sea level rise and they also may help buffer some of the more violent effects of climate change such as storm surges and flooding.

The Sea Level Affecting Marshes Model (SLAMM) uses elevation, accumulation of sediments, wetland accretion and erosion rates, salinity, overwash, inundation and other physical processes to predicatively model long-term wetland and shoreline change (Warren Pinnacle 2012, Edmonds 2011). SLAMM was first developed with EPA funding in the mid-1980s. It has since undergone many iterations, (SLAMM 6.0.1 was released in 2009), and has been used to predict SLR-caused effects to numerous coastal marshes along the Atlantic, Pacific and Gulf Coasts (Lee et al. 1992, Park et al. 1991, Park et al. 1993, Galbraith et al. 2003, Craft et al., 2009). For more on SLAMM, please refer to technical documentation at www.warrenpinnacle.com.

In 2011 the Maryland Department of Natural Resources ran SLAMM 6.0.1 on all 16 of its coastal counties. The model was run assuming a sea level rise of 1.04 meters by 2100, reflecting the IPCC's A1B scenario which was identified by the Maryland Commission on Climate Change as an acceptable high emissions scenario for the Chesapeake Bay region. The model employed 1-meter resolution LiDAR (Light Detection and Ranging) elevation data and it adjusted the other physical parameters by county to account for regional variations. Table 4 shows the predicted sea level rise for each of 4 benchmark years.

Table 4 - Predicted sea level rise elevation and benchmark year equivalents used in the MD DNR SLAMM model runs.

Benchmark Year	Meters Sea Level Rise	Feet Sea Level Rise
2025	0.19	0.6
2050	0.42	1.4
2075	0.72	2.4
2100	1.04	3.4

TARGET MARSH TYPES

The coastal habitat categories as described by the U.S. Fish & Wildlife Service National Wetlands Inventory Classes were adopted by SLAMM as the landcover types on which the predictive modeling was done. These categories are listed in Table 5.

In identifying locations for future marshes, we selected irregularly flooded (high) marsh as our conservation target because the high marsh zone is required as nesting habitat by all of the saltmarsh specialist birds that are the focal species of the project. Two of the focal species, Clapper Rail and Seaside Sparrow also nest in low marsh but the daily tidal flooding regime of the low marsh zone precludes the majority of saltmarsh birds from nesting there. Hence we selected high marsh as the target habitat type in order to ensure a focus on what we believe will become the principal limiting factor for saltmarsh bird populations in the future under most sea level rise scenarios.

<u>Irregularly Flooded (Brackish) Marsh</u>: Irregularly flooded estuarine inter-tidal emergent wetlands, lower salinity than saltmarsh. Representative plant species include saltmeadow cordgrass, salt reed grass, black needlerush and short smooth cordgrass (Spartina pectinata). *These marshes make up the majority of the coastal marsh types in the region and provide food and habitat for many species of mammals, reptiles, amphibians and birds. They also support fish species such as rockfish, white perch, herring and shad. In addition, they absorb excess nutrients and pollution and anchor loose soils.*

(p4, Glick et al. 2008)

We added transitional marsh (SLAMM code 7) to the high marsh (SLAMM code 20) conservation target because one of the focal bird species, Coastal Plain Swamp Sparrow, prefers shrub communities of marsh elder as nesting habitat and also because of the potential for transitional marsh to convert to open high marsh by way of the mechanical removal of dead and salt-stressed trees in the transition zone. Although not included in the (SLAMM) description of transitional marsh, most upland transition zones in the project area are dominated by dying salt-stressed forests of loblolly pine.

<u>Transitional Marsh</u>: Estuarine intertidal scrub-shrub wetlands with broad-leaved deciduous vegetation, provides a transition zone between saltmarsh and the upland border. Typically comprised of marsh elder and groundsel tree. These habitats support numerous songbird species.

(p4, Glick et al. 2008)

Table 5 - Land cover classes as used in SLAMM and their current representation in our study area. Non-wetland land cover types are in italics. Asterisks "*" denote classes that were not used / not present in our study area and are thus absent from the SLAMM model outputs.

SLAMM code	SLAMM category	Area (ac)	% Cover
1	*Developed Dry Land*	8,263.5	1.8%
2	*Undeveloped Dry Land*	286,519.3	63.4%
3	Freshwater Swamp	66,088.0	14.6%
4	Cypress Swamp	45.6	0.01%
5	Inland Freshwater Marsh	6,461.7	1.4%
6	Tidal Freshwater Marsh	641.2	0.1%
7	**Transitional Saltmarsh**	**3,404.6**	**0.8%**
8	Regularly Flooded Saltmarsh ("low marsh")	14,472.4	3.2%
9	Mangrove*		
10	*Estuarine Beach*	1,108.2	0.2%
11	*Tidal Flat*	3,238.3	0.7%
12	*Ocean Beach**		
13	*Ocean Flat**		
14	*Rocky Intertidal**		
15	*Inland Open Water*	1,655.7	0.4%
16	*Riverine Tidal Open Water*	1,493.4	0.3%
17	*Estuarine Water (not counted in area totals)*		
18	*Tidal Creek*	7.1	0.002%
19	*Open Water**		
20	**Irregularly Flooded Saltmarsh ("high marsh")**	**51,188.0**	**11.3%**
21	*NOT USED**		
22	*Inland Shore**		
23	Tidal Swamp	7,412.6	1.6%
24	*BLANK**		
25	*Vegetated Tidal Flat**		
26	*Backshore**		
	TOTAL	451,999.6	100%

MIGRATION, LOSS AND PERSISTENCE OF SALTMARSH OVER TIME

As physical conditions change over time due to sea level rise, an area's ability to support saltmarsh can be lost, maintained, or improved. In other words, saltmarsh may disappear, persist, or migrate to new areas on the landscape.

We took the marsh extent projections made by the 2011 Maryland Department of Natural Resources SLAMM 6.0.1 model runs and specifically investigated the high (irregularly flooded, SLAMM code 20) and transitional marsh types (SLAMM code 7), as those are the marsh types most important to the focal bird species used in this analysis. **Map 4 (pg. 51)** shows the results of these SLAMM projections, highlighting the effects of sea level rise (SLR) on high and transitional marsh in Somerset and Wicomico counties over the next century.

NOTE: We ran an additional iteration of our analyses including regularly flooded (intertidal) saltmarsh ("low marsh" – SLAMM code 8). Results from those analyses are not presented in this report, but are available upon request.

Table 6 and Figure 2 depict the modeled effects of sea level rise on irregularly flooded (high) saltmarsh, transitional saltmarsh and the two combined. The individual trend lines for high marsh and transitional marsh acreages differ greatly over this time period (Figure 2). Transitional marsh shows a net gain in area over the century, while nearly all (94.8 percent) high marsh is lost. This disparity illustrates the importance of future management of transitional marsh zones to facilitate the shift to open high marsh habitat, a management process recently coined as "Managed Marsh Transition" (Lerner et al. 2013).

Table 6 - Areas (in acres) of marsh that were lost to SLR, gained via marsh migration, or persistent over the 5 modeled time steps from 2010 to 2100.
(Return to page 32).

	high (irregularly flooded) marsh				transitional marsh				high and transitional marsh			
	loss	persistence	migration	*TOTAL*	loss	persistence	migration	*TOTAL*	loss	persistence	migration	*TOTAL*
2010	–	–	–	*51,188*	–	–	–	*3,405*	–	–	–	*54,593*
2010 - 2025	5,049	46,139	2,756	*48,894*	497	2,685	3,523	*6,209*	5,546	49,047	6,279	*55,325*
2025 - 2050	19,752	29,142	3,269	*32,411*	4,382	2,049	11,134	*13,182*	24,134	31,191	14,403	*45,594*
2050 - 2075	26,386	6,025	1,233	*7,258*	12,710	472	10,865	*11,337*	39,096	6,497	12,098	*18,595*
2075 - 2100	4,897	2,361	325	*2,685*	11,215	122	9,790	*9,912*	16,113	2,482	10,115	*12,598*

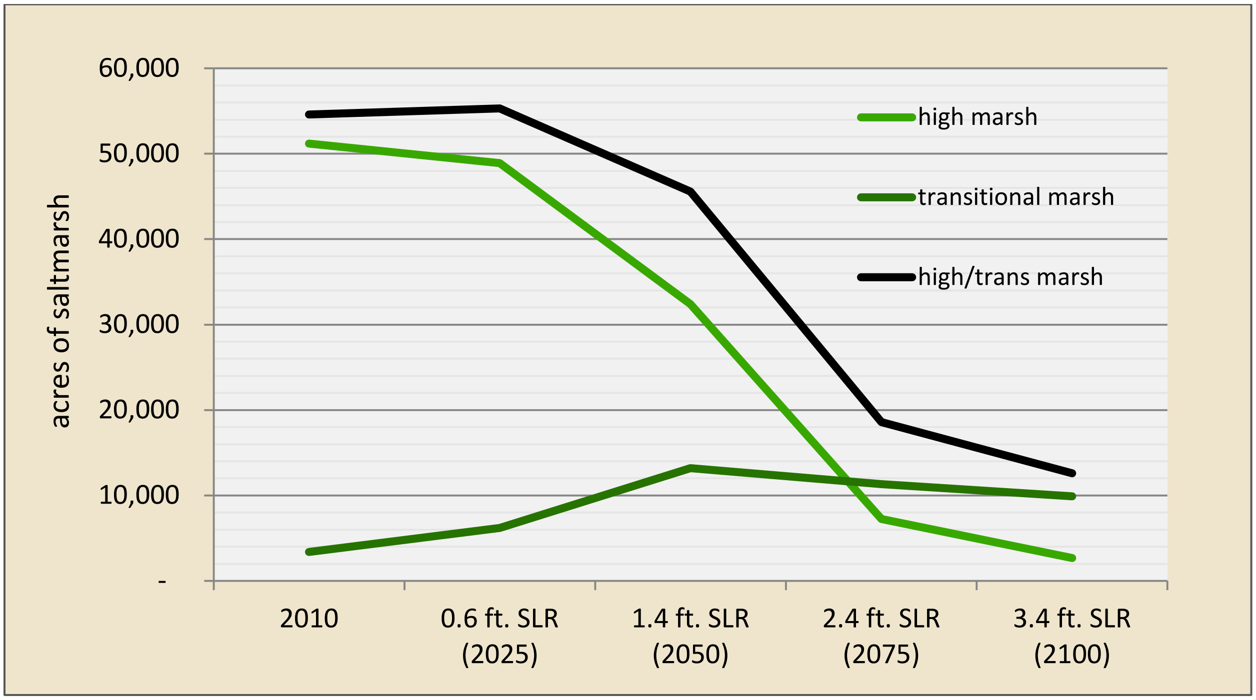


Figure 2 - Areas (in acres) of high, transitional and total marsh over the 5 modeled time steps from 2010 to 2100. (Return to page 32).

One can see from these figures that by the end of the century, suitable conditions for the sustenance of saltmarsh in Somerset and Wicomico counties are sparse. 85+ years however is a very long planning horizon, and it is generally accepted that the accuracy of predictive models such as SLAMM diminishes the further away we get from present conditions. Map 5 (pg. 52) depicts the cumulative gain, loss and persistence of saltmarsh habitat over the next century. While the bottom two panels (~2075 and ~2100) are still interesting, by focusing on the top three panels we can get a sense for the current areas of high and transitional saltmarsh that are expected to persist over the next four (as opposed to nine) decades, a much more realistic planning horizon for conservation decision-makers.

Bird Habitat Modeling

The primary spatial objective of the project was to identify land conservation priorities according to the likely ecological value of tidal marshes that will occupy these areas in the future. One contributing factor to the overall ecological value of marshlands is their potential to be quality habitat for birds. To measure this, we identified marsh habitat patches in each time step from the SLAMM models and then selected those patches meeting known habitat requirements of saltmarsh specialist birds.

Marsh habitat patches were first identified, and then refined to reflect the habitat requirements of saltmarsh specialist birds. As discussed in the previous section, many saltmarsh birds are habitat area-sensitive and are absent from habitat patches smaller than 160 acres in size (Watts, 1992). However, the nature of this area-sensitivity changes across a species' geographic range.[3] We elected to use the 65 ha size threshold due to the limited predicted extent of high marsh in the latter part of the 21st Century. Furthermore, results from the 2011 and 2012 Saltmarsh Habitat Avian Research Project (SHARP) bird surveys (see Section I and Appendix II) showed that saltmarsh specialist birds have a strong preference for high quality interior habitat (500 meters or more from the upland edge). We applied this 500 m distance to upland edge threshold in our model in order to distinguish high priority interior "core" marsh habitat from lower priority edge marsh.

Map 6 (pg. 53) shows the projected habitat suitability for saltmarsh specialist bird species in Somerset and Wicomico counties over the next century. This map was created by taking the projections made by the SLAMM model of marsh extent under sea level rise, and refining the marsh patches based on the minimum size threshold and distance to upland edge as determined in the literature and by the SHARP surveys. The projected bird habitat is displayed as core habitat and edge habitat.

Areas projected to be core bird habitat at any point over the modeled SLR time steps were then combined into a map showing the most important areas for saltmarsh bird habitat conservation over time (Map 7, pg. 54). These identified areas then were overlaid onto the model of priority areas for conservation (described later in this section) to incorporate the needs of a specific biodiversity conservation target (saltmarsh birds) and to further refine the model's use as a decision support tool.[4]

---

[3] In Connecticut, at the northern edge of its range, Seaside Sparrow tends to be absent from marshes smaller than 100 ha (Benoit and Askins, 2002), but in the Virginia portion of the Chesapeake Bay Seaside Sparrow occupies marshes 5 ha or greater in size (Watts 1992). Habitat area relationships are poorly known for most saltmarsh birds. Maryland DNR used a size threshold of 150 acres (61 ha) to prioritize marsh habitat for most breeding birds and 650 acres (263 ha) to include breeding areas for Northern Harrier (Maryland DNR, 2011). Watts (1992) used 65 ha as a size threshold of habitat to support the full assemblage of saltmarsh birds in the Virginia portion of the Chesapeake Bay.

[4] Although the ecological context and adaptation strategies contained and reviewed in these sections are specific to the project's geographic area of interest, we hope that by providing a detailed account of the considerations and methodologies that were used, it will make it easier for projects in other regions to develop similar tools for their own use. For instance, while we focused on saltmarsh birds as a measure of biodiversity value in this specific ecological context, other representative species, groups, or systems could be substituted if a similar approach were replicated elsewhere. Likewise, we have tried to be explicit about the factors that we selected to identify ecologically valuable areas of tidal marsh, so that the details and specific inputs associated with the model can be adapted as needed to identify marsh migration corridors within other contexts. The same can be said for the outreach strategies and tools; we hope that this report will serve as an example that can be replicated for other tidal and saltmarsh regions.

IDENTIFICATION OF MARSH MIGRATION CORRIDORS

Marsh "migration" corridors are chains of saltmarsh habitat spatially linked across time steps. Identification and conservation of these corridors is important in order to create an environment in which saltmarsh ecosystems have the freedom to move to newly suitable inland locations as sea levels rise. Such corridors can be visually interpreted by looking at composite images of marsh over all time steps such as in Map 8 (pg. 55) and linking zones that progress from marsh in the present all the way to marsh in the future.

In order to identify these corridors computationally however, we ran a step-wise analysis on marsh patches for each time step (2100, 2025, 2050, 2075 and 2100) (Figure 3). We first identified all of the marsh patches in 2025 that had a spatial overlap with marsh patches in 2010, and then eliminated any patches in 2025 that were not part of this identified set. Next, we identified all of the marsh patches in 2050 that had a spatial overlap with the pre-screened marsh patches in 2025 (those identified in the previous step), and then eliminated any patches in 2050 that were not part of this identified set. We then identified all of the marsh patches in 2075 that had a spatial overlap with the pre-screened marsh patches in 2050, and then eliminated any patches in 2075 that were not part of this identified set. Finally, we identified all of the marsh patches in 2100 that had a spatial overlap with the pre-screened marsh patches in 2075, and then eliminated any patches in 2100 that were not part of this identified set. The selected sets of marsh patches from all future time steps (2025 – 2100) were combined in the same map and any overlapping boundaries were dissolved (removed). The final result was a map showing all the regions of saltmarsh that are contiguous across time and space (Map 9, pg. 56). See Appendix III for more thorough details on these operations.

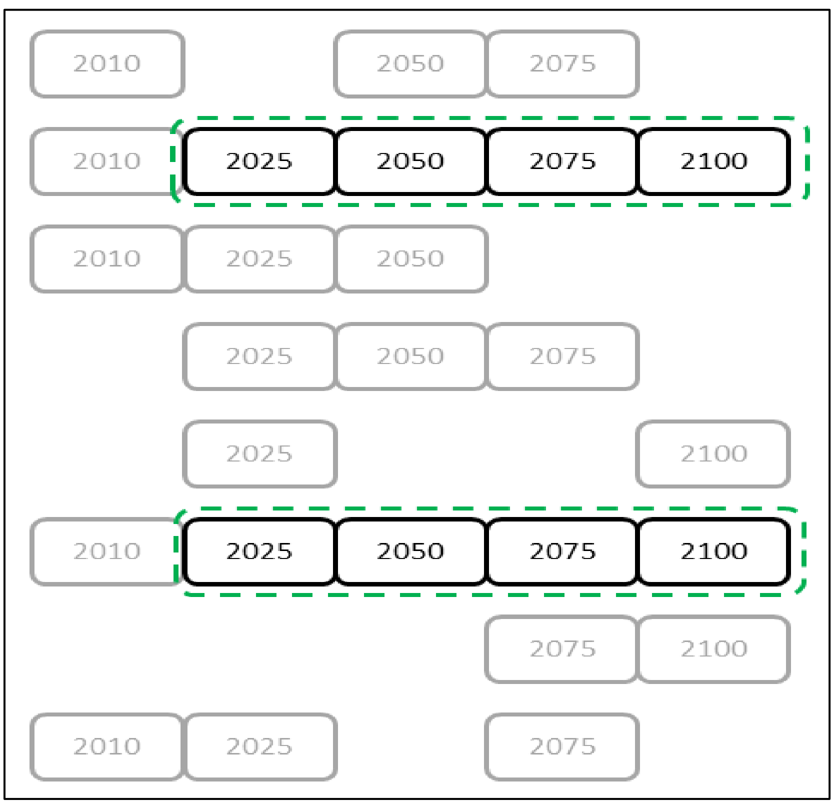


Figure 3 - Schematic showing the concept behind identification of marsh migration corridors. Patches of marsh can be connected in a variety of ways across time and space on the landscape, but only those patches that are links in the full 2010 to 2100 chain can be considered part of a marsh migration corridor.

Determining the Ecological Value of Saltmarsh Over Time

Before determining which areas were of the highest priority for saltmarsh conservation, we analyzed the landscape to assess which areas of saltmarsh are most important in terms of intrinsic ecological value over time. The ecological value of saltmarsh has already been discussed to some extent in this report. Our aim here was to score each pixel of saltmarsh on the landscape based on its contribution to the existence and persistence of an intact and functional saltmarsh ecosystem. To do this we modeled three marsh ecosystem characteristics: patch size, relative extent and habitat connectivity. (See Appendix III for a more detailed description for how these characteristics were spatially calculated and modeled).

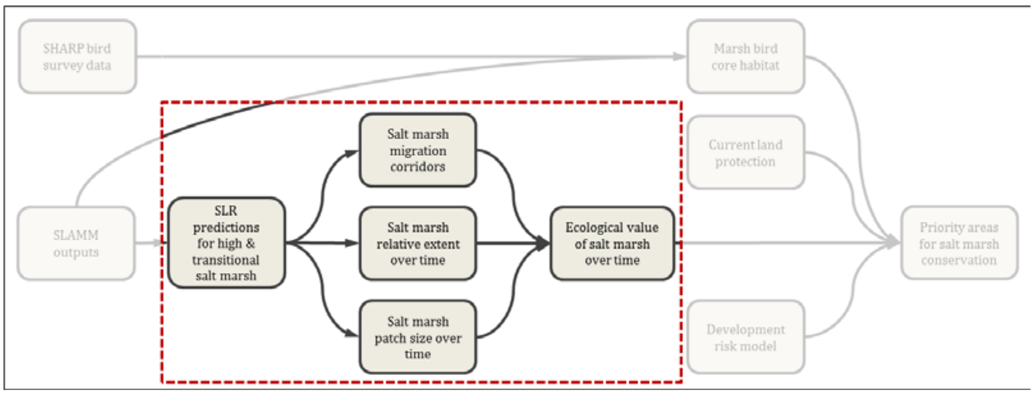


Figure 4 - Conceptual model: ecological value of saltmarsh over time.

Patch Size

We first assumed that larger patches of habitat are better at supporting bird populations and other ecological functions. This assumption was verified by the marsh bird habitat suitability analyses conducted as part of the SHARP surveys. For each time individual step, the absolute size for each patch of saltmarsh was calculated. In order for patch sizes to be compared across time steps, the absolute patch size values were rescaled to reflect the size of each patch relative to the distribution of patch sizes present during that time step: *relative patch size = 10 * (absolute patch size / maximum patch size present during time step)*. Each 30m x 30m cell in the patch size raster file was assigned the value corresponding to the patch in which it was a part. These relative patch size layers for each time step were then combined into one "all-times" patch size layer, where each cell was assigned the maximum value from all 5 time steps as its final value (Map 10, pg. 57).

Relative Extent

Next we looked at the relative extent of saltmarsh on the landscape at each time step. This measure of relative extent addresses the idea that there is value in scarcity. That is, during times when there is less marsh on the landscape (e.g. at the end of the century as projected by SLAMM), those areas of marsh are of higher relative value than areas of marsh that exist during times when marsh is more abundant on the landscape (in the present). (In practical terms however, this high relative value trades off against the declining predictability of habitat transitions modeled over such a long period of time). Relative extent is measured as the ratio of the maximum marsh extent across all five time steps to the marsh extent at time (n): *relative extent at t(n) = extent at t(0) / extent at t(n), where t(0) is the maximum extent of marsh and t(n) is the extent of marsh at time step "n"*. Extent is calculated as the total number of cells that are in saltmarsh at each time step. Once calculated, each cell of marsh is then assigned the value of the relative extent of marsh during that time step. As in the patch size metric, the layers for each time step were combined into one “all-times” relative extent layer, where each cell was assigned the maximum value from all 5 time steps as its final value. Finally, the relative extent values were rescaled so they would be on a common scale to the other characteristics: *relative extent (rescaled) = 10 * (relative extent value / maximum relative extent value)*, **Map 11 (pg. 58)**.

HABITAT CONNECTIVITY

In the context of this project, habitat connectivity is important both across space and across time. To model habitat connectivity in this context we use our model of marsh migration corridors (described earlier in this section). Identification and conservation of these corridors is important to facilitate saltmarsh movement to newly suitable inland locations as sea level rises. We considered patches of marsh that are part of an identified migration corridor to be more valuable than patches that stand alone or are not fully connected across time. Regions which are part of a corridor exhibit connectivity of saltmarsh both across the landscape (space) and across the five time steps (time). In terms of evaluating this characteristic against itself and against the other two characteristics, we chose a binary system where a pixel of saltmarsh that is part of a corridor is assigned the maximum value, and a pixel of saltmarsh that is not part of a corridor is assigned zero value. This characteristic can be further refined by assigning weights to the corridors based on corridor size (area), as is represented in **Map 9 (pg. 56)**.

By combining the above three saltmarsh value characteristics in a simple weighted sum overlay—we used equal weights—we were able to highlight the most important areas of ecological value for saltmarsh persistence on the landscape (**Map 12, pg. 59**).

(Note: in **Maps 9-13**, the Jenks Natural Breaks method (Jenks and Caspall, 1971) was used to reclassify the ranges of values into five data classes. Different methods of reclassification could of course be employed, and would yield different sets of lands identified as high, medium, low, etc. ecological value).

Many areas of high value for saltmarsh persistence—areas currently occupied by marsh or projected to be marsh in the future—are already under one form of protection or another.[5] Table 7 summarizes the protection status each of the ecological value classes in the study region.

Table 7 - Protection status of each of the 5 modeled ecological value classes for salt marsh in Somerset and Wicomico counties.

		unprotected		protected		all
	ecological value	**acres**	**%**	**acres**	**%**	**acres**
	5 (VH)	10,051	38%	16,712	62%	26,763
	4 (H)	10,658	43%	14,031	57%	24,689
	3 (M)	6,235	39%	9,954	61%	16,188
	2 (L)	1,314	16%	6,951	84%	8,265
	1 (VL)	1,002	8%	10,817	92%	11,819
	TOTAL	*29,259*	*33%*	*58,464*	*67%*	*87,723*

The fact that there is existing protection in place for 62 percent of the lands modeled to have high ecological value reflects the success of communities and conservation partners to protect these important resources. However, in order to ensure the continued persistence of these ecosystems given the pressures of sea level rise, the portfolio of conservation lands must be expanded inland. One method for identifying which saltmarsh areas are of the highest priority for conservation would be to simply mask out all currently protected areas and see what remains on the map of highly important saltmarsh lands (**Map 13, pg. 60**).

INCORPORATING DEVELOPMENT RISK

This simplified method for identifying priorities relies solely on our knowledge of current land ownership and our landcover-based model projections for where saltmarsh will be in the future. However, landcover is dynamic and can be dramatically altered by pressures such as urban development and land use change. When identifying priority areas for current and future saltmarsh conservation, it is important to take into account factors such as development risk in addition to ecological value. To do this, we incorporated a model of future development risk that was designed by the Dorchester County Climate Adaptation Project (Lerner et al. 2013). This model uses a combination of zoning, land ownership and land use to qualitatively assess future development potential. Development potential is assessed according to the following categories:

1. Existing Development: Unsuitable for marsh migration for obvious reasons and already excluded from the preceding marsh analyses.
2. Unprotected, undeveloped land within Priority Funding Areas (PFA) and land not in PFAs and within areas exceeding 10 buildings per square kilometer: High potential for future development given the presence of existing higher density development and the high likelihood of future development within a PFA.
3. Unprotected, undeveloped land not in PFA and within areas of less than 5 to 10 buildings per square kilometer. Moderate potential for future development given the occurrence of these lands outside of officially designated development areas with a relatively lower density of buildings.

[5] "Protected" areas are identified as federal, state, local and private conservation lands, as well as any lands that are currently classified as wetlands and are thus protected by the Clean Water Act.

4. Unprotected wetlands, private land under permanent easement and protected public land. Low potential for future development given strong wetland regulatory controls and restrictions imposed on eased and publicly owned lands.

In this development risk model (Map 14, pg. 61), pixels are scored according to the ease of affecting land management and probability of future development (Table 8).

Table 8 - Classification table for development risk model.

Class	Value (risk of development)
Protected public land	1 – very low
Private land under permanent easement	1 – very low
Unprotected wetlands (unlikely to be developed)	1 – very low
Unprotected, undeveloped land not in PFA and within areas <5 buildings/km^2	2 – low
Unprotected, undeveloped land not in PFA and within areas 5-10 buildings/km^2	3 – medium
Unprotected, undeveloped land not in PFA and within areas >10 buildings/km^2	4 – high
Unprotected, undeveloped land within Priority Funding Areas	5 – very high
Existing Development	5 – very high

There exist a variety of different development risk and growth models for this region and many of them could be adopted in this application. The hope is that as better models are produced, they could easily be swapped into our framework to produce an updated conservation priorities map which reflects the latest knowledge on development risk.

INCORPORATING MARSH BIRD CORE HABITAT

As discussed earlier and shown in Map 6 (pg. 53), core bird habitat was modeled for each sea level rise scenario/level. Map 7 (pg. 54) shows these identified core habitat areas layered on top of one another in a composite image with the present on the bottom and the 3.4 ft. SLR (2100) scenario on the top. We incorporated the marsh bird core habitat analysis with the priority saltmarsh conservation area analysis by using the outline of these composite core bird habitat areas to highlight the importance for conservation of any area modeled as core bird habitat from the present day until the end of century sea level rise scenario.

COMBINING MODELS INTO A FINAL OUTPUT

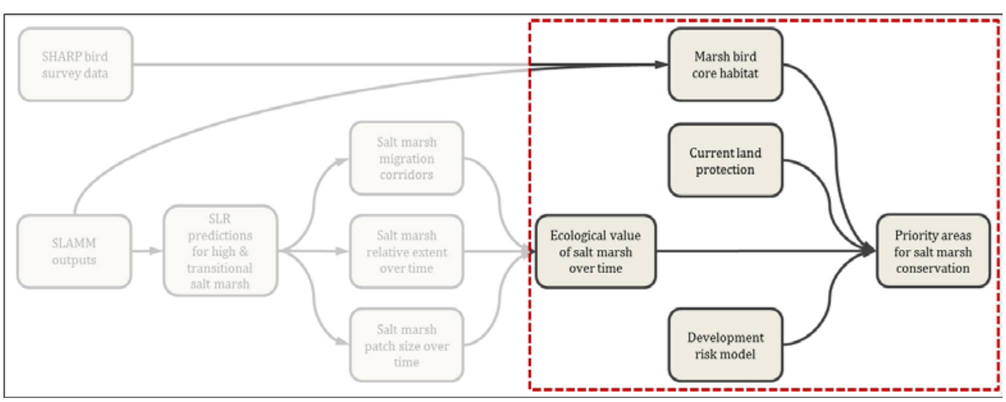


Figure 5 - Conceptual model: conservation priorities.

As illustrated in Figure 5, this development risk layer was combined with the ecological value layer and the marsh bird core habitat layer to produce a map identifying the highest priority areas for current and future saltmarsh conservation.

Table 9 shows a classification matrix which highlights the subjectivity of combining these two quantitative model outputs (development risk and ecological value) into one layer. The reclassification scheme we chose is conservative, for we feel it is better to exercise the precautionary principle and highlight more areas as "of high conservation value" than to inadvertently miss what could be an important area simply due to a classification error.

Table 9 - Classification matrix showing the combination of the ecological value layer and the development risk layer. Percentages within the cells represent the amount of the modeled landscape that falls into each category. Cells are color coded according to the precautionary principle-directed reclassification scheme for the final output map: dark green = very high; light green = high; yellow = medium; light blue = low; and dark blue = very low.

ecological value		development risk: very high 5	high 4	med. 3	low 2	very low 1
very high	5	5.2%	18.8%	3.6%	3.8%	3.0%
high	4	7.1%	16.5%	5.0%	3.9%	3.9%
medium	3	2.5%	8.0%	1.9%	6.1%	2.9%
low	2	0.7%	2.3%	0.6%	0.5%	0.4%
very low	1	0.7%	1.0%	0.4%	0.4%	1.0%

Map 15 (pg. 62) and Map 16 (pg. 63) show the final results of this analysis, both with and without the overlay of the modeled marsh bird core habitat. The amount of the landscape in each resulting conservation priority category is shown in Table 10.

Table 10 - Acres, hectares and percentages of each marsh conservation priority category for the modeled landscape.

marsh conservation priority	ac	ha	%
Very High	13,901	5,625	48%
High	6,892	2,789	24%
Medium	6,866	2,778	23%
Low	1,089	441	4%
Very Low	508	206	2%

OTHER FACTORS TO CONSIDER

MARSH CONVERSION SUITABILITY

All of the models presented thus far assume that all current land cover classes are equally suitable for conversion to saltmarsh, given the parameters adopted in the SLAMM model. However, there may be reason to believe that certain land cover types might in fact be unsuitable for conversion to saltmarsh. For instance, evidence shows that when inundated under sea level rise, the elevated root structure of woody wetlands is susceptible to collapse and thus instead of converting to saltmarsh, woody wetlands are more likely to convert directly to open water. To account for this, we chose to run three distinct iterations of our entire analysis:

Iteration 1) All land cover classes are suitable for marsh; this is the baseline condition.

Iteration 2) Developed land and woody wetlands are excluded from the model.

Iteration 3) Developed land, woody wetlands, upland forest and shrub/scrub are excluded from the model.

As would be expected, limiting the landcover types that are suitable for conversion to saltmarsh reduced the overall areas of saltmarsh projected for the future. Further modeling and conservation planning work in this region would benefit from a more in-depth investigation of which land cover types should be considered suitable for saltmarsh conversion.

ROADS AS BARRIERS TO MARSH MIGRATION

Although the SLAMM model does account for all identifiable impervious surface areas as marsh migration barriers, including roads, there are no particular distinctions made between road network types or individual road characteristics. Of greatest concern are negative impacts from roads that would disrupt or significantly alter wetland hydrology including hydrologic flows and hydroperiods over large landscape areas where future marsh sites are predicted by SLAMM. For example, major roads that are part of the regional transportation network are most likely to be continuously maintained and elevated in response to future storm surge events and relative sea level rise. Therefore, without careful design modifications that address changing hydrological conditions these and other road networks may well become formidable barriers to marsh migration (Figure 6).

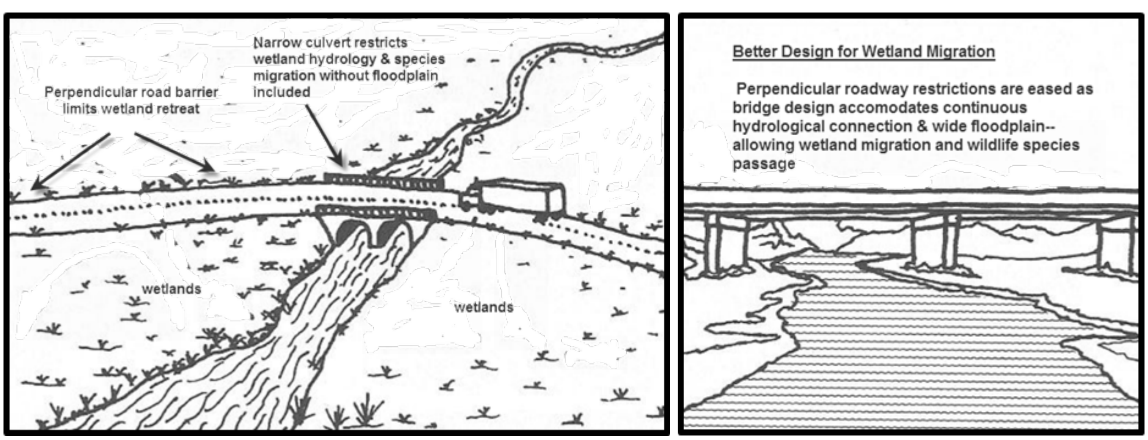


Figure 6 - Perpendicular road barrier blocks migration (left); Better design for wetland migration (right).

We were unable for this analysis to quantitatively model the effects of roads on saltmarsh migration. However, viewing the existing road network as an overlay on the conservation priority maps can provide decision-makers with a qualitative way of evaluating candidate areas based on assumed levels of threat due to road type, and proximity and orientation to water bodies and hydrological characteristics.

MARSH CONSERVATION PRIORITIES FOR PARCEL ACQUISITIONS & CONSERVATION EASEMENTS

Land trusts and other conservation stakeholders face an assortment of competing prerogatives when setting their physical conservation targets. In order to provide a product that can help to explicitly inform those decisions, we took the results from the priority saltmarsh conservation areas analysis and scored each land ownership parcel according to the maximum value of saltmarsh present within its borders. The resulting map is informative to the Lower Shore Land Trust and to partners with which they wish to share the map, but for reasons of confidentiality of parcel level information this map cannot be displayed in this report.

General Synopsis and Discussion of the Bird and Marsh Migration Analysis Results

The SLAMM models predict dramatic reductions in the extent of tidal marsh in the project area through the 21st Century, with a decline in high and transitional marsh from 54,593 acres in 2010 (current conditions) to 12,598 acres in 2100 (1.04 m SLR; **Table 6, pg. 21**). Here we describe the model projections using benchmark years. However, it is important to realize that the model predicts future conditions based on amount of sea level rise, and that estimates of the years in which benchmark increases in sea level will occur will likely change over time. This affects the accuracy of the timing of predicted future conditions but does not affect the spatial sequence of changing conditions shown in the maps.

Rate of Marsh Loss

The combined area of the high and transitional marsh categories actually increases slightly from 2010 to 2025 due to marsh migration increasing the acreage of transitional marsh (**Figure 2, pg. 22**). After 2025 a decline begins and accelerates through the middle part of the century. The greatest marsh losses occur between 2050 (0.42 m SLR) and 2075 (0.72 m SLR). The rate of decline is lower after 2075.

The individual trend lines for high marsh and transitional marsh acreages differ greatly. Transitional marsh shows a net gain in area over the century while high marsh shows an extreme loss of 94.8 percent. This disparity illustrates the importance of future management of transitional marsh zones to assist their transition to open high marsh habitat, a management process recently coined as "Managed Marsh Transition" (Lerner et al. 2013). The need for Managed Marsh Transition will increase through this century as high marsh acreages decrease and marsh migration expands areas of transitional marsh.

Patterns of Marsh Migration And Loss

Spatial, and temporal, patterns of marsh migration are illustrated in **Map 5**, which shows areas of cumulative gain and loss of high and transitional marsh at each benchmark year. By 2050 significant areas of new marsh occur as a band, up to a mile wide in places, adjacent to the landward side of current marshes. This band is present adjacent to all major marsh areas except the Nanticoke River marshes which have very little potential for upslope migration. In 2050 new marsh areas of significant size could potentially occur at the following locations:

- North of Ellis Bay WMA.
- East of Deal Island WMA from Monie Creek to the village of Champ.
- East of Fairmount WMA, at the village of Fairmount.
- North of Crisfield, in the vicinity of Crisfield Municipal Airport.
- East of Crisfield at Lawsonia and Johnson Creek.
- Indian Hammock in the vicinity of Paul Gumby Road.
- Between East creek and the village of Marumsco.

These areas with greatest potential for marsh migration are well distributed across Somerset County, and at Ellis Bay in Wicomico County, however, not all of these areas are equally suitable for supporting tidal marsh, because they currently contain varying amounts of development.

In 2050, the locations of greatest loss of high and transitional marsh are at the Nanticoke River near Vienna, Ellis Bay WMA, Deal Island WMA, Cedar Island WMA, Marumsco Creek north of Marumsco Road and Marumsco Marsh.

By 2100, the only areas of current high and transitional marsh predicted to remain in the project area are within impoundments at Deal Island WMA and Fairmount WMA. However, these impoundments will likely support target marsh types in the long term only if managed appropriately. At the end of the century, all areas of new marsh identified above for 2050, resulting from marsh migration, have themselves been lost to sea level rise. Areas with the greatest potential for marsh migration late in the 21st Century are in the southern half of Somerset County. **Map 8** shows the location of high and transitional marsh at benchmark years throughout the century and shows that the marsh migration corridors with the longest-term potential for supporting tidal marsh are in southern Somerset County.

Predicted Impacts on Priority Bird Habitat

We modeled sea level rise impacts on priority habitat for saltmarsh birds by incorporating patch size thresholds and by distinguishing between high priority interior marsh and low priority edge marsh. **Map 6** shows that by 2050 the following changes are predicted to occur: no interior marsh will remain at Ellis Bay and very little remains along the Nanticoke River. It should be noted, however, that the extensive Nanticoke River marshes shown in Map 6 are not suitable habitat for saltmarsh birds – SHARP bird surveys in 2011 and 2012 found most of the focal saltmarsh birds to be absent due to lack of saltmarsh vegetation in this oligohaline environment. Interior marsh will be much reduced at Janes Island and Cedar Creek WMA and adjacent marshes.

In contrast, the extent of interior marsh will generally be maintained in 2050 on the Deal Island peninsula, the Fairmount peninsula and the Pocomoke Sound marshes east of Crisfield because marsh migration will compensate for marsh losses. These areas comprise the current marshes of highest priority for saltmarsh birds, including nearly all of the marshes where Saltmarsh Sparrow and Black Rail are known to occur in the breeding season. The persistence up to 2050 of extensive interior marsh in the areas will depend in part on the conversion of transitional marsh to open high marsh by appropriate habitat management (Managed Marsh Transition).

The outlook for saltmarsh bird habitat in the latter part of the 21st Century appears very gloomy indeed (**Map 6**). By 2075 priority habitat will be confined to narrow marginal bands in southern Somerset County and by 2100 no interior marsh will remain, except for the impoundment at Deal Island WMA.

Delineating Marsh Migration Corridors

Marsh migration corridors are areas of land that are currently non-tidal (upland) but which can potentially support tidal marsh in the future as sea level rises. Marsh migration corridors are mapped by spatial extent in **Map 9**. Most corridors are on the landward side of present-day marshes but some are islands of upland entirely surrounded by present-day marshes. Not all areas of a marsh migration corridor will support marsh simultaneously, but protection of all land within a corridor is necessary to maximize the potential extent of marsh in the future. The practical value of identifying marsh migration corridors as units is to facilitate a well-planned strategy of land protection for conservation.

Conservation Value of Marshes According to Relative Scarcity

As the overall extent of tidal marsh diminishes due to sea level rise, remaining marsh areas will have greater relative value for conservation. **Map 11** illustrates this concept for all current and future areas of marsh in the project area. The marsh patches with the greatest value according to their extent relative to total marsh extent are the marsh patches predicted to be created by marsh migration at the end of the planning horizon of this analysis. In practical terms this high relative value trades off against the declining predictability of events over such a long period of time.

Conservation Value of Marshes Over Time

Map 12 maps the conservation value of marshes over the 21st Century by combining patch size (**Map 10**), relative extent (**Map 11**) and value as marsh migration corridor (**Map 9**). This analysis combines current and future value of marsh complexes based on spatial extent. The resulting index and map (**Map 12**) identifies the Deal Island peninsula and the marshes east of Crisfield along the Pocomoke Sound as the largest landscapes having high and very high value. These areas comprise the current marshes of highest priority for saltmarsh birds, including nearly all of the marshes where Saltmarsh Sparrow and Black Rail are known to occur in the breeding season. As previously mentioned, marsh persistence to 2050 is greater for these areas than elsewhere in the project area. These factors suggest that conservation efforts should be focused on these areas.

Map 13 shows the same data as **Map 12** but excludes current wetlands and protected areas. This identifies the highest priority areas for the conservation strategy of land protection in marsh migration corridors.

Map 15 incorporates potential future development risk into the prioritization analysis and identifies those areas not only of the highest ecological value, but also of the highest perceived threat of conversion to development.

SECTION III: OUTREACH STRATEGIES AND LAND CONSERVATION TOOLS

The focus of the Lower Shore Tidal Marsh Climate Adaptation Project is to identify, prioritize and develop a strategy for protecting existing and future saltmarsh in Wicomico and Somerset counties. Previous sections have outlined the process for identifying those marshes with the highest conservation values, mapping areas with the highest threat from sea level rise, and ranking priorities for protection and marsh migration. There are limited resources for preserving these natural resources and the outreach and communications strategy serves to identify available conservation tools and the audience that needs to be engaged in the process to successfully manage and maintain viable saltmarsh habitat.

STAKEHOLDER OUTREACH AND COMMUNICATIONS

This strategy proposes a timeline with which to begin measures that will protect existing saltmarsh and adjacent lands suitable for marsh migration. Critical to the success of maintaining viable habitat for targeted bird species and other benefits is commitment from public agencies, landowners and other conservation partners. This strategy proposes that a working group be formed from a broad-base of the targeted community that will serve to monitor the project for the best possible ecological outcome. A model for such a group is the Climate Adaptation Working Group (CAWG), on Virginia's Eastern Shore, consisting of conservation partners, county planning agencies, municipalities, health agencies, emergency service providers, seafood and fisheries representatives and interested landowners and citizens.

This proposed working group would serve to review ongoing technical and scientific information about sea level rise and coastal weather patterns as they impact the lower shore counties. A broad-based stakeholder group could be instrumental in conveying information to local communities about the benefits of managing lands for resiliency, not just for wildlife benefits, but for water quality and economic impact to fisheries and other resource-based industries. Although reports suggest that sea level rise may impact coastal areas sooner and more severely than initially anticipated, much of the public remains ambivalent or in denial about the cause of climate change. This strategy does not serve to address causes, but to work toward solutions and engage the public in measures that will help protect resources. A broad-based working group is more likely to reach local governments and public agencies and result in a deeper understanding of potential impacts and the need to plan for a range of scenarios.

Materials should be developed that can be used to communicate impacts from sea level rise that are currently affecting our coastal communities. Increased flooding from storms, erosion and loss of habitat are occurring now and many residents can identify with messaging that includes the human element. Materials should stress coastal resilience and preparedness alongside information about programs for restoration and land protection.

Early in the process a roundtable for conservation partners should be held to share information about available programs, resources, priorities and contacts. Conservation groups and land trusts will work together to achieve mutual goals in targeted areas. A laundry list of tools, including workshops, targeted letters, newsletters and one-on-one meetings with landowners will be used to provide information about voluntary land protection and conservation programs. Land trusts and conservation partners will work with landowners to implement projects in targeted areas. Conservation goals should be considered within the context of the saltmarsh adaptation strategy. Groups should work to maintain and enhance relations with county agencies involved in land protection, resource management and emergency response as well as traditional conservation partners to work on mutual priorities. Ongoing outreach and communications to public officials, the general community and organizational supporters should be conducted by respective organizations as well as the proposed working group, and include newspaper articles and editorials, newsletters, website information and social media and radio interviews about coastal resilience and preparedness.

These outreach strategies are summarized in Table 11.

Table 11 - Stakeholder outreach strategies.

Outreach Activities	Target Audience	Messaging/Purpose
Working group	Health and safety, natural resources; agriculture, fisheries, planners and emergency medical services agencies	Develop standards for preparedness and coastal resiliency
Regional Roundtable	Conservation partners–agency, non- profit, private, etc.	Promote resources; i.e., TNC website with NOAA
Landowner conservation tools brochure	Landowners, partners, local government	Educate on available programs and funding
Personal letters	Landowners	Communicate significance of coastal flooding and expected impacts to coastal areas from sea level rise
One-on-one meetings and/or workshops with landowners	Potential easement grantors	Communicate that best management practices and restoration options will promote resiliency
Newspaper articles/editorials; radio interviews	Public	Focus on coastal resiliency and preparedness
Website message development	Conservation partners	Focus on coastal resiliency, preparedness and programs for restoration and land protection
Information about best management practices	Land trusts and partners	Maintain list of completed projects and interested landowners
Workshop and tour	Landowners and partners	Highlight preparedness, major storms, floods, benefits, etc.
Meet with county planners	County government	Promote resources

LAND CONSERVATION TOOLS

Conservation easements have been and will continue to be one of the most critical tools for protecting high priority land from development. With little local regulatory land use controls in place in Somerset and Wicomico counties and increased vulnerability to sea level rise and impacts from severe weather, land protection must be accomplished in other ways. Available programs include permanent protection of land with fee simple purchases and through acquisition of conservation easements of land, giving the conservation entity a partial interest in the land. These conservation options depend on voluntary agreements between willing landowners and public agencies or private, nonprofit land conservation organizations willing to hold conservation easements.

The Land and Water Conservation Fund (LWCF) – This program provides funding to federal, state and local agencies to acquire conservation interests in land and water property, including easements. Funds for the LWCF come from off-shore oil and gas development, and projects are generally for recreation, parks and refuges. LWCF is divided into two distinct funding pools: state grants and federal acquisition funds. A distribution formula is based upon population density and other factors. Congress typically appropriates far less than the authorized funding level ($900 million). The Administration prepares an annual project list for Congressional action. Congress makes final decisions on both funding levels and also projects to be funded. On the Federal side of LWCF, the US Fish and Wildlife Service, National Park Service, US Forest Service and Bureau of Land Management can propose projects. LWCF state-side funds go to the Maryland Department of Natural Resources and are administered through its Program Open Space.

Maryland's Program Open Space (POS) was created within the DNR to preserve large blocks of working rural lands for future generations. The Program protects natural, cultural, agricultural, forest and environmental resources from urban sprawl development and promotes land conservation statewide by granting funds to local governments and land trusts to conserve land through easement and fee purchases within designated rural legacy areas. The RLP is using an objective scoring approach similar to the POS Targeting to review and allocate its limited grant funds.

Donated Easement Program is available for landowners who voluntarily restrict development based upon mutual goals agreed to between a land trust and the landowner. There are potential federal tax benefits when a landowner donates a conservation easement to a land trust. The State of Maryland provides state tax incentives to landowners who willingly donate a conservation easement to the Maryland Environmental Trust.

Maryland Environmental Trust (MET) – The mission is to provide landowners with information and tools to permanently protect natural, historic and scenic resources in the state. MET works with landowners and local land trusts to protect Maryland's most treasured landscapes and natural resources as a legacy for future generations. As one of the oldest and most successful land trusts in the country, MET holds over 1,040 conservation easements preserving over 129,000 acres statewide.

Maryland Agricultural Land Preservation Foundation (MALPF) – This program is funded by a fraction of a percent of the real estate transfer tax. This program provides funding to purchase easements for agricultural land preservation.

Agricultural Conservation Easement Program (ACEP) – This program retains most of the program provisions in the repealed easement programs (Wetlands Reserve Program WRP, Grasslands Reserve Program GRP, and Farmland and Ranchlands Protection Program FRPP). The program provides matching funds to help purchase development rights to keep productive farm and ranchland in agricultural uses. Landowners who wish to voluntarily protect and restore and enhance wetlands on their property may also be eligible for this program. The USDA partners with State, tribal or local governments and non-governmental organizations to acquire conservation easements or other interests in land from landowners. USDA provides up to 50 percent of the fair market easement value of the conservation easement.

Maryland Conservation Reserve [Enhancement] Program (CREP/CRP) is a federal-state natural resources conservation program that addresses state and nationally significant agricultural related environmental concerns related to agriculture. CREP/CRP pays landowners for temporary (10-15 years) or permanent implementation of conservation practices on eligible cropland and marginal pastureland. Practices include vegetative buffers along ditches, streams and wetlands, as well as wetland and wildlife habitat restoration. Although the project area includes all Maryland in the MD CREP, this state-federal partnership has set a goal of enrolling 100,000 acres of eligible cropland or marginal pastureland in 14 to 15 year contracts within the Chesapeake Bay watershed.

Readiness and Environmental Protection Initiative (REPI) The Department of Defense Readiness and Environmental Protection Initiative enables the military to work with willing partners who help provide cost-sharing land solutions to limit incompatible development and protect valuable open space and habitat around key test and training areas. This initiative provides funding for the military to work with local government and non-government organizations (NGOs), and willing landowners to help prevent encroachment of test and training areas by leveraging public/private partnerships and other financial resources to promote innovative land conservation solutions that benefit both the military readiness and the environment.

National Coastal Wetlands Conservation Grant Program – Established in 1990, the U.S. Fish and Wildlife Service provides matching grants to States for acquisition, restoration, management or enhancement of coastal wetlands. Funding for the program comes from excise taxes on fishing equipment and motorboat and small engine fuels. States are required to provide 50 percent of the total costs of a project. Grants awarded under the National Coastal Wetlands Conservation Grant Program cannot exceed $1 million for an individual project.

The North American Wetlands Conservation Act program – The North American Wetlands Conservation Act of 1989 provides matching grants to organizations and individuals who have developed partnerships to carry out wetlands conservation projects in the United States, Canada and Mexico for the benefit of wetlands-associated migratory birds and other wildlife. There is a Standard and a Small Grants Program. Both are competitive grants programs and require that grant requests be matched by partner contributions at no less than a 1-to-1 ratio. Funds from U.S. Federal sources may contribute towards a project, but are not eligible as match.

Land Owner Incentive Program (LIP) – The LIP, funded by the U.S. Fish and Wildlife Service, is a competitive grant program that establishes partnerships between federal and state government and private landowners. LIP is a voluntary state program that provides landowners with incentives to help conserve habitat for species-at-risk in the state of Maryland. The goal of the program is to provide cost-share assistance to private landowners to protect, enhance and restore habitat for rare, threatened and endangered species.

The State role in implementing LIP is to provide technical and financial assistance to private landowners for projects that enhance, protect, or restore habitats that benefit species-at-risk on privately owned lands. Working in coordination with landowners and other partners, Maryland Department of Natural Resources staff biologists can uniquely design each project to best suit the needs of individual landowners, their land and the diversity of wildlife present. Projects can include: reforestation, grassland buffers, invasive species control, vegetation management and livestock exclusion and fencing. For additional information, refer to: http://www.dnr.state.md.us/wildlife/Habitat/LIP/index.asp

Mitigation Requirements – Mitigation is required when losses of non-tidal wetlands are authorized in a Non-tidal Wetlands and Waterways Permit or approved in a Soil Conservation and Water Quality Plan. The goal of mitigation is to compensate for lost non-tidal wetland acreage and functions, which is necessary for the State of Maryland to attain the overall goal of "no net loss" of non-tidal wetland acreage and functions. For more information, refer to: http://www.mde.state.md.us/programs/Water/WetlandsandWaterways/AboutWetlands/Documents/www.mde.state.md.us/assets/document/wetlandswaterways/MITGUIDEfeb72011.pdf

Trading of Development Rights – Transfer of development rights programs allow landowners to transfer the right to develop one parcel of land to a different parcel of land. Generally, TDR programs are established by local zoning ordinances. These programs vary from county to county in Maryland and are not widely used, if implemented at all, and with limited success. There is a potential to utilize this tool for increasing the protection of vulnerable lands.

MODEL CONSERVATION EASEMENT LANGUAGE

Finally, with a changing climate creating conservation easements that are perpetually enduring under uncertain future conditions is a challenge. In drafting conservation easements, land trusts have always had to anticipate likely areas of change by drafting easements that are flexible enough to accommodate change, yet enduring enough to protect conservation values in perpetuity. This difficulty is especially pertinent in regards to sea level rise and marsh conservation. For example, some groups may wish to avoid placing an easement on land that will like be inundated in the future. Others may struggle with justifying the protection of lands that are expected to hold higher biodiversity conservation value in the future than in the present. As part of this project, we outlined some pointers for drafting conservation easements when faced with changing conditions as a result of climate change:

- Identify conservation values that will endure.
- Provide sufficient flexibility.
- Define specific terms.
- Do not restrict unnecessarily.
- Consider rolling easements.
- Consider including discretionary approval or consent provisions and specify amendment criteria and procedures.
- Provide comprehensive recitals.
- Strive for clarity.
- Consider performance standards.
- Carefully define how the easement can be terminated or modified.
- Utilize existing frameworks for responding to climate change.
- Consider whether easement requirements that look to law should be fixed to current law.

See Appendix IV for more detail on designing conservation easement language to accommodate sea level rise.

CONCLUDING THOUGHTS

Forward thinking is essential when combating threats such as sea level rise. The results of this project address these conservation challenges in a changing landscape, first by identifying important biodiversity values such as marsh birds and modeling the trajectory of conservation threats such as sea level rise, then mapping the areas with the highest potential conservation value and devising strategies to mobilize partners and build conservation coalitions—all through the lens of consideration for what the next 50 to 100 years are likely to hold.

The model results and conservation priority maps from this study, combined with dedicated working groups, targeted stakeholder outreach and other strategies can go a long way toward ensuring conservation of the important saltmarsh landscapes of the Lower Eastern Shore of Maryland.

The Chesapeake Bay is a unique and special place. It is home to amazing wetlands, diverse biota and vibrant local communities. The challenges that this region faces as a result of climate change and rising sea level are extreme, but they are also shared by many other coastal areas. Our hope is that this study will provide a conceptual framework for modeling marsh migration across time, and that others confronting similar conservation problems can adapt the methods, strategies and tools described here and apply them elsewhere. Similarly, while our study focused on saltmarsh birds as a measure of biodiversity value, there are numerous other species, groups and systems that may be applicable in other contexts. The technical tools and strategies developed in this project will help ensure that ecologically significant coastal wetlands can persist and remain viable despite the looming threat of sea level rise and thereby maintain the ecological services they provide.

References

Beadell, J., R. Greenberg, S. Droege, and J. A. Royle. 2003. Distribution, abundance, and habitat affinities of the Coastal Plain Swamp Sparrow. Wilson Bulletin 115: 38-44.

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

Boesch, D.F. (editor). 2008. Global Warming and the Free State: Comprehensive Assessment of Climate Change Impacts in Maryland. Report of the Scientific and Technical Working Group of the Maryland Commission on Climate Change. University of Maryland Center for Environmental Science, Cambridge, Maryland. This report is a component of the Plan of Action of the Maryland Commission on Climate Change, submitted to the Governor and General Assembly pursuant to Executive Order 01.10.2007.07.

Boesch, D.F., L.P. Atkinson, W.C. Boicourt, J.D. Boon, D.R. Cahoon, R.A. Dalrymple, T. Ezer, B.P.,Horton, Z.P. Johnson, R.E. Kopp, M. Li, R.H. Moss, A. Parris, C.K. Sommerfield. 2013. Updating Maryland's Sea level Rise Projections. Special Report of the Scientific and Technical Working Group to the Maryland Climate Change Commission, 22 pp. University of Maryland Center for Environmental Science, Cambridge, MD. http://www.mdsg.umd.edu/sites/default/files/files/Sea level_Rise_Projections_Final.pdf, accessed: 8/20/2013.

Brewer, G. 2010. American Black Duck (*Anas rubripes*). Pages 46-47 *In* the Second atlas of the breeding birds of Maryland and the District of Columbia. (W. G. Ellison, ed). Johns Hopkins University Press.

CCSP, 2009: Coastal Sensitivity to Sea level Rise: A Focus on the Mid-Atlantic Region. A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [James G. Titus (Coordinating Lead Author), K. Eric Anderson, Donald R. Cahoon, Dean B. Gesch, Stephen K. Gill, Benjamin T. Gutierrez, E. Robert Thieler, and S. Jeffress Williams (Lead Authors)]. U.S. Environmental Protection Agency, Washington D.C., USA, 320 pp.

Chambers, R. M., K. J. Havens, S. Killeen, and M. Berman. 2008. Common reed *Phragmites australis* occurrence and adjacent land use along estuarine shoreline in Chesapeake Bay. Wetlands 28:1097-1103.

Chesapeake Bay Foundation. 2012. www.cbf.org, accessed: 8/16/2013.

Chesapeake Bay Foundation. 2012b. 2012 State of the Bay Report. http://www.cbf.org/about-the-bay/state-of-the-bay/2012-report, accessed: 8/16/2013.

Chesapeake Bay Program. 2008. Chesapeake Bay Mean Surface Salinity. Map online at www.chesapeakebay.net, accessed 10 January, 2012.

Lerner, J., D. R. Curson, M. W. Whitbeck, E. Meyers, and J. Bonomo. 2013. Saving the Tidal Marshes of Blackwater National Wildlife Refuge: Final report on Assessing Sea Level Rise Impact and Recommending Comprehensive Strategies for Marsh Management and Migration in Southern Dorchester County, Maryland. Unpublished report.

Cole, W.D. 2008. Sea Level Rise: Technical Guidance for Dorchester County. Prepared for Maryland Department of Natural Resources, Coastal Zone Management Division. Maryland Eastern Shore Resource Conservation & Development Council, Easton, MD. 60 pp. http://dnr.state.md.us/dnrnews/pdfs/Dorchester.pdf, accessed: 8/26/2013.

Coskren, T. D. 2010. Seaside Sparrow (*Ammodramus maritimus*). Pages 390-391 *In* the Second atlas of the breeding birds of Maryland and the District of Columbia. (W. G. Ellison, ed). Johns Hopkins University Press

Craft C, Clough J, Ehman J, Guo H, Joye S, Machmuller M, Park R, and Pennings S. Effects of Accelerated Sea Level Rise on Delivery of Ecosystem Services Provided by Tidal Marshes: A Simulation of the Georgia (USA) Coast. *Frontiers in Ecology and the Environment.* 2009; 7, doi:10.1890/070219

Davidson, L. M. 2010. Black rail (*Laterallus jamaicensis*). Pages 122-123 *In* the Second atlas of the breeding birds of Maryland and the District of Columbia. (W. G. Ellison, ed). Johns Hopkins University Press.

Davidson, L. M. 2010. Willet (*Catoptrophorus semipalmatus*). Pages 146-147 *In* the Second atlas of the breeding birds of Maryland and the District of Columbia. (W. G. Ellison, ed). Johns Hopkins University Press.

DiQuinzio, D. A., P, W. C. Paton, and W. R. Eddleman. 2002. Nesting ecology of saltmarsh sharp-tailed sparrows in a tidally restricted saltmarsh. Wetlands 22: 179-185.

Eddleman, W. R., and C. J. Conway. 1998. Clapper Rail (*Rallus longirostris*). In The Birds of North America, No. 340 (A. Poole and F. Gill, eds). The Birds of North America Inc., Philadelphia, PA.

Eddleman, W. R., R. E. Flores, and M. L. Legare. 1994. Black Rail (*Laterallus jamaicensis*). *In* The Birds of North America, No. 123 (A. Poole and F. Gill, eds). Philadelphia: The Academy of Natural Sciences; Washington, DC: American Ornithologists Union.

Edmonds, G. 2011. Developing and enhancing Maryland's coastal atlas planning and mapping tools: GIS methodology for the sea level vulnerable wetland areas project. Prepared for Maryland Department of Natural Resources and Maryland Department of the Environment, Chesapeake and Coastal Program. Center for GIS at Towson University, Towson, MD. 39 pp.

Galbraith, H., R. Jones, R. A. Park, J. S. Clough, S. Herrod-Julius, B. Harrington, and G. Page. 2002. Global climate change and sea level rise: potential losses of intertidal habitat for shorebirds. *Waterbirds* 25: 173-183.

Gjerdrum, C., C. S. Elphick, and M. Rubega. 2005. Nest site selection and nesting success in saltmarsh breeding sparrows: the importance of nest habitat, timing, and study site differences. Condor 107: 849-862.

Glick, P., J. Clough, and B. Nunley. 2008. Sea level rise and coastal habitats in the Chesapeake Bay region. National Wildlife Federation, Washington, DC, 124 pp.

Greenberg, R, and S. Droege. 1990. Adaptations to tidal marshes in breeding populations of the Swamp Sparrow. Condor 92: 393-404.

Greenberg, R., and J.E. Maldonado. 2006. Diversity and endemism in tidal-marsh vertebrates. *Studies in Avian Biology*, 32: 32.

Greenlaw, J. S., and J. D. Rising. 1994. Sharp-tailed Sparrow (*Ammodramus caudacutus*). *In* The Birds of North America, No. 112 (A. Poole and F. Gill, eds). Philadelphia: The Academy of Natural Sciences; Washington, DC: American Ornithologists Union.

Jenks, G. F., and F. C. Caspall. 1971. Error on choroplethic maps: definition, measurement, reduction. Annals of the Association of American Geographers 61(2): 217-244.

Joyce, J.M. and M.S. Scott. 2005. An assessment of Maryland's vulnerability to flood damage. Maryland Department of the Environment. 87 pp. http://www.esrgc.org/pdf/hazus/An%20Assessment%20of%20Maryland's%20Vulnerability%20to%20Flooding.pdf, accessed: 8/19/2013.

Johnson, Z. 2011. The times they are a-changin': The impact of climate change on Maryland. The Maryland Natural Resource Magazine, Spring 2011. Maryland Department of Natural Resources. http://www.dnr.state.md.us/naturalresource/spring2011/7.asp, accessed: 8/19/2013.

Lee, J. K., R. A. Park, and P. W. Mausel. 1992. Application of Geoprocessing and Simulation Modeling to Estimate Impacts of Sea Level Rise on the Northeast Coast of Florida. Photogrammetric Engineering and Remote Sensing 58: 1579-1586.

Longcore, J. R., D. G. McAuley, G. R. Hepp, and J. M. Rhymer. 2000. American Black Duck (*Anas rubripes*). *In* The Birds of North America, No. 481, ed. A. Poole and F. Gill. Philadelphia and Washington, DC: Academy of Natural Sciences and American Ornithologists Union.

Lowther, P. E, H. D. Douglas III, and C. L. Gratto-Trevor. 2001. Willet (*Catoptrophorus semipalmatus)*. *In* The Birds of North America, No. 579 (A. Poole and F. Gill, eds). The Birds of North America Inc., Philadelphia, PA.

Maryland Commission on Climate Change. 2008. Climate Action Plan. Interim Report to the Governor and the Maryland General Assembly. Maryland Department of the Environment, Baltimore, MD. 110 pp.

Maryland Department of Natural Resources. 2005. Maryland Wildlife Diversity Conservation Plan. Online at http://www.dnr.state.md.us/wildlife/Plants_Wildlife/WLDP/ accessed 10 January, 2012.

Maryland Department of Natural Resources. 2007. Maryland Species Ranking Form: Black rail. Natural Heritage Program, Maryland Department of Natural Resources.

Maryland Department of Natural Resources. 2011. Developing and Enhancing Maryland's Coastal Atlas, Planning and Mapping Tools: GIS Methodology for the Sea Level Vulnerable Wetland Areas Project, v1.0.

McCormick, J., and H. A. Soames, Jr. 1982. The Coastal Wetlands of Maryland. Prepared for Maryland Department of Natural Resources, Coastal Zone Management Program. Jack McCormick and Associates Inc., Chevy Chase, MD. 243 pp.

Meiman, S. T. 2011. Modelling Saltmarsh Sparrow distribution in Connecticut. M.S. Thesis, University of Connecticut.

Meyerson, L. A. K. Saltonstall, and R. M. Chambers. 2009. Phragmites australis in eastern North America: a historical perspective. Pp 57-82 In Silliman, B. R., E. D. Grosholz, and M. D. Bertness. Eds. Human Impacts on Saltmarshes. University of California Press.

NRCS. 2007. Black needlerush (*Juncus roemerianus)*. The PLANTS database (http://plants.usda.gov, accessed 13 January, 2012.

Park, R. A., J. K. Lee, P. W. Mausel, and R. C. Howe. 1991. Using Remote Sensing for Modeling the Impacts of Sea Level Rise. *World Resource Review* 3: 184-205.

Park, R. A., J. K. Lee, and D. Canning. 1993. Potential Effects of Sea Level Rise on Puget Sound Wetlands. *Geocarto International* 8: 99-110.

Parker, S., and G. Crichton. 2011. The Eastern Shore of Virginia: Strategies for Adapting to Climate Change. Report from the Eastern Shore Climate Change Adaptation Strategies Workshop. The Nature Conservancy in Virginia, Charlottesville, VA. 72 pp. http://www.virginia.edu/ien/sealevelrise/docs/VA%20Eastern%20Shore%20CC%20Adaptation%20Report%20Final.pdf, accessed: 8/26/2013.

Pennings, S. C., M-B Grant, and M. D. Bertness. 2005. Plant zonation in low-altitude saltmarshes: disentangling the roles of flooding, salinity and competition. Journal of Ecology 93: 159-167.

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

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

Somerset County, MD. 2008. Rising Sea Level Guidance. Prepared for Somerset County, MD. URS & RC Quinn Consulting, Inc. 38 pp. http://maryland.coastsmart.org/wp-content/themes/checkmate/documents/SomersetSLRGuidance.pdf, accessed: 8/26/2013.

Tiner, R. W. and D. G. Burke. 1995. Wetlands of Maryland. U.S. Fish and Wildlife Service, Ecological Services, Region 5, Hadley, MA and Maryland Department of Natural Resources, Annapolis, MD. Cooperative publication. 193 pp. plus Appendices.

U.S. Climate Change Science Program. 2008. Preliminary review of adaptation options for climate sensitive ecosystems and resources. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [Julius, S.H., J.M. West (eds.), J.S. Baron, B. Griffith, L.A. Joyce, P. Kareiva, B.D. Keller, M.A. Palmer, C.H. Peterson, and J.M. Scott (Authors)]. U.S. Environmental Protection Agency, Washington, DC.

Warren Pinnacle Consulting. 2012. SLAMM Model Overview. http://www.warrenpinnacle.com/prof/SLAMM/SLAMM_Model_Overview.html, accessed: 8/23/2013

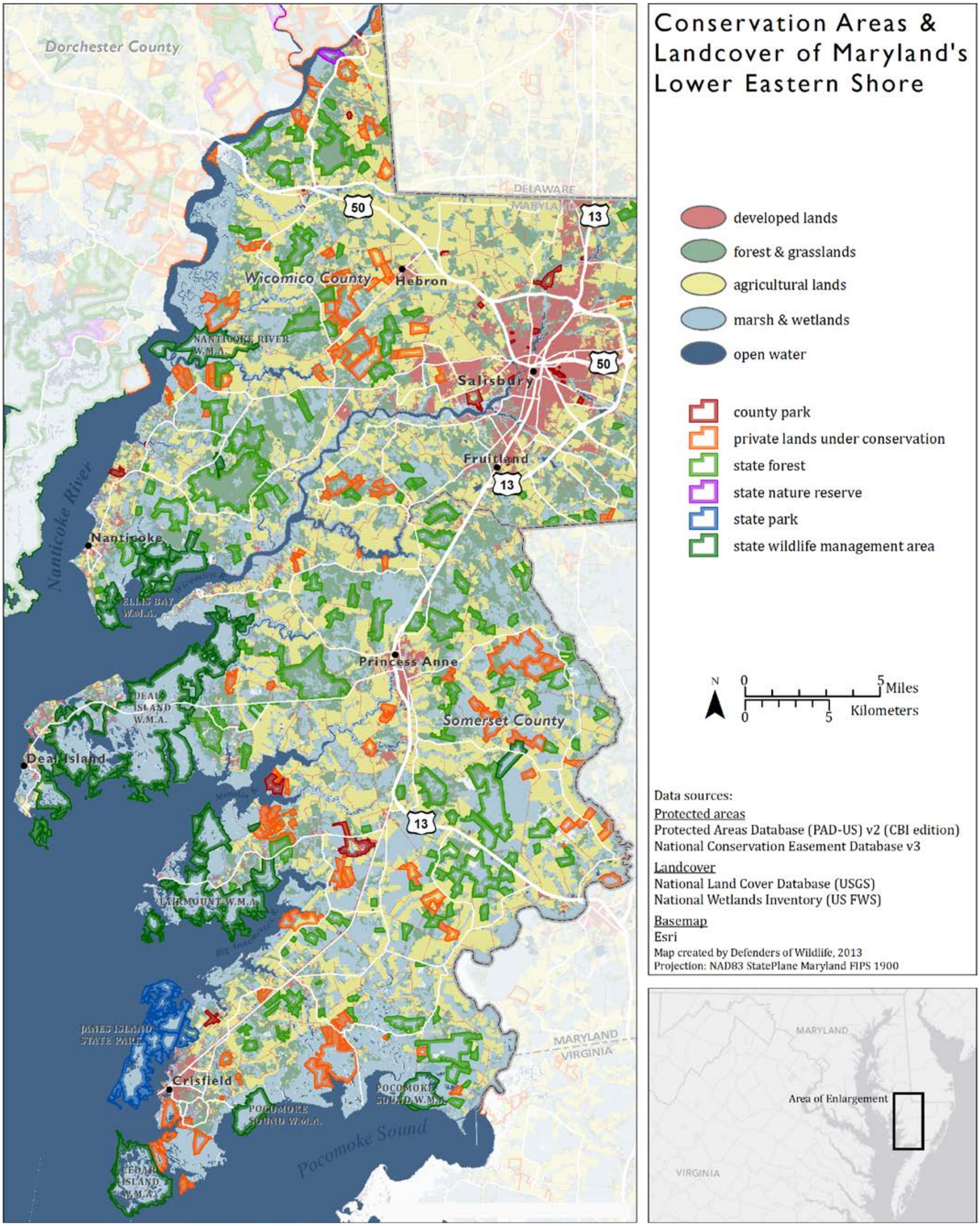
Watts, B. D. 1992. The influence of marsh size on marsh value for bird communities of the lower Chesapeake Bay. Center for Conservation Biology Technical Report, CCBTR-92-01. College of William and Mary, Williamsburg, Virginia.

Watts, B. D. 1999. Partners in Flight bird conservation plan for the Mid-Atlantic coastal plain (physiographic area no. 44). Partners in Flight and American Bird Conservancy.

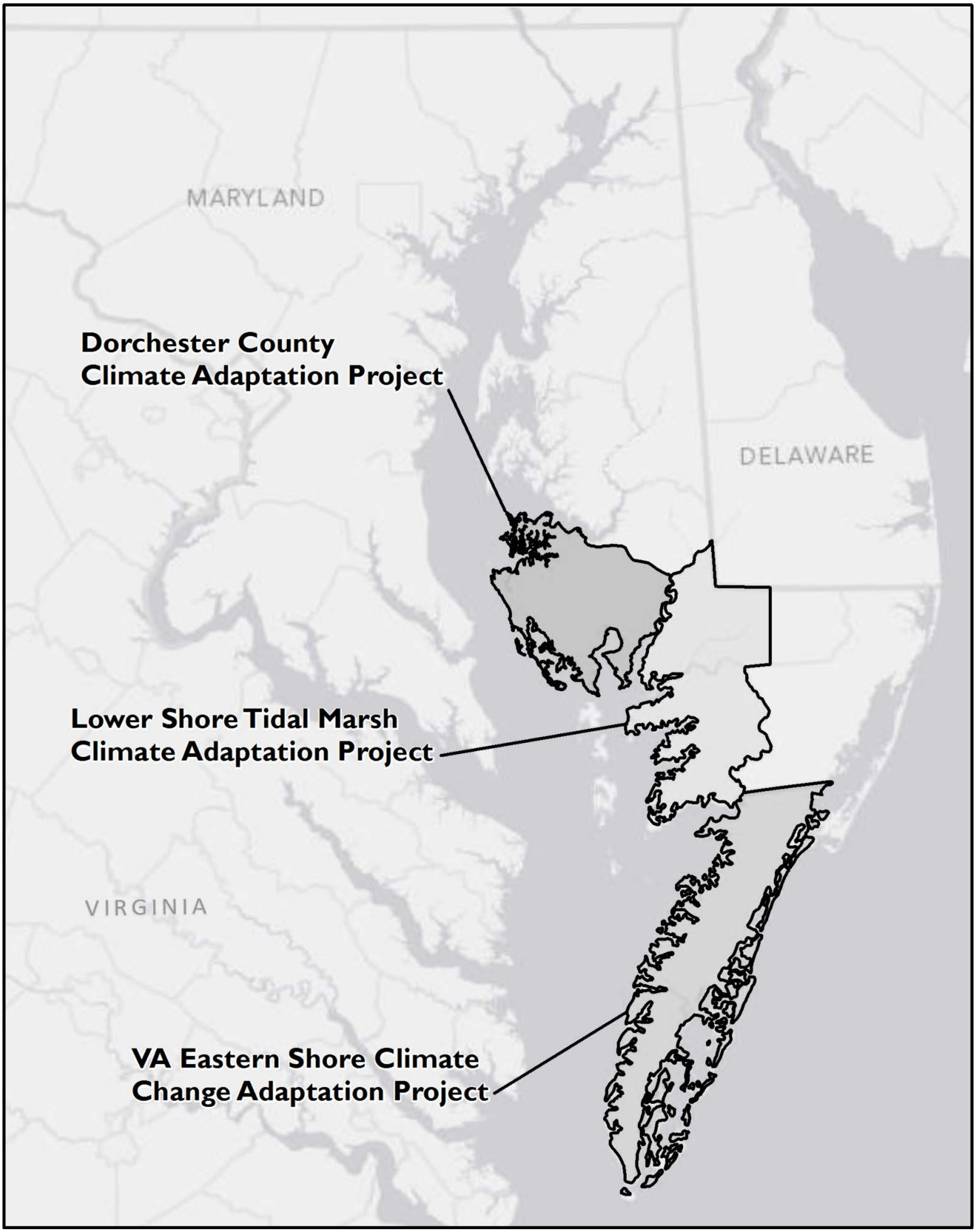
Wilson, M. D., B. D. Watts, and D. F. Brinker. 2007. Status review of Chesapeake Bay marsh lands and breeding marsh birds. Waterbirds 30 (Special Publication 1): 12-137.

Worcester County, MD. 2008. Sea Level Rise Response Strategy: Worcester County, MD. Prepared for Worcester County, MD, Department of Comprehensive Planning. CSA International, Inc., Stuart, FL. 103 pp. http://www.dnr.state.md.us/dnrnews/pdfs/Worcester.pdf, accessed: 8/26/2013.

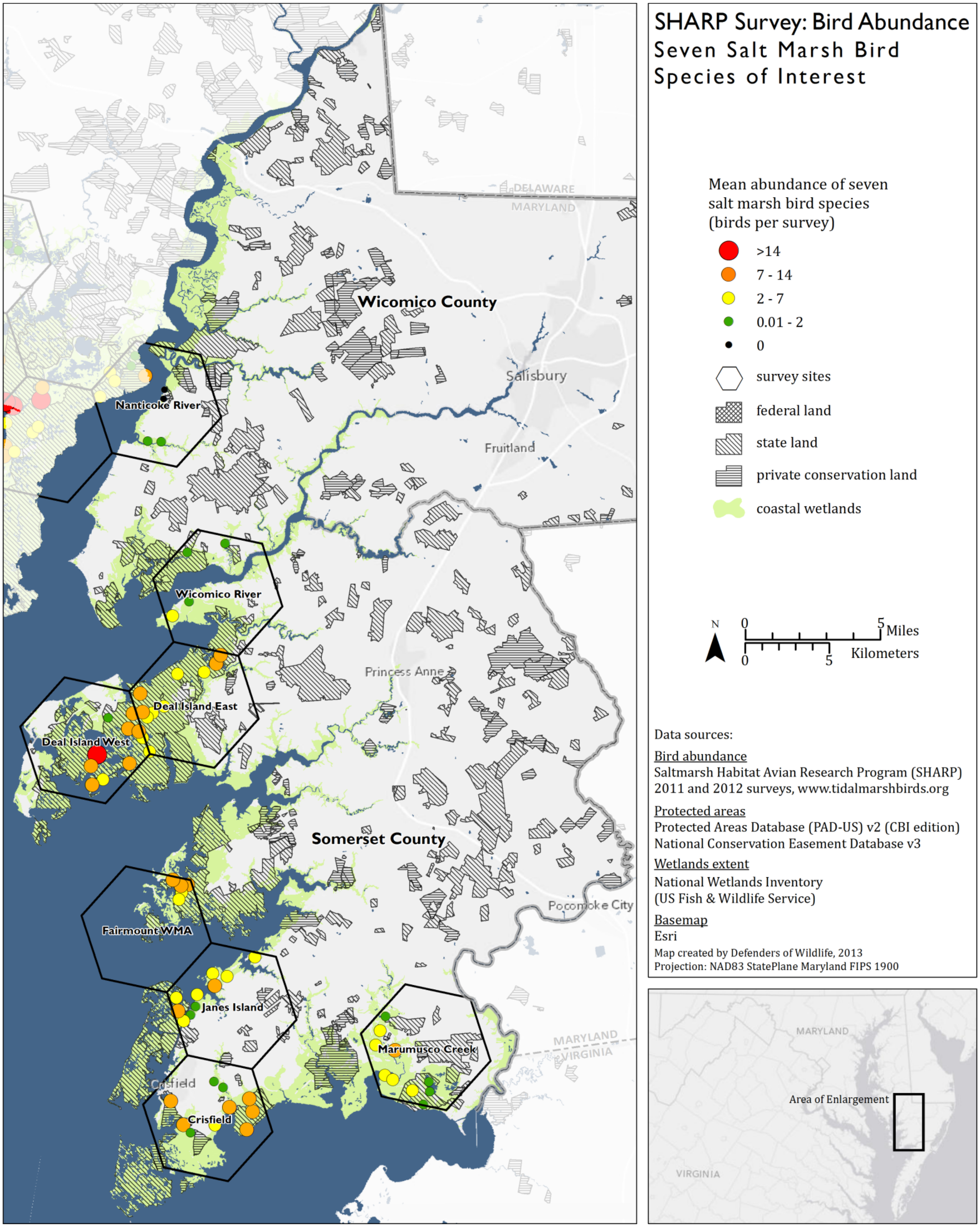
APPENDIX I: MAPS



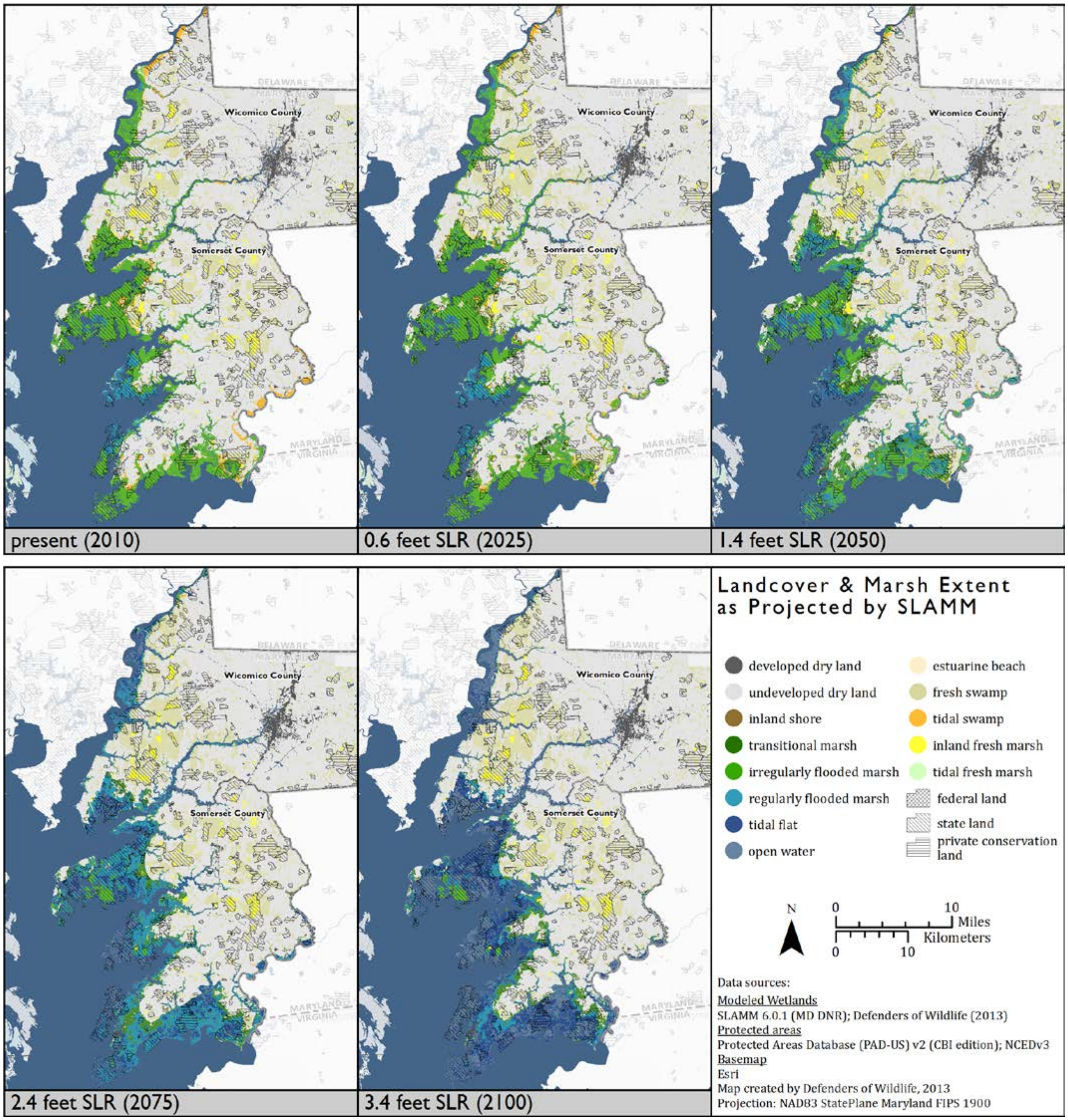
Map 1 - Maryland's Lower Eastern Shore, the region of interest for this study. This region is largely rural and agricultural with extensive marsh lands lining much of its western waterfront. (Return to page 4 or 9).



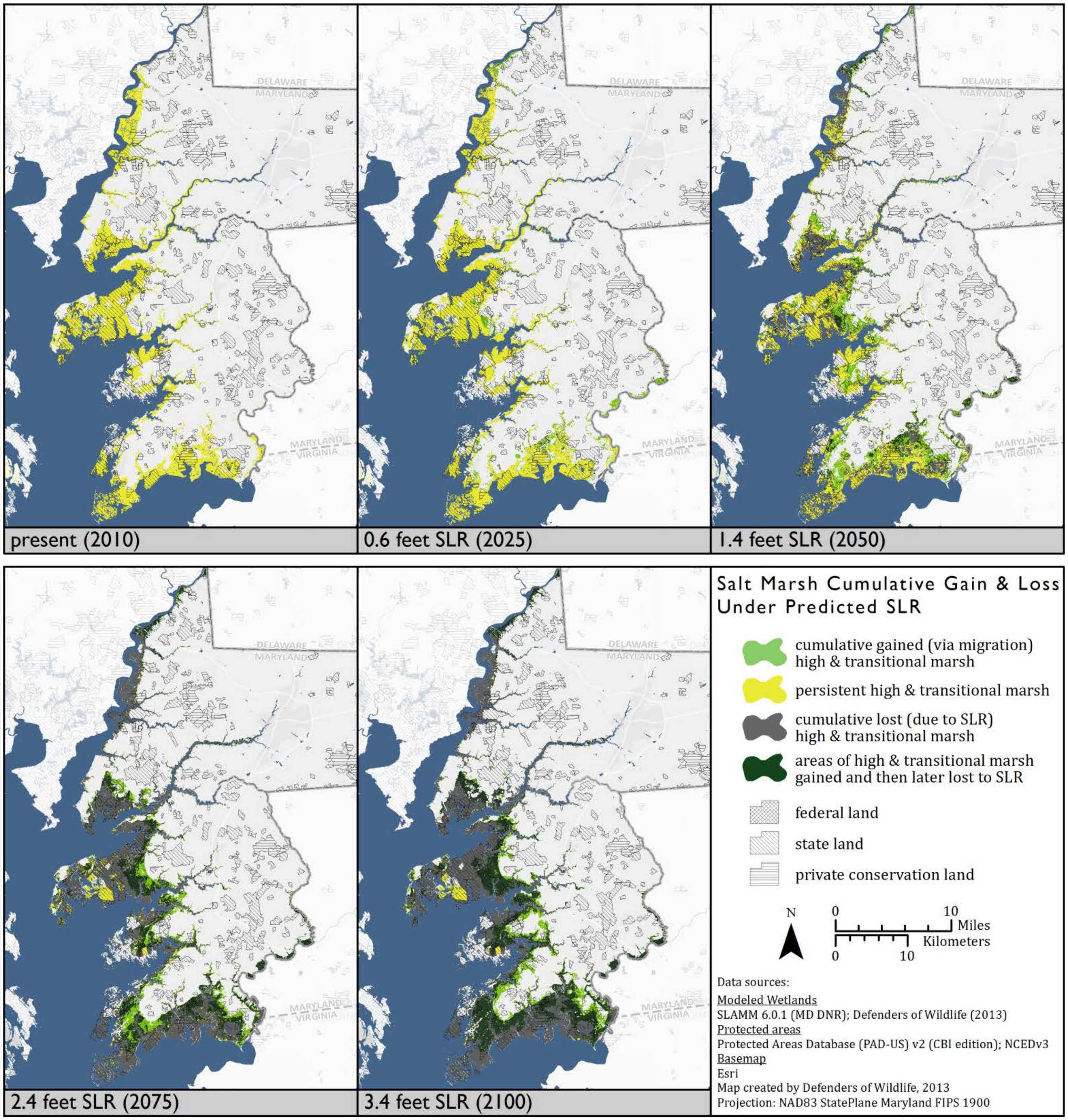
Map 2 - Overview map showing the region of study for this project and also for the Dorchester County, MD and the Accomack County, VA projects. (Return to page 5).



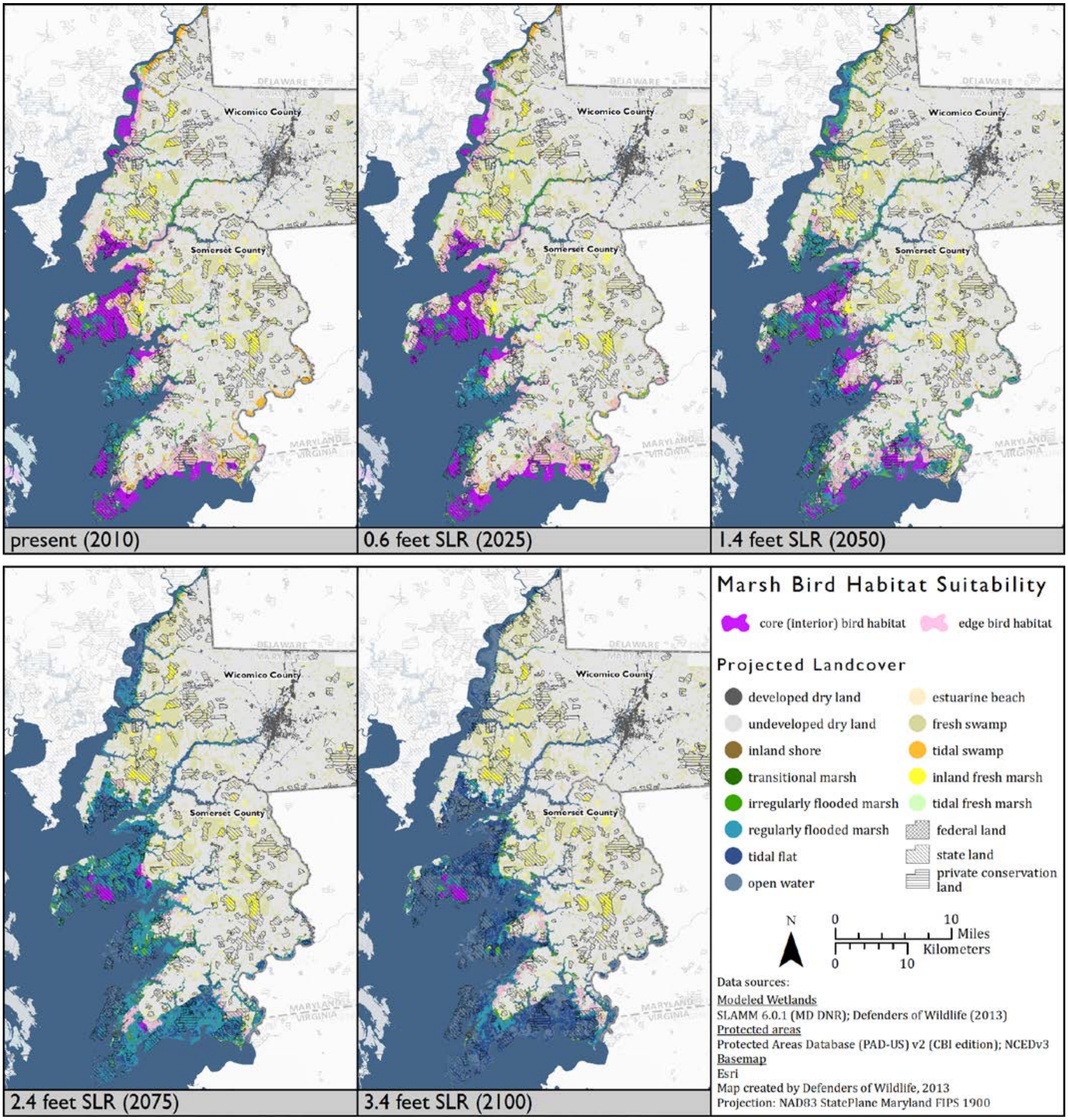
Map 3 - Map of combined abundance (detection rates) of seven focal saltmarsh species detected during SHARP surveys, 2011-2012. Bird species included are: American Black Duck, Black Rail, Clapper Rail, Willet, Saltmarsh Sparrow, Seaside Sparrow, and Coastal Plain Swamp Sparrow. (Return to page 15).



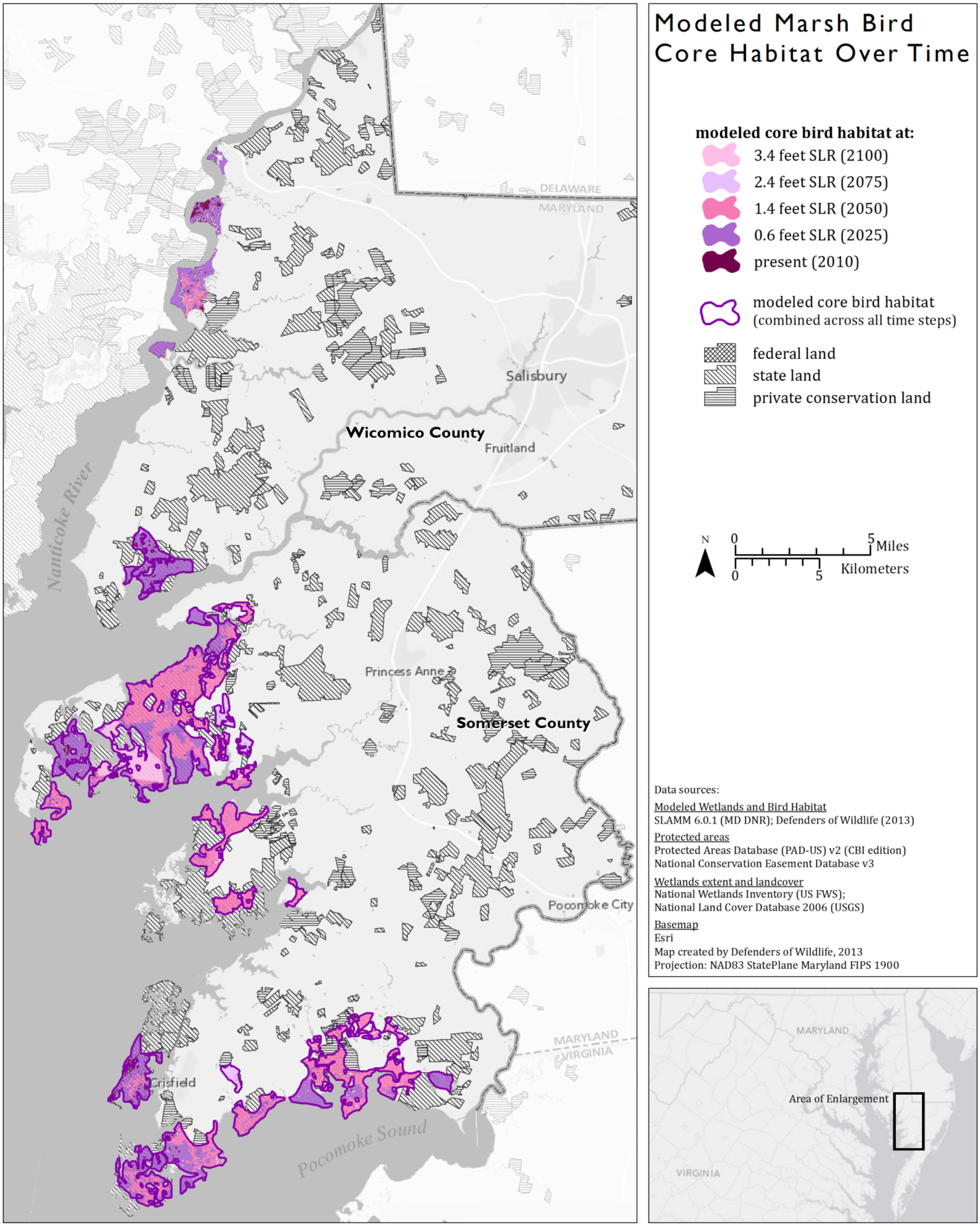
Map 4 - Sea Level Affecting Marshes Model (SLAMM) output maps for Somerset and Wicomico counties in Maryland. These maps show stages of land cover and marsh extent from present conditions to 3.4 feet of sea level rise at the end of the century. (Return to page 21).



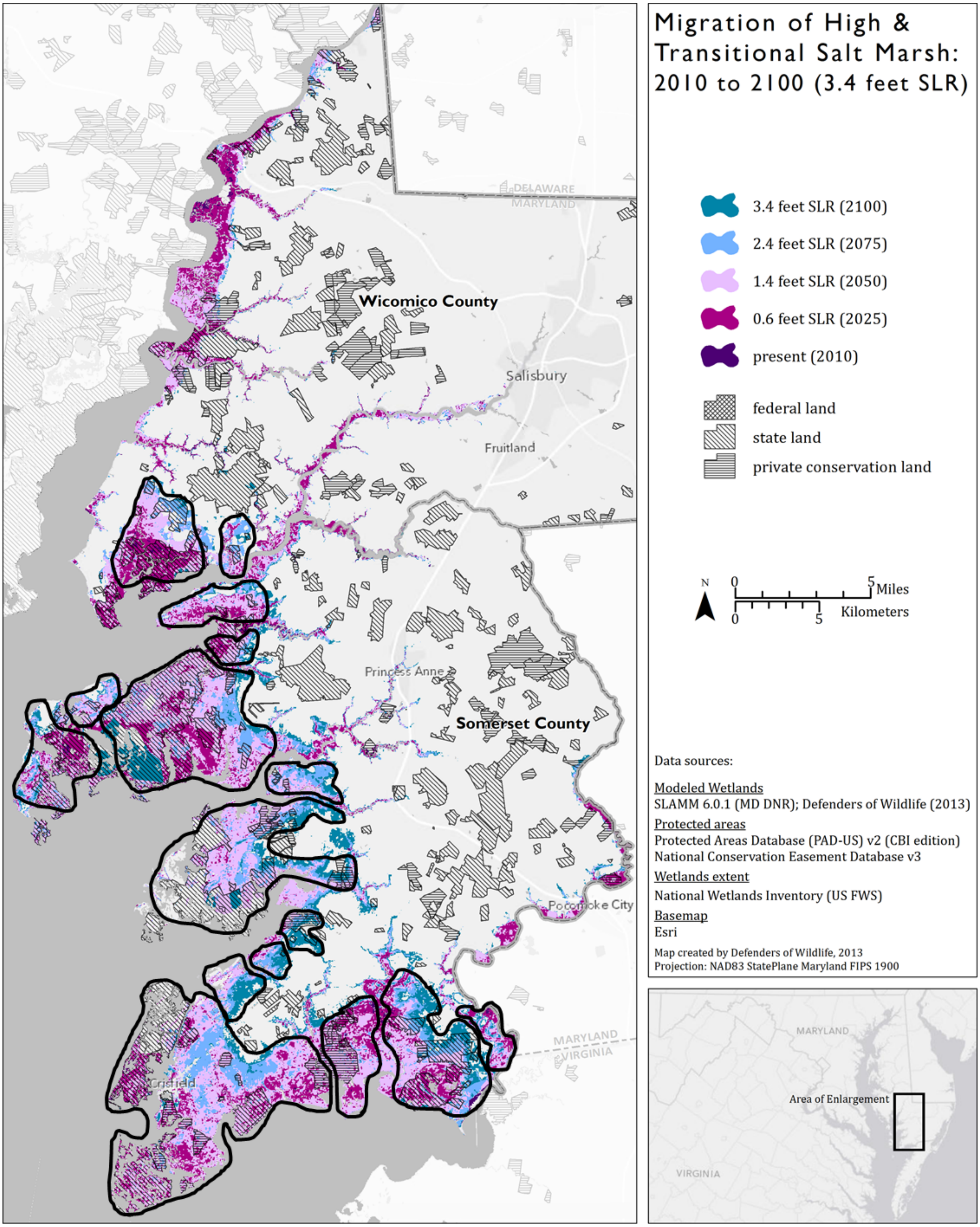
Map 5 - Cumulative gain and loss of transitional and irregularly flooded marsh modeled over 25 year intervals in Somerset and Wicomico counties. While the bottom two panels (~2075 and ~2100) are certainly interesting, it is generally accepted that the accuracy of predictive models such as SLAMM diminishes the further away we get from present conditions. By focusing on the top three panels we can get a sense for the current areas of high and transitional saltmarsh that are expected to persist over the next four (as opposed to nine) decades. (Return to page 22 or 32).



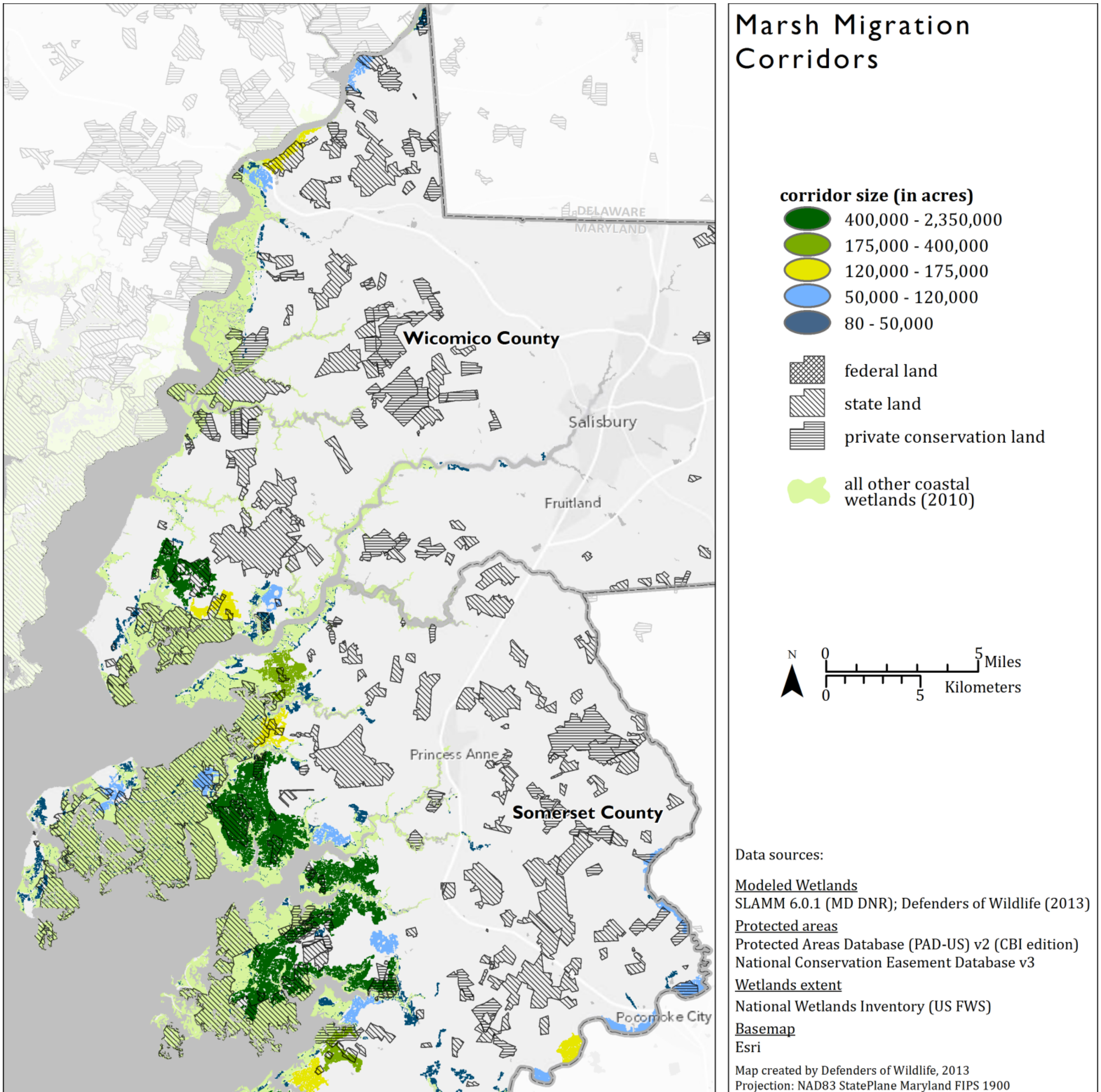
Map 6 - Land cover and projected habitat suitability for saltmarsh birds over the next century in Somerset and Wicomico counties, Maryland. (Return to page 23, 28 or 33).



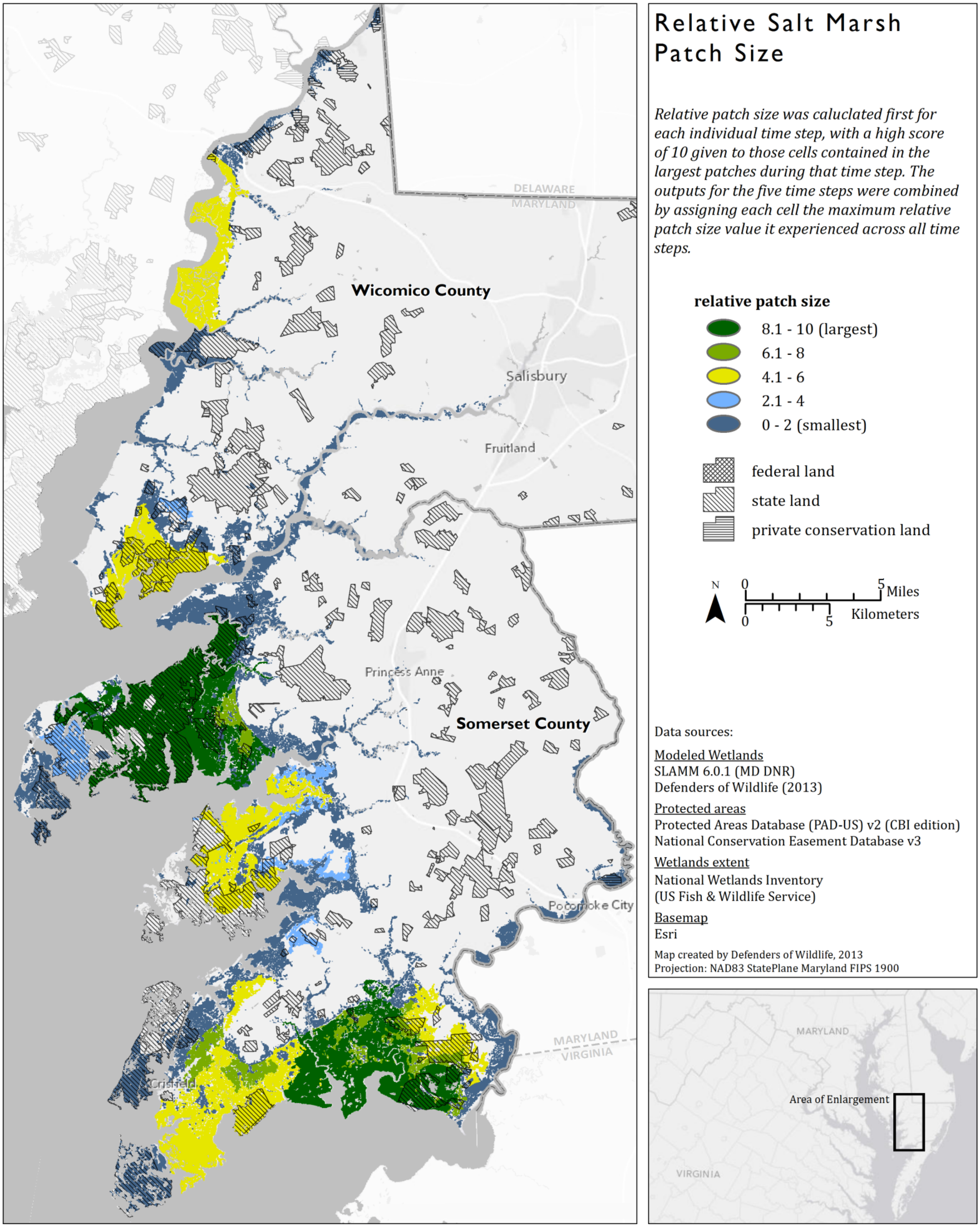
Map 7 - Composite map of saltmarsh bird core habitat over time. Core bird habitat was modeled for each sea level rise scenario/level. These identified core habitat areas are layered on top of one another with the present on the bottom and the 3.4 ft. SLR (2100) scenario on the top. For the conservation priorities map, we use the resulting composite outline, which highlights as important any area modeled as core bird habitat from the present day until the end of century sea level rise scenario. (Return to page 23 or 28).



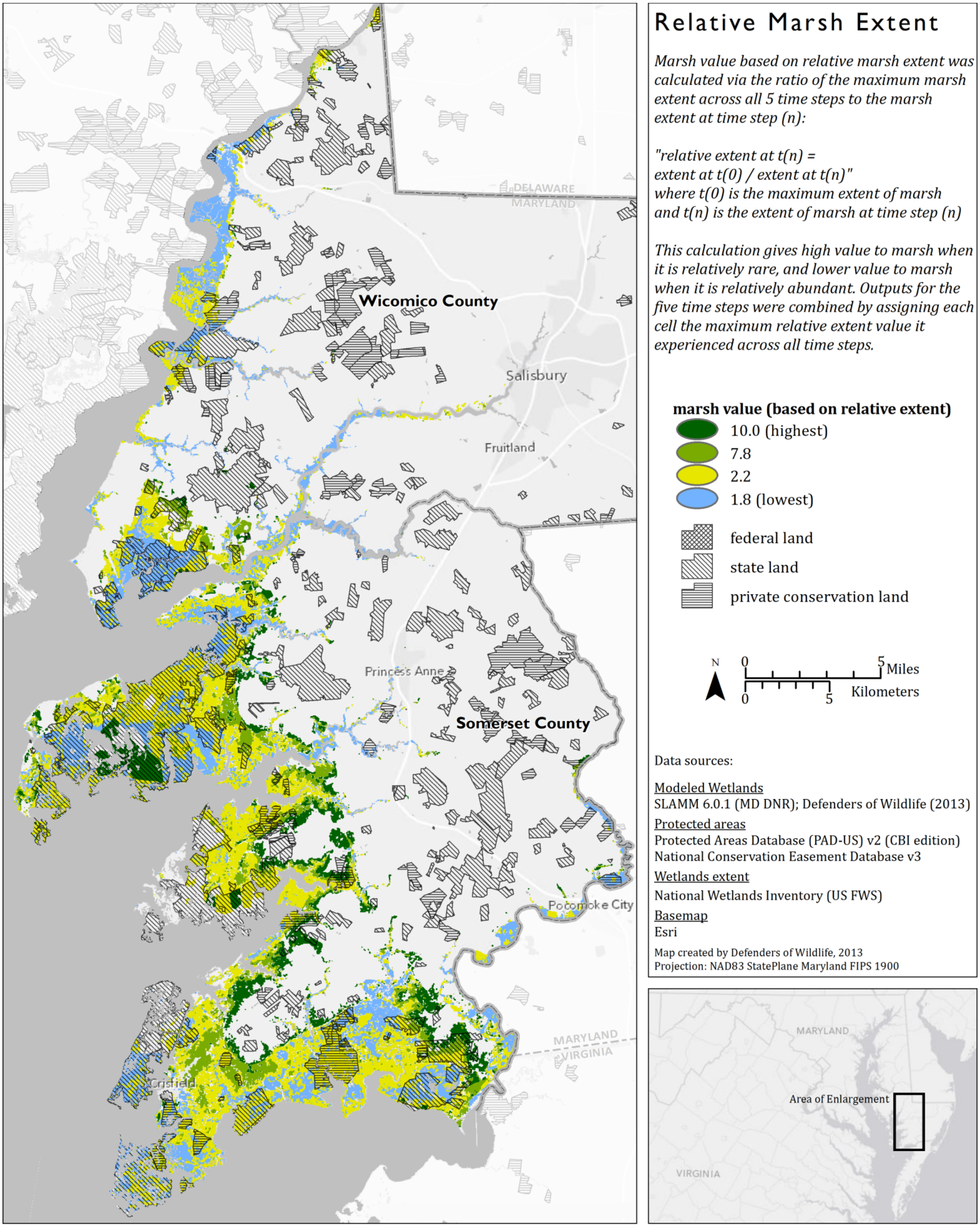
Map 8 - Habitat connectivity was assessed by modeling marsh migration corridors - chains of saltmarsh habitat that are linked across time and space. The image above is a conceptual representation of these corridors on a composite map showing saltmarsh transgression across the landscape over time, with current marsh (2010) on the bottom and future marsh (2100) on the top. (Return to page 24 or 33).



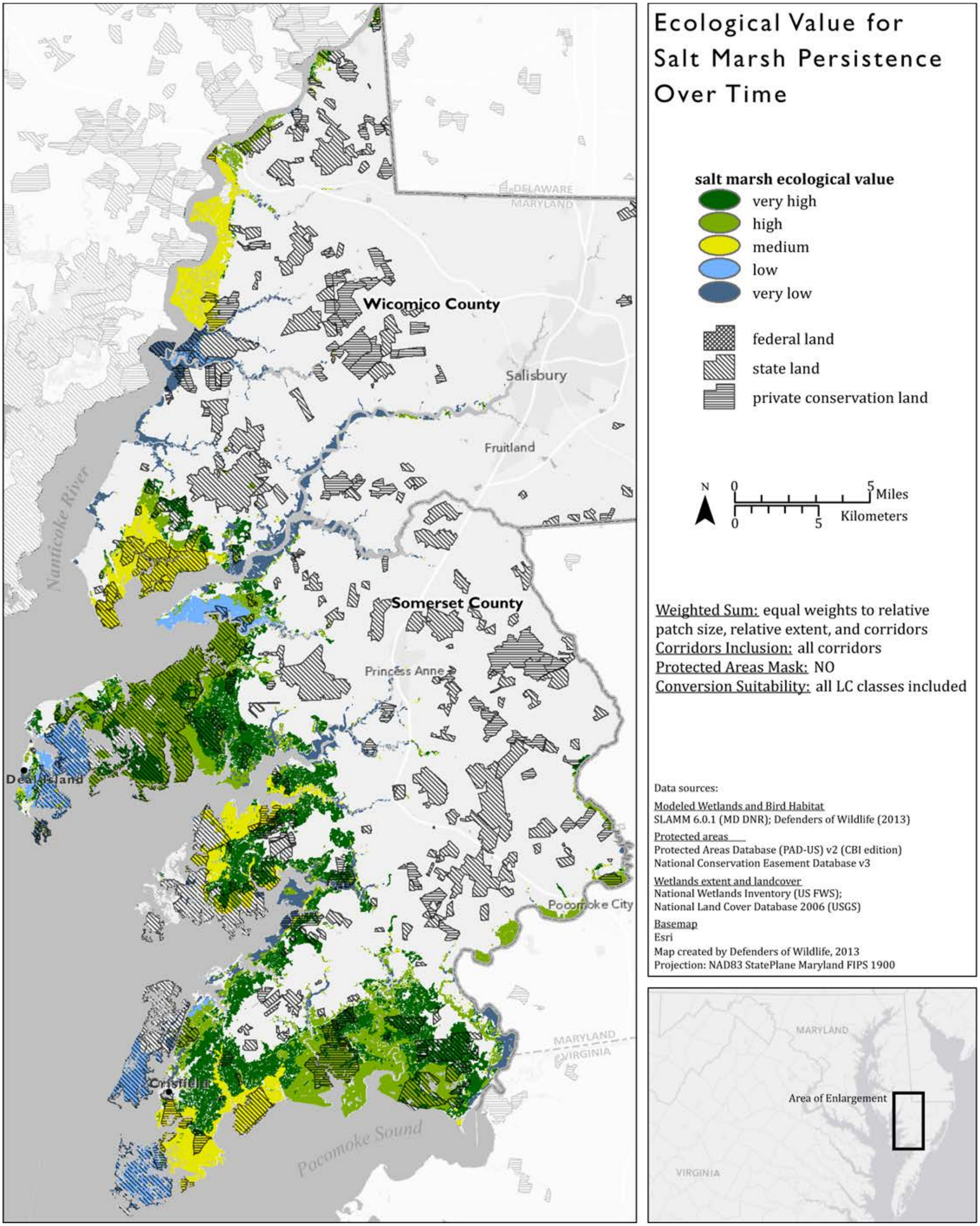
Map 9 - Modeled marsh migration corridors. These were quantitatively derived as explained in Section II of the report, and in Appendix III. For visualization, the outputs were classified according to corridor "patch size". (Return to page 24, 26, 33 or 34).



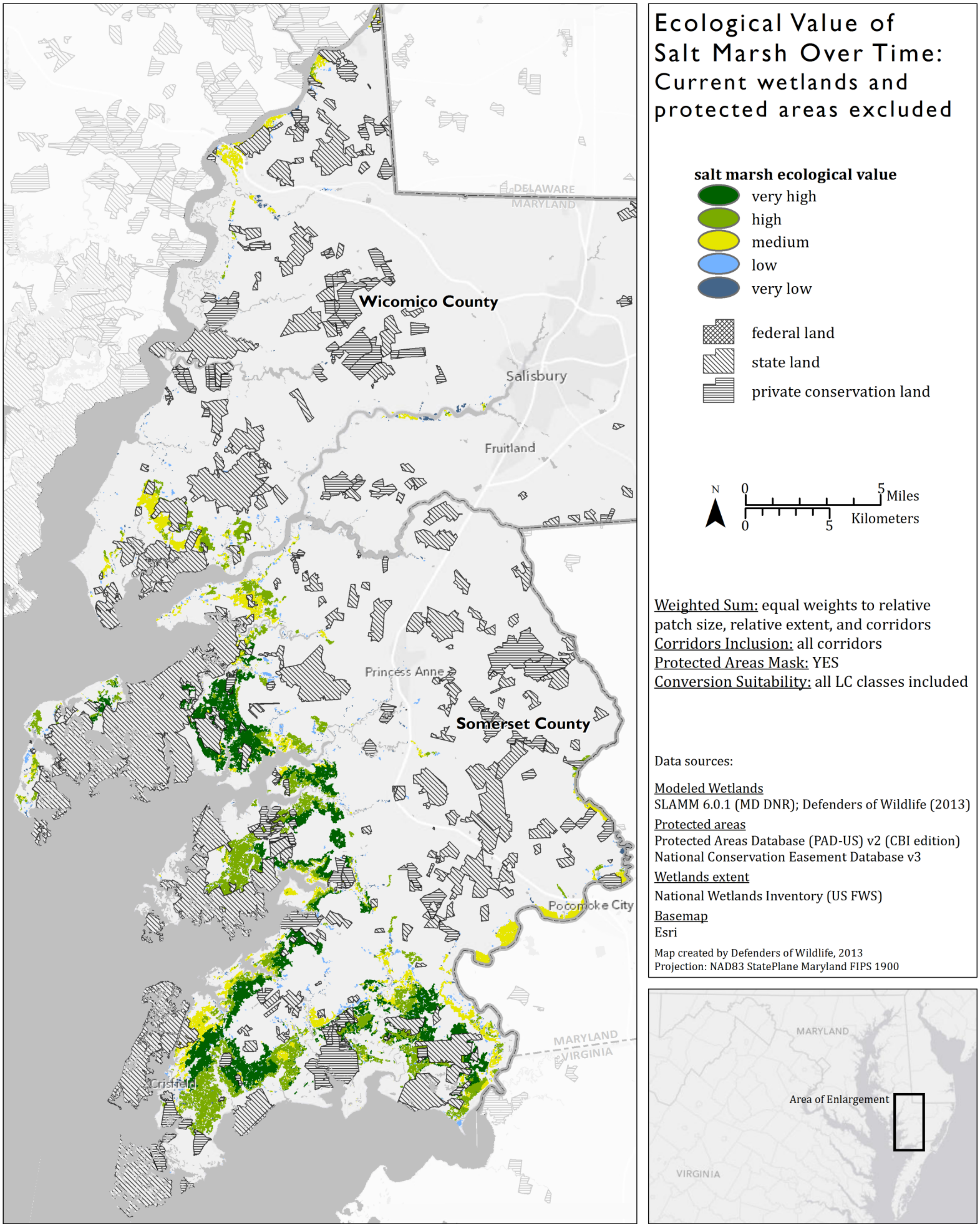
Map 10 - Relative patch size was assessed first for each individual time step, with pixels/cells in larger patches being of higher value than those in smaller patches. The individual maps for each time step were then combined by assigning each cell the value for the maximum size patch that it experienced across all five time steps. (Return to page 25 or 34).



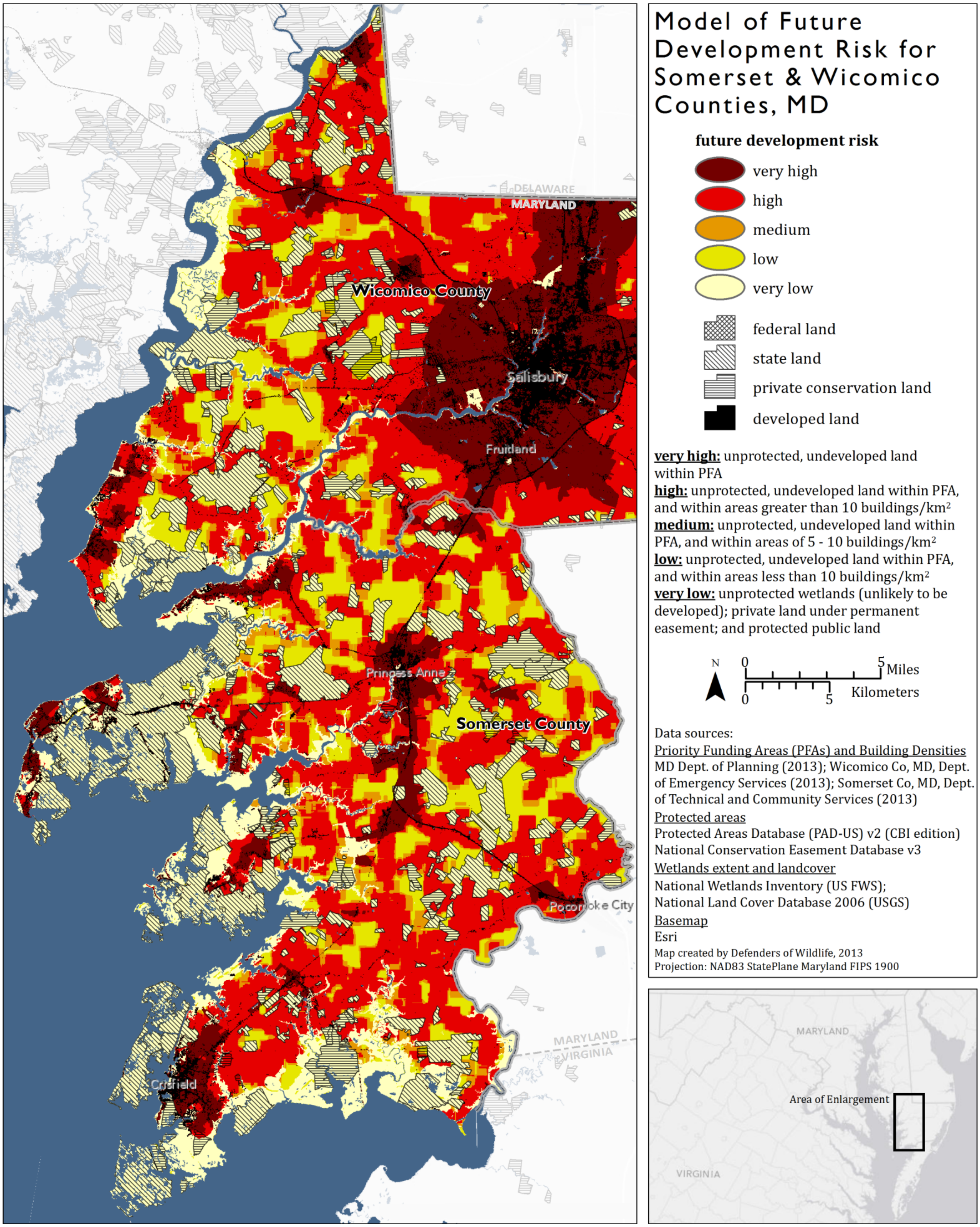
Map 11 - Relative marsh extent was calculated as the ratio of the maximum marsh extent across all five time steps to the marsh extent at any one time step. The calculation gives high value to cells of marsh when marsh is relatively rare on the landscape, and lower value to cells when marsh is relatively abundant. The individual maps for each time step were then combined by assigning each cell the value for the maximum relative extent value that it experienced across all five time steps. (Return to page 26, 33 or 34).



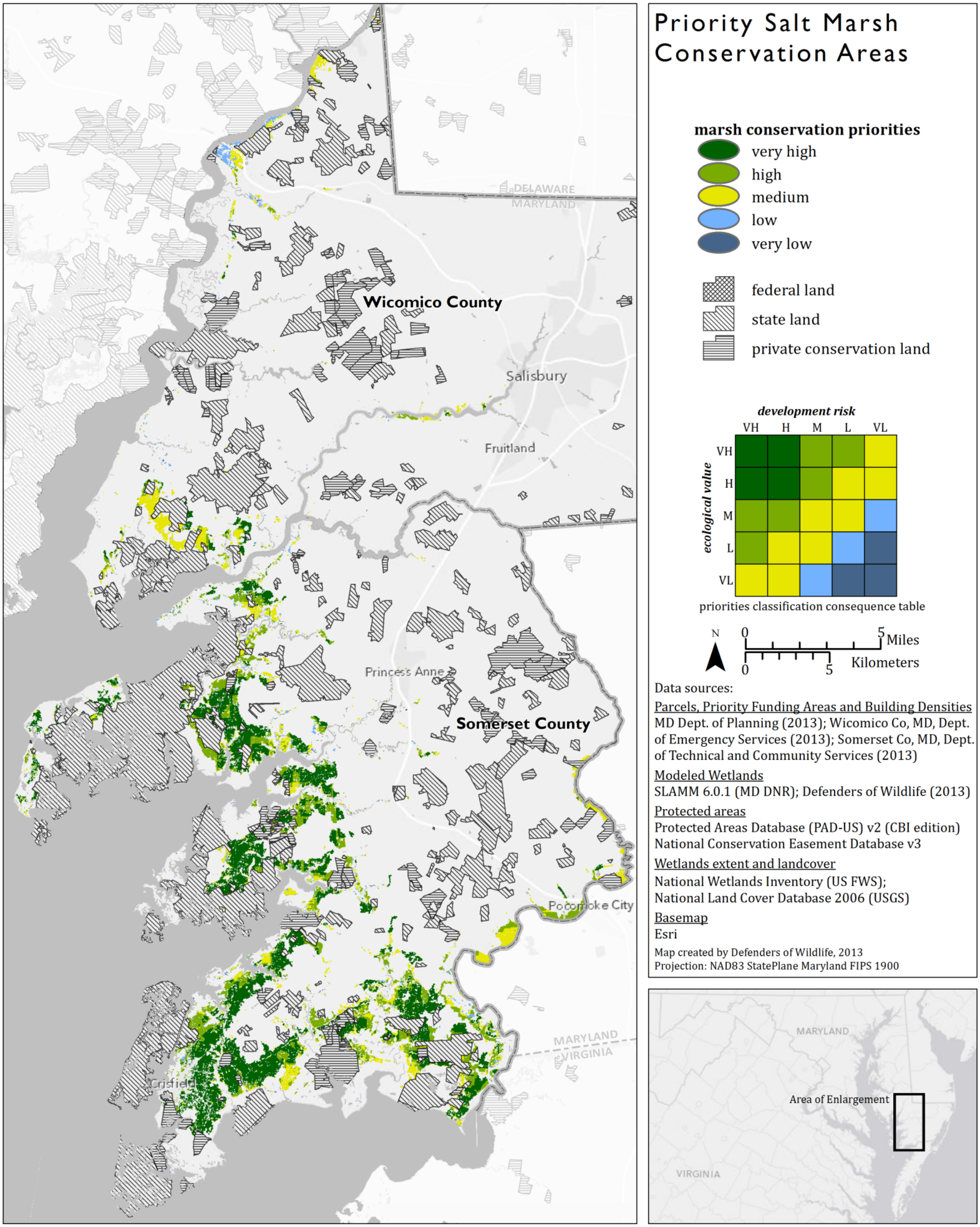
Map 12 - Modeled ecological value of land for saltmarsh persistence over time. The ecological value of marsh over time is calculated based on patch size, relative marsh extent and presence of marsh migration corridors. For this model's parameters, all identified marsh migration corridors were included; we did not mask-out areas that are already protected and we assumed all current land cover (LC) types are suitable to convert to marsh. (Return to page 26 or 34).



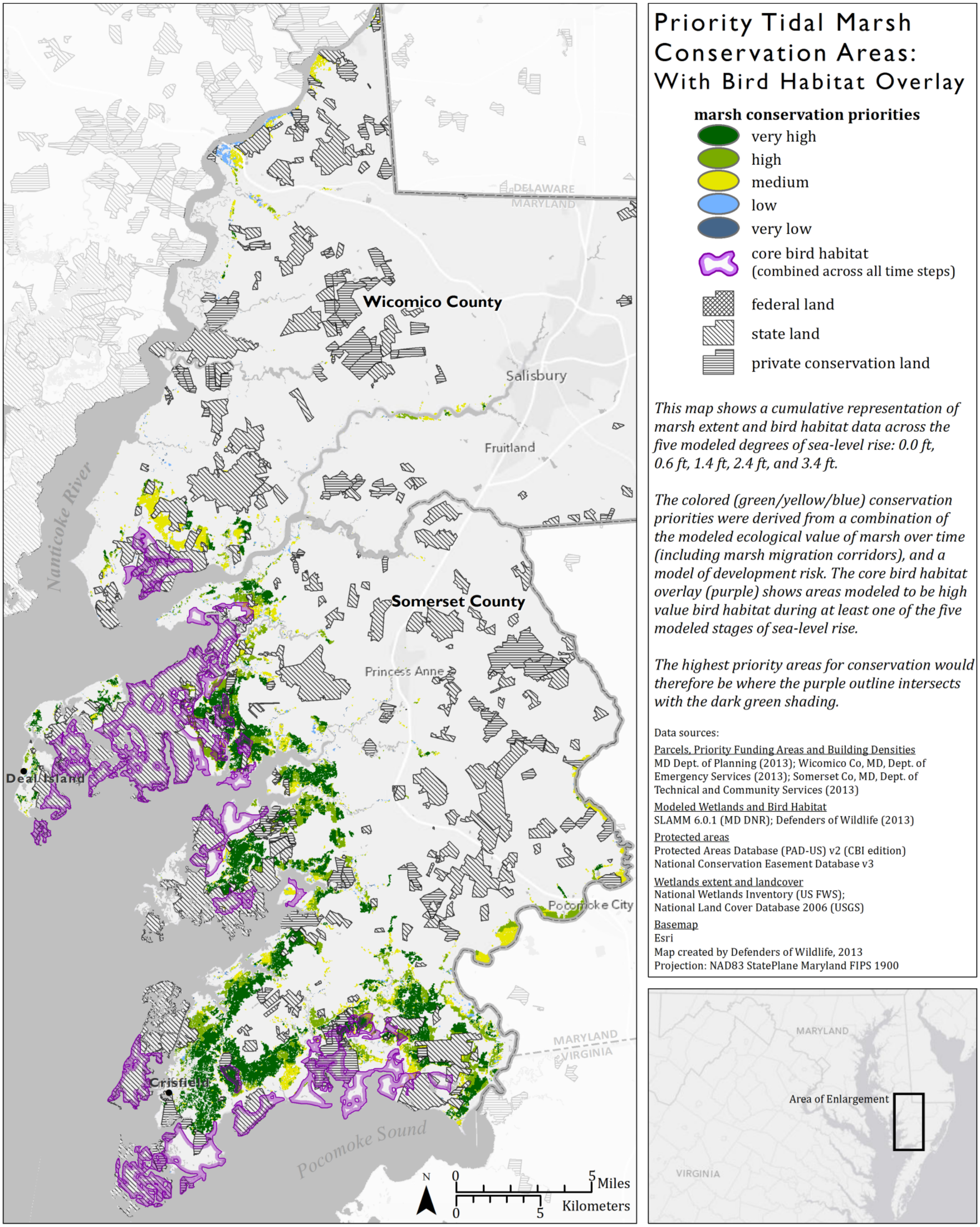
Map 13 - Ecological value of saltmarsh over time. Same as Map 12, but for this map all protected areas and current wetlands are excluded. (Return to page 27 or 34).



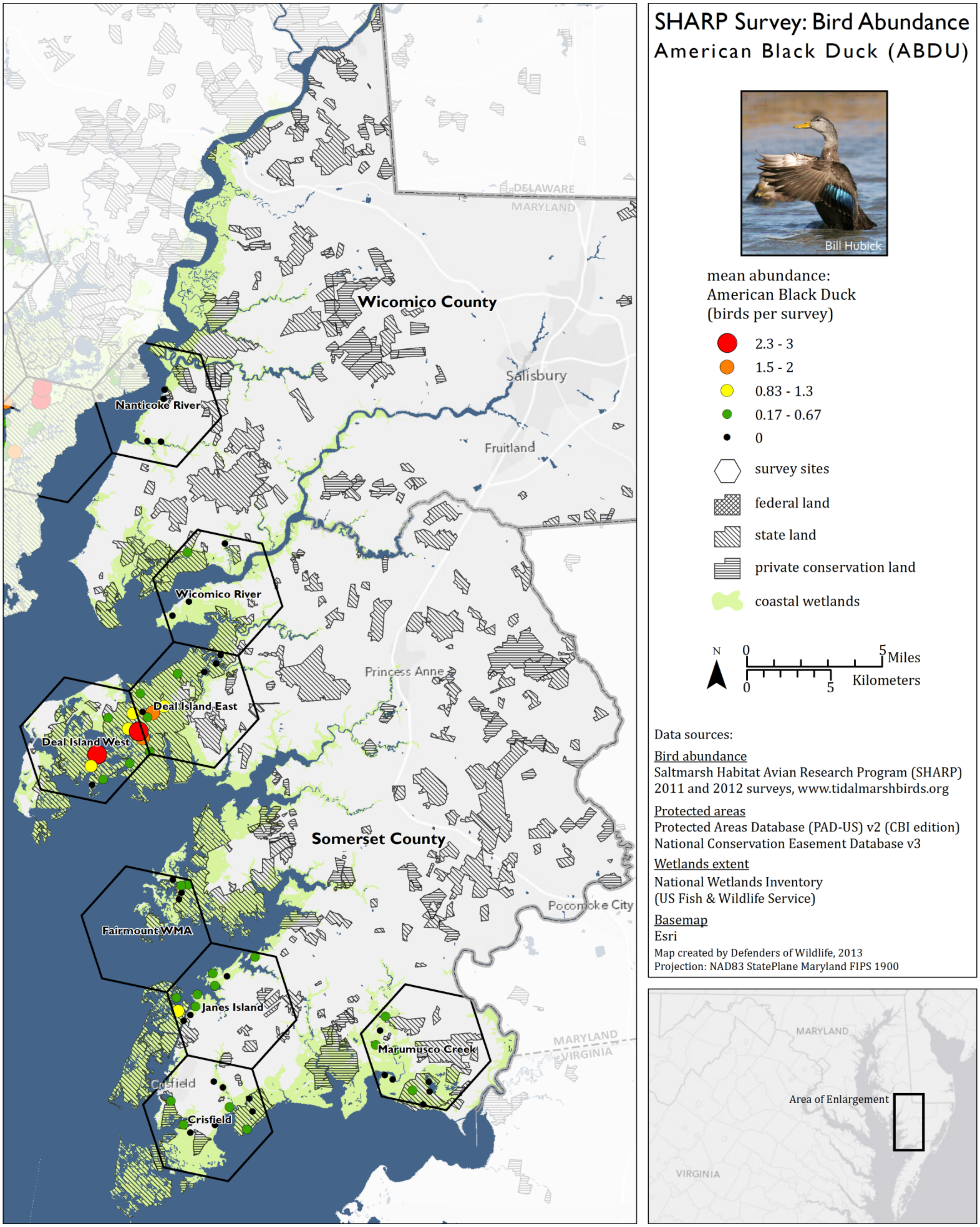
Map 14 - Model of future development risk for Somerset and Wicomico counties, Maryland. This model incorporates zoning, land ownership and land use to qualitatively assess future development potential. “Very high” risk areas are those that are unprotected, undeveloped and zoned as a “priority funding area” (PFA); “high” risk areas are those that are unprotected, undeveloped, zoned as a PFA and have greater than 10 buildings/km²; “medium” risk areas are those that are unprotected, undeveloped, zoned as a PFA and have between 5 and 10 buildings/km²; “low” risk areas are those that are unprotected, undeveloped, zoned as a PFA and have fewer than 5 buildings/km²; “very low” risk areas include unprotected wetlands, private lands under permanent easement and protected public lands. (Return to page 28).



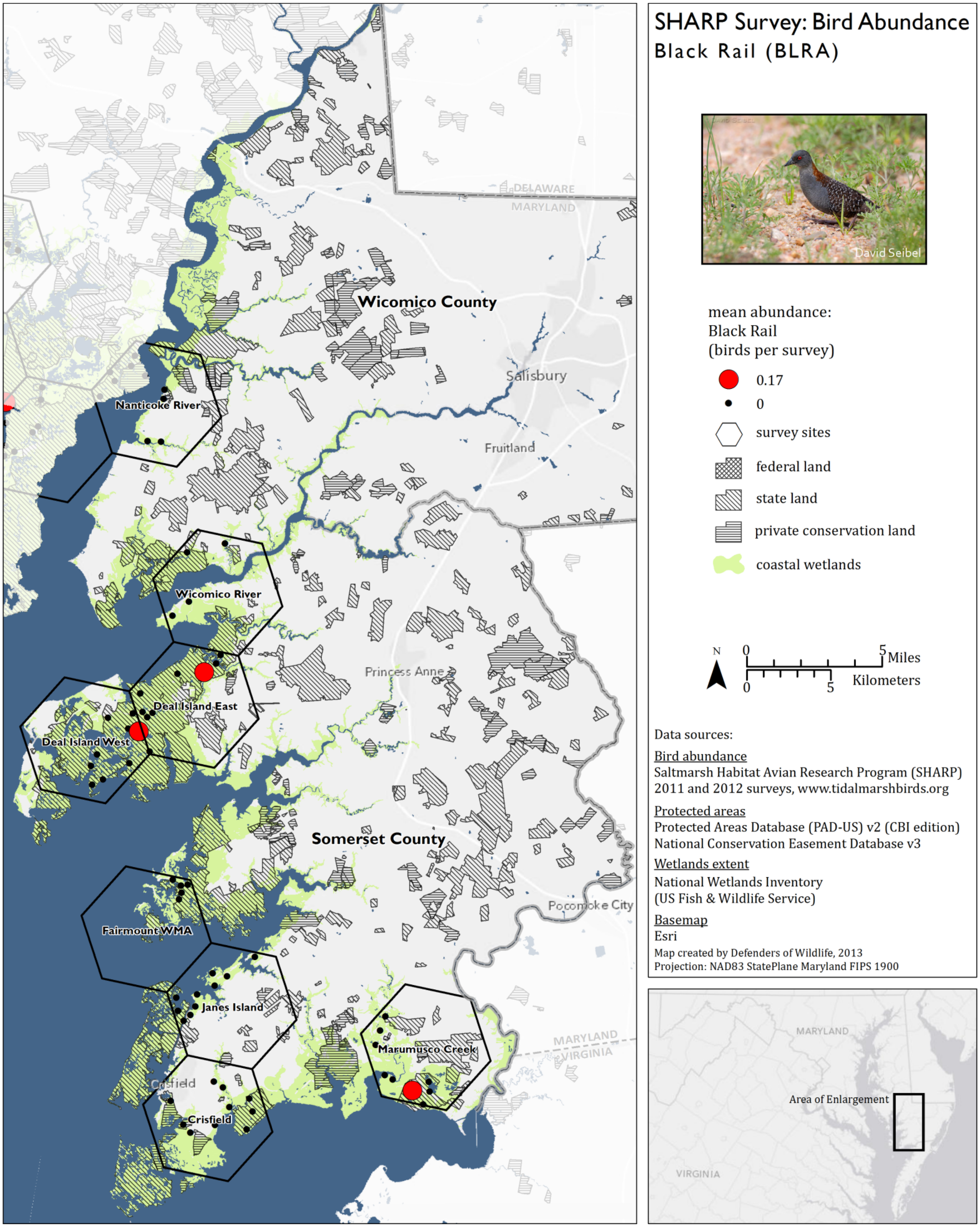
Map 15 - Priority areas for saltmarsh conservation. This model is based on the ecological value of marsh over time and the risk of future development. This map does not depict added conservation value due to the presence of core saltmarsh bird habitat. All currently protected federal, state and private lands (hatch marks) are excluded from these conservation priority (green/yellow/blue) designations. (Return to page 29 or 34).



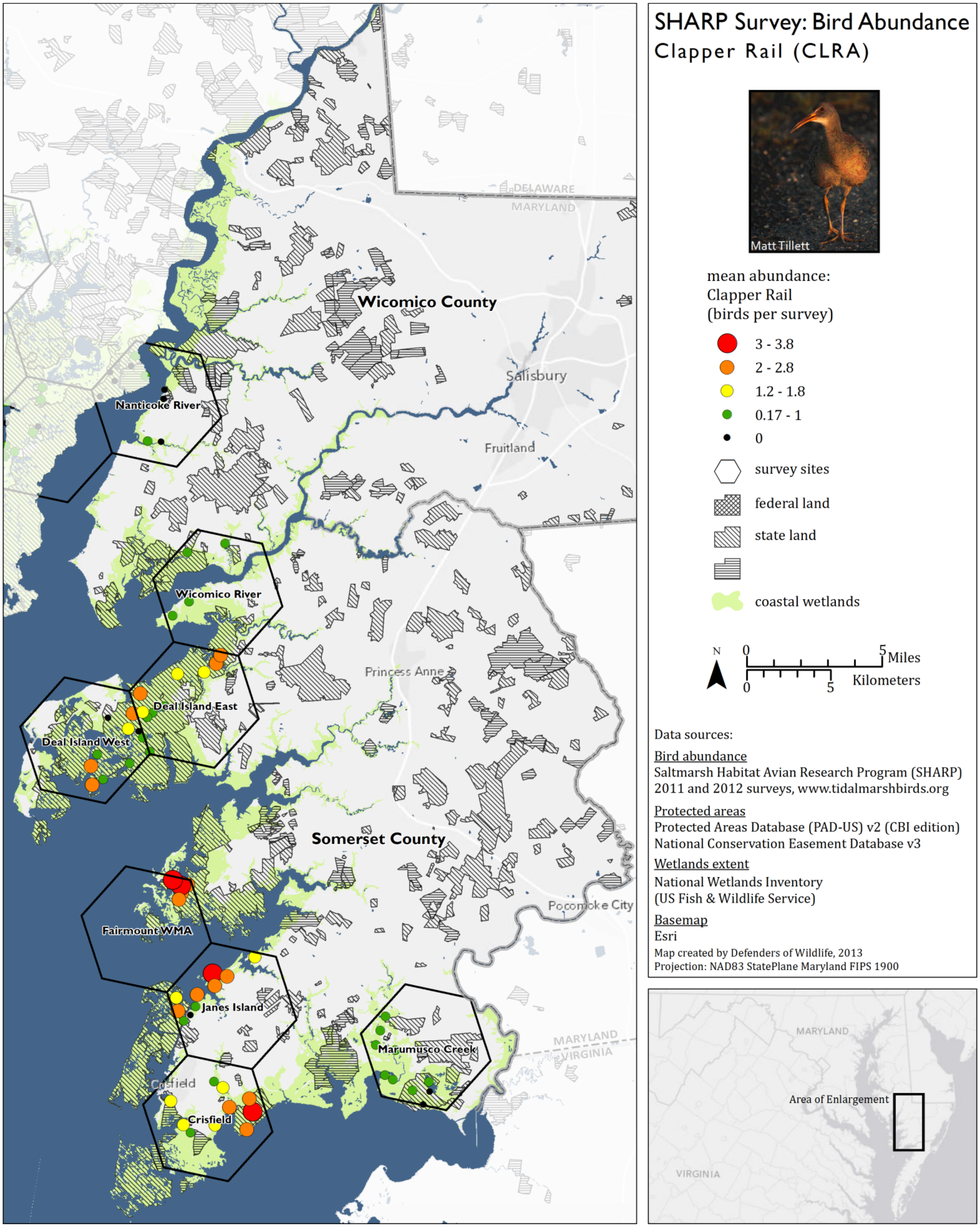
Map 16 - Priority areas for saltmarsh conservation. This model is based on the ecological value of marsh over time, the risk of future development and the presence of core saltmarsh bird habitat. All currently protected federal, state and private lands (hatch marks) are excluded from these conservation priority (green/yellow/blue) designations. (Return to page 29).



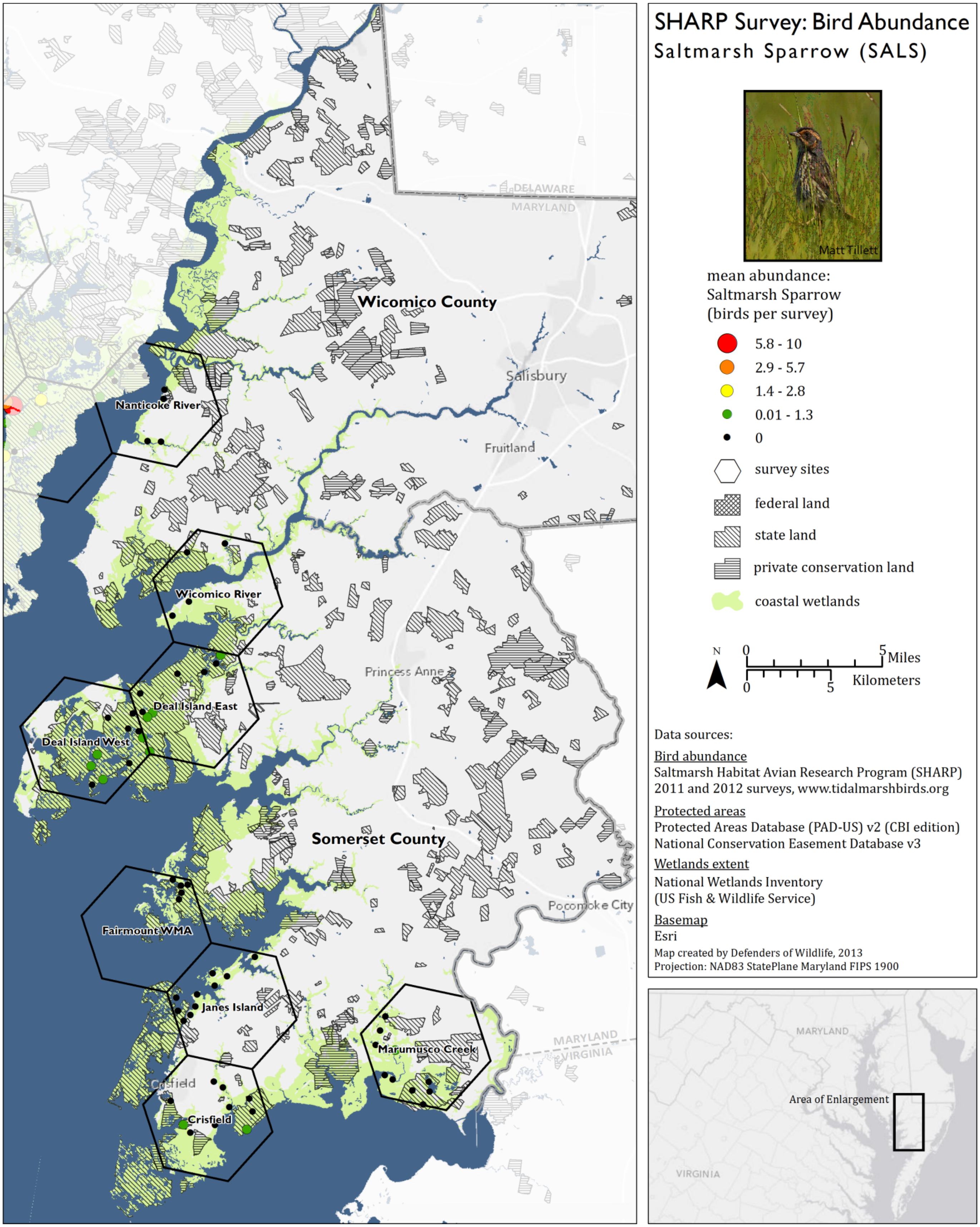
Map 17 - Map of mean number of American Black Duck detected per survey visit in Somerset and Wicomico counties, 2011-2012. (Return to page 74, Appendix II).



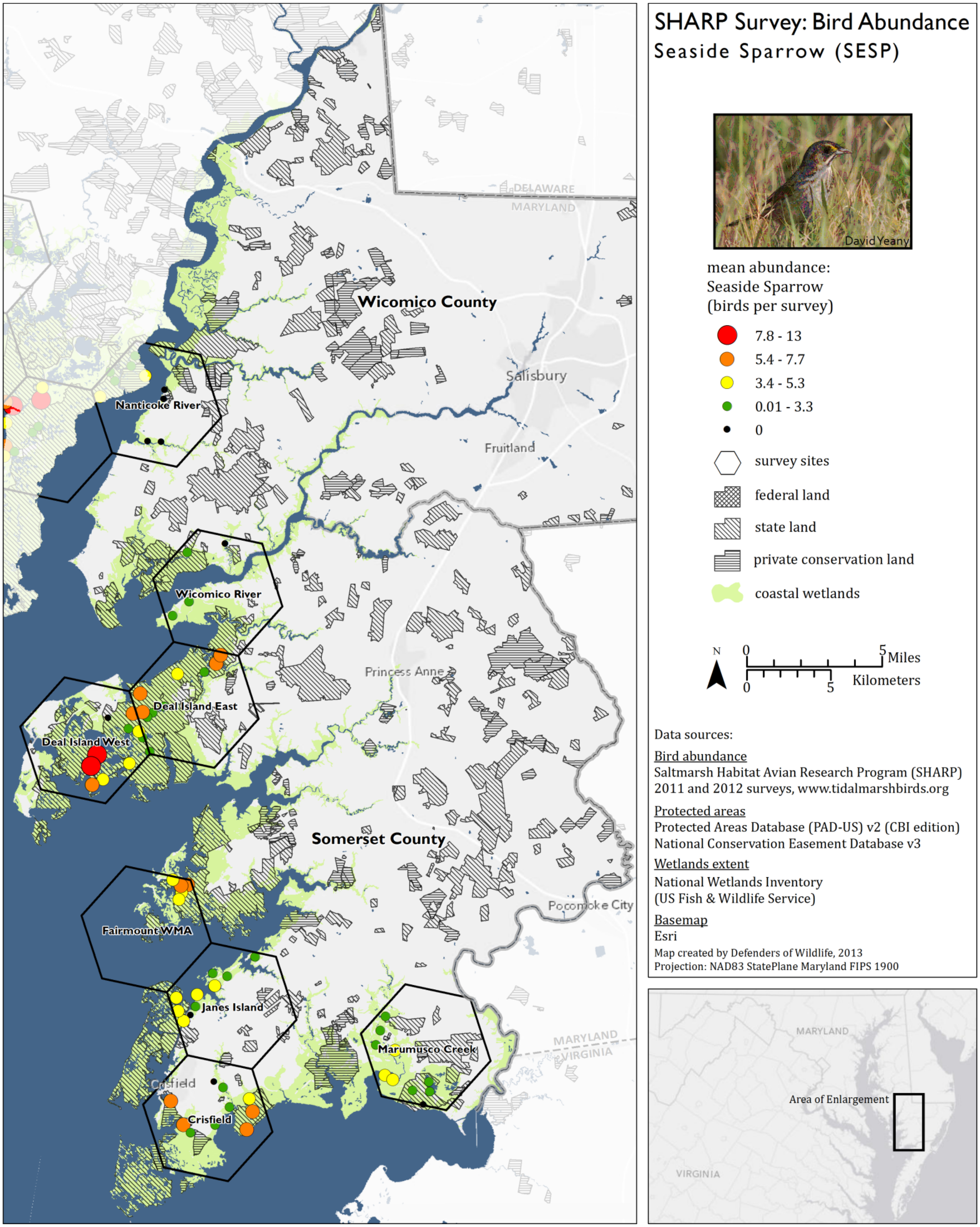
Map 18 - Map of mean number of Black Rail detected per survey visit in Somerset and Wicomico counties, 2011-12. (Return to page 75, Appendix II).



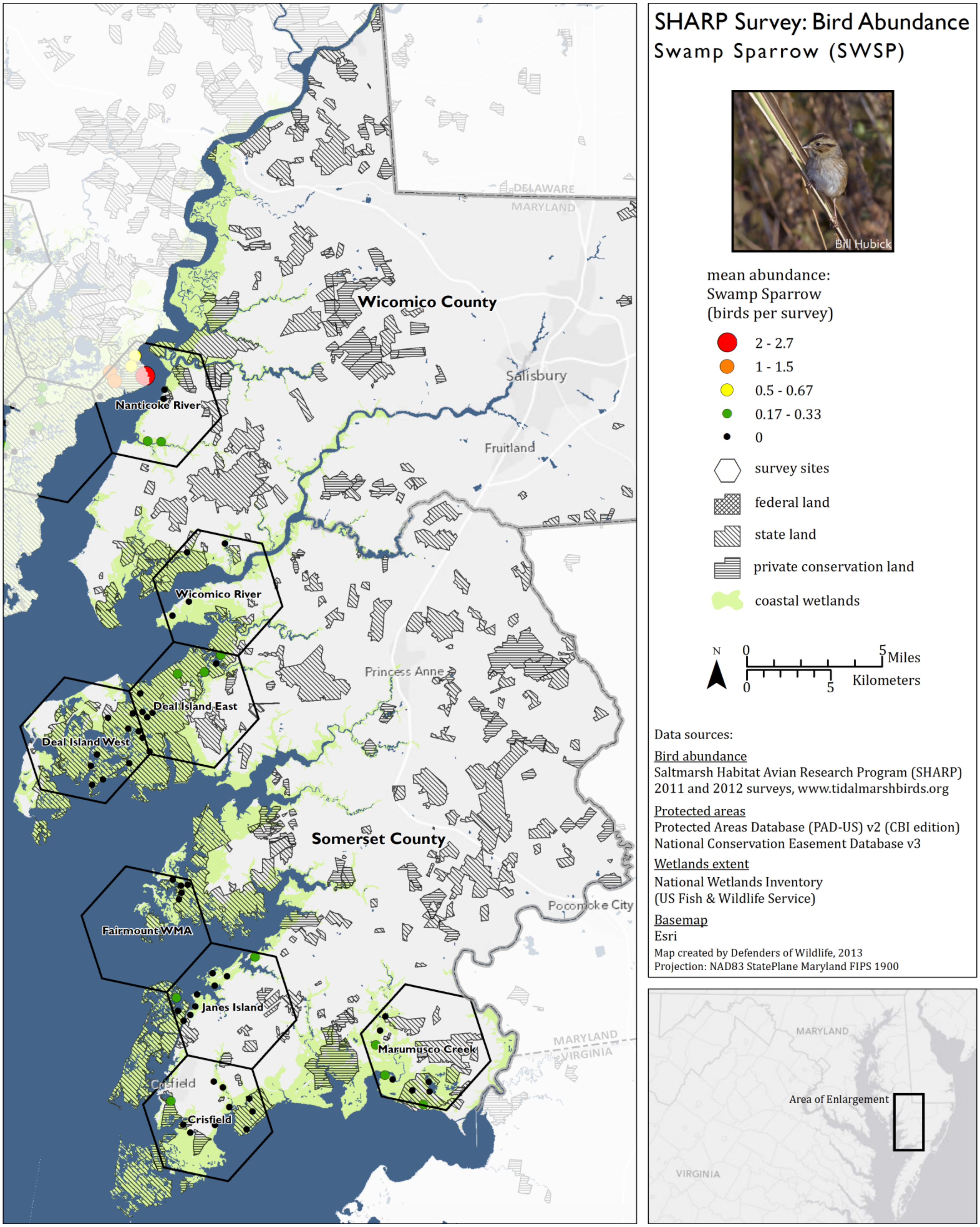
Map 19 - Map of mean number of Clapper Rail detected per survey visit in Somerset and Wicomico counties, 2011-12. (Return to page 76, Appendix II).



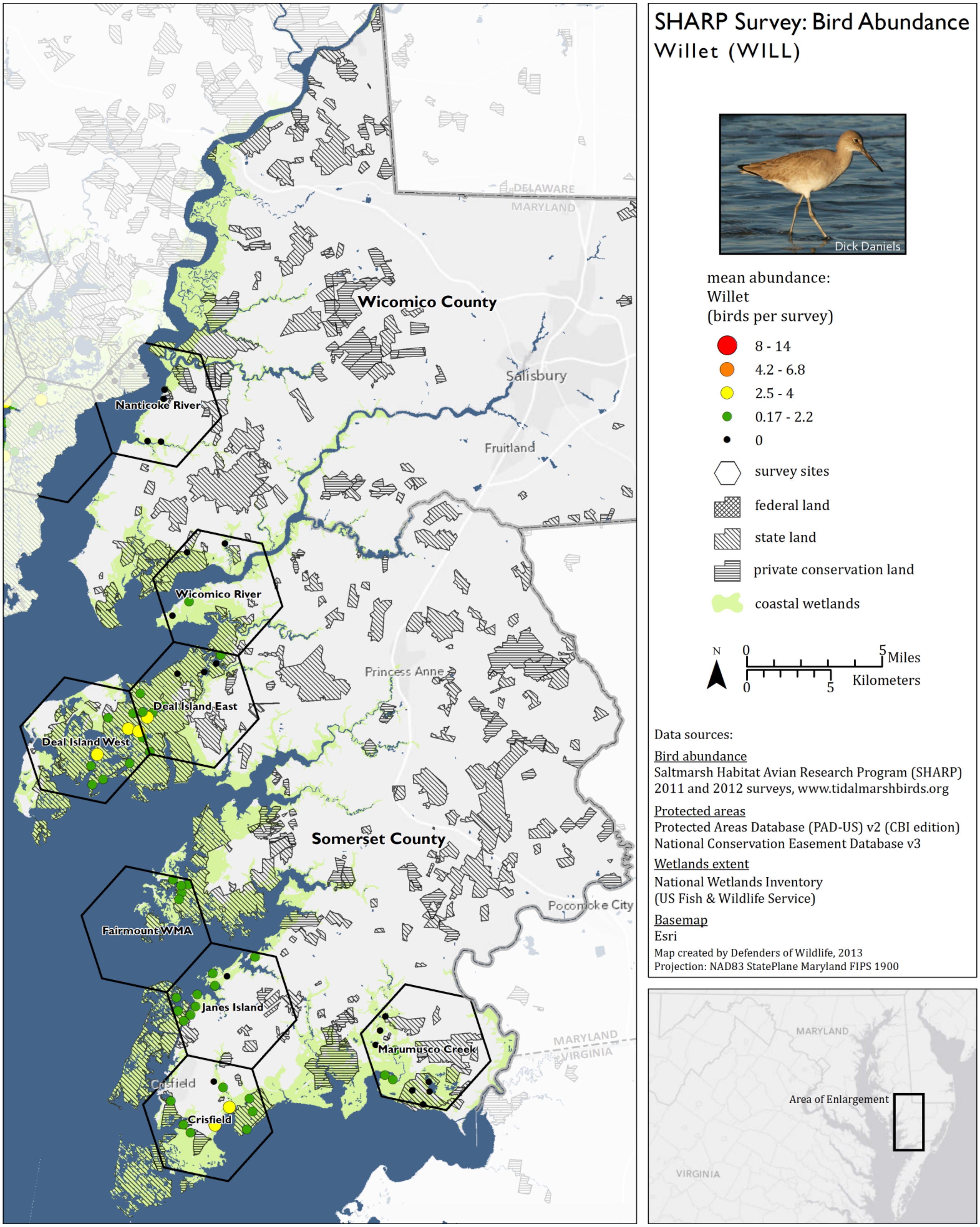
Map 20 - Map of mean number of Saltmarsh Sparrow detected per survey visit in Somerset and Wicomico counties, 2011-2012. (Return to page 77, Appendix II).



Map 21 - Map of mean number of Seaside Sparrows detected per survey visit in Somerset and Wicomico counties, 2011-2012. (Return to page 78, Appendix II).



Map 22 - Map of mean number of Coastal Plain Swamp Sparrow detected per survey visit in Somerset and Wicomico counties, 2011-2012. (Return to page 79, Appendix II).



Map 23 - Map of mean number of Willets detected per survey visit in Somerset and Wicomico counties, 2011-2012. (Return to page 80, Appendix II).

APPENDIX II: SALTMARSH BIRD VULNERABILITY AND SURVEY DATA

VULNERABILITY OF FOCAL BIRD SPECIES TO CLIMATE CHANGE

Each of the focal bird species has been assessed for vulnerability to climate change at the statewide scale by the Maryland DNR, using the NatureServe Climate Change Vulnerability Index (Release 2.01; NatureServe 2010). Five of the seven focal species are rated Highly Vulnerable to climate change by the CCVI, and this rating is defined as "abundance and/or range extent within geographical area assessed likely to decrease significantly by 2050." Two of the focal species, American Black Duck and Willet are rated Moderately Vulnerable, defined as "abundance and/or range extent within geographical area assessed likely to decrease by 2050." The confidence in the species information used to make these assessments is very high for all of the focal species. For each of the species the vulnerability rating is influenced mostly by sea level rise and the species distribution in relation to barriers to migration of marsh habitat.

Table 12 - Vulnerability ratings of saltmarsh focal bird species according to NatureServe's Climate Change Vulnerability Index.

Species	Climate Change Vulnerability Index value	Confidence in Species Information
American Black Duck	Moderately Vulnerable	Very high
Black Rail	Highly Vulnerable	Very high
Clapper Rail	Highly Vulnerable	Very high
Coastal Plain Swamp Sparrow	Highly Vulnerable	Very high
Saltmarsh Sparrow	Highly Vulnerable	Very high
Seaside Sparrow	Highly Vulnerable	Very high
Willet	Moderately Vulnerable	Very high

Table 13 - Additional bird species of conservation priority that will benefit from conservation strategies for tidal marsh in Somerset and Wicomico counties.

Species	Endemism category (breeding populations)[a]	Conservation priority		
		National [b]	Regional (BCR 30)	State of Maryland [d]
American Bittern			M	GCN
American Oystercatcher		BCC	HH	GCN
American Wigeon			M	
Black-crowned Night Heron			M	GCN
Blue-winged Teal	4			
Canada Goose			HH	
Common Moorhen				I, GCN
Common Tern			M	GCN
Dunlin			H	GCN
Forster's Tern			H	GCN
Gadwall	4		M	
Glossy Ibis			H	GCN
Great Egret				GCN
Greater Yellowlegs			H	GCN
Green-winged Teal			M	
King Rail		WL Yellow	M	GCN
Least Bittern			M	I, GCN
Lesser Yellowlegs		BCC	M	
Little Blue Heron			M	GCN
Mallard			H	
Marsh Wren	4		H	GCN
Northern Harrier	4			GCN
Northern Pintail			M	
Pied-billed Grebe				GCN
Sedge Wren			M	E, GCN
Semipalmated Sandpiper		WL Yellow	H	GCN
Short-billed Dowitcher		BCC	H	GCN
Short-eared Owl		WL Yellow, BCC		GCN
Snowy Egret			M	GCN
Solitary Sandpiper		BCC	H	GCN
Stilt Sandpiper		BCC		
Tricolored Heron			M	GCN
Tundra Swan			H	
Virginia Rail				
Western Sandpiper		WL Yellow	M	
White-rumped Sandpiper		WL Yellow	H	

[a] *Endemism:* Category: 1 = species endemic to tidal marsh; 2 = subspecies endemic to tidal marsh; 3 = species with majority of populations in North America restricted to tidal marsh; 4 = species with majority of populations in Mid-Atlantic region restricted to tidal marsh (adapted from Greenberg and Maldonado 2006)
[b] *National priority*: WL = Audubon/American Bird Conservancy WatchList; Red category = Highest national concern; Yellow category = Declining or rare. See http://birds.audubon.org/2007-audubon-watchlist ; BCC = USFWS Birds of Conservation Concern (2008) http://www.fws.gov/migratorybirds/NewReportsPublications/SpecialTopics/BCC2008/BCC2008.pdf
[c] *Regional priority (BCR 30):* HH = Highest priority; H = High priority; M = Moderate priority. See http://www.northatlanticlcc.org/rep_species.html
[d] *State priority:* Listed in the Code of Maryland Regulations (COMAR 08.030.08) as E = Endangered, T = Threatened, I = In Need of Conservation. See website: http://www.dnr.Maryland.gov/wildlife/rteanimals.asp GCN = Listed in Maryland Wildlife Diversity Conservation Plan as a Species of Greatest Conservation Need. See http://www.dnr.state.md.us/wildlife/Plants_Wildlife/WLDP/divplan_about.asp

AMERICAN BLACK DUCK

American Black Ducks were detected at 33 of 63 survey points in Somerset and Wicomico counties with a mean detection rate of 0.34 ducks per survey visit. This species was found in 7 of the 8 primary sampling units, and was most abundant on the Deal Island peninsula (Map 17).

Univariate analyses indicated relatively few associations with vegetation and landscape variables. Black Ducks were more abundant at points where Olney threesquare was present than absent, more abundant where high marsh exceeded 50 percent of the vegetation survey plot and more abundant where tidal marsh exceeded 50 percent of the landscape within 200 m, and 1000 m (see Table 16 at end of this appendix). The logistic regression model derived from the significant variables above, included only one of these variables, percentage estuarine emergent marsh within 1000 m (see Table 22 at end of this appendix). Figure 7 shows no strong evidence for selection of particular vegetation components by Black Ducks but indicates that they may show some preference for meadow cordgrass, pannes and creeks and threesquare.

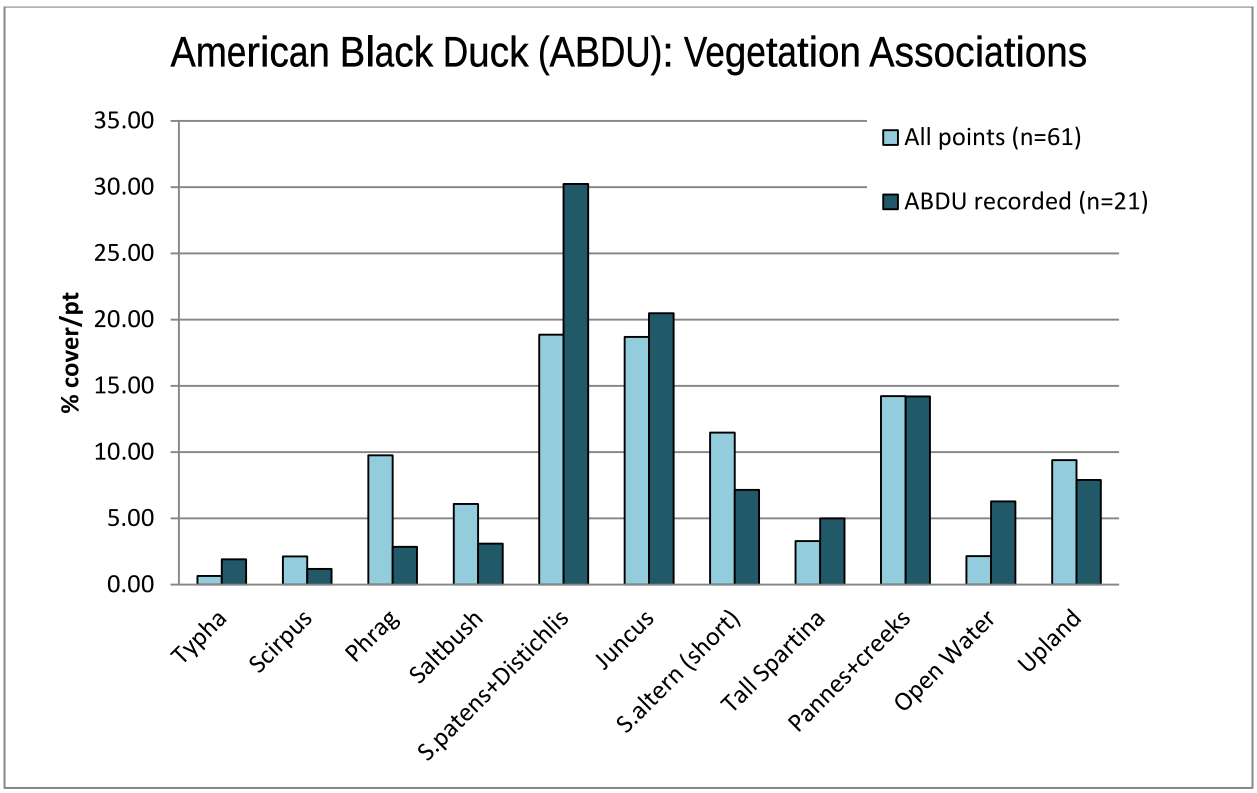


Figure 7 - Vegetation cover at all SHARP survey points in Somerset and Wicomico counties and points where American Black Duck was detected. Based on 2011 data.

Black Rail

Black Rail was detected at 3 of 63 survey points in Somerset and Wicomico counties with a mean detection rate of 0.01 rails per survey visit. Black Rails were found on the Deal Island peninsula and at Marumsco marsh near the Pocomoke Sound (**Map 18**). Statistical analyses were not completed for Black Rail due to the limited number of detections.

CLAPPER RAIL

Clapper Rail was detected at 56 of 63 survey points in Somerset and Wicomico counties with a mean detection rate of 1.25 rails per survey visit. This species was found in all 8 primary sampling units. It occurred in high densities at Deal Island, Fairmount, and the vicinity of Crisfield (Map 19), and was more abundant in Somerset County than in Wicomico, Worcester and Dorchester counties. The survey results indicate that Somerset County is this species' stronghold in Maryland.

Univariate analyses revealed several associations with vegetation and landscape variables. Clapper Rails were more abundant at points where smooth cordgrass (short form) and black needlerush were present but showed negative associations with threesquare and *Phragmites*. Clapper Rails were more abundant where high marsh exceeded 50 percent of the vegetation survey plot and more abundant where tidal marsh exceeded 50 percent of the landscape within 200 m, 500 m and 1000 m. Finally this species showed a significant relationship with distance to upland, being more abundant beyond 250 m from the nearest upland edge (see Table 17 at end of this appendix). The logistic regression model derived from the significant variables above included a positive effect of distance to upland and percentage estuarine marsh within 200 m on rail presence and a negative effect of *Phragmites* (see Table 22 at end of this appendix).

Figure 8 reflects the univariate analyses in showing selection by Clapper Rail for black needlerush and avoidence of *Phragmites*, but other vegetation relationships are not clear. Clapper Rails appear to show selection for pannes and creeks.

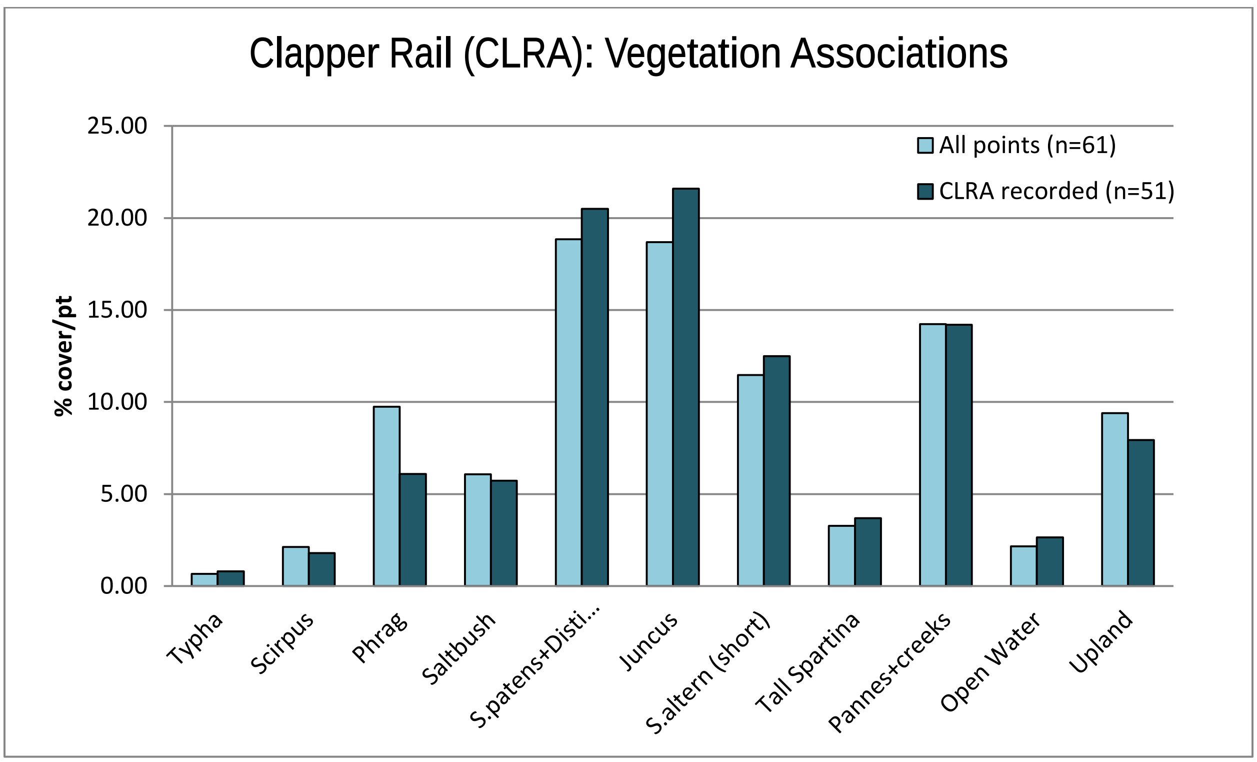


Figure 8 - Vegetation cover at all SHARP survey points in Somerset and Wicomico counties and points where Clapper Rail was detected. Based on 2011 data.

Saltmarsh Sparrow

Saltmarsh Sparrow was detected at 11 of 63 survey points in Somerset and Wicomico counties with a mean detection rate of 0.08 sparrows per survey visit. Saltmarsh Sparrows were found in 4 of 8 primary sampling units, at Crisfield, Marumsco Creek and on the Deal Island peninsula (Map 20). Saltmarsh Sparrow density was generally lower in the project area than in Worcester County and the Fishing Bay region of Dorchester County.

Univariate analyses revealed several associations with vegetation and landscape variables. Saltmarsh Sparrows were more abundant at points where smooth cordgrass was present, but surprisingly, did not show an effect of meadow cordgrass and spikegrass (for all Maryland data), unless these were combined with smooth cordgrass. Saltmarsh Sparrows were negatively associated with black needlerush and *Phragmites*. They were more abundant where open water exceeded 25 percent of the landscape within 200 m, 500 m and 1000 m, and also at sites more distant from the upland edge (see Table 19 at end of this appendix). The logistic regression model derived from the significant variables above included only two of these variables, distance to upland and short *Spartina,* which both showed a positive effect on sparrow presence (see Table 22 at end of this appendix).

Figure 9 shows clear selection for meadow cordgrass, spikegrass and short form smooth cordgrass (described by others as Saltmarsh Sparrows preferred habitat) in Somerset and Wicomico counties. Saltmarsh Sparrow also shows avoidance of black needlerush and, to a lesser extent, Phragmites, reflecting the patterns revealed by the univariate analyses.

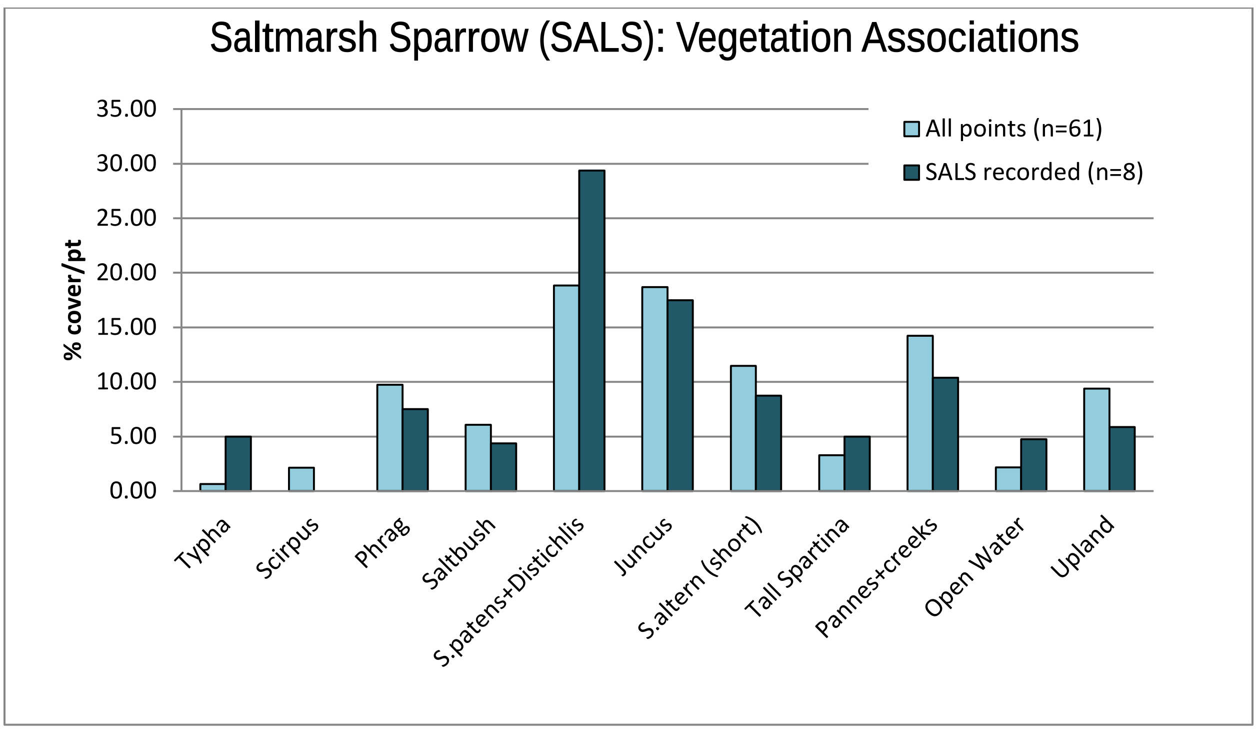


Figure 9 - Vegetation cover at all SHARP survey points in Somerset and Wicomico counties and points where Saltmarsh Sparrow was detected. Based on 2011 data.

SEASIDE SPARROW

Seaside Sparrow was detected at 54 of 63 survey points in Somerset and Wicomico counties with a mean detection rate of 3.2 sparrows per survey visit. Seaside Sparrows were found in 7 of the 8 primary sampling units, being absent from the Nanticoke River marshes. They were most abundant at Fairmount, the Crisfield vicinity and the Deal Island peninsula (Map 21).

Univariate analyses revealed relationships with most vegetation and landscape variables, more than for any other bird species, possibly because the greater abundance of Seaside Sparrow provided more power to detect relationships. Saltmarsh Sparrows were more abundant at points where smooth cordgrass was present, but as with Saltmarsh Sparrow, did not show an effect of meadow cordgrass and spikegrass (for all Maryland data), unless these were combined with smooth cordgrass.

Seaside Sparrows were positively associated with black needlerush and negatively associated with *Phragmites* and saltbush shrubs. They were more abundant where open water exceeded 25 percent of the landscape within 200 m, and 500 m, and also at sites more distant from the upland edge and exceeding 50 percent estuarine marsh cover within 200 m, 500 m, and 1000 m (see Table 20 at end of this appendix). The logistic regression model derived from the significant variables above included (for all Maryland sites) a negative effect of *Phragmites* and a positive effect of estuarine marsh cover within 1000 m and open water within 200 m (see Table 22 at end of this appendix). When Worcester County sites were excluded, short *Spartina* and black needlerush both entered the model and had a positive effect on sparrow presence.

Figure 10 shows Seaside Sparrow relationships with vegetation components in the same direction as the univariate analyses, but sparrows do not show strong selection or avoidance for any component except cat-tail (*Typha*) which appears to be strongly avoided.

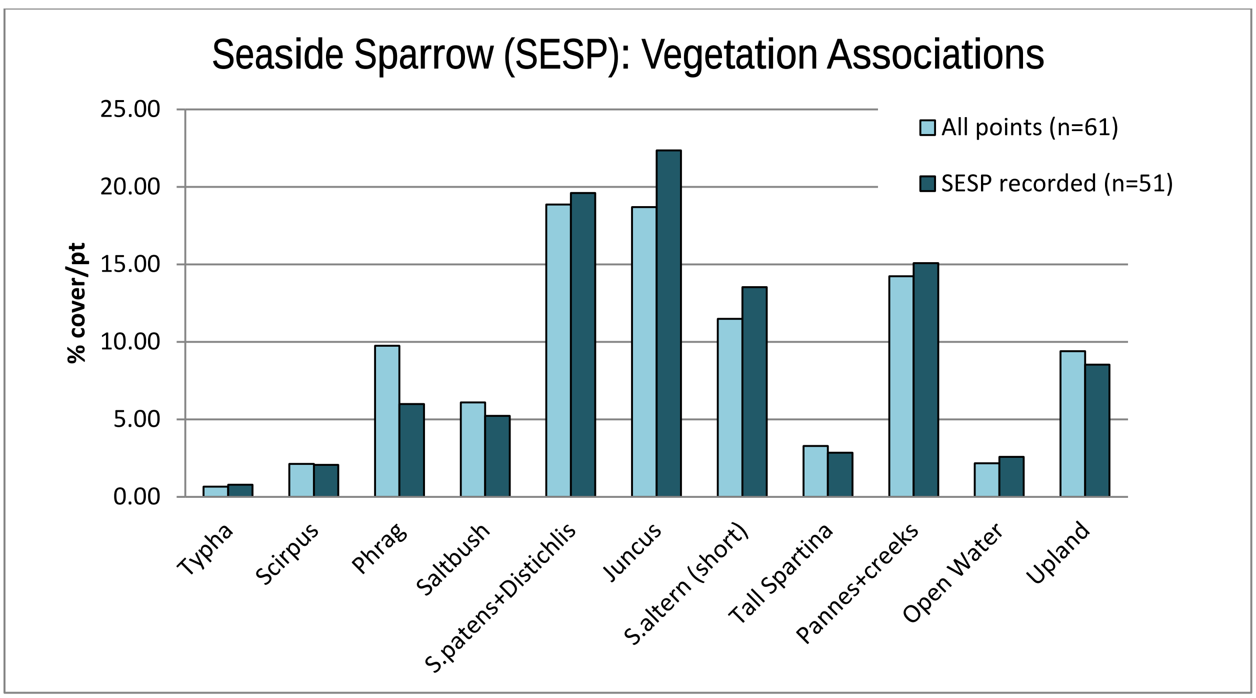


Figure 10 - Vegetation cover at all SHARP survey points in Somerset and Wicomico counties and points where Seaside Sparrow was detected. Based on 2011 data.

Coastal Plain Swamp Sparrow

Coastal Plain Swamp Sparrow was detected at 11 of 63 survey points in Somerset and Wicomico counties with a mean detection rate of 0.04 sparrows per survey visit. Swamp Sparrows were found in 5 of 8 primary sampling units and occurred at low density in these locations (**Map 22**).

Univariate analyses revealed few associations with vegetation and landscape variables. Swamp Sparrows were more abundant at points where big cordgrass (*Spartina cynosuroides*) or tall form smooth cordgrass was present, the only focal saltmarsh bird species to show this association. Although this species showed no influence of distance to upland, it was more abundant in landscapes dominated by marsh, being more abundant at points exceeding 50 percent estuarine marsh cover within 500 m and 1000 m. Swamp Sparrows were less abundant where open water exceeded 25 percent of the landscape within 200 m. (see **Table 18** at end of this appendix). The logistic regression model derived from the significant variables above included two of these variables, tall *Spartina* and percentage estuarine marsh within 1000 m, both of which both showed a positive effect on swamp sparrow presence (see **Table 22** at end of this appendix).

A comparisons of vegetation associations between points where swamp sparrows were detected and all survey points was not completed because of the low number of swamp sparrow detections in 2011.

Willet

Willets were detected at 43 of 63 survey points in Somerset and Wicomico counties with a mean detection rate of 0.72 birds per survey visit. Willets were found in 7 of 8 primary sampling units, being absent from marshes at Nanticoke River, an were most abundant in the Crisfield vicinity, at Fairmount and on the Deal Island peninsula (Map 23).

Univariate analyses revealed several associations with vegetation and landscape variables, and these patterns were very similar to those for Saltmarsh Sparrow. Willets were more abundant at points where smooth cordgrass was present, but surprisingly, did not show an effect of meadow cordgrass and spikegrass (for all Maryland data), unless these were combined with smooth cordgrass. Willets were negatively associated with black needlerush, threesquare, and *Phragmites*. They were more abundant where open water exceeded 25 percent of the landscape within 500 m and 1000 m, and also at sites more distant from the upland edge (see Table 21 at end of this appendix). The logistic regression model derived from the significant variables above included three of these variables, distance to upland, short *Spartina* and threesquare. Distance to upland and short *Spartina* had a positive effect on sparrow presence and threesquare had a negative effect (see Table 22 at end of this appendix).

Figure 11 shows clear selection by Willet for meadow cordgrass, spikegrass and short form smooth cordgrass and avoidance of threesquare in Dorchester County, reflecting some but not all of the patterns revealed by the univariate analyses.

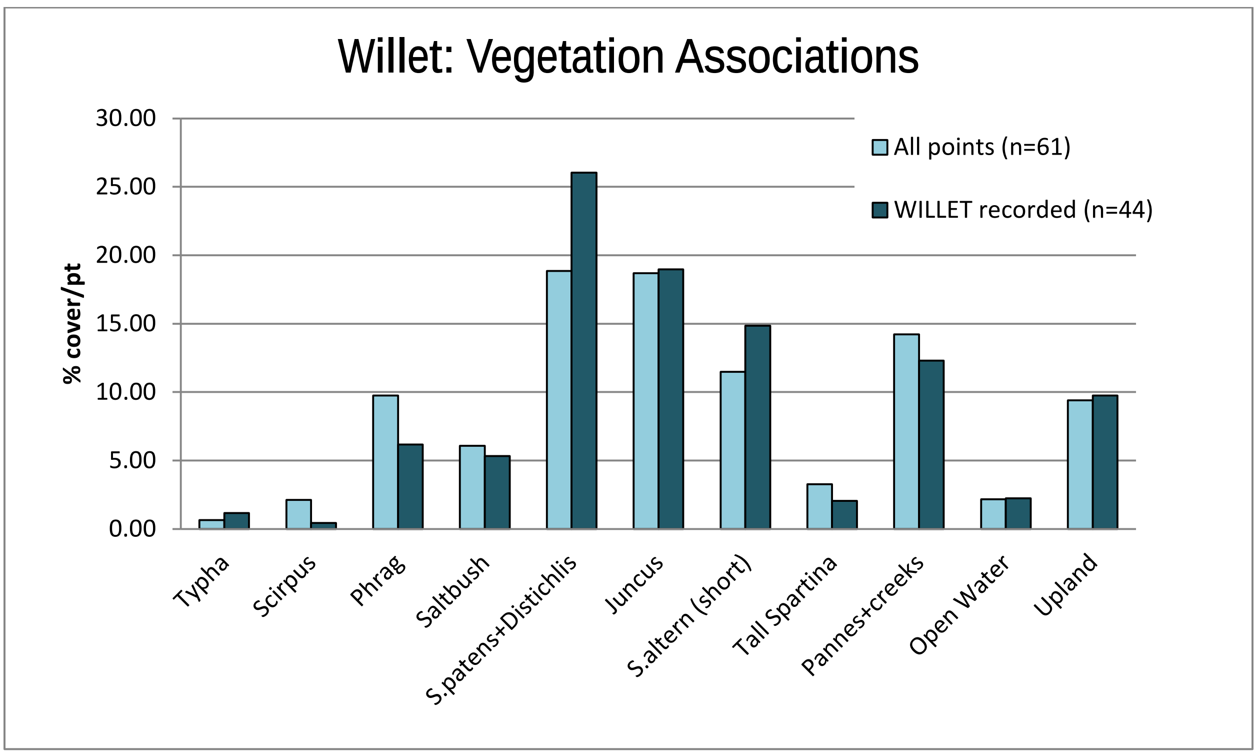


Figure 11 - Vegetation cover at all SHARP survey points in Somerset and Wicomico counties, and points where Willet was detected. Based on 2011 data.

The SHARP survey data revealed a preference for the marsh interior and avoidance of the upland marsh edge in the majority of the focal bird species. Univariate analyses found that four species (Clapper Rail, Saltmarsh Sparrow, Seaside Sparrow, and Willet) were more abundant beyond 250 m from the upland edge, and logistic regression models for Saltmarsh Sparrow and Willet included distance from upland edge as a variable having positive influence on abundance.

The relationship between distance from upland edge and abundance for Clapper Rail, Saltmarsh Sparrow, Seaside Sparrow and Willet is shown in more detail in Figure 12. Saltmarsh Sparrow abundance increased toward the marsh interior to a maximum in distance categories >390 m from the upland edge. Seaside Sparrow shows a similar pattern with greater abundance in distance categories >390 m from upland edge, but the pattern suggests that abundance may continue increasing into the greatest distance category >810m from upland edge.

Clapper Rail and Willet show lower detection rates <75m from the upland edge and similar densities at all distance categories >75m. For these species this apparent relationship may be an artifact of the reduced areas of marsh sampled at points close to the marsh edge.

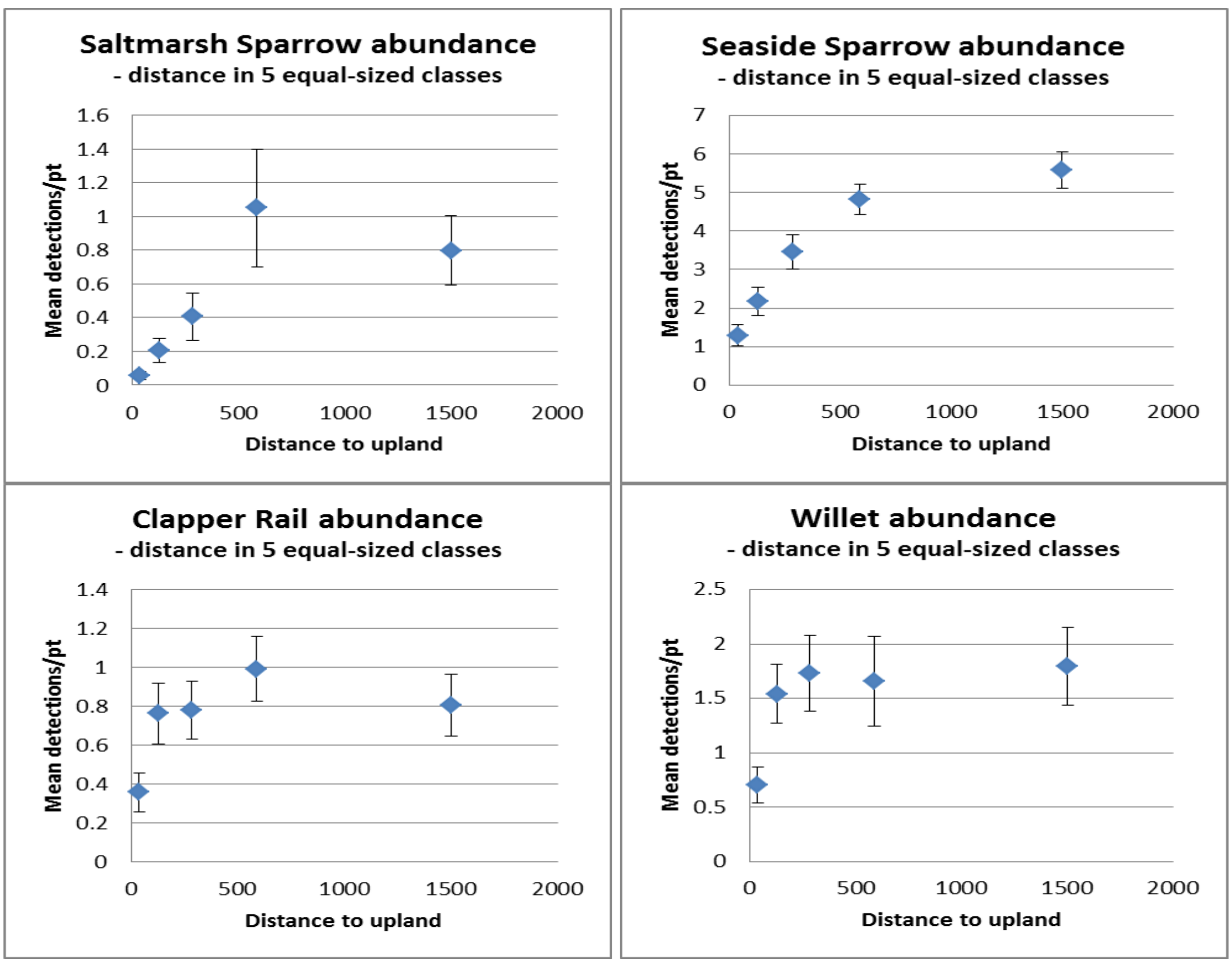


Figure 12 - Saltmarsh bird abundance (±SE) by 5 distance categories from upland marsh edge in Maryland, 2011. Distance categories and sample sizes are: 0-74 m (n=42), 75-192 m (n=42), 193–390 m (n=41), 391-810 m (n=41), 811-2884 m (n=41).

BIRD DATA FROM OTHER SOURCES

The SHARP surveys were not comprehensive in their coverage of the project area. Because PSUs were randomly selected, some coverage gaps exist in some areas. For one of these areas, at Rumbly Point Road on the Pocomoke Sound, bird data collected by Audubon Maryland-DC in 2009 indicates tidal marsh habitat of high conservation value to saltmarsh birds. This site includes the Irish Grove Sanctuary, owned by Maryland Ornithological Society, and adjacent private lands between East Creek and Marumsco Creek. Walking transect bird surveys were conducted here in late May 2009, covering 3 km in a 5-hour period on two separate mornings. Although the data collection method does not allow direct comparison with SHARP survey data, the large numbers of saltmarsh specialist birds, particularly Saltmarsh Sparrow (see Table 14), indicate this site is of high conservation importance.

Table 14 - Saltmarsh birds detected at tidal marsh in the vicinity of Rumbly Point Road, Somerset County, during a 3-km transect survey in May 2009.

Species	Total detected
American Black Duck	39
Clapper Rail	13
Coastal Plain Swamp Sparrow	2
Saltmarsh Sparrow	49
Seaside Sparrow	144
Willet	18

The habitat at Rumbly Point Road included extensive meadows of meadow cordgrass and short-form of smooth cordgrass, ideal habitat for Saltmarsh Sparrow. Casual examination of aerial imagery suggests that short-statured *Spartina* grass meadows are more extensive here than at many other tidal marsh locations in the project area.

SHARP SURVEYS: STATISTICAL ANALYSES

Univariate analyses (Wilcoxon Signed Rank Sum tests) and multivariate (logistic regression) analyses of the influence of vegetation and landscape variables on abundance of seven focal saltmarsh bird species in tidal marsh on Maryland's Lower Eastern Shore. Data on vegetation and bird abundance were collected in 2011 at 207 points as part of the SHARP saltmarsh bird survey.

Table 15 - Names and descriptions of independent variables used in univariate analyses and multivariate analyses of focal bird species abundance. All vegetation variables = % cover in 50m radius circle.

Variable name	*Variable description*
Vegetation variables	
S. patens + Distichlis	Meadow cordgrass *(Spartina patens)* + Spikegrass (*Distichlis spicata)*
S. alterniflora (short)	Smooth cordgrass *(Spartina alterniflora)* (short form)
Short *Spartina*	*Spartina patens* + *Distichlis spicata*+ *S. alterniflora* (short form)
Tall *Spartina*	*S.alterniflora* (tall form) + *S. cynosuroides*
Black needlerush	Black needlerush *(Juncus roemerianus)*
Olney threesquare	Olney threesquare *(Schoenoplectus americanus)*
Salt bush	Marsh elder *(Iva frutescens)* + Groundsel-bush (*Baccharis halimifolia)*
Phragmites	Common reed *(Phragmites australis*)
Habitat variables	
Low marsh	% cover low marsh in 50m radius circle
High marsh	% cover high marsh in 50m radius circle
Saltmarsh terrestrial border	% cover saltmarsh terrestrial border in 50m radius circle
Landscape variables	
Distance to upland	Distance to nearest upland edge of estuarine marsh measured in GIS
%E2Em in 200m	% cover estuarine emergent marsh in a 200m radius circle, measured from NWI wetlands layer in GIS
%E2Em in 500m	% cover estuarine emergent marsh in a 500m radius circle, measured from NWI wetlands layer in GIS
%E2Em in 1km	% cover estuarine emergent marsh in a 1000m radius circle, measured from NWI wetlands layer in GIS
% upland in 200m	% cover upland in a 200m radius circle, measured in GIS
% upland in 500m	% cover upland in a 500m radius circle, measured in GIS
% upland in 1km	% cover upland in a 1000m radius circle, measured in GIS
% open water in 200m	% open water in a 200m radius circle, measured in GIS
% open water in 500m	% open water in a 200m radius circle, measured in GIS
% open water in 1km	% open water in a 200m radius circle, measured in GIS

Table 16 - Influence of individual vegetation and landscape variables on American Black Duck abundance, Maryland's Lower Eastern Shore; Wilcoxon Signed Rank Sum tests. Total pts = 207. (Return to page 74).

Independent Variable	*Comparison*	*Mean Black Duck detections/point (n)*		*Z-score*	*P value (2-tailed)*
		Group 1	*Group 2*		
Vegetation variables					
S. patens + Distichlis	x=0 v x>0	0.239 *(103)*	0.372 *(104)*	-1.209	0.227
S. alterniflora (short)	x=0 v x>0	0.391 *(92)*	0.238 *(115)*	0.694	0.488
Short *Spartina*	x<=50% v x>50%	0.277 *(143)*	0.370 *(64)*	0.960	0.337
Tall *Spartina*	x=0 v x>0	0.294 *(176)*	0.376 *(31)*	1.068	0.285
Black needlerush	x=0 v x>0	0.265 *(147)*	0.406 *(60)*	0.904	0.366
Olney threesquare	x=0 v x>0	0.249 *(174)*	0.606 *(33)*	2.504	0.012
Salt bush	x=0 v x>0	0.325 *(153)*	0.253 *(54)*	-0.289	0.772
Phragmites	x=0 v x>0	0.331 *(146)*	0.246 *(61)*	-1.023	0.306
Habitat variables					
Low marsh	x=0 v x>0	0.275 *(115)*	0.344 *(92)*	0.931	0.352
High marsh	x<=50% v x>50%	0.210 *(92)*	0.383 *(115)*	-1.983	0.047
Saltmarsh terrestrial border	x=0 v x>0	0.257 *(83)*	0.339 *(124)*	-0.178	0.859
Landscape variables					
Distance to upland	x<=250m v x>250m	0.226 *(96)*	0.375 *(111)*	-1.269	0.204
%E2Em in 200m	x<=50% v x>50%	0.113 *(53)*	0.372 *(154)*	-2.280	0.023
%E2Em in 500m	x<=50% v x>50%	0.238 *(119)*	0.398 *(88)*	1.584	0.113
%E2Em in 1000m	x<=50% v x>50%	0.165 *(123)*	0.512 *(84)*	2.846	0.004
% upland in 200m	x=0 v x>0	0.350 *(121)*	0.244 *(86)*	-0.688	0.492
% upland in 500m	x=0 v x>0	0.430 *(79)*	0.229 *(128)*	1.708	0.088
% upland in 1000m	x=0 v x>0	0.548 *(31)*	0.263 *(176)*	1.553	0.120
% open water in 200m	x<=25% v x>25%	0.307 (150)	0.304 (57)	-0.025	0.980
% open water in 500m	x<=25% v x>25%	0.336 (134)	0.251 (73)	-0.874	0.382
% open water in 1000m	x<=25% v x>25%	0.388 (103)	0.224 (104)	-0.824	0.410

Table 17 - Influence of individual vegetation and landscape variables on Clapper Rail abundance, Maryland's Lower Eastern Shore; Wilcoxon Signed Rank Sum tests. Total pts = 207. (Return to page 76).

Independent Variable	*Comparison*	*Mean Clapper Rail detections/point (n)*		*Z-score*	*P value (2-tailed)*
		Group 1	*Group 2*		
Vegetation variables					
S. patens + Distichlis	x=0 v x>0	0.770 *(103)*	0.705 *(104)*	-0.601	0.548
S. alterniflora (short)	x=0 v x>0	0.638 *(92)*	0.817 *(115)*	-2.239	0.025
Short *Spartina*	x<=50% v x>50%	0.699 *(143)*	0.823 *(64)*	0.945	0.345
Tall *Spartina*	x=0 v x>0	0.729 *(176)*	0.785 *(31)*	0.115	0.908
Black needlerush	x=0 v x>0	0.562 *(147)*	1.167 *(60)*	3.949	0.00008
Olney threesquare	x=0 v x>0	0.812 *(174)*	0.343 *(33)*	-2.65	0.008
Salt bush	x=0 v x>0	0.821 *(153)*	0.500 *(54)*	-1.543	0.123
Phragmites	x=0 v x>0	0.872*(146)*	0.415*(61)*	-2.721	0.007
Habitat variables					
Low marsh	x=0 v x>0	0.597 *(115)*	0.913 *(92)*	1.56	0.119
High marsh	x<=50% v x>50%	0.511 *(92)*	0.919 *(115)*	-2.882	0.004
Saltmarsh terrestrial border	x=0 v x>0	0.687 *(83)*	0.772 *(124)*	-0.788	0.430
Landscape variables					
Distance to upland	x<=250m v x>250m	0.562 *(96)*	0.889 *(111)*	-2.527	0.012
%E2Em in 200m	x<=50% v x>50%	0.283 *(53)*	0.894 *(154)*	-3.63	0.00028
%E2Em in 500m	x<=50% v x>50%	0.56 *(119)*	0.977 *(88)*	2.842	0.004
%E2Em in 1000m	x<=50% v x>50%	0.591 *(123)*	0.952 *(84)*	2.18	0.029
% upland in 200m	x=0 v x>0	0.846 *(121)*	0.585 *(86)*	-2.036	0.042
% upland in 500m	x=0 v x>0	0.882 *(79)*	0.648 *(128)*	1.802	0.072
% upland in 1000m	x=0 v x>0	0.828 *(31)*	0.722 *(176)*	0.301	0.764
% open water in 200m	x<=25% v x>25%	0.776 (150)	0.637 (57)	0.013	0.990
% open water in 500m	x<=25% v x>25%	0.754 (134)	0.708 (73)	0.556	0.578
% open water in 1000m	x<=25% v x>25%	0.670 (103)	0.804 (104)	-1.366	0.172

Table 18 - Influence of individual vegetation and landscape variables on Coastal Plain Swamp Sparrow abundance in Dorchester County only; Wilcoxon Signed Rank Sum tests. Total pts = 74. (Return to page 79).

Independent Variable	*Comparison*	*Mean Coastal Plain Swamp Sparrow detections/point (n)*		*Z-score*	*P value (2-tailed)*
		Group 1	*Group 2*		
Vegetation variables					
S. patens + Distichlis	x=0 v x>0	0.46 *(29)*	0.23 *(45)*	0.376	0.707
S. alterniflora (short)	x=0 v x>0	0.286 *(49)*	0.387 *(25)*	0.154	0.877
Short *Spartina*	x<=25% v x>25%	0.26 *(41)*	0.394 *(33)*	0.799	0.424
Tall *Spartina*	x=0 v x>0	0.2 *(60)*	0.833 *(14)*	1.967	0.049
Black needlerush	x=0 v x>0	0.32 *(51)*	0.319 *(23)*	-0.099	0.921
Olney threesquare	x=0 v x>0	0.31 *(43)*	0.333 *(31)*	0.909	0.363
Salt bush	x=0 v x>0	0.226 *(56)*	0.611 *(18)*	1.109	0.268
Phragmites	x=0 v x>0	0.393 *(45)*	0.207 *(29)*	-0.819	0.413
Habitat variables					
Low marsh	x=0 v x>0	0.267 *(40)*	0.382 *(34)*	0.342	0.733
High marsh	x<=50% v x>50%	0.301 *(31)*	0.333 *(43)*	-0.433	0.665
Saltmarsh terrestrial border	x=0 v x>0	0.2 *(35)*	0.427 *(39)*	-1.066	0.286
Landscape variables					
Distance to upland	x<=250m v x>250m	0.16 *(25)*	0.401 *(49)*	-0.823	0.411
%E2Em in 200m	x<=50% v x>50%	0.042 *(16)*	0.397 *(58)*	-1.339	0.18
%E2Em in 500m	x<=50% v x>50%	0.138 *(33)*	0.472 *(41)*	-2.088	0.037
%E2Em in 1000m	x<=50% v x>50%	0.011 *(29)*	0.519 *(45)*	-2.89	0.004
% upland in 200m	x=0 v x>0	0.401 (54)	0.10 *(20)*	-1.187	0.235
% upland in 500m	x=0 v x>0	0.444 *(39)*	0.181 *(35)*	-0.731	0.465
% upland in 1000m	x<=1 v x>1	0.559 *(34)*	0.117 *(40)*	-1.768	0.077
% open water in 200m	x<=25% v x>25%	0.432 (54)	0.017 (20)	-2.081	0.037
% open water in 500m	x<=25% v x>25%	0.418 (55)	0.035 (19)	-1.633	0.102
% open water in 1000m	x<=25% v x>25%	0.472 (41)	0.131 (33)	-1.734	0.083

Table 19 - Influence of individual vegetation and landscape variables on Saltmarsh Sparrow abundance, Maryland's Lower Eastern Shore; Wilcoxon Signed Rank Sum tests. Total pts = 207. (Return to page 77).

Independent Variable	*Comparison*	*Mean saltmarsh sparrow detections/point (n)*		*Z-score*	*P value (2-tailed)*	*P value (1-tailed)*
		Group 1	*Group 2*			
Vegetation variables						
S. patens + Distichlis	x=0 v x>0	0.586 *(103)*	0.413 *(104)*	0.094	0.925	0.463
S. alterniflora (short)	x=0 v x>0	0.098 *(92)*	0.820 *(115)*	-4.362	0.00001	0.00001
Short *Spartina*	x<=50% v x>50%	0.343 *(143)*	0.849 *(64)*	2.874	0.037	0.018
Tall *Spartina*	x=0 v x>0	0.523 *(176)*	0.366 *(31)*	-0.379	0.705	0.352
Black needlerush	x=0 v x>0	0.667 *(147)*	0.089 *(60)*	-2.830	0.005	0.002
Olney threesquare	x=0 v x>0	0.550 *(174)*	0.232 *(33)*	-0.765	0.444	0.222
Salt bush	x=0 v x>0	0.625 *(153)*	0.142 *(54)*	-1.596	0.11	0.055
Phragmites	x=0 v x>0	0.623 *(146)*	0.202 *(61)*	-2.064	0.039	0.02
Habitat variables						
Low marsh	x=0 v x>0	0.528 *(115)*	0.464 *(92)*	-0.06	0.953	0.476
High marsh	x<=50% v x>50%	0.293 *(92)*	0.664 *(115)*	-1.657	0.098	0.049
Saltmarsh terrestrial border	x=0 v x>0	0.679 *(83)*	0.379 *(124)*	1.02	0.308	0.154
Landscape variables						
Distance to upland	x<=250m v x>250m	0.163 *(96)*	0.79 *(111)*	-3.66	0.00025	0.00013
%E2Em in 200m	x<=50% v x>50%	0.579 *(53)*	0.472 *(154)*	-0.372	0.710	0.355
%E2Em in 500m	x<=50% v x>50%	0.538 (119)	0.447 (88)	0.645	0.519	0.259
%E2Em in 1000m	x<=50% v x>50%	0.531 (123)	0.452 (84)	0.337	0.736	0.368
% upland in 200m	x=0 v x>0	0.763 (121)	0.128 (86)	-3.621	0.00029	0.00015
% upland in 500m	x=0 v x>0	0.916 (79)	0..242 (128)	3.159	0.002	0.001
% upland in 1000m	x=0 v x>0	0.935 (31)	0.422 (176)	2.517	0.012	0.006
% open water in 200m	x<=25% v x>25%	0.376 (150)	0.825 (57)	2.348	0.019	0.009
% open water in 500m	x<=25% v x>25%	0.259 (134)	0.941 (73)	3.085	0.002	0.001
% open water in 1000m	x<=25% v x>25%	0.275 (103)	0.721 (104)	-1.852	0.064	0.032

Table 20 - Influence of individual vegetation and landscape variables on Seaside Sparrow abundance, Maryland's Lower Eastern Shore; Wilcoxon Signed Rank Sum tests. Total pts = 207. (Return to page 78).

Independent Variable	*Comparison*	*Mean Seaside Sparrow detections/point (n)*		*Z-score*	*P value (2-tailed)*
		Group 1	*Group 2*		
Vegetation variables					
S. patens + Distichlis	x=0 v x>0	3.252 *(103)*	3.641 *(104)*	-0.670	0.503
S. alterniflora (short)	x=0 v x>0	2.804 *(92)*	3.962 *(115)*	-3.095	0.002
Short *Spartina*	x<=50% v x>50%	3.021*(143)*	4.401 *(64)*	3.178	0.0014
Tall *Spartina*	x=0 v x>0	3.411 *(176)*	3.656 *(31)*	0.551	0.582
Black needlerush	x=0 v x>0	3.204 *(147)*	4.044 *(60)*	2.100	0.036
Olney threesquare	x=0 v x>0	3.398 *(174)*	3.707 *(33)*	0.504	0.614
Salt bush	x=0 v x>0	3.693 *(153)*	2.753 *(54)*	-2.06	0.039
Phragmites	x=0 v x>0	4.075 *(146)*	1.945 *(61)*	-4.686	0.00000
Habitat variables					
Low marsh	x=0 v x>0	2.988 *(115)*	4.022 *(92)*	2.852	0.004
High marsh	x<=50% v x>50%	2.308 *(92)*	4.359 *(115)*	-4.955	0.00000
Saltmarsh terrestrial border	x=0 v x>0	3.514 *(83)*	3.403 *(124)*	0.041	0.967
Landscape variables					
Distance to upland	x<=250m v x>250m	1.920 *(96)*	4.769 *(111)*	-6.783	0.00000
%E2Em in 200m	x<=50% v x>50%	2.635 *(53)*	3.727 *(154)*	-2.551	0.011
%E2Em in 500m	x<=50% v x>50%	2.81 *(119)*	4.311 *(88)*	3.743	0.00018
%E2Em in 1000m	x<=50% v x>50%	2.661 *(123)*	4.599 *(84)*	4.895	0.00000
% upland in 200m	x=0 v x>0	4.702 *(121)*	1.682 *(86)*	-7.114	0.00000
% upland in 500m	x=0 v x>0	5.198 *(79)*	2.367 *(128)*	-6.517	0.00000
% upland in 1000m	x=0 v x>0	6.065 *(31)*	2.987 *(176)*	5.004	0.00000
% open water in 200m	x<=25% v x>25%	3.176 (150)	4.164 (57)	2.052	0.04
% open water in 500m	x<=25% v x>25%	3.129 (134)	4.032 (73)	2.006	0.045
% open water in 1000m	x<=25% v x>25%	3.362 (103)	3.532 (104)	-0.370	0.711

Table 21 - Influence of individual vegetation and landscape variables on Willet abundance, Maryland's Lower Eastern Shore; Wilcoxon Signed Rank Sum tests. Total pts = 207. (Return to page 80).

Independent Variable	*Comparison*	*Mean Willet detections/point (n)*		*Z-score*	*P value (2-tailed)*
		Group 1	*Group 2*		
Vegetation variables					
S. patens + Distichlis	x=0 v x>0	1.735 *(103)*	1.234 *(104)*	0.035	0.972
S. alterniflora (short)	x=0 v x>0	0.46 *(92)*	2.301 *(115)*	-7.207	0.00000
Short *Spartina*	x<=50% v x>50%	1.144 *(143)*	2.240 *(64)*	5.011	0.00000
Tall *Spartina*	x=0 v x>0	1.553 *(176)*	1.086 *(31)*	-0.904	0.366
Black needlerush	x=0 v x>0	1.794 *(147)*	0.722 *(60)*	-3.214	0.00131
Olney threesquare	x=0 v x>0	1.657 *(174)*	0.566 *(33)*	-3.276	0.00105
Salt bush	x=0 v x>0	1.571 *(153)*	1.235 *(54)*	-0.473	0.636
Phragmites	x=0 v x>0	1.779 *(146)*	0.776 *(61)*	-3.754	0.00017
Habitat variables					
Low marsh	x=0 v x>0	1.646 *(115)*	1.279 *(92)*	-0.328	0.743
High marsh	x<=50% v x>50%	1.301 *(92)*	1.629 *(115)*	-2.056	0.04
Saltmarsh terrestrial border	x=0 v x>0	1.723 *(83)*	1.323 *(124)*	0.380	0.704
Landscape variables					
Distance to upland	x<=250m v x>250m	1.052 *(96)*	1.856 *(111)*	-2.254	0.024
%E2Em in 200m	x<=50% v x>50%	1.541 *(53)*	1.463 *(154)*	-1.107	0.268
%E2Em in 500m	x<=50% v x>50%	1.756 *(119)*	1.114 *(88)*	-1.218	0.223
%E2Em in 1000m	x<=50% v x>50%	1.813 *(123)*	1.0 *(84)*	-1.361	0.173
% upland in 200m	x=0 v x>0	1.752 *(121)*	1.105 *(86)*	-1.631	0.103
% upland in 500m	x=0 v x>0	1.814 *(79)*	1.279 *(128)*	1.092	0.275
% upland in 1000m	x=0 v x>0	1.774 *(31)*	1.432 *(176)*	1.639	0.101
% open water in 200m	x<=25% v x>25%	1.216 (150)	2.187 (57)	1.799	0.072
% open water in 500m	x<=25% v x>25%	0.998 (134)	2.374 (73)	3.85	0.00012
% open water in 1000m	x<=25% v x>25%	0.822 (103)	2.138 (104)	-3.490	0.00048

Table 22 (a-f) - Multiple logistic regression models of the effect of vegetation and landscape characteristics on occupancy patterns of six focal saltmarsh bird species in tidal marshes on Maryland's Lower Eastern Shore. Data on vegetation and bird abundance were collected in 2011 at 207 points as part of the SHARP saltmarsh bird survey. (Return to page: 74, 76, 77, 78, 79, or 80).

(a) American Black Duck		*Significance of variables*		*Species occupancy*	
Variable	*β*	*Wald Z-value*	*P*	*n*	*% correctly classified*
% E2Em in 1km	-1.59	-2.11	0.03	Absent = 130	86.2
County: Somerset	0.51	1.39	0.16	Present = 77	33.8
County: Wicomico	1.15	1.00	0.32		
County: Worcester	0.69	1.70	0.09		

(b) Clapper Rail		*Significance of variables*		*Species occupancy*	
Variable	*β*	*Wald Z-value*	*P*	*n*	*% correctly classified*
County: Somerset	-2.59	-5.26	<0.001	Absent = 86	60.5
County: Wicomico	-2.00	-2.04	0.04	Present = 121	85.1
County: Worcester	-1.76	-4.01	<0.001		
%E2Em in 200m	-1.86	-2.43	0.02		
Distance to upland	-0.0009	-2.54	0.01		
Phragmites	0.03	2.23	0.03		

(c) Coastal Plain Swamp Sparrow		*Significance of variables*		*Species occupancy*	
Variable	*β*	*Wald Z-value*	*P*	*n*	*% correctly classified*
County: Somerset	1.85	2.73	0.01	Absent = 182	98.4
County: Wicomico	9.74	0.06	0.96	Present = 25	28.0
County: Worcester	0.69	0.89	0.37		
% E2Em in 1km	-4.43	-3.29	0.001		
Tall *Spartina*	-0.04	-1.91	0.06		

(d) Saltmarsh Sparrow		*Significance of variables*		*Species occupancy*	
Variable	*β*	*Wald Z-value*	*P*	*n*	*% correctly classified*
County: Somerset	0.85	1.65	0.1	Absent = 132	81.1
County: Wicomico	10.07	0.06	0.96	Present = 75	62.7
County: Worcester	-1.5	-3.48	<0.001		
Distance to upland	-0.002	-4.76	<0.001		
Short *Spartina*	-0.02	-2.79	0.005		

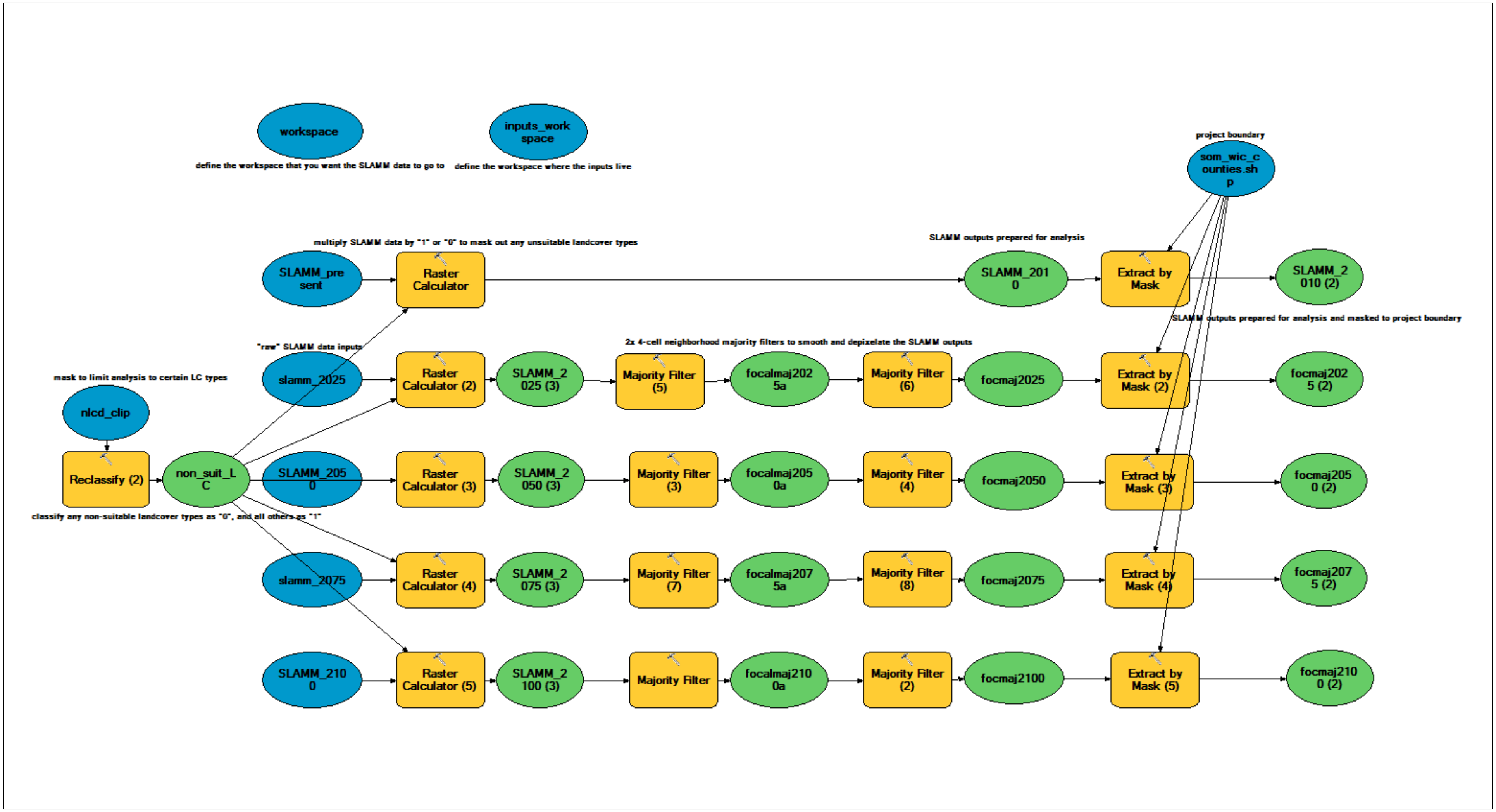
(e) Seaside Sparrow		*Significance of variables*		*Species occupancy*	
Variable	*β*	*Wald Z-value*	*P*	*n*	*% correctly classified*
County: Somerset	-2.73	-3.19	0.001	Absent = 42	52.4
County: Wicomico	-0.51	-0.28	0.78	Present = 165	96.4
County: Worcester	-2.36	-3.75	<0.001		
% E2Em in 1km	-7.08	-5.15	<0.001		
Phragmites	-0.1	-1.74	0.08		
% Open water in 200m	-3.96	-2.97	0.003		
County: Somerset*Phragmites	0.07	1.92	0.05		
County: Wicomico*Phragmites	0.06	0.62	0.54		
County: Worcester*Phragmites	0.17	1.77	0.08		
Phragmites*Phragmites	0.002	1.88	0.06		

(f) Willet		*Significance of variables*		*Species occupancy*	
Variable	*β*	*Wald Z-value*	*P*	*n*	*% correctly classified*
County: Somerset	-0.29	-0.67	0.51	Absent = 76	77.6
County: Wicomico	0.69	0.59	0.55	Present = 131	83.2
County: Worcester	-2.33	-3.87	<0.001		
Olney threesquare	0.05	3.07	0.002		
Short *Spartina*	-0.04	-4.22	<0.001		
Distance to upland	-0.001	-2.66	0.008		

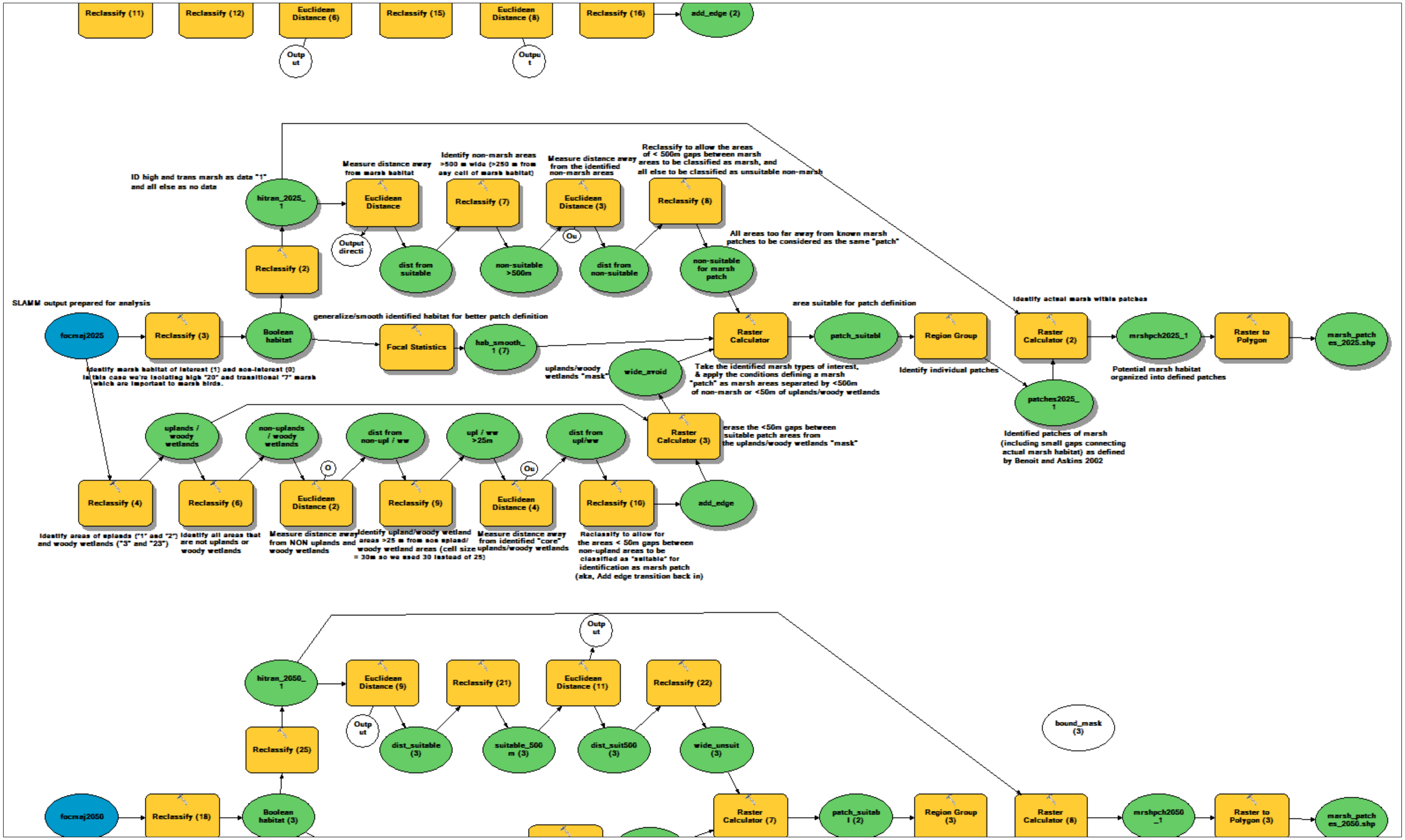
APPENDIX III: GIS MODELS

*An ArcGIS Toolbox "MD_Lower_Shore_GIS_tools" can be downloaded from: www.defenders.org/climatechange/mdwildlife. Input files and pathways will have to be modified to fit new applications, but the operations and workflow should still be intact and functional.

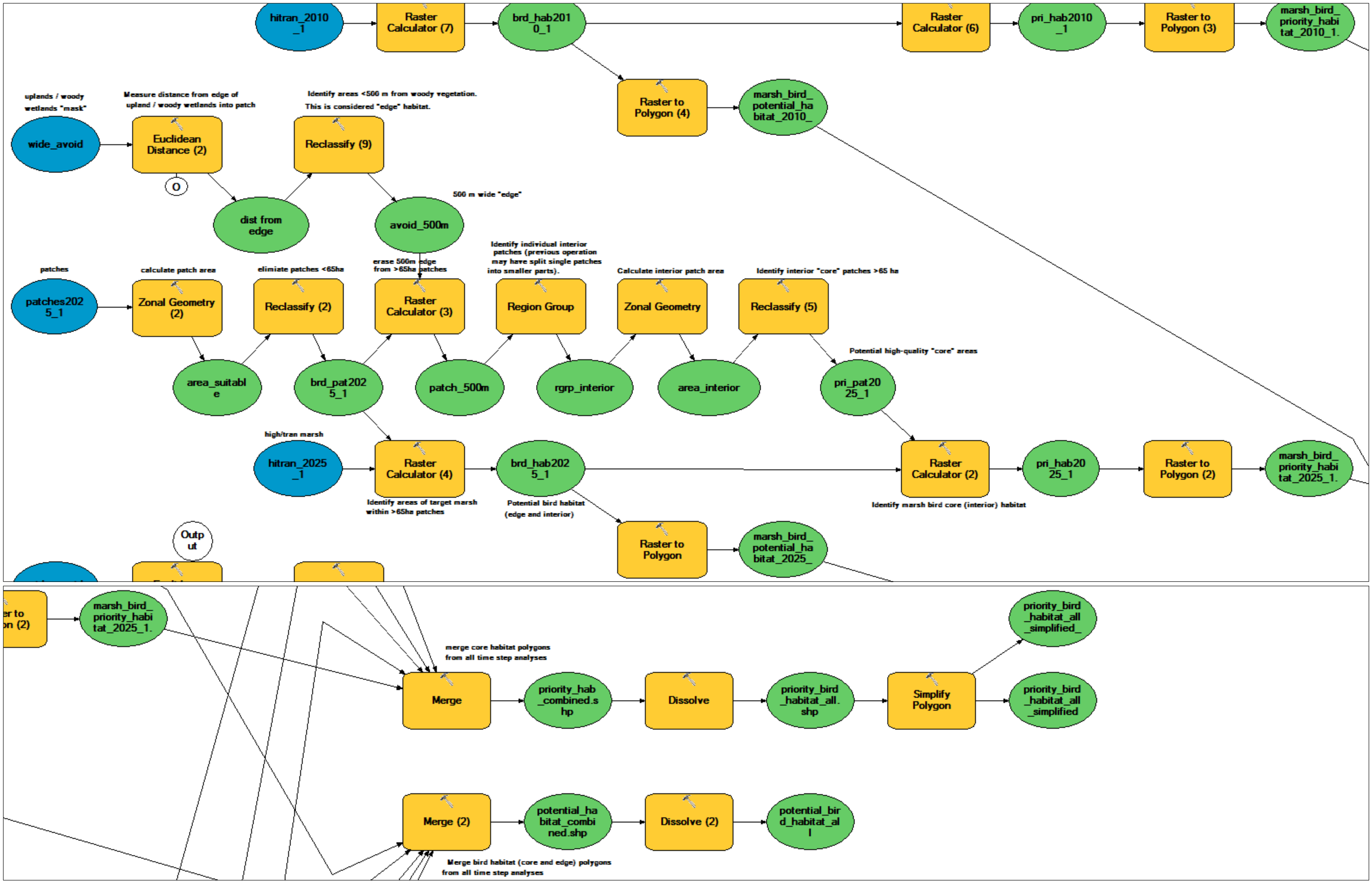
Model #1: Take raw SLAMM data (unprocessed SLAMM outputs that have already been stitched together for study area) and perform the following: a) apply an "unsuitable landcover" mask if desired; b) smooth and depixelate the SLAMM data; c) clip/extract the data to project boundaries.



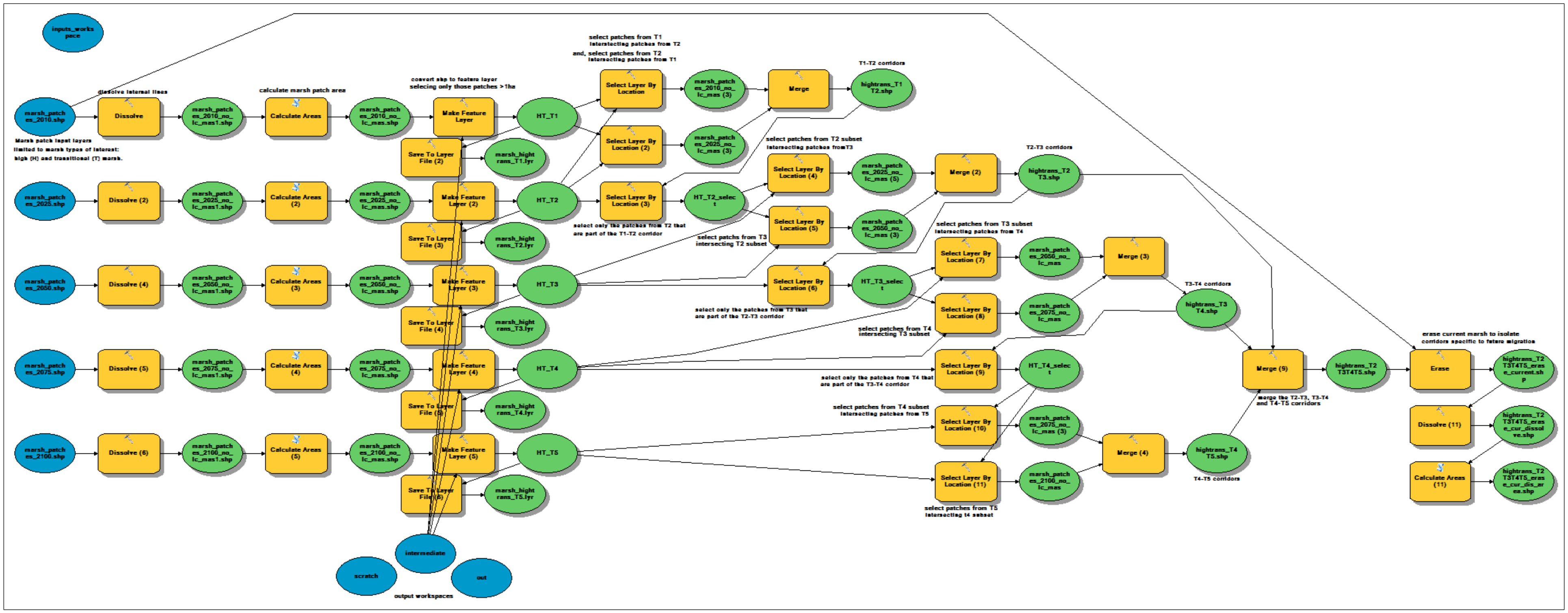
Model #2: Define marsh patches (one string of tools/model for each time step analysis). A marsh "patch" is defined as all marsh not separated by >500m of open water or >50m of uplands or woody wetlands (Benoit and Askins 2002). To do this, we identify our target marsh types of interest (in the case of this study, high and transitional marsh), use the Euclidean Distance and Reclassify tools to mask out all unsuitable areas as defined by the above assumption (and thereby to count as suitable those inter-marsh areas that are within the stated thresholds), and then use the Region Group tool to identify individual patches.



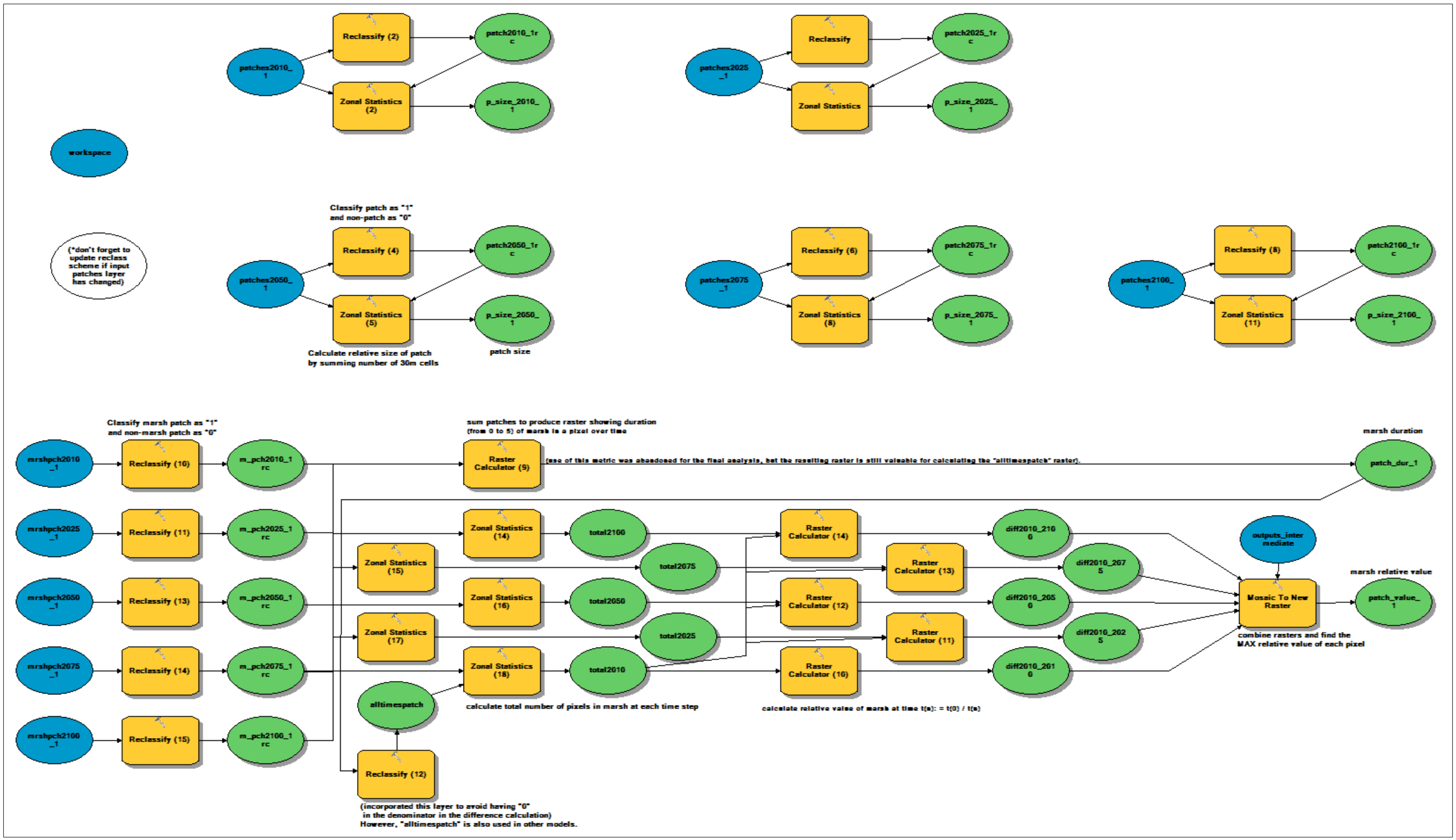
Model #3: Identify important bird habitat; (one string of tools/model for each time step analysis). Functional marsh habitat patches for saltmarsh birds are identified as patches that are greater than 65 ha in size. Furthermore, core bird habitat is identified as being >500 m from the upland / non-marsh edge. Core and edge habitat areas are then combined across all time steps for a visualization showing all potentially important marsh bird habitat.



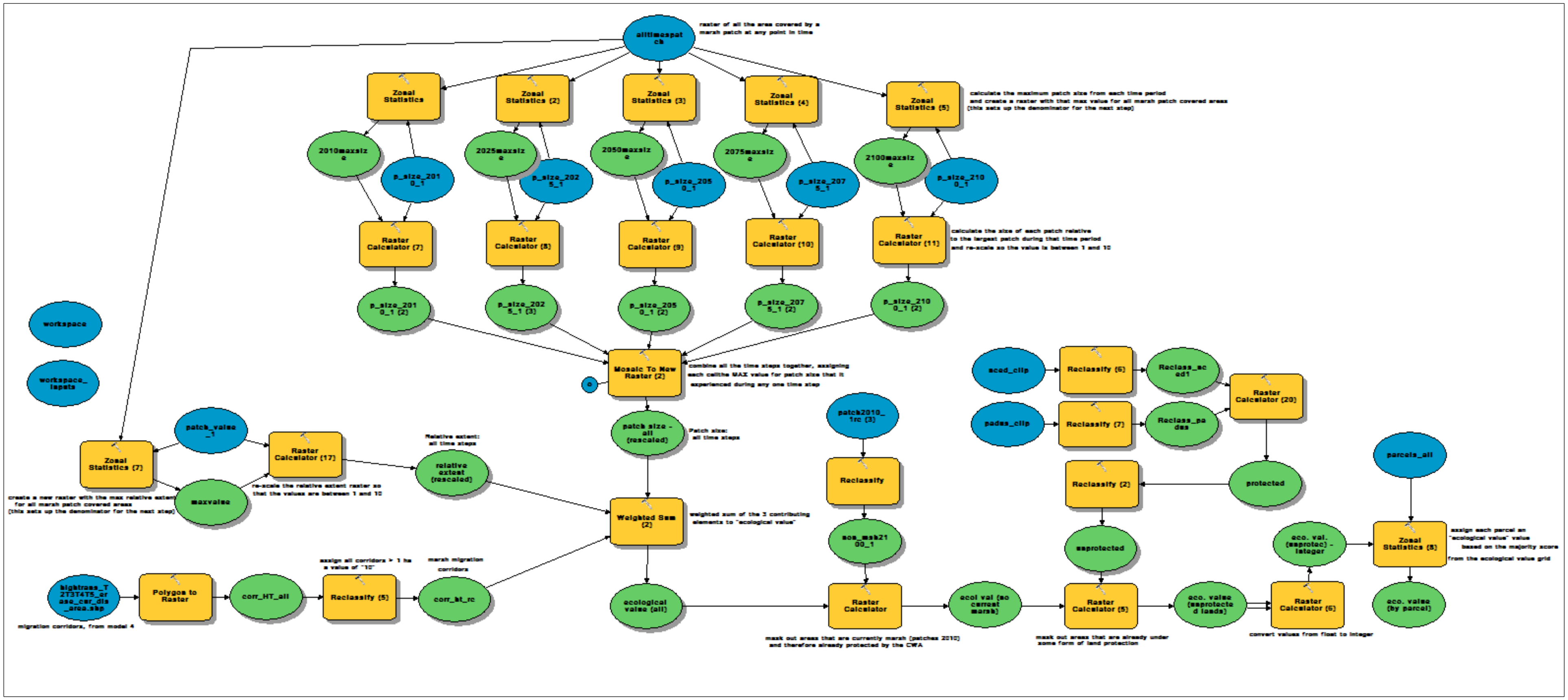
Model #4: Marsh migration corridors. This model looks at marsh patches >1ha for each time step and compares them spatially against the location of patches in the previous and the next time step. The goal is to identify chains/corridors of patches that are linked across all time steps. To do this, we first isolate the patches from 2010 (T1) that intersect patches in 2025 (T2), and vise versa, then merge the result to yield a T1-T2 corridor. The next step is to do the same thing with patches from 2025 (T2) and 2050 (T3), but we are careful to only look at those T2 patches that are identified as part of the T1-T2 corridor. We repeat this for 2050 (T3) and 2075 (T4), and 2075 (T4) and 2100 (T5). We then merge these together and erase anything that is current marsh so that we focus only on those areas that are modeled as corridors for future marsh occupancy and migration. (Note: conversion to layer allows for the use of the "select layer by location" tool).



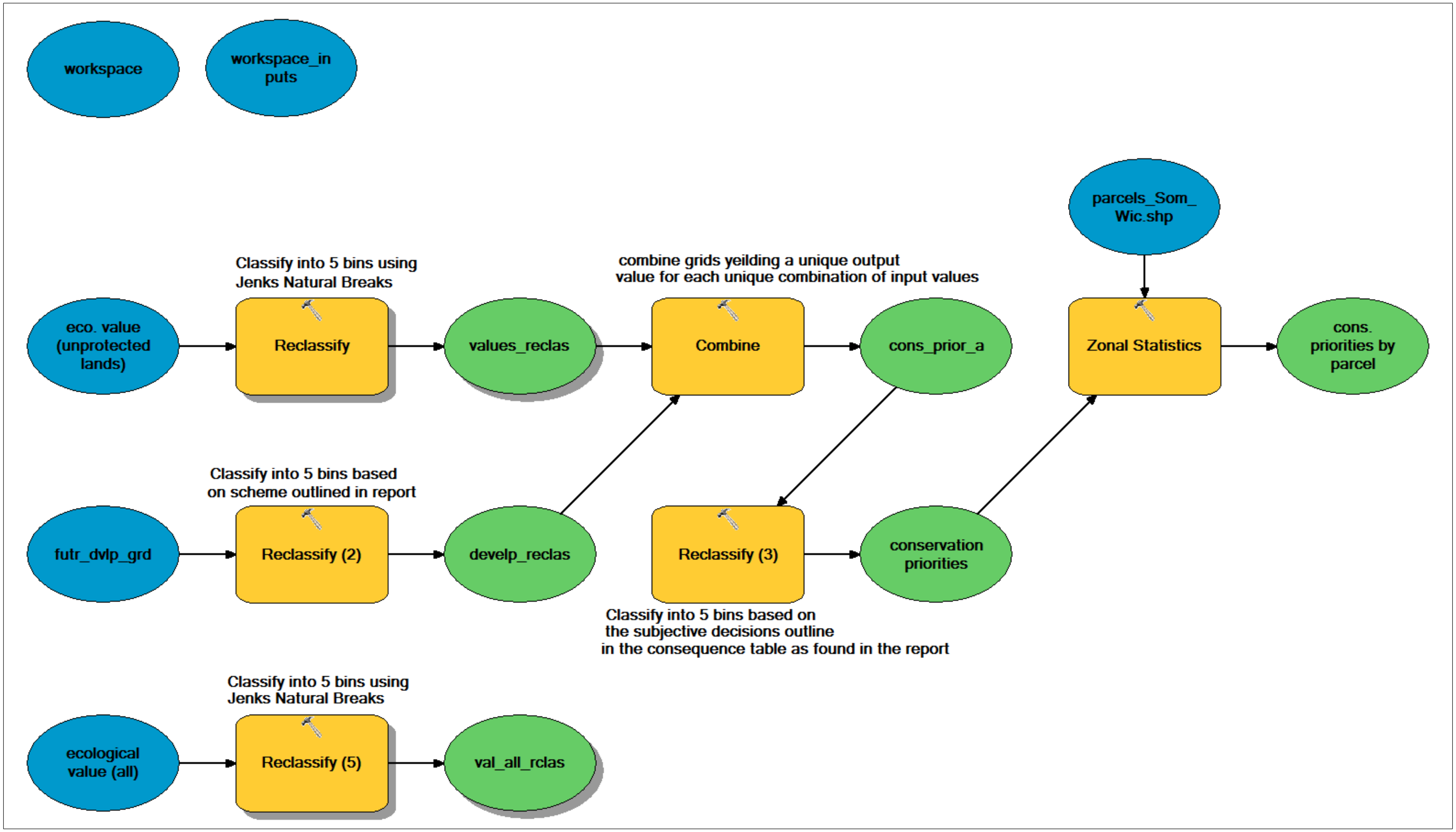
Model #5: Marsh patch size and relative extent. Patch size is calculated based on number of cells in each patch. *Relative* patch size is all that is important for this analysis, so the summed number of 30m x 30m cells were not converted to real area, but easily could be if desired. Relative extent refers to the ratio of the maximum marsh extent across all five time steps to the marsh extent at time (n): relative extent at t_n = extent at t_0 / extent at t_n, where t_0 is the maximum extent of marsh and t_n is the extent of marsh at time step "n". Extent is calculated as the total number of cells that are in saltmarsh at each time step. Once calculated, each cell of marsh is then assigned the value of the relative extent of marsh during that time step. This highlights the characteristic that each cell of marsh during times of less total marsh has a higher relative value than each cell of marsh during times of more total marsh extent. The layers for each time step were combined into one "all-times" relative extent layer, where each cell was assigned the maximum value from all 5 time steps as its final value.



Model #6: Ecological Value. Ecological value is calculated based on three components: 1) patch size, 2) relative extent, and 3) migration corridors. Each of these are rescaled so that values fall between 1 and 10. In the case of patch size, the patch size grids for each individual time step are first individually rescaled as mentioned above, then they are all combined so that each cell in the final "patch size, all times" grid holds the value equal to the maximum patch size value it experienced across all 5 time steps. (E.g., in 2050 a cell may have been in a patch of size "8" and thus scored an "8" during that time step, while in 2025 it was in a patch of size "7" and scored a "7" during that time step. The combined grid would score that cell as an "8"). These three ecological value components are combined in a weighted sum (in this case equally weighted) to produce an "ecological value" grid with values between 1 (low) and 10 (high). This grid is then further refined to mask out all current marsh and current protected areas, and is used to create a layer where each parcel is assigned an ecological value score.



Model #7: Conservation Priorities. Conservation priorities were modeled by combining the ecological values grid (for all unprotected lands) with the development model. Both inputs (ecological value and development risk were classified on an integer scale of 1 to 5. (1 = very low, 2 = low, 3 = medium, 4 = high, and 5 = very high). These two grids were combined so that a unique output value was assigned to each unique combination of input values. This combined grid was then reclassified based on a classification/consequence table as defined in the report. The assignments in this table are subjective and can be changed according to the user's values. Finally, this "conservation priorities" grid was zoned out by parcel, and each parcel was scored based on the maximum conservation priority value found within it.



APPENDIX IV: DRAFTING CONSERVATION EASEMENTS TO ADAPT TO CLIMATE CHANGE

In drafting conservation easements, land trusts have always had to anticipate likely areas of change by drafting easements that are flexible enough to accommodate change, yet enduring enough to protect conservation values in perpetuity – no easy task! But with a changing climate, creating easements that are perpetually enduring under uncertain future conditions is even more of a challenge. How do we ensure that conservation values will be protected, while species' ranges and habitats are shifting, and community composition is changing?

The following pointers[6] are applicable to drafting conservation easements generally, and become even more relevant when designing your easements to take into account how conditions will change as a result of climate change.

Identify conservation values that will endure

Identify the conservation values that warrant protection. It is important to recognize that ecological functions, structure, and composition may change over time with climate changes and determine what it will take to conserve those values over time. Be clear about the purposes of the easement, and directly link easement restrictions to these purposes and to protection of the conservation values.

If a conservation value, for example, protection of a sensitive habitat, is dependent on an ecological attribute, for example ground water levels, you will need to determine how climate change may affect that habitat, and how you should therefore define the conservation values and purpose in the easement.

Provide comprehensive recitals

Have comprehensive, detailed, project-specific background information. Especially if a restriction or a reserved right is unusual, include recitals or background information to support and explain it. Ensure that the reader, perhaps the judge in an enforcement action, understands the details and what makes them important.

For example, if an owner reserves the right to develop ecosystem functions (*e.g.* carbon sinks, stream bank restoration, biodiversity mitigation, carbon sequestration, wetland and stream mitigation) to deal with the effects of climate change, explain what types of ecosystem functions will be permitted, why these functions are important, and what the intent is behind allowing them to be developed. Include any other information necessary to ensure that the reader understands what the land trust and owner had in mind when they agreed to the future development of ecosystem services.

Provide sufficient flexibility

An easement must protect the identified conservation values, yet still be flexible enough to respond to change, such as species composition, as well as the uncertain effects of change. An easement reflects a partnership, between a landowner and a land trust, to preserve conservation values forever, so be sure to discuss the need for flexibility with the easement grantor; and negotiate and draft the easement for holder flexibility so it can adapt to changing conditions over time, while continuing to protect the land's conservation values in perpetuity.

---

[6] Many of these pointers are derived from "Drafting Conservation Easements to Adapt to Climate Change," part of a presentation titled "The Use of Conservation Easements in Adapting Conservation to a Changing Climate" given at the 2009 LTA Rally, available at http://learningcenter.lta.org.

Consider what flexibility successor landowners will need to respond to climate change, especially for working land. Distinguish which restrictions will be strictly applied from those that have flexibility in interpretation.

Whenever possible, predict and address potential points of friction to avoid challenges from future owners, such as easements that are too restrictive or become out-of-date due to changing circumstances. Do not assume that environmental and social conditions and resource needs existing at the time the conservation easement is negotiated and executed will exist in the future.

A good example of the need for flexibility is in setting the building envelope. While the types and extent of structures and improvements which can be constructed should generally be strictly adhered to, the boundaries of the building envelope should be flexible in order to account for changing ocean levels, changing river or creek location, erosion of the property, and other effects of climate change. The land trust and owner should work cooperatively to readjust the boundaries of the building envelope as necessary.

Strive for clarity

Be clear about what an easement prohibits and permits, what approvals an owner must seek before undertaking certain activities, and what notice the owner must provide to the holder under certain situations. Clarity and lack of ambiguity make it easier for a landowner to understand and accept easement terms and for a land trust to monitor and enforce them.

If, for example, an easement prohibits commercial alternative energy production through the use of current technology (huge wind turbines, large arrays of solar panels), but leaves open the possibility of future alternative energy production if changes in technology render such energy production consistent with the protection of conservation values, explain in detail why current technology is incompatible and what would need to change in order for technology to be compatible, so as to avoid confusion about what is and is not prohibited.

Define specific terms

Review the draft easement for terms that should be defined, either in the easement or by reference to a different source. Review the document again to locate and correct defined terms that are used inconsistently with their definitions. It is especially important to define terms which may be interpreted differently depending on the context or location.

For example, if utilizing a rolling easement, it would be important to define the term "ordinary high water mark," because courts in different states have defined the term differently.

Consider performance standards

Performance standards may be appropriate in some circumstances, and easier to uphold than rigid standards, because they offer a flexible goal. Some technical violations of rigid standards do not affect the protected conservation values, making performance standards more suitable. For example, if the goal is to protect migration corridors through an area that includes the easement property, it might be more effective to include a standard that no barriers to wildlife migration, including fences, will be constructed between points A and B, than to say that no fences can be constructed on the property.

Combine prescriptive and performance standards so that easement goals are more likely to be met as technology and scientific understanding emerge in regards to climate change. Consider whether some reserved rights should float based on changing best practices in agriculture, forestry, or land management. If so, define criteria in the easement and provide for change over time, using a recognized source of rules and backup for that source, coupled with land trust approval of a management plan.

Consider including discretionary approval or consent provisions and specify amendment criteria and procedures

The objective is to protect conservation values while preventing easement obsolescence; guiding amendment decisions; meeting unforeseen circumstances; and adapting to changing conservation practices, evolving science, and shifting environmental, climate, economic, and cultural circumstances.

Consider whether easement requirements that look to law should be fixed to current law

If so, attach a copy of the law as an exhibit, as it may be very hard to prove what a particular local jurisdiction's zoning law was 50 years earlier.

Don't restrict unnecessarily

Keep in mind the fundamental purposes of the easement when drafting the restrictions. Remember that conservation easements are limited interests in land that work best to prevent activities harmful to conservation values rather than to prescribe affirmative land management activities. If rigorous restrictions substantially strip all economic value from the land, include strong explanatory recitals so that all parties understand the rationale for the restriction.

Recognize that land may change. Landscape features, such as shorelines and river channels, as well as ecological conditions, may change over time due to temperature, water, and other influences. Flexible management plans and zone boundaries may be helpful.

Again, the example of flexible building envelope boundaries is applicable – it is important to recognize that the features of the property may change over time, altering the areas where structures and improvements are feasible and/or will have the least impact on conservation values. If an easement is drafted too restrictively and cannot adapt to a changing landscape, it may not be able to effectively protect conservation values.

Carefully define how the easement can be terminated or modified

Provide for easement termination or modification contrary to its stated purposes only in accordance with all state and federal laws, court approval, and full proportional compensation of the easement holder, to be used for similar conservation purposes.

Consider Rolling Easements

If it is unrealistic to prevent development of low-lying coastal lands that could eventually be submerged by a rising sea, an alternative is to allow development with the conscious recognition that land will be abandoned if and when the sea rises enough to submerge it. A rolling easement is a property right to ensure that wetlands, beaches, barrier islands, or access along the shore moves inland with the natural retreat of the shore. Rolling easements enable ecosystems to migrate inland and allow society to avoid the costs and hazards from protecting low lands from a rising sea.[7]

Utilize Existing Frameworks for Responding to Climate Change

Working within existing frameworks can be an effective way to advance conservation values and ensure consistency. For example, the Maryland Department of Natural Resources has drafted the following sample easement language regarding implementation of a Climate Change Adaptation and Mitigation Management Plan, which may be considered for incorporation into a conservation easement:

> The Grantor shall implement a Climate Change Adaptation Management Plan ("CCAMP") in the *[defined area OR on the Entire Property]*, approved by the Maryland Department of Natural Resources, in accordance with the Management Practice Schedule of the CCAMP, within two (2) years of the date of this Conservation Easement. Revisions to the CCAMP, including the schedule of implementation, may be made by Grantors and the Maryland Department of Natural Resources, as adaptation practices or management changes, however, Grantors shall be in full compliance with the CCAMP within six (6) years of the date of this Conservation Easement. Exceptions may be considered by Grantees on a case by case basis. Grantors shall provide a copy of the CCAMP and any revisions to the CCAMP to Grantees.
>
> The Plan's primary objective is [here insert an objective from the list below], and the Plan's secondary objective is [here insert an objective from the list below, if there is one]. At a minimum, the Plan shall include:
>
> (1) an inventory of any physical and natural features of the land (including wetlands, streams, water bodies, roads, trails, public use areas, special plant and wildlife habitats, rare or unique species and communities, and other aquatic resource priorities and/or environmentally sensitive features) including any features identified in this Conservation Easement;
> (2) topographic map, depicting sea level rise vulnerability zones (25, 50, 100-year)
> (3) historic erosion/shoreline change data and potential 50-year shoreline position
> (4) a vegetation map and a soils map
> (5) existing erosion control measures, specifically addressing water bodies and wetland areas; and
> (6) management strategies to address the following, as necessary:
> (a) Shoreline and Buffer Area Management
> Specify erosion control and/or storm surge buffer maintenance
> (b) Sensitive Habitat Protection
> Outline protection of riparian areas (including the need to leave cover over streams and water bodies), endangered or threatened species habitat, steep slopes, and features identified in the inventory described in (1) above.
> (c) Ecosystem Resiliency
> Identify wetland/habitat restoration activities or designate migration corridors.
> (d) Environmental Hazard Management
> Specify removal of septic systems, roadways or building debris.

---

[7] Climate Ready Estuaries Rolling Easements Primer, Environmental Protection Agency, June 2011, http://water.epa.gov/type/oceb/cre/upload/rollingeasementsprimer.pdf, at 4-6.

(e) Historical/Cultural Preservation
Outline a plan for the protection of familial burial grounds, etc.

(f) Nutrient Management
Require best management practices to reduce nutrient/sediment loads in agricultural areas subject to inundation.

(g) Invasive Species Managemetn
Detail measures to manage and control invasive and non-native species and plants on site.

(h) Land-Use/Development Rights
Specify process for phasing out development rights over time.

This information was drawn from the following resources, which contain more in-depth explanations of the principles outlined in this document:

Climate Change and Conservation Easement Clause Examples, The Learning Center (Land Trust Alliance), available at http://learningcenter.lta.org

Climate Ready Estuaries Rolling Easements Primer, Environmental Protection Agency, June 2011, http://water.epa.gov/type/oceb/cre/upload/rollingeasementsprimer.pdf

Conservation Easement Paragraph Databank, August 31, 2010, http://www.bbklaw.com/?t=40&an=3775&format=xml

Drafting Conservation Easements to Adapt to Climate Change (part of a presentation titled "The Use of Conservation Easements in Adapting Conservation to a Changing Climate" given at the 2009 LTA Rally), available at http://learningcenter.lta.org

Olmsted, James L., The Butterfly Effect: Conservation Easements, Climate Change, and Invasive Species (2011). Boston College Environmental Affairs Law Review, Vol. 38, No. 1, p. 41, 2011. Available at SSRN.

Olmstead, James L. Esq., Climate Surfing: A conceptual Guide to Drafting Conservation Easements in the Age of Global Warming. 23 St. John's Legal Comment. 765 2008-2009

Note: These guidelines are not intended to be legal advice. If legal advice or other expert assistance is required, the services of competent professionals should be sought.