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Strategy development to enhance the conservation and adaptation of Virginia coastal wetlands under climate change

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Introduction:

This project focuses on developing strategies to improve our understanding and strengthen the sustainability of Virginia's coastal wetlands climate change. Marsh migration under sea level rise is a primary pathway for marsh persistence. However, the rate at which migration occurs and the resulting extent and habitat function of the newly migrated marsh is dependent on factors including location and its nexus to developed lands. It builds on a previous EPA grant (CD96347001-0), which developed an assessment methodology for wetland conservation actions by addressing the function of the migrating marsh. This project addresses Virginia regional priority 1, to develop a framework to overcome barriers to use existing wetland assessment methodologies and studies for restoration/compensatory mitigation projects to improve functional performance of aquatic resources.

Project activities addressed four priority elements in Virginia's approved state wetlands plan. The existing monitoring and assessment strategy will be strengthened through incorporation of new data on the habitat function of existing and newly migrated marsh. Field surveys (information acquisition) will enhance existing understanding of marsh habitat function under sea level rise; and together with a water quality potential assessment, will support the refinement of an existing, EPA funded, marsh vulnerability analysis for conservation planning. Web-based tools for planners and managers (e.g., WetCAT) will be extended to incorporate information useful in planning wetland protection. Outreach and education will be enhanced through development of materials to better inform the public and decision-makers increasing coastal wetland sustainability.

Task 1: Identify areas of recent marsh migration that coincide with important marsh obligate breeding bird habitat

Contemporary marsh bird habitat identification

We identified areas of recently (since 1992) migrated high marsh areas. High marsh is an important Marsh migration under sea level rise is a primary pathway for marsh persistence. However, the rate at which migration occurs and the resulting extent and habitat function of the newly migrated marsh is dependent on a variety of factors. The first step to assessing the value of newly migrated marsh is to identify areas where tidal marshes have replaced upland habitats (forest, agricultural fields, lawn) since the early 1990s. This time frame coincides with a vertical increase in mean sea level in Virginia of approximately 21 cm, or close to a quarter meter (https://www.vims.edu/research/products/slrc/localities/nova/index.php). In the flat lands frequently adjacent to tidal marshes in Virginia's coastal plain, this vertical shift can translate to meters or even tens of meters of landward migration of the tidal frame.

Data layers

New marsh ID – This layer identifies areas which were not in the upper range of tidal marsh elevation under the 1992 tidal regime, but are likely to be under the current tidal regime and are expected to be providing habitat for marsh birds. This does not identify all of the high marsh currently present, since it centers only on the newly formed high marsh. Shapefile.

Methods

Areas of likely migration were identified using a LIDAR-based digital elevation model (CoNED) for the lower Chesapeake Bay regions. The original plan was to use the elevation of the Highest Astronomical Tide (HAT) from the current tidal epoch as the back edge of the marsh in the early 1990s. This tidal epoch was calculated based on data from 1983-2001, and is centered in 1992. The Virginia Tidal Marsh Inventory would be used to identify the back edge of the current marsh; with the difference between the 2 representing new marsh created through marsh migration. However, there were issues with both datasets when compared with aerial photography.

1. HAT for the tidal datum centered in 1992 for Norfolk, VA is 0.615m NAVD88. When looking at 1994 Google Earth photos of the Peninsula, Middle Peninsula, Eastern Shore and Southside, it was clear that the marsh in 1994 extended to higher elevations than HAT. This is likely because HAT is the highest astronomical (predicted) tide—weather events and storm surge can result in higher actual water levels. Using elevations extracted from CoNED data for (Mitchell et al. 2020), we found that 0.76 m was a more accurate match for the back edge of the marsh in 1994.
2. The Virginia Tidal Marsh Inventory is digitized to encompass current marshes, however, comparing it to aerial photos (ArcGIS basemaps), it is clear that it is not catching the newest migratory areas. In addition, marsh complexes are all digitized

as marsh—the treed areas within the marshes are not identified (i.e. they are coded as marsh, not upland). Since these areas are a large source of recent marsh migration lands, using the TMI underestimated the amount of migration. Using elevations extracted from CoNED data for (Mitchell et al. 2020), we found that 0.91 m was a more accurate match for the current elevations where marsh grass is visibly moving into forested areas (areas with standing dead trees).

Newly migrated marsh potential areas were defined as areas between 0.76 - 0.91 m NAVD88. The New Marsh ID was coded with landuse/land cover (LULC) data from the Virginia Land Cover Dataset (vgin.maps.arcgis.com). Only areas of undeveloped LULC categories (natural land covers only –no turf/agriculture or developed/impervious) were retained since this is the only landcover that is likely to be providing marsh habitat services.

Figure 1. An example of the identification of new and transitioning marsh from the early 1990's to today. Small dots scattered through the marsh may be an artifact of noise in the DEM used to generate the dataset or may be capturing marsh hummocks.

Results

The analysis suggests that there are ~6500 hectares of newly migrated marsh in the Lower Chesapeake Bay that may be used as habitat by obligate marsh breeding birds (Table 1). However, this gain is offset in at least some part by a transition of areas that where high marsh in 1990s and are currently low marsh.

Table 1. New and transitioning marsh areas by locality (areas in hectares) and summed by landuse from the Virginia Land Cover Dataset (vgin.maps.arcgis.com).

	Virginia Land Cover						
Locality	Forest	Harvested/Disturbed	NWI/Other	Pasture	Shrub/Scrub	Tree	Total
Charles City	27.9	0.4	132.8	0.1	0.2	2.9	164.2
Hampton	10.1	0.0	153.6	1.5	0.0	16.6	181.8
Hanover	2.7	0.4	31.3	0.0	0.0	0.5	35.0
Henrico	5.0	0.0	24.6	0.0	0.0	0.8	30.5
James City	77.7	0.8	85.1	0.2	1.2	6.5	171.5
New Kent	37.2	0.4	176.2	>0.1	0.1	4.8	218.8
Newport News	38.6	0.0	81.9	0.0	>0.1	14.8	135.3
Poquoson	7.8	0.0	138.7	0.9	0.0	12.5	159.9
Richmond	0.5	0.0	1.5	0.0	0.1	0.2	2.4
Williamsburg	1.0	0.0	2.2	0.0	0.0	0.1	3.4
York	27.1	0.0	74.9	0.2	>0.1	14.7	116.8
Caroline	8.0	0.0	105.0	0.0	0.0	0.4	113.4
Essex	43.9	0.0	109.4	0.4	2.7	5.6	162.0
Fredericksburg	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Gloucester	125.3	0.1	499.6	5.5	6.4	39.6	676.5
King and Queen	43.5	0.0	111.9	0.1	0.5	1.7	157.9
King William	47.6	0.5	194.7	>0.1	1.5	2.8	247.1
Mathews	178.1	7.4	228.5	15.8	7.9	56.1	493.9
Middlesex	34.2	1.9	49.7	0.3	>0.1	10.6	96.7
Spotsylvania	0.8	0.0	1.0	0.0	>0.1	>0.1	1.8
Stafford	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Accomack	337.6	5.9	2267.2	6.8	38.0	113.3	2768.8
Northampton	61.2	0.0	468.9	0.3	15.5	13.3	559.2
Total	1116.1	17.8	4938.9	31.9	74.1	317.9	6496.8

Task 2: Assess changes in ecosystem function (habitat provision) in marshes impacted by rapid rates of sea level rise

Marsh bird survey

To enhance the use of marsh migration forecasts for conservation it is important to understand how sea level rise-driven loss of marsh has affected marsh-obligate fauna and how these species might use the newly formed marsh habitat. In this task, we focus specifically on avian marsh-obligate breeders (i.e., Seaside Sparrow, Saltmarsh sparrow, Marsh Wren, Virginia Rail, Clapper Rail) that have been used as a sentinel species for marsh habitat quality. Some of these species breed in the high marsh/upland ecotone where inundation events are rare. Incubation and nestling phases are when things are completely confined to the nest and the clutch/brood are fixed and vulnerable. After they leave the nest, the young have a dependency period when they are vulnerable to tides, although the response varies by species.

Data layer

Sampling summary – This layer shows the location of the survey points for 2021 and includes information about marsh species detection (binary, across all sampling periods). Shapefile.

Methods

Avian marsh-obligate breeder in the lower Chesapeake Bay, Virginia were previously surveyed in 1992. The marsh “patches” were selected for an EPA project in 1992 based on size, the vegetational composition of marshes (from VIMS original inventory) and access. Size categories were also from the VIMS inventory. Sampling areas were selected via a random draw from a long list of candidate sites. The survey “points” were arranged along a general elevational gradient to sample both low and high marsh areas within each patch but were spaced 70+ m apart to reduce overlap of the 30-m fixed radius sampling plots.

These data can be used as baseline information for assessing how populations are faring in current marshes and assess the habitat value of newly migrated marsh areas. Activities in this reporting period were focused on selecting sites and planning field activities. Sites were selected based on past sampling sites (see map below). The sampling sites were added to the mapped areas of new marsh to identify adjacent new marsh patches that can be added to the survey. The priority for this project is to survey the network within the 10 ha and 50 ha patches and adjacent sites in newly formed marsh.

We sampled marsh birds along the western shore of the lower Chesapeake Bay between Grandview Beach (City of Hampton) and New Point Comfort (Mathews County) in Virginia (Table 1). Marshes within the area are polyhaline (18-30 ppt) with a vegetational community dominated by smooth cordgrass (*Spartina alterniflora*), black needlerush (*Juncus roemerianus*), salt meadow hay (*Spartina patens*), salt grass (*Distichilis spicata*) and groundsel tree (*Baccharis halimifolia*). Patch size, plant composition and accessibility (accessible from uplands or within 2 km by boat) were used as criteria for selection. Patches were considered for inclusion if they were dominated (>90%) by and contained all of the plant forms including smooth cordgrass (≥30%), black needlerush (≥20%), salt meadow hay and salt grass combined (≥15%) and groundsel tree (≥10%). Replicate patches were randomly selected for each size category from a pool of marshes that met the sampling criteria.

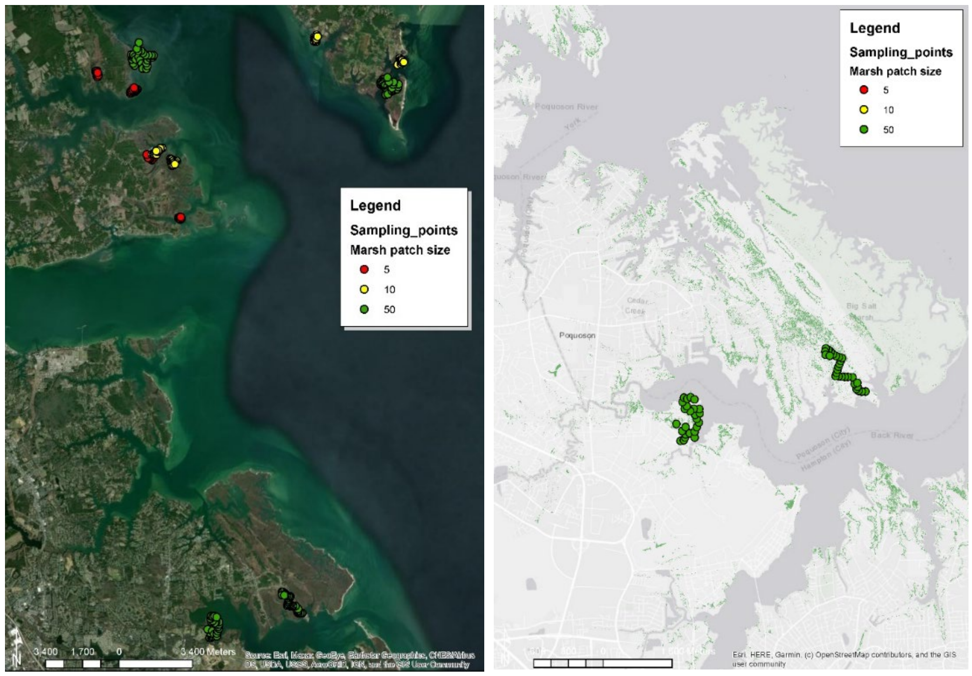

Figure 2. Map of sampling sites selected, with priority on the 10 & 20 ha marsh patches. The close up shows sampling sites in Hampton and Poquoson on top of identified areas of new and transitioning marsh.

Surveys were conducted between sunrise and 4 hrs after sunrise. All marshes were surveyed four times during each year. To reduce seasonal bias and insure even coverage, marshes were surveyed in four rounds where all marshes were surveyed in each round and the survey order was randomly determined. Because some of the birds of interest exhibit distinctly different peaks of calling and residency a split approach to surveys was used. Two survey rounds were conducted between 6 May and 3 June. This early period is the time when rails of interest are most vocal and transients move through marshes. Because some species have migration periods that extend into early June, the later survey rounds were not initiated until 11 June. Two survey rounds were conducted between 11 June and 10 July.

Table 2. Marsh survey details

Marsh Code	Name	Size Category	Size (ac)	Patch Size (ha)	Round 1	Round 2	Round 3	Round 4
G98	Marius	5	13	5.26	5/22/21	6/5/21	6/16/21	6/23/21
G123	Belvins Creek	5	14	5.67	5/7/21	5/29/21	6/19/21	6/26/21
G213	Potato Neck	5	13	5.26	5/22/21	6/5/21	6/16/21	6/23/21
G219	Lands End	5	14	5.67	5/11/21	5/24/21	6/7/21	7/11/21
G126	Seafood	10	22	8.90	5/7/21	5/29/21	6/19/21	6/26/21
G129	Browns Bay	10	22	8.90	5/11/21	5/24/21	6/7/21	7/11/21
M188	Tatterson	10	20	8.09	5/13/21	6/8/21	6/18/21	6/29/21
M226	Bur Marsh	10	24	9.71	5/13/21	6/8/21	6/18/21	6/29/21
H191	langley	>65	159	64.35	5/9/21	5/23/21	6/13/21	6/27/21
P254	Messick	>65	460	186.16	5/8/21	6/2/21	6/17/21	6/25/21
G224	Four Points	>65	197	79.72	5/11/21	5/24/21	6/24/21	7/5/21
M217	New Point	>65	160	64.75	5/10/21	6/7/21	6/20/21	7/3/21

Bird were surveyed within 30-m fixed radius plots using a call-response technique (Conway and Nadeau 2010) to increase rail detections. The call-response survey consisted of a 5-min sequence of alternating silent listening periods and species recordings in the following order; 1) 30 sec of silence; 2) 50 sec of black rail advertising call; 3) 10 sec of silence; 4) 50 sec of Virginia rail advertising call; 5) 10 sec of silence; 6) 50 sec of clapper rail advertising call; 7) 10 sec of silence; 8) 50 sec of king rail advertising call; 9) 40 sec of silence. Although black and king rails were never detected during either survey period, the playback sequence was maintained for consistency. Counts were executed by standing at the plot center and recording birds seen or heard during the playback sequence.

Marsh vegetation was surveyed by drone survey in most of the marshes. The resulting drone flights were examined for plant height and visual appearance and vegetative communities were outlined. Sampling points were overlaid on the marsh community types to look for relationships between plant communities and avian species usage.

Results

We conducted 1,480 surveys of plots (n = 185) during the two time periods (1992, 2021) and recorded 3,069 detections of target marsh-nesting species. The community was dominated (72.1%) by obligate salt marsh species followed by obligate marsh species (17.9%) and facultative marsh species (10.0%).

Comparison of results from 1992-2021 show that abundances across all groups declined over time and that the composition of the assemblage shifted toward salt marsh obligates. Community-wide and group occupancy and abundance patterns show declines by all groups but higher declines for facultative marsh nesters and obligate marsh nesters compared to salt marsh nesters (Figure 3). The clapper rail (an obligate salt marsh nester) is one of only two species that did not experience a decline and the only species where colonization exceeded extinction. All marsh patches supported clapper rails during both time periods, the number of occupied points was comparable and the number of detections increased through time. All of the obligate marsh nesters except for red-winged blackbird declined dramatically over the survey interval. The highest declines were seen in the sedge wren and Virginia rail populations. The decline of the sedge wren was linked to habitat change. In 1992, this species was confined to a band of high marsh that supported scattered salt bush but nearly all of the saltbush had been replaced by other vegetation by 2021. Marsh wrens switched primary habitat between the two time periods, with the majority found in tall cord grass during the 1992 survey, and the majority in black needlerush in the 2021 survey. However, black needlerush is a very different habitat, and typically lower in elevation than tall cordgrass which may result in decline in populations. Red-wing black birds also switched habitat, but to a morphologically similar species (*Phragmites*) which is expanding and may have benefitted these populations.

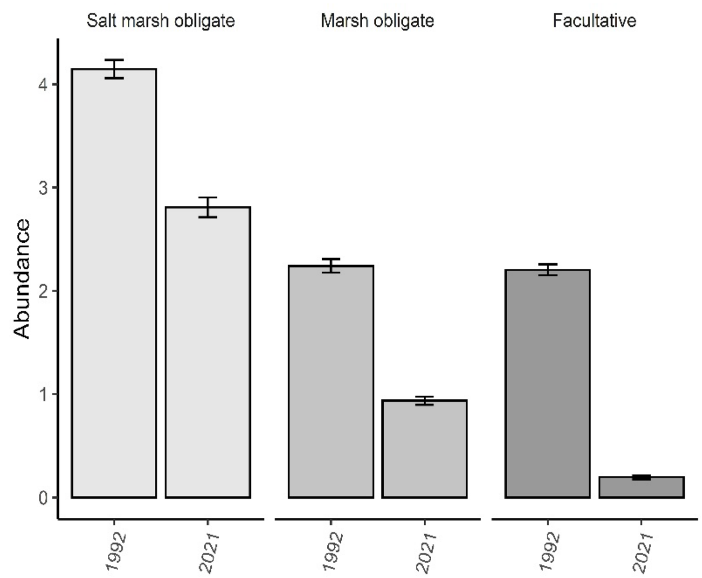

Figure 3. Abundance patterns for marsh bird usage of species surveyed within the Lower Chesapeake Bay. Bars represent mean values +/- 1 standard error unit.

Four species (saltmarsh sparrow, sedge wren, eastern meadowlark and song sparrow) were extirpated or nearly extirpated within focal marshes during the study period (Table 2 & 3). The saltmarsh sparrow is confined to salt marshes, has been declining throughout its range, has been projected to be pushed to extinction under current sea-level rise scenarios, and is a candidate for federal listing. A nest found within the study area in 1992 is the last nesting record known for the study area and the broader western shore of the Chesapeake Bay (Watts 2004). The eastern meadowlark was widespread throughout patches of high marsh dominated by saltmeadow hay and salt grass in 1992 but only a single point in 2021. This species continues to nest within upland farm fields and grasslands within the region. Song sparrows were widespread within all focal marshes in 1992 but were detected only twice within a single marsh in 2021.

Table 3. Detection (±SE), Colonization (±SE), and Extinction (±SE) for marsh birds surveyed within the Chesapeake Bay region in Virginia, USA.

Species	Detection	Colonization	Extinction
Obligate Salt marsh	0.78 (0.01)	0.15 (0.20)	0.25 (0.03)
Clapper Rail	0.32 (0.06)	0.45 (0.07)	0.32 (0.06)
Willet	0.33 (0.03)	0.22 (0.01)	0.71 (0.06)
Seaside Sparrow	0.73 (0.01)	0.09 (0.08)	0.42 (0.04)
Obligate Marsh	0.45 (0.02)	0.21 (0.08)	0.50 (0.05)
Virginia Rail	0.21 (0.04)	0.04 (0.04)	0.87 (0.06)
Sedge Wren	0.49 (0.09)	0.00 (0.00)	1.00 (0.01)
Marsh Wren	0.37 (0.03)	0.05 (0.03)	0.85 (0.05)
Red-winged Blackbird	0.41 (0.03)	0.27 (0.05)	0.49 (0.08)
Facultative Marsh	0.41 (0.03)	0.10 (0.04)	0.94 (0.02)
Song Sparrow	0.45 (0.04)	0.02 (0.01)	1.00 (0.00)
Boat-tailed Grackle	0.18 (0.04)	0.07 (0.05)	0.89 (0.07)
Eastern Meadowlark	0.22 (0.05)	0.01 (0.01)	1.00 (0.00)
All Species	0.83 (0.01)	0.01 (0.01)	0.17 (0.03)

Table 4. Detection (±SE), Recruitment (±SE), and Apparent Survival (±SE) for marsh birds surveyed within the Chesapeake Bay region in Virginia, USA.

Species	Detection	Recruitment	Apparent Survival
Obligate Salt marsh	0.43 (0.01)	1.10 (0.19)	0.41 (0.04)
Clapper Rail	0.25 (0.03)	0.77 (0.16)	0.27 (0.12)
Willet	0.12 (0.02)	0.82 (0.20)	0.04 (0.05)
Seaside Sparrow	0.50 (0.02)	0.59 (0.11)	0.41 (0.04)
Obligate Marsh	0.35 (0.03)	0.66 (0.17)	0.12 (0.07)
Virginia Rail	0.12 (0.04)	0.45 (0.38)	0.05 (0.05)
Sedge Wren	0.26 (0.00)	0.00 (0.00)	0.00 (0.00)
Marsh Wren	0.22 (0.05)	0.09 (0.05)	0.04 (0.05)
Red-winged Blackbird	0.22 (0.03)	0.60 (0.11)	0.20 (0.08)
Facultative Marsh	0.30 (0.04)	0.09 (0.03)	0.00 (0.01)
Song Sparrow	0.36 (0.04)	0.01 (0.01)	0.00 (0.00)
Boat-tailed Grackle	0.07 (0.03)	0.31 (0.15)	0.00 (0.04)
Eastern Meadowlark	0.17 (0.05)	0.02 (0.01)	0.00 (0.00)
All Species	0.38 (0.02)	1.80 (0.30)	0.28 (0.04)

All of the mapped marshes had both low and high marsh plant communities. Three of the marshes (G219, G126 and M226) had significant *Phragmites* communities, although many of the marshes had some *Phragmites* presence. There were no strong correlations between the plant communities present and the detection of species (Figure 4), but that is likely because the plant communities were very similar between all of the marshes.

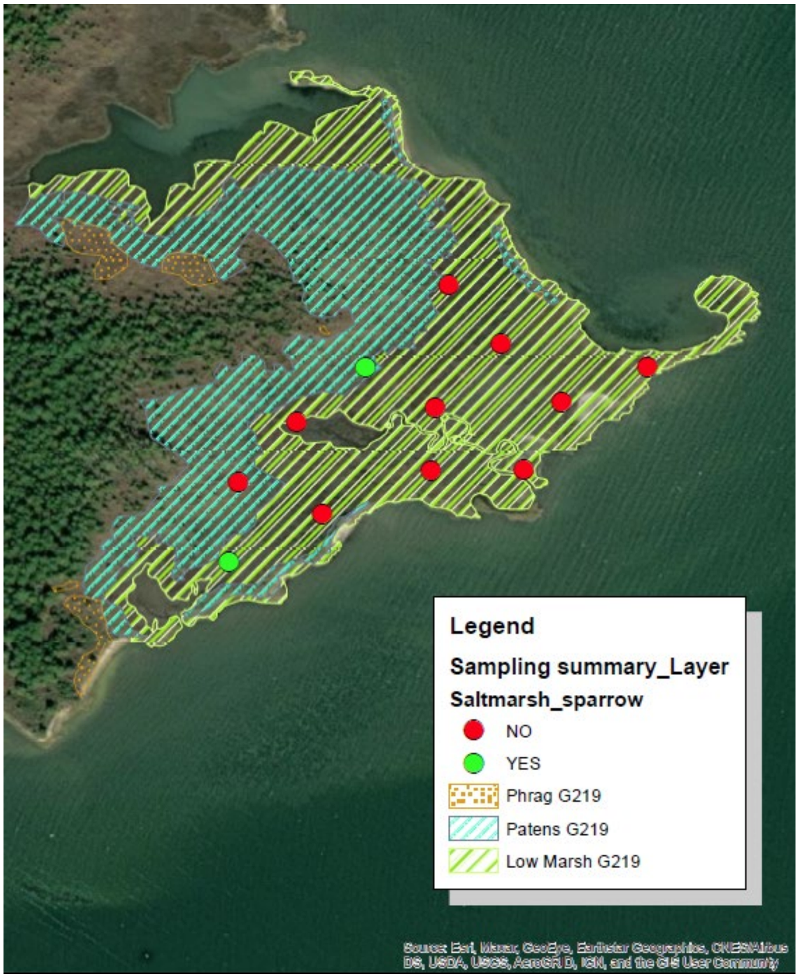

Figure 4. Mapped plant communities with a summary of Saltmarsh sparrow detection overlain. The color of the dots indicates if Saltmarsh sparrow was detected during any of the sampling times.

Task 3: Initiate development of an assessment tool to identify areas with a high likelihood to support marsh obligate breeders in the future

Marsh Habitat Vulnerability

In the marsh vulnerability assessment (product of CD96347001-0; incorporated into Virginia Wetlands Condition Assessment for management use), marshes with low vulnerability ratings have sufficient natural lands to migrate and low potential for erosion. These marshes have the potential to provide robust habitat for avian marsh-obligate breeders if they maintain their high marsh area during the migration process. The area of high marsh can be limited by upland elevation or the utility of the high marsh area for marsh bird habitat can be limited by human land use such as development, mowing (turf) and agricultural practices.

Data layers

HighMarsh2020 - elevation range of 0.6 to 0.91m (2 - 3ft) with undeveloped (natural land covers only –no turf/agriculture). In HighMarshHabitat.gdb.

HighMarsh2050 - elevation range of 1.07-1.37m (3.5-4.5ft) with undeveloped (natural land covers only –no turf/agriculture). In HighMarshHabitat.gdb.

HighMarsh2100 - elevation range 2.44m to 2.74m (8-9 ft) with undeveloped (natural land covers only –no turf/agriculture). In HighMarshHabitat.gdb.

Methods

Tide gauge data from Windmill Point, Virginia for a 19-year period was downloaded and analyzed for frequency of spring inundation (hours of flooding) at 0.1m increments. Windmill Point was chosen as the tide gauge most likely to represent water conditions at the survey marshes. Because water levels in the fall tend to run high and might be over-estimating the inundation experience by the nesting birds in the spring we used only the spring/summer tide gauge data. High marsh habitat was defined as areas with elevations within the tidal marsh regime but which were never inundated during the nesting season. This is a conservative definition of habitat, since in the survey some marsh bird species did use black needle rush communities, which are found at a lower tidal elevation. An approximate increase in mean sea level of 1.5 ft for 2050 and 6ft for 2100 was added to the tide gauge record to model future high marsh habitat. Elevation ranges for high marsh habitat were developed using marsh migration models from a previous EPA grant (CD-963470-01-0).

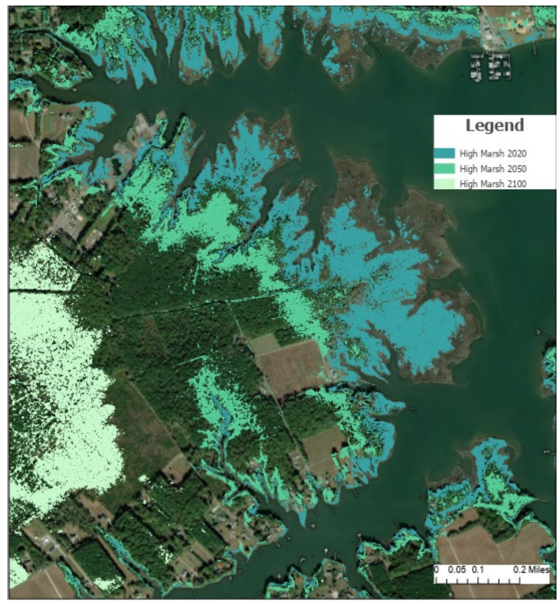

Figure 5. Projected high marsh habitat for 2020, 2050, and 2100 in an area of Gloucester County.

The appropriate elevation layers were developed using the ArcGIS geoprocessing tools on the existing layers (Figure 5). For the high marsh habitat in 2020, we used the intersection of elev_5 (0.61-1.37m) and elev_3 (0.30-0.91m); for high marsh habitat in 2050 we used Elev_8 (1.07-1.68m) erase elev_10 (1.37-1.98m); for high marsh habitat in 2100 we used Elev_17 (2.44-3.20m) erase elev_19 (2.74-3.35m). Areal extent of high marsh habitat was summarized by 12-digit HUC unit and compared between 2020 and 2050 and 2020 and 2100. Originally, we planned to compared changes in patch size also; however, the use of the 1m marsh migration dataset made this comparison useless. In 2020, 83% of polygons were 3 pixels or smaller; by area, 10% are less than 7 sq m or less. In 2050, 87% of polygons were 3 pixels or smaller; by area, 10% are less than 7 sq m or less.

Results

Total projected high marsh habitat area declined over time from 251 km^2 (2020) to 133 km^2 (2050) and 125 km^2 (2100). However, there were significant variations between localities (Table 5). The largest losses were predicted in localities with significant amounts of current potential habitat, such as Accomack, Northampton, and Virginia Beach.

Table 5. High Marsh Habitat (sq meters), by Time Period

Locality	2020	2050	2100
Accomack County	76099335	31674722	18607596
Alexandria City	98088	93133	57421
Arlington County	23184	23335	19600
Caroline County	2086411	1380647	248395
Charles City County	4360238	2455659	1696751
Chesapeake City	10510131	8625978	14782313
Chesterfield County	2967942	942248	581547
Colonial Heights City	449195	157571	126763
Essex County	4775915	2000941	1534539
Fairfax County	1248048	601747	522981
Fredericksburg City	2684	3799	18251
Gloucester County	14696068	9974993	11802354
Hampton City	4441205	2347412	1845452
Hanover County	647755	284507	345347
Henrico County	793415	475084	358609
Hopewell City	174676	91171	89309
Isle of Wight County	6066634	2189666	1520108
James City County	4801614	2600670	1805676
King and Queen County	4808375	2208437	2506145
King George County	2545348	1560646	1421580
King William County	7890838	3104130	1923283
Lancaster County	3838424	2810945	3510856
Mathews County	10012416	8289135	13267728
Middlesex County	2030828	1690015	1642017
New Kent County	6638028	1404453	1345167
Newport News City	3410004	1970651	1117067
Norfolk City	950655	929192	1857994
Northampton County	18692552	14139111	6272971
Northumberland County	4273142	3330859	5523224
Petersburg City	36727	17895	10152
Poquoson City	5384726	1163950	1046907
Portsmouth City	396983	414595	1122290
Prince George County	2370438	1061231	841325
Prince William County	1039983	465758	354624

Richmond City	37419	71969	104557
Richmond County	5680790	1895107	2612332
Spotsylvania County	37094	32698	26465
Stafford County	1250010	656407	718148
Suffolk City	7326697	1815148	1568057
Surry County	2071801	1297173	711278
Virginia Beach City	19743823	12439686	13530886
Westmoreland County	3102028	2258494	3009647
Williamsburg City	83546	57083	51471
York County	3369522	2347555	3638520

Task 4. Assess multiple place-based benefits of specific wetlands to include habitat and water quality benefits

Tidal marsh benefits assessment

The Marsh Vulnerability Model (product of CD96347001-0; incorporated into Virginia Wetlands Condition Assessment (WetCat) for management use) assesses the future resilience of marshes under rising sea levels. Currently, it does not incorporate any assessment of the habitat or water quality benefits associated with migrating marshes. We expanded the vulnerability analysis to include marsh bird habitat considerations using the results from task 3.

This task was planned as a pilot study for just Gloucester County Bay-front marshes looking at both Water Quality and Habitat benefits. The Water Quality pilot was unsatisfactory, but the Habitat pilot was effective, so we expanded the Habitat pilot to the entire Virginia coastline and incorporated the results into WetCat.

Data Layers

Final_VaWetlandVulnerability_Updated_Marshes - This layer assesses the vulnerability of tidal marshes to climate change for the time periods 2050 and 2100 throughout Virginia. The vulnerability scores given to the marshes combine exposure, habitat potential for sentinel species (added 2021), sensitivity and adaptive capacity of wetland habitats within tidally-connected wetland complexes. Shapefile.

Methods

Water Quality - Potential future marsh location for 2050 and 2100 (from CD96347001-0) were clipped to the target study area (Gloucester County Bay-front). Only landuses likely to provide water quality benefits (tree, forest, barren, NWI/Other, harvested/disturbed, and scrub-shrub) were included in the analysis. A previously developed Inundation Pathway (IP) layer was spatially joined to each of the time step layers to record intersection. The IP layer identifies flow pathways from houses to the shorelines and this step identified the potential for a tidal marsh to intercept and remove NPS from overland flow prior to it entering the estuary. We created a model to count IPs within each 12-digit HUC for current, 2050, and 2100 marsh distribution.

Habitat – Habitat layers from Task 3 were used as the basis for the analysis and the analysis was done for the entire coastal plain of Virginia. Habitat area was summarized by 12-digit HUC for each of the 3 time periods (current, 2050, 2100). Change in total area of habitat within each HUC was calculated between current and 2050 and current and 2100. The habitat potential score was developed by dividing HUCs into a gain category and two equal sized loss categories.
Final categories:

- Gain/No Loss: >= 0 sq meters loss == Score 0 == Not Vulnerable
- Low Loss: less than 0 – 250,000 m2 loss
- High Loss: -250,000 ▯ -8,035,152 m2 loss

For inclusion in the Marsh Vulnerability layer in WetCat, we added new field for Habitat Score to the existing layer and calculated new combined scores If a marsh crossed a HUC boundary, the highest score (most vulnerability) was assigned.

Results
Water Quality - In general, water quality benefits don't change significantly between 2020 and 2050, but drop at 2100. However, that drop is indicative of issues in the

Figure 6. Examples of Inundation Pathway intersection with potential marsh. Note the houses in or shoreward of the 2100 potential marsh.

modeling method. In Gloucester, most of the difference is due to the fact that so many of the at-risk buildings lie at a lower elevation than 2100 potential marshes (Figure 6). For example, in the 2100 scenario, 1605 of 3547 (45%) of Gloucester buildings are within or below the tidal marsh elevations while in the current time frame only 18 of 3547 buildings are within the tidal marsh elevations (Note: this is not an error in the current time frame, there are elevated houses in tidal marsh elevations currently in Gloucester).

It is clear from the projected movement of the marshes that there will be necessary landuse changes in the nearshore areas prior to 2100 that cannot be projected based on current conditions. Based on this analysis, we concluded is that not appropriate to look forward to tidal marsh water quality service provision using this method. Improving the methodology would require the addition of an altered shoreline and the inclusion of IPs for buildings at higher elevations (currently limited to buildings less than 10ft in elevation) to better capture the future water quality benefits of tidal marshes. Due to concerns about appropriate interpretation of the pilot project results, and their limited geographic scope, they were not incorporated into the Marsh Vulnerability assessment in WetCat.

<u>Habitat</u> – Most of the marshes experience some level of loss in habitat area by 2050, although a portion of that loss is re-gained through marsh migration by 2100 (Table 6). However, about half of the marshes experience a high loss of marsh bird habitat in both time periods.

Table 6. Marsh polygons within each change category.

	2050	% of total	2100	% of total
High Loss	26522	57%	25726	56%
Low Loss	13807	30%	6643	14%
Gain	5948	13%	13908	30%

Adding the Habitat Vulnerability into the overall Marsh Vulnerability Scoring had a slight impact on the composite score (Figure 7). Looking at overall score changes after adding in Habitat Potential scores. Trends are:

- Fewer marshes are Highly Vulnerable and Not Vulnerable after additional category added.
- Marshes tended to move into the Somewhat and Slightly categories.

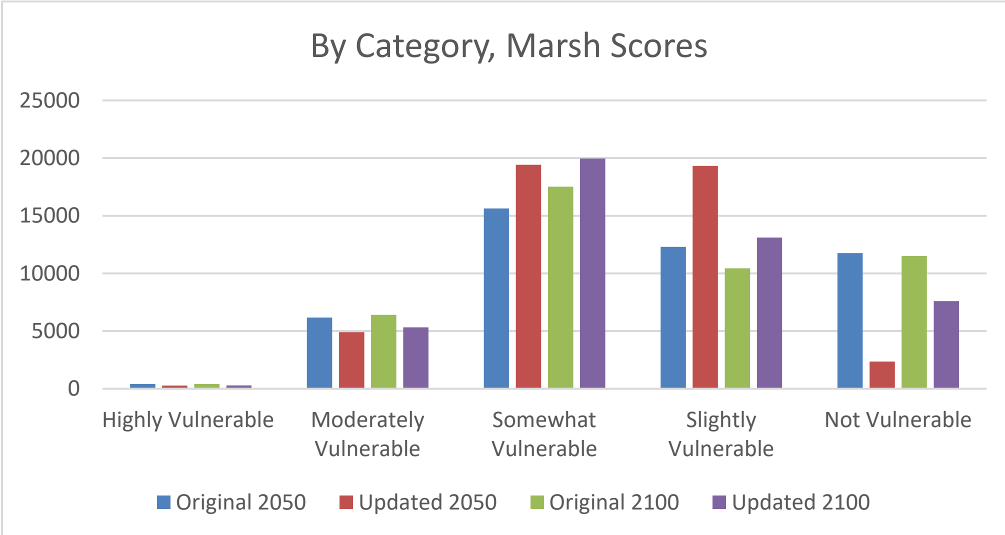

Figure 7. Change in composite marsh vulnerability score after inclusion of habitat vulnerability

Task 5: Outreach

This project is designed to provide information that is both accessible and useful to a diverse group of scientists, managers, policy makers, and the public.

- Marsh habitat quality analyses for the pilot area is being incorporated into the existing Marsh Vulnerability layer in the Virginia Wetland Condition Assessment tool (WetCat) to enable its use by decision makers.
- Information on the updated marsh vulnerability layer will be incorporated into future trainings on the Virginia Wetland Condition Assessment tool.
- Information about the Marsh Vulnerability layer in the Virginia Wetland Condition Assessment tool (WetCat) was included in a presentation for the NEBAWWG-MAWWG 2021 Joint Virtual Meeting [Communicating to and engaging stakeholders and the public. M. Mitchell. Oct 2021]
- Results from the marsh bird survey were presented at the Center for Coastal Resources Management's Shoreline Management Webinar in August 2021 on Tidal Marsh Ecology. Over 150 participants joined representing local, state, and federal government agencies, private businesses, NGOs, Virginia Master Naturalists and Virginia Master Gardeners. The webinar was recorded and related material is posted on the CCRM web site for future reference. https://www.vims.edu/ccrm/outreach/workshops/2021/index.php
- A draft manuscript "Decline of salt marsh-nesting birds within the lower Chesapeake Bay (1992-2021)" has been written by B. Watts and will be submitted to the Journal of Wildlife Management in Dec 2021.

Conclusions

Marshes and their vegetative communities have shifted since the 1990s. Marsh edges have eroded, marshes have migrated landward, moving into forests and lawns, and high marsh has progressively converted to low marsh. These shifts have changed the habitat provision of tidal marshes for marsh-associated sentinel bird species. An exploration of shifts in the tide range, showed that new marsh has been created at the upper end of the tidal range through migration. However, the new marsh is not always equivalent habitat. When marshes migrate into lawn or agricultural fields, marsh grasses quickly achieve densities equivalent to those in the previous marsh extent and likely serve as equal habitat, if property owners stop mowing the area. When the marsh is mown and maintained as lawn, it has limited capacity to provide habitat. When marshes migrate into forested areas, the shading can cause sparseness of marsh vegetation until the trees die and completely defoliate. Migrating marshes are also frequently composed of the invasive grass *Phragmites australis*. This species of grass is not equivalent habitat for some marsh-obligate fauna and therefore may inhibit their use of the new marsh area and eventually lead to the loss of the fauna from the marsh. Many of the locations surveyed in the 1990s are now in locations of low marsh vegetation, indicating a reduced role as nesting habitat.

Birds that have nested historically within salt marshes of the Chesapeake Bay are declining such that the habitat role that these marshes have played is diminishing. In particular, salt marsh obligates are of high conservation concern over the longer term due to their specialization on a habitat that is currently experiencing rapid change. How to mitigate the effects of SLR and predation on tidal marsh bird populations before they are extirpated from the Atlantic Coast is a topic of urgent interest. Flooding risk reflects the height of nests (and associated marsh elevation) and the magnitude of flooding events when nests are present. Strategies to ameliorate flooding risk are limited and would require either elevating the marsh surface or facilitating the appropriate marsh vegetation to migrate upslope. Changing plant communities are a significant issue for habitat provision. Currently the patches of newly migrated marsh on the lower Chesapeake Bay, Virginia are typically quite small and it might be that they just aren't big enough to attract usage yet. Another possibility is that the sediment doesn't support a good prey community for them. Sediment development in newly migrated marsh tends to lag temporally behind grass establishment and may take 10+ years to develop fully.

The changes in marsh sentinel species since the 1990s raises concerns about the future role of marshes as habitat provision. In addition to changing plant communities, our analysis showed that total high marsh habitat is projected decline over time, although the shifts are marsh specific. Incorporating this information, combined with other marsh vulnerability metrics, into management efforts should help insure that marsh bird habitat provision continues to be an important role of tidal marshes in Virginia.

Quality Assurance Project Plan Update

QAPP was approved by EPA on June 14, 2021.

Areas Of Concern - Deficiencies/Corrective Action

Using lidar to identify areas of newly migrated marsh worked well for the lower Chesapeake Bay, and results could be verified using Google Earth images. However, the results appeared problematic in the Northern Neck where tidal elevations appeared in farm fields and road ditches. This may indicate a difference in tide range from the lower Chesapeake Bay that requires a different approach or may indicate that areas within the tidal range are being actively farmed. Since the approach could not be verified in this region, only the lower Chesapeake Bay was included in the analysis.

The Water Quality pilot study suggested that the approach did not appropriately capture future water quality benefits of projected marsh area. Due to concerns about appropriate interpretation of the pilot project results, and their limited geographic scope, they were not incorporated into the Marsh Vulnerability assessment in WetCat. In contrast, the Habitat vulnerability analysis was successful implemented, expanded to the entire Coastal Plain, and was incorporated into WetCat.