Sea Level Affecting Marshes Model of the

Apalachicola National Estuarine Research Reserve, Florida

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Introduction

The global archaeological record along coastlines is in peril from many of the cascading effects of the climate emergency, especially sea level rise. Archaeological modeling of this current and anticipated loss is important, and while general models have been developed to assess the impact of rising sea levels, few offer sophisticated modeling of when and the mechanism of how those sites are likely to become damaged and/or destroyed at a site-specific scale as applied to archaeological and heritage at risk contexts [1–4]. There are a number of explanations for why the coastal archaeological record is important, including an enhanced understanding of ecological baselines, documenting the loss of sacred sites for Indigenous peoples and descendent communities, and demonstrating the role that such information can play regarding the nature of ecosystem restoration, among other factors [5–7].

The data presented here represent a report of findings based on the creation of a predictive model of estimated wetland reallocation and shoreline changes as a result of climate changes to the Apalachicola NERR in the panhandle of Florida (Figure 1). The purpose of this model is to estimate at a site-specific level, the timing of shoreline changes from global sea level rise that will impact cultural heritage sites and resources. The analysis was conducted for a 1.5- and 2-meter global mean sea level rise (GMSLR) scenarios.

In the Southeast United States, recent studies demonstrate the importance of archaeology and paleobiology to understanding oyster reef loss and resilience and how Native American inhabitants played a role in shaping these environments over the past 5000 years, often in sustainable ways [8,9]. Native American communities along with other populations, such as the Gullah Geechee, still maintain a connection to vulnerable archaeological sites in the region. Similar to coastal scientists and conservationists around the world [10], we in the Southeast are in a race against the rising seas to develop better tools and strategies to more effectively understand and protect these landscapes. Given these concerns and the realities of climate change, archaeologists need a detailed understanding of how local regions respond to changing sea levels, so that we can develop effective response protocols before these historical legacies are lost. Specifically, detailed predictive models are necessary to document the impact of sea level rise on these resources.

Human activities, especially since the beginning of the European colonization of the Americas and the industrial revolution, have greatly accelerated the pace of climate related environmental change [11,12], resulting in a number of effects, including rising sea levels. Florida's coastlines are already experiencing a suite of deleterious effects from increased global mean sea level rise (GMSLR) and a warming earth [13], notably including changing wetlands[14], increased salinization and acidification, cultural and environmental resource submergence, nuisance and event-based flooding, and shoreline erosion and beach migration [14]. The effects of these global climate changes, especially the anticipated 1-2 meter sea level rise (SLR) this century (*AR5 Synthesis Report: Climate Change 2014*.; Change, 2016; IPCC, 2007), to terrestrial above- and below-ground cultural resources will be severe and permanent to the many and varied cultural heritage sites on the Atlantic coast [18 19 20].

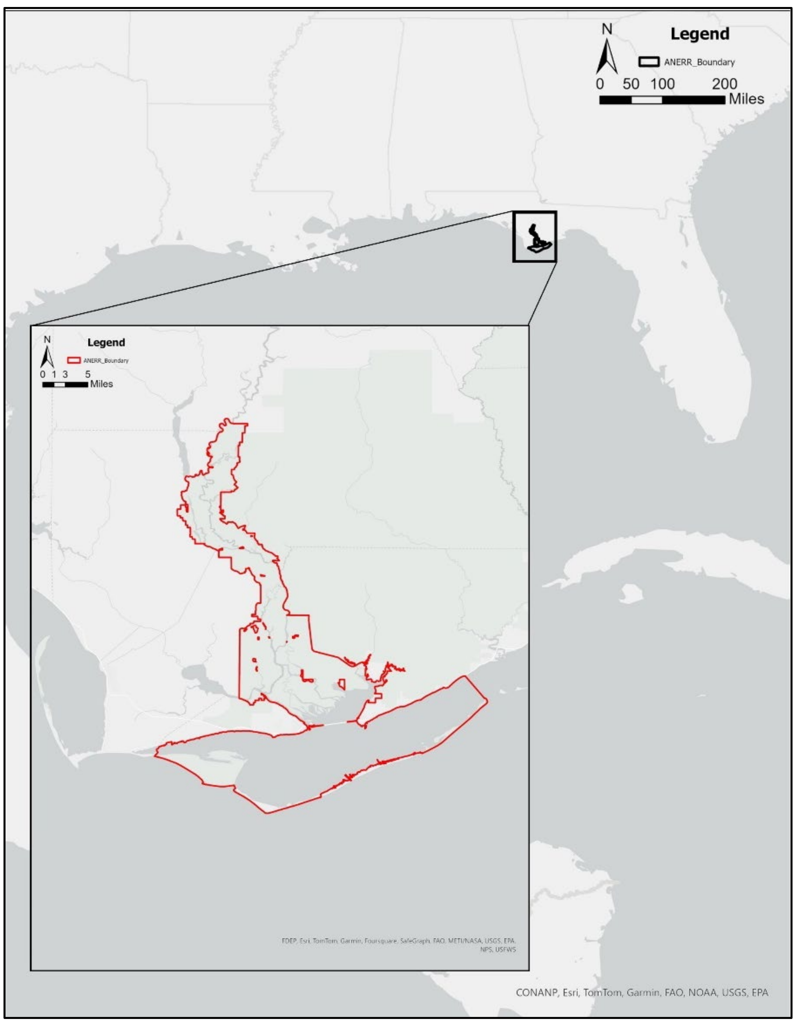

Figure 1. Area of Interest, Apalachicola National Estuarine Research Reserve (ANERR).

Methods

SLAMM is a mathematical model based on digital elevation models (DEM) or LiDAR to simulate potential impacts of sea level rise to shorelines and wetlands. The program has been in production since the mid-1980s and modeling within the program begins in the year 2006. Every aspect of the SLAMM interface can be manipulated by the user, allowing additional data, such as the location of areas protected by dikes or sea walls, as well as specific erosion and accretion rates. Some models adopt data from the marshes equilibrium model (MEM) to estimate changes to carbon sequestration and marsh health alongside SLAMM results from long-term sea level changes. These data facilitate efforts of marsh and shoreline preservation, restoration, and conservation. By proxy, these efforts also facilitate the identification of areas that are likely to contain at-risk cultural resources. Once those sites are identified, archaeologists can work to likewise preserve, protect, and document these critical resources.

SLAMM itself is a network of complex decision trees that "incorporate geometric and qualitative relationships to represent transfers among coastal classes" [21]. These coastal classes are adapted from the NWI, then crosswalked to one of 23 SLAMM categories. The model simulates the processes involved in wetland conversions that will occur with long-term sea level rise, namely inundation, erosion, accretion, soil saturation, and barrier island overwash—all of which have already been occurring at ANERR. A sample of this conversion process is shown in Table 1.

Table 1. A sample of the conversion between NWI attributes to SLAMM categories.

NWI ATTRIBUTE	SLAMM CODE	WETLAND TYPE	ACRES	Shape_Length	Shape_Area	SLAMM NAME
E1ABL	3	Estuarine and Marine Deepwater	0.45576221	240.8411944	1844.405855	Swamp
E1ABLx	3	Estuarine and Marine Deepwater	12.3398238	4577.914824	49937.53914	Swamp
E2US2N	3	Estuarine and Marine Wetland	1.57919794	1218.878545	6390.79297	Swamp
E2USN	3	Estuarine and Marine Wetland	0.19226618	113.7703567	778.0743013	Swamp
PAB4Hh	3	Freshwater Pond	1.36735518	799.2430786	5533.494996	Swamp
PABF	3	Freshwater Pond	0.39375147	192.9996387	1593.45707	Swamp

PABHh	3	Freshwater Pond	1.83669254	738.5889331	7432.837583	Swamp
PABHx	3	Freshwater Pond	1.65525768	631.3655635	6698.596109	Swamp
PEM1/FO4B	3	Freshwater Emergent Wetland	14.7293476	1460.011868	59607.60762	Swamp
PEM1/SS1C	3	Freshwater Emergent Wetland	0.20058107	130.5369471	811.7234974	Swamp
PEM1/SS3C	3	Freshwater Emergent Wetland	2.41809792	611.8559074	9785.703759	Swamp
PEM1A	3	Freshwater Emergent Wetland	0.86411672	342.6267462	3496.959376	Swamp

Sea Levels Affecting Marshes Model (SLAMM) Methods

This model was created using the open source program Sea Levels Affecting Marshes Model (SLAMM). The data input are: DEM/LiDAR, slope, and wetland characteristics of an AOI from the National Wetlands Inventory (NWI). The program uses three types of data to create estimates of wetland reallocation at user-generated time intervals based on sea level changes estimated from the Intergovernmental Panel on Climate Change (IPCC). The start date of the model was predated from 2006 and run until 2100 at both 5- and 25-year intervals (2006, 2025, 2050, 2075, 2100). Results from the 25-year interval model for a 2-meter SLR are presented in this report; full data are available in the data package. Data were processed in ERSI ArcGIS Pro in WGS 1984 (EPSG 4326) NAVD 88.

Elevation data were derived from two sources: (1) an adjusted digital elevation model for ANERR's Apalachee Bay adjusted for vegetation elevations (Mederiros et al. 2022); a NOAA LiDAR dataset that was flown after Hurricane Michael in 2020 at a 1m horizontal accuracy and 5.7cm non-vegetated vertical accuracy and 15.87cm vegetated vertical accuracy (https://www.fisheries.noaa.gov/inport/item/69038). Both datasets were merged to the larger pixel size (1m) and exported as a new DEM, then clipped to shape of the ANERR (Figure 2). Slope was derived from this DEM for the SLAMM inputs in a GIS framework.

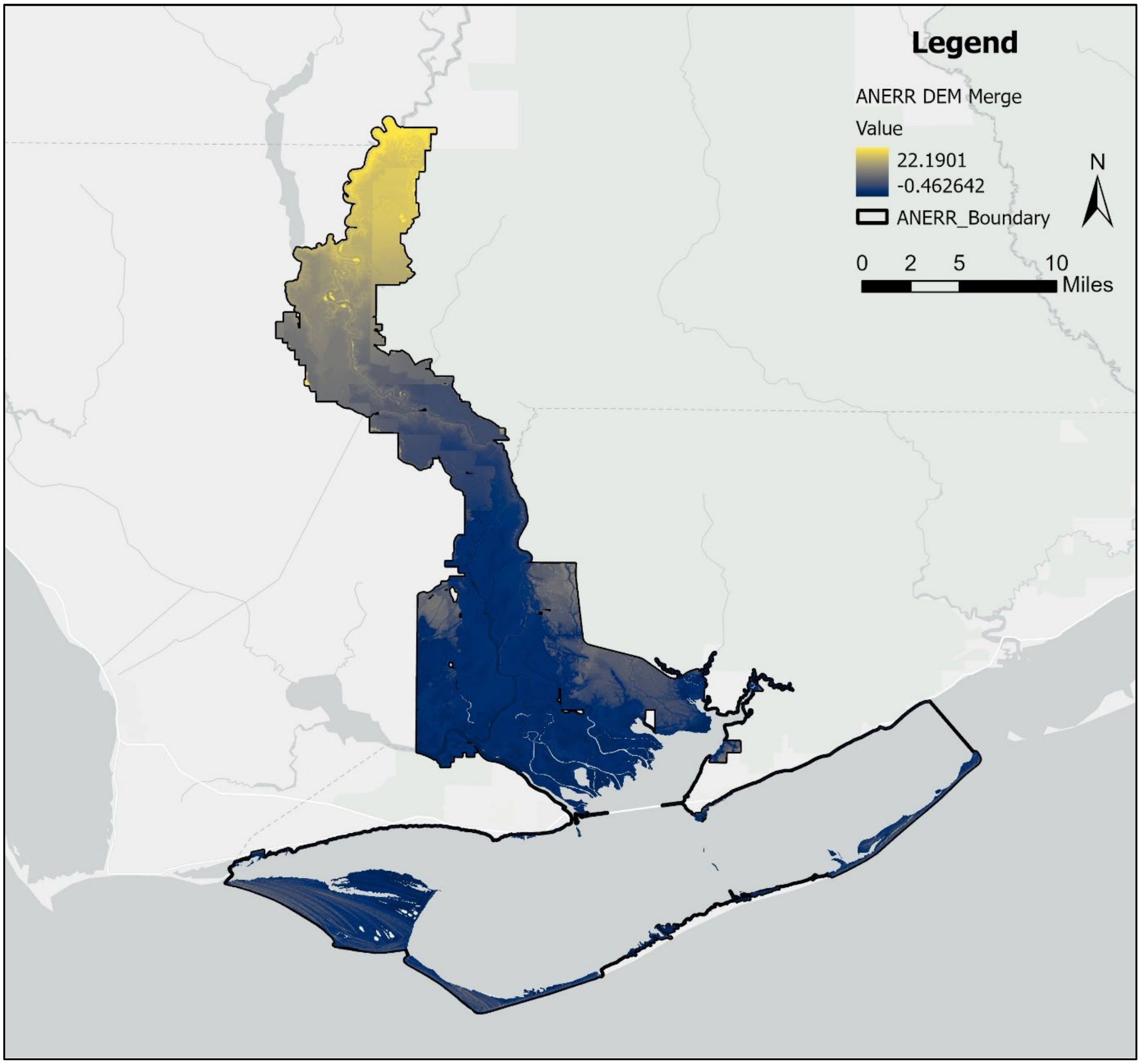

Figure 2. Merged DEM using vegetation corrected DEM for the Apalachee Bay and LiDAR from 2020 for the northern portion of the NERR.

The NWI code definitions are located at the National Wetlands Inventory website or from the SLAMM documentation package found on the Warren Pinnacle Consulting webpage. Since the NWI categories are essentially endless and may not always directly match one of the SLAMM categories, the SLAMM user does need to preform QAQC on each entry, as well as filling in many of the samples, especially if there are multiple NWI designations or modifiers, such as PABHh vs PABHx or PEM1/SS1C vs PEM1/SS3C. Just within the ANERR AOI there are 293 wetland categories for over 1,680 records, illustrating the importance of the SLAMM NWI code conversion; without it, the SLAMM processing time would be significantly longer. Many of the parent attributes are modified in some way, so while the crosswalk and VLOOKUP functions are essential tools, they cannot be relied upon exclusively.

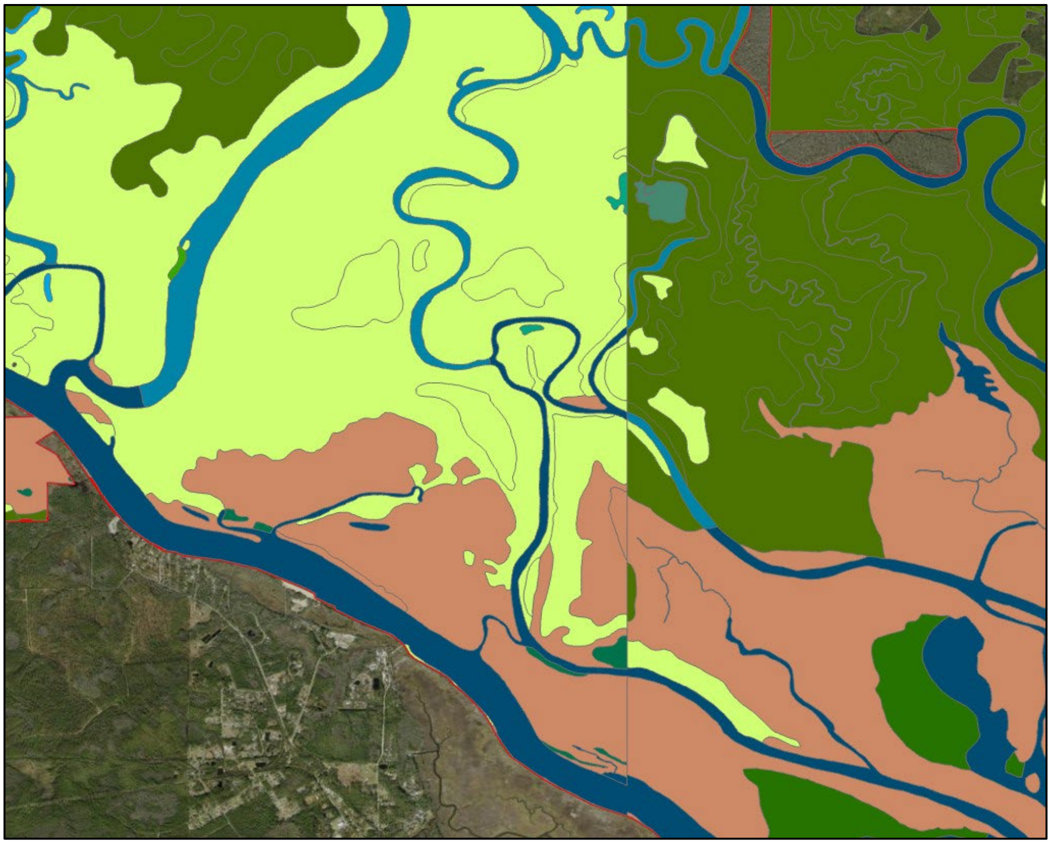

Figure 3. One example of a slight inconsistency in NWI data with implications for the model. Bright green is listed as PFO1R (Freshwater Forested/Shrub Wetland, SLAMM Code 23: Tidal Swamp) and dark green is listed as PFO1E (Freshwater Forested/Shrub Wetland, SLAMM

I must note that some inconsistencies were visible in some sections of the NWI dataset (Figure 3)—perhaps these are from property boundaries, or an averaging of results between survey tracts, or results from other unknown variables, but I did not change or “smooth” any results from the NWI dataset for input into the model, and used what was reported in the raw dataset. The notable implication is that some of the “Freshwater Forested/Shrub Wetland” NWI categories can be translated into either a tidal swamp (SLAMM Code 23) or as a swamp (SLAMM Code 3). Further, because a tidal swamp is “a dense forest occurring along relatively flat, low wave energy, marine and estuarine shorelines. The dominant plants of tidal swamp are red mangrove (Rhizophora mangle), black mangrove (Avicennia germinans), white mangrove (Laguncularia racemosa), and buttonwood (Conocarpus erectus)” (Florida Natural Areas Inventory 2009) it is at increased risk for wetland reallocation and deleterious effects from sea level rise. The subtle but important difference between a tidal swamp and a swamp is reflected in SLAMM results.

Visuals of the three inputs are presented below in Figure 4. The overall key to preparing data for the model is to ensure that all cell sizes and projections are the same. These steps can be streamlined by setting the environments of the map before importing any data, or just after importing the DEM. All data, whether processed in R or ArcGIS is exported as an ascii file prior to importation into SLAMM. Exported files may be in ascii, csv, or shp file formats, depending on user preference.

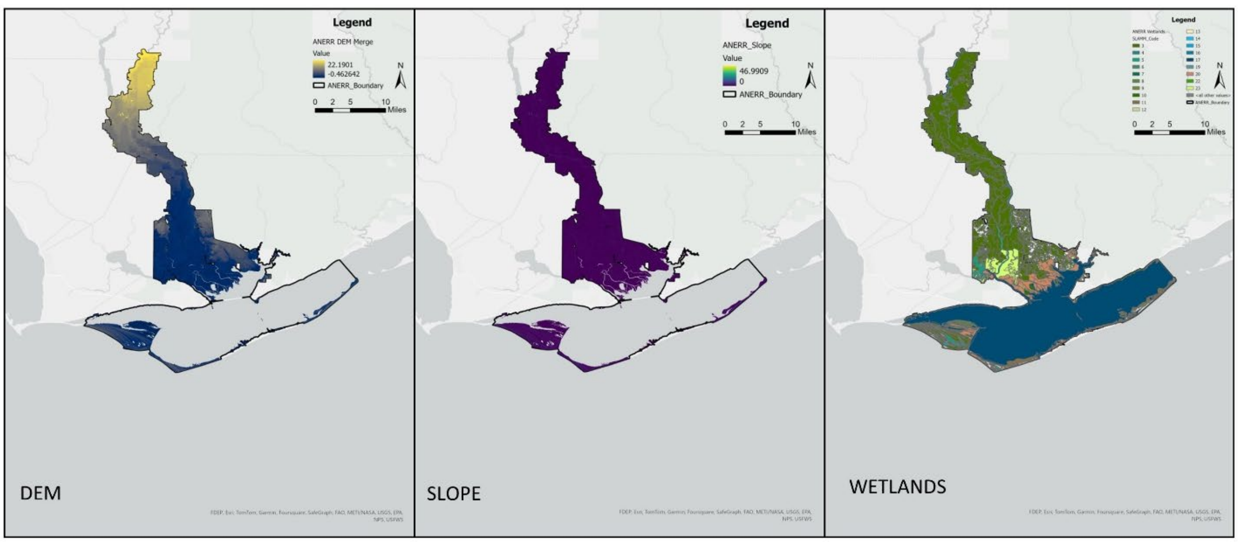

Figure 4. Input DEM, Slope, and NWI datasets.

Some of the NWI/SLAMM categories are not included in this study, such as ocean flats or rocky intertidal zones because they do not exist this this area, to the author's knowledge. Table 2 presents the SLAMM code and category, as well as the NWI description (adapted from http://www.basic.ncsu.edu/dsl/slr.html).

After preparing the raw data for the SLAMM interface but before running the model itself, the user has a series of options to enter site- or region-specific data (Table 3). The majority of site parameters were derived from NOAA's Tides and Currents site using the Apalachicola River Datum (8728711) was used to obtain mean tidal levels and the Apalachicola, Florida Datum (8728690) was used to obtain sea level trends (Figure 6). The NOAA VDATUM product was used for vertical datum corrections. When unavailable directly from NOAA, additional parameters were derived from Passeri et al. (2016), Hovenga et al. (2016), Krebs et al (2023), Darst and Light (2008), Elder et al. (1988), Edmiston (2008), Windom and Palmer (2023), and Alizad et al. (2016, 2018). Hurricane inundation data in m above mean tidal levels were derived from FEMA's National Flood Hazard Layer. When data parameters were unavailable, I defaulted to the pre-programmed values in SLAMM, listed in the Technical Document.

Table 2. NWI Classes to SLAMM Categories

		NWI code characters					
SLAMM Code	Name	System	Subsystem	Class	Subclass	Water Regime	Notes
1	Developed Dry Land (upland)	U					SLAMM assumes developed land will be defended against sea-level rise. Categories 1 & 2 need to be distinguished manually.
2	Undeveloped Dry land (upland)	U					
3	Nontidal Swamp	P	NA	FO, SS	1, 3 to 7, None	A,B,C,E,F,G,H,J,K None or U	Palustrine Forested and Scrub-Shrub (living or dead)
4	Cypress Swamp	P	NA	FO, SS	2	A,B,C,E,F,G,H,J,K None or U	Needle-leaved Deciduous forest and Scrub-Shrub (living or dead)
5	Inland Fresh Marsh	P	NA	EM, **f****	All None	A,B,C,E,F,G,H,J,K None or U	Palustrine Emergents; Lacustrine and Riverine Nonpersistent Emergents
		L	2	EM	2 None	E, F, G, H, K None or U	
		R	2, 3	EM	2 None	E, F, G, H, K None or U	
6	Tidal Fresh Marsh	R	1	EM	2, None	Fresh Tidal N, T	Riverine and Palustrine Freshwater Tidal Emergents
		P	NA	EM	All, None	Fresh Tidal S, R, T	
7	Transitional Marsh / Scrub Shrub	E	2	SS, FO	1, 2, 4 to 7,None	Tidal M, N, P None or U	Estuarine Intertidal, Scrub-shrub and Forested (ALL except 3 subclass)
8	Regularly Flooded Marsh (Saltmarsh)	E	2	EM	1 None	Tidal N None or U	Only regularly flooded tidal marsh No intermittently flooded "P" water Regime
9	Mangrove **Tropical settings only, otherwise 7**	E	2	FO, SS	3	Tidal M, N, P None or U	Estuarine Intertidal Forested and Scrub-shrub, Broad-leaved Evergreen
10	Estuarine Beach old code BB and FL = US	E	2	US	1,2 Important codes	Tidal N, P	Estuarine Intertidal Unconsolidated Shores
		E	**2**	**US**	**None**	**Tidal N, P**	**Only when shores (need images or base map)**
11	Tidal Flat old code BB and FL =US	E	2	US	3,4 None	Tidal M, N None or U	Estuarine Intertidal Unconsolidated Shore (mud or organic) and Aquatic Bed; Marine Intertidal Aquatic Bed
		E	2	AB	All Except 1	Tidal M, N None or U	
		E	**2**	**AB**	**1**	**P**	**Specifically, for wind driven tides on the south coast of TX**
		M	2	AB	1, 3 None	Tidal M, N None or U	
12	Ocean Beach old code BB and FL = US	M	2	US	1,2 Important	Tidal N, P	Marine Intertidal Unconsolidated Shore, cobble-gravel, sand
		M	2	US	None	Tidal P	
13	Ocean Flat old code BB and FL = US	M	2	US	3,4 None	Tidal M, N None or U	Marine Intertidal Unconsolidated Shore, mud or organic, (low energy coastline)

Table 2 (cont'd). NWI Classes to SLAMM Categories

		NWI code characters					
SLAMM Code	Name	System	Subsystem	Class	Subclass	Water Regime	Notes
14	Rocky Intertidal	M	2	RS	All None	Tidal M, N, P None or U	Marine and Estuarine Intertidal Rocky Shore and Reef
		E	2	RS	All None	Tidal M ,N, P None or U	
		E	2	RF	2, 3 None	Tidal M, N, P None or U	
		E	2	AB	1	Tidal M, N None or U	
15	Inland Open Water old code OW = UB	R	2	UB, AB	All, None	All, None	Riverine, Lacustrine, and Palustrine Unconsolidated Bottom, and Aquatic Beds
		R	3	UB, AB, RB	All, None	All, None	
		L	1, 2	UB, AB, RB	All, None	All, None	
		P	NA	UB, AB, RB	All, None	All, None	
		R	5	UB	All	Only U	
16	Riverine Tidal Open Water old code OW = UB	R	1	All **Except EM**	All None **Except 2**	Fresh Tidal S, R, T, V	Riverine Tidal Open water **R1EM2 falls under SLAMM Category 6**
17	Estuarine Open Water (no h* for diked / impounded) old code OW=UB	E	1	All	All None	Tidal L, **M**, N, P	Estuarine subtidal
18	Tidal Creek	E	2	SB	All, None	Tidal **M**, N, P Fresh Tidal R, S	Estuarine Intertidal Streambed
19	Open Ocean old code OW = UB	M	1	All	All	Tidal L, **M**, N, P	Marine Subtidal and Marine Intertidal Aquatic Bed and Reef
		M	2	RF	1,3, None	Tidal M, N, P None or U	
20	Irregularly Flooded Marsh	E	2	EM	1, 5 None	P	Irregularly Flooded Estuarine Intertidal Emergent marsh
		E	**2**	**US**	**2, 3, 4 None**	**P**	**Only when these salt pans are associated with E2EMN or P**
21	Not Used						
22	Inland Shore old code BB and FL = US	L	2	US, RS	All	All Nontidal	Shoreline not pre-processed using Tidal Range Elevations
		P	NA	US	All, None	All Nontidal None or U	
		R	2, 3	US, RS	All, None	All Nontidal None or U	
		R	4	SB	All, None	All Nontidal None or U	
23	Tidal Swamp	P	NA	SS, FO	All, None	Fresh Tidal R, S, T	Tidally influenced swamp

* **h=Diked/Impounded** - When it is desirable to model the protective effects of dikes, an additional raster layer must be specified.

** Farmed wetlands are coded Pf
All: valid components
None: no Subclass or Water regime listed
U: Unknown water regime
NA: Not applicable

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Water Regimes	
Nontidal	A, B, C, E, F,G, J, K
Saltwater Tidal	L, M, N, P
Fresh Tidal	R, S,T, V

Note: Illegal codes must be categorize by intent.
Old codes BB, FL = US
Old Code OW = UB

Source, Bill Wilen, National Wetlands Inventory

For more information on the NWI coding system see Appendix A of Dahl et al 2009.

Table 3. Site Parameters to Inform SLAMM

Parameter	Global
Description	
NWI Photo Date (YYYY)	0
DEM Date (YYYY)	2020
Direction Offshore [n,s,e,w]	North
Historic Trend (mm/yr)	3.02
Historic Eustatic Trend (mm/yr)	0
MTL-NAVD88 (m)	0.37
GT Great Diurnal Tide Range (m)	1.36
Salt Elev. (m above MTL)	1
Marsh Erosion (horz. m /yr)	0.04
Marsh Erosion Fetch (km)	0.76
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	1.4
Reg.-Flood Marsh Accr (mm/yr)	1.5
Irreg.-Flood Marsh Accr (mm/yr)	4
Tidal-Fresh Marsh Accr (mm/yr)	3
Inland-Fresh Marsh Accr (mm/yr)	1
Mangrove Accr (mm/yr)	0.5
Tidal Swamp Accr (mm/yr)	1.8
Swamp Accretion (mm/yr)	2.5
Beach Sed. Rate (mm/yr)	1
Irreg-Flood Collapse (m)	0
Reg-Flood Collapse (m)	0
Use Wave Erosion Model [True,False]	True
Use Elev Pre-processor [True,False]	False
H1 inundation (m above MTL)	0.01
H2 inundation (m above MTL; H2>H1)	0.041
H3 inundation (m above MTL: H3>H2)	0.51
H4 inundation (m above MTL; H4>H3)	2.042
H5 inundation (m above MTL; H5>H4)	3.5616

Archaeological Triage Assessment (ATA)

After SLAMM outputs were calculated, an Archaeological Triage Assessment (ATA) was conducted to determine which known cultural heritage sites are likely to be threatened, damaged, destroyed, or experience no impacts by climate changes. These calculations are only estimates, and only take into account gradual change over time rather than events such as storm surge, extreme tides, or storm events. Future research should combine relevant ecological, environmental, and archaeological literature to better refine the impact of specific impacts from wetland category shifts to archaeological sites. After the colormap was updated, each raster was converted to a polygon to increase functionality for future statistical testing. Notably, I chose to simplify polygons within each shapefile to take into consideration the imperfect nature of SLAMM. Although SLAMM was conducted at a sub-5 meter cell size, that does not mean that the estimates created by the program are going to occur at a 5 meter interval. Some archaeological sites are smaller than 5 or 10 meters, and by simplifying the polygons for the ATA segment of this study, it is my hope to communicate the imprecise nature of modeling programs.

Table 5. NWI Category Conversions to the Archaeological Triage Assessment. Threat assessments are based on the anticipated damaged to cultural heritage sites that lie within each of the 22 NWI categories. Once a site is fully underwater it is assumed destroyed; a site within an area susceptible to flooding or significant storm surge is considered threatened; sites on dry land are expected to sustain no to minimal impacts from that wetland category type.

SLAMM Category		**NWI Category**	**Archaeological Triage Assessment**
1		developed dry land	no impacts
2		undeveloped dry land	no impacts
3		nontidal swamp	threatened
4		cypress swamp	destroyed
5		inland fresh marsh	threatened
6		tidal fresh marsh	damaged
7		transitional marsh scrub shrub	threatened
8		regularly flooded saltmarsh	damaged
9		mangrove	damaged
10		estuarine beach	damaged
11		tidal flat	destroyed
12		ocean beach	damaged

13		ocean flat	damaged
14		rocky intertidal	damaged
15		inland open water	destroyed
16		riverine tidal open water	destroyed
17		estuarine open water	destroyed
18		tidal creek	destroyed
19		open ocean	destroyed
20		brackish irregularly flooded marsh	damaged
22		inland shore	destroyed
23		tidal swamp	destroyed

Next, site polygons of the priority sites (n=9) were converted to points. An intersecting spatial join was preformed between the site point data and ATA models for the years 2025, 2050, 2075, and 2100 to determine which known archaeological sites are likely to be threatened, damaged, or destroyed based on the ATA using SLAMM input data. Summary statistics were obtained from the "gridcode" attribute and exported into a standalone table. Numbers of sites per gridcode or ATA category were input by hand into an excel file that summarizes findings between years, and then site polygons were reestablished.

Results

The following section discusses results from SLAMM outputs of the estimated wetland category changes that result in long-term sea-level rise. A benefit of SLAMM are the large outputs of raw data, which are all included in the attached data package. All excel charts of processed data were created with formulas that can be simply copy and pasted to further process any additional data beyond what is included here.

I was admittedly surprised by the results of the SLAMM outputs, as they seem to indicate that even in the most conservative estimate of global sea level rise that result in a 1m local SLR, the vast majority of the ANERR will be a regularly flooded marsh by 2050 (Figure 5). In more extreme scenarios that do reflect the current RCP estimates from the IPCC, a 1.5m or 2m SLR, the majority of the ANERR will be some sort of transitional marsh by 2050 and open water by 2100. These results correspond to the NOAA Sea Level Rise map viewer for a 1, 1.5, and 2m SLR for intermediate high and high SLR projections (Figure 5), SLOSH inundation patterns (Figure 6), and trajectories in Alizad et al. (2016, 2018, 2020) and Garwood et al. (2023).

This figure contained sensitive archaeological information and was redacted from this version of this report. For access to the original image, please contact Nicole Grinnan, Assistant Director, Archaeology Institute, University of West Florida, Email: ngrinnan@uwf.edu.

Figure 5. Results of SLAMM (top) and ATA (bottom) for 1m SLR at a 25-year time increment.

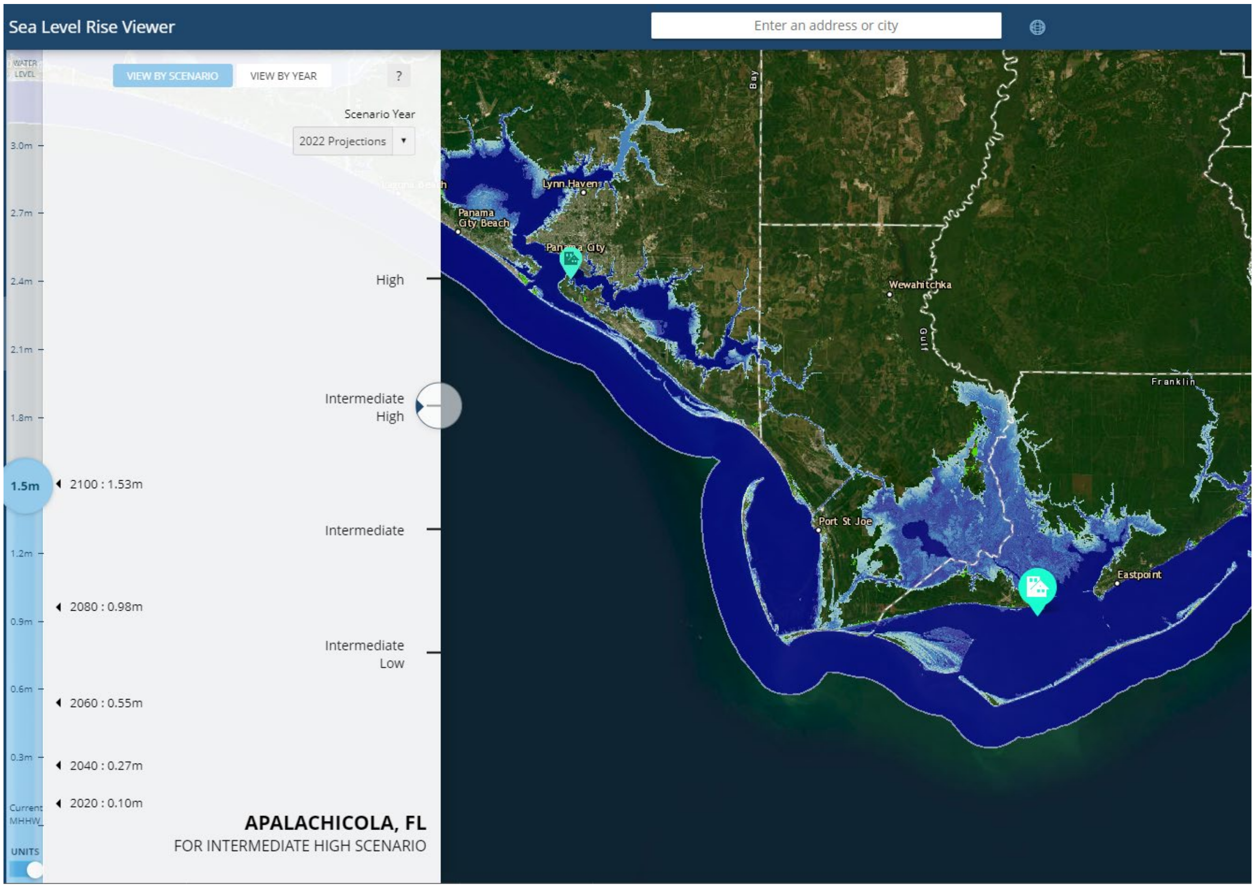

Figure 6. NOAA SLR Viewer, Intermediate High scenario, 1.5m water level.

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Figure 7. SLOSH Cat 1 Hurricane Inundation Estimates

Archaeological Triage Assessment Results

The Archaeological Triage Assessment results (Table 4) indicate that few of the 145 archaeological sites within the study area are not likely to be threatened, damaged, or destroyed by 2100 due to shifting wetland categories because of climate change. All image series are included in attached layer packages. For the years 2025, 2050, 2075, and 2100, categories that indicate likely destruction or are open water (SLAMM Categories 4, 11, 15, 16, 17, 19, 22, 23), a new shapefile can be created using the SQL expression is included in this data package as ATA_SLAMM_Buffer.exp. The code simply selects all polygons that are of the eight categories that are most likely to destroy an archaeological site. After those polygons are selected, export features to create a new polygon shapefile of the most threatened areas.

Discussion and Recommendations

The major changes illustrated in the above SLAMM images between 2025-2100 are the drastic increases of open water moving north up the Apalachicola River and washing into the marshes. According to the SLAMM outputs, the majority of the ANERR will transition to regularly flooded salt marsh by 2050, tidal flats by 2075, and estuarine open water by 2100 with a 1m SLR, including the destruction of all nine priority cultural resources Figure 7.

This figure contained sensitive archaeological information and was redacted from this version of this report. For access to the original image, please contact Nicole Grinnan, Assistant Director, Archaeology Institute, University of West Florida, Email: ngrinnan@uwf.edu.

Figure 8. Anticipated environmental change by 2050 given a 1m SLR scenario. Priority cultural resources are circled in yellow with a red mesh.

Landscapes change. The landscape of ANERR will continue to change, but at an increasing rate as waters warm, shorelines migrate, and storms continue to strengthen. While beach accretion and migration are part of the natural system, we can anticipate many upcoming changes to this estuarine and marsh system. One major upside is the incredible volume of excellent research that has been conducted in the ANERR—people have been asking questions about the properties of the Apalachicola system for decades, providing more information than is typical of an at-risk area, especially one as critical for archaeological and cultural resources as here.

All associated data has been packaged and delivered with this report including: (1) raw input data; (2) SLAMM output; (3) SLAMM organized by year in 25-year increments; (4) project area; (5) SLAMM data organized by areas with the most rapid change; (6) archaeological triage assessment shapefiles and excel tables; (7) archaeological triage assessment calculations as shapefiles.

Conclusions

The major impact of climate changes is not the final product of change; rather, it is what happens during the periods of environmental and biotic change that these coastal archaeological resources are subjected to. Though rising water levels are the fundamental threat to archaeological sites and other above-ground cultural resources, the majority of effects to archaeological sites come from wetland reallocation and shoreline erosion. Archaeological sites, if they were in a vacuum, may persist perfectly well during a transition from undeveloped dry land to a transitional marsh. However, it is the ebb and flow of tides, the shoreline changes, the death of old growth forest and rebirth of secondary scrub that are the most deleterious to fragile resources. It is the context in which the contents of a site are found, not simply the materials representative of a small part of past cultures that answer the most questions about our collective human past [22–26]. The first step to protecting our cultural heritage is knowing *when* coastal managers need to deploy conservation and mitigation efforts. An accurate timeline of site-specific climate impacts is essential to create an effective planning system.

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