Marine Vulnerability Assessment of Cumberland Island National Seashore:
Determining the Vulnerability of Marine Habitats to Climate Change Stressors

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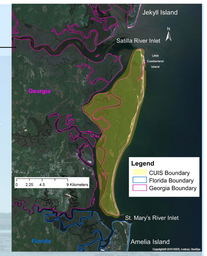
Introduction & Purpose



PRIMARY GOAL
The goal of this project is to develop a methodology framework for assessing the vulnerability of NPS-managed marine habitats, beginning with a pilot project at Cumberland Island National Seashore (CUIS). This framework employs an assessment approach in which vulnerability is defined as the sum of exposure (the magnitude of the stressor), sensitivity (how strongly a system is affected by the stressor), & adaptive capacity (the potential to adjust in response to the stressor).

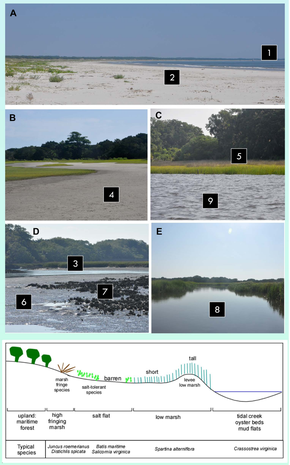
WHY?
The impacts of climate change resulting from elevated levels of atmospheric carbon & manifested primarily through increasing global temperatures are affecting coastal & marine habitats & are anticipated to become more significant in the coming decades. Sea-level rise (SLR) & changes in ocean chemistry make coastal habitats among the most vulnerable. NPS, managing almost 12,000 km of shoreline, has an urgent need to better understand, characterize, & forecast the effects of climate change for mitigation & management purposes.

WHAT?
9 marine-influenced habitats within CUIS (see below) were identified, delineated & assessed for their vulnerability to 4 climate change-related stressors: SLR, temperature change, salinity change, & ocean acidification. For each habitat-stressor combination, exposure, sensitivity, & adaptive capacity were rated on a qualitative scale of low-medium-high. The key objective of this study was to assess the vulnerability of marine-influenced habitats at CUIS to climate change stressors, using existing literature, data & research, & to establish a protocol & methodology for these types of vulnerability assessments.

Marine Habitats of Interest

Nine marine habitats/environments of interest were defined for CUIS. These environments include only those within the intertidal & subtidal zones surrounding the island.

Habitat	Basic Description	Common Organisms
1. Marine Nearshore Subtidal (MNS)	below lowest tide in Atlantic Ocean	fish, shellfish
2. Intertidal Beach	sandy beach zone, between high & low tide	crabs, snails, shorebirds
3. Low Salt Marsh	low elevation salt marsh, daily inundation	cordgrass, crabs, snails
4. Salt Flats	barren zone between high & low marsh, high pore salinity	some salt tolerant plants (salt grass, spike grass), crabs, snails
5. High Fringing Salt Marsh (HFSM)	higher elevation marsh, less frequent inundation	black needlerush, some salt tolerant plants, crabs, snails
6. Tidal Mud Flats	muddy area below salt marsh, lower intertidal zone	crabs, snails, wading birds
7. Shellfish Beds	hard substrate formed primarily by oysters, in tidal creeks/ estuary	eastern oyster (*Crassostrea virginica*), mussels
8. Tidal Creeks	tidal portion of the creeks on estuarine side of island	fish, shellfish, bottlenose dolphin
9. Estuarine Nearshore Subtidal (ENS)	deeper tidal creeks, estuary/sound (Cumberland Sound)	fish, bottlenose dolphin



Climate Change Stressors of Interest

Stress resulting from a rapidly changing climate is likely to be greater along the coast due to the added impact of SLR on marine habitats & organisms. Although different climate change-related stressors will pose a variety of threats to marine-influenced habitats within coastal NPS units, the 4 most substantial climate stressors were defined for this study.

1. Sea-Level Rise (SLR)
2. Ocean Acidification (OA)
3. Temperature Change
4. Salinity Change

Marine Habitat GIS Delineation

o Over half (55%) of the land area at CUIS is comprised of marine/estuarine intertidal & subtidal habitats.

o The intertidal & subtidal zones comprise approximately 32% & 23% of the total area of CUIS, respectively.

o Salt marsh habitat was most widespread of the delineated habitats, making up almost 1/2 of the total marine habitat area (9,250 acres, 46% of Marine Habitat).

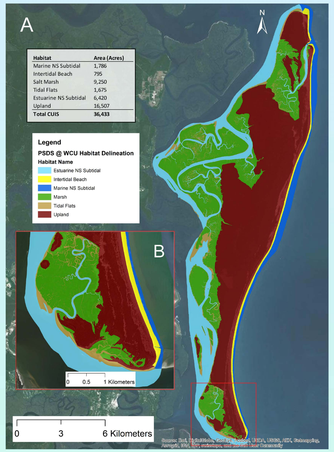
o Most salt marsh habitat is likely low marsh, comprised primarily of *Spartina alterniflora*. We estimate (from aerial analysis & field study) that HFSM & salt flats habitats comprise < 20% of the total salt marsh GIS category.

Combined habitats of interest delineated using GIS methods

GIS Delineation Habitat Name	Original Habitats of Interest Name
Marine Nearshore Subtidal	Marine Nearshore Subtidal
Intertidal Beach	Intertidal Beach
Salt Marsh	Low Salt Marsh + Fringing High Marsh + Salt Flats
Tidal Flats	Tidal Creeks + Tidal Mud Flats + Oyster Reefs
Estuarine Nearshore Subtidal	Estuarine Nearshore Subtidal

Percentage of each habitat delineated for CUIS using GIS.

Habitat Name	Area (acres)	% of Marine Habitat	% of CUIS
Marine Nearshore Subtidal	1,786	9%	5%
Intertidal Beach	795	4%	2%
Salt Marsh	9,250	46%	25%
Tidal Flats	1,675	8%	5%
Estuarine Nearshore Subtidal	6,420	32%	18%
Marine Habitat Totals	19,926	100%	55%
Upland	16,507	n/a	45%
CUIS Totals	36,433	n/a	100%



Climate Change Vulnerability Assessment

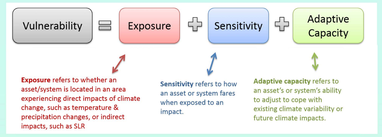
o Qualitative scores were given for the metrics of vulnerability for each stressor-habitat combination. This assessment was focused on current & short term (decadal scale) climate change vulnerability.

o This study was not meant to provide the vulnerability of these marine habitats over the long term (century scale) or during extreme or rapid stressor change scenarios.

o Most of the habitats at CUIS have a relatively high physical adaptive capacity to gradual changes, especially to SLR. *Results would change with a rapid shift in the direction/magnitude of the stressors.

o Sensitivity & adaptive capacity values reference the current rate (or amount) of change for each stressor, or changes expected in the near future.

o The physical or intrinsic adaptive capacity (e.g., the ability of a habitat to migrate) was the primary consideration for the adaptive capacity scores.



Vulnerability Scoring Framework

A simple qualitative scale (1 = low, 2 = medium, 3 = high) was used to score each metric of vulnerability for all habitat-stressor combinations. Values were summed for each stressor & possible outcomes range between 3 & 9, with total stressor vulnerability rankings as follows:

- 3 or 4 = low vulnerability
- 5 = moderate-low vulnerability
- 6 = moderate vulnerability
- 7 = moderate-high vulnerability
- 8 or 9 = high vulnerability

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Results: Metrics of Vulnerability & Climate Change Stressors

Example of raw scores for metrics of vulnerability (exposure, sensitivity, & adaptive capacity) for each of the climate change stressors. Also included are total non-weighted vulnerability scores.

Vulnerability Metric	High Fringing Salt Marsh (HFSM) — Climate Stressor			
	SLR	OA	Salinity	Temp.
Exposure	high (3)***	low (1)***	moderate (2)***	moderate (2)***
Sensitivity	high (3) **	low (1)*	moderate (2) **	low (1) **
Adaptive Capacity	moderate (2)**	moderate (2)*	moderate (2) **	high (1)**
Total	high (8)	low (4)	moderate (6)	low (4)

Confidence level for each score is assigned using number of asterisks (1 = lowest confidence, 3 = highest confidence).

Example of stressor-specific results. SLR vulnerability for all habitats of interest at CUIS, sorted by total score.

Habitat	Metrics of Vulnerability: Exposure (1=low)	Sensitivity (1= low)	AC (1=high)	SLR Total Score
HFSM	3	3	2	8
Low Salt Marsh	3	2	1	6
Tidal Mud Flats	3	2	1	6
Shellfish Beds	3	2	1	6
Salt Flats	3	2	1	6
Intertidal Beach	3	1	1	5
Tidal Creeks	3	1	1	5
MNS	3	1	1	5
ENS	3	1	1	5

Major Findings

o SLR is likely the most significant climate-related stressor at CUIS (currently).

o Results for combined stressor vulnerability show shellfish beds to be the most vulnerable habitat at CUIS. This habitat is highly exposed to all stressors except OA & is moderately sensitive to all stressors.

o HFSM is *potentially* the most vulnerable habitat considering SLR is the most significant stressor at CUIS. This habitat is limited in area & confined to more specific conditions. Migration is also partially hindered by terrestrial habitat. Changes in salinity & sea level would likely reduce the overall suitability for the growth of HFSM species (i.e., *Juncus roemerianus*) as well as increase competition, particularly with the ubiquitous low marsh species *Spartina alterniflora*.

o MNS & intertidal beach habitats are most vulnerable to OA since they are highly exposed to, & directly influenced by, this stressor.

o Salt flats are most vulnerable to salinity change as the vegetation in this zone is dependent on high interstitial salinity.

o Tidal creeks & ENS zones are most vulnerable to temperature change due to existing problems with high summer water temperatures leading to low dissolved oxygen. ENS habitat is likely more vulnerable to temperature, as it already experiences issues with this stressor.

o Interactions between the climate change stressors of interest (as well as other climate & non-climate threats) are inevitable, but are hard to predict. SLR & salinity are two stressors that have a clear link. With increased SLR, salinity will also increase in most of the marine-influenced environments at CUIS.

o Not only should the physical or intrinsic adaptive capacity be considered, but also the extrinsic or "management-based" adaptive capacity. The adaptation strategies for some stressors may limit or enhance the overall adaptive capacity of a habitat.

o The confidence level for the metric of vulnerability scores can be used to help focus resources for adaptation strategies within CUIS. Vulnerable habitats with a high confidence level are a reasonable place to start adaptation planning.

Combined climate change stressor vulnerability scores & ranking of habitats at CUIS. Red & orange colors represent the highest ranked habitats for combined vulnerability; yellow is moderate; green & blue represent the lowest.

Habitat	Stressor	Raw Scores: Exposure (1=low)	Sensitivity (1= low)	Adaptive Capacity (1=high)	Totals: Totals for Each Stressor	Total Score All Stressors	Overall Habitat Vulnerability Rank (1=highest)
Marine Nearshore Subtidal	SLR	3	1	1	5	21	3
	OA	3	2	2	7		
	Salinity	1	2	2	5		
	Temp.	1	2	1	4		
Intertidal Beach	SLR	3	1	1	5	21	3
	OA	3	2	2	7		
	Salinity	1	2	2	5		
	Temp.	2	1	1	4		
Low Salt Marsh	SLR	3	2	1	6	20	4
	OA	1	1	1	3		
	Salinity	3	1	2	6		
	Temp.	3	1	1	5		
Salt Flats	SLR	3	2	1	6	22	2
	OA	1	1	2	4		
	Salinity	2	3	2	7		
	Temp.	2	1	2	5		
High Fringing Salt Marsh	SLR	3	3	2	8	22	2
	OA	1	1	2	4		
	Salinity	2	2	2	6		
	Temp.	2	1	1	4		
Tidal Mud Flats	SLR	3	2	1	6	19	5
	OA	1	1	1	3		
	Salinity	3	1	1	5		
	Temp.	3	1	1	5		
Shellfish Beds	SLR	3	2	1	6	23	1
	OA	1	2	2	5		
	Salinity	3	2	1	6		
	Temp.	3	2	1	6		
Tidal Creeks	SLR	3	1	1	5	21	3
	OA	2	1	1	4		
	Salinity	3	1	1	5		
	Temp.	3	2	2	7		
Estuarine Nearshore Subtidal	SLR	3	1	1	5	21	3
	OA	2	1	1	4		
	Salinity	3	1	1	5		
	Temp.	3	2	2	7		

Western Carolina University





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