

Case Study: Chase Cove, Warren, RI

Habitat Description

The approximately 13 acre salt marsh is a component of the Touisset Marsh Wildlife Refuge, a 66 acre property protected and managed by the Audubon Society of Rhode Island. Located at the terminal end of Chase Cove on the Kickemuit River, it is bounded by managed upland fields and wooded habitat within a rural setting with limited access (via boat and hiking trail).



The overall condition of tidal salt marsh within the State of Rhode Island is considered poor (as evidenced by the frequent and wide-spread formation of anoxic pools deteriorating high marsh) with an overall high degree of threat (rank=3). Threats to the unique vegetation communities (e.g. low salt marsh, high salt marsh, salt panne, salt scrub) that comprise this habitat include: habitat shifting and alteration, invasive non-native /alien species, household sewage and urban waste water, housing and urban areas, and recreational activities (RI DEM 2015).

Assessment Period

The team considered an array of time frames for this assessment and opted for an end period of 2050. They felt this would give an appropriate long-term view for making current and near-term management decisions and current models predicting the expected change in environmental conditions were available for this end date. The assumed change in environmental condition for the assessment period included an increase in temperature and precipitation, with a general shift toward greater winter precipitation and more frequent extreme precipitation events (see Appendix), as well as a two foot increase in sea level.

Site Stressors and Characteristics Summary

- Part of it is tidally restricted
- Ditched
- Buffered by red maple swamp and agricultural parcel/restoration site
- High edge erosion
- *Phragmites australis* present
- Stone wall
- Higher tide range (Upper Bay)
- Area for migration potential exists

Final Scores:

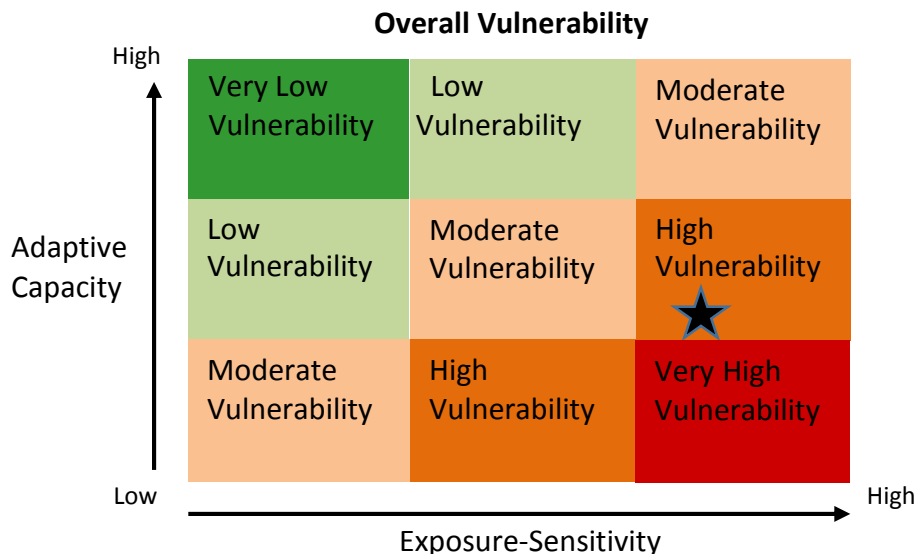
Exposure-sensitivity = 59.5

Adaptive Capacity = 10.0

Certainty = 2.0

Scoring Summary

HIGH exposure-sensitivity,
MODERATE adaptive capacity,
HIGH overall vulnerability.



The marsh at Chase Cove is split into two general areas with tidal restrictions occurring in the northern portion resulting in a less impacted state currently than the tidally exposed area to the south. The tidal restriction may actually continue to provide benefit in the short term but altered precipitation patterns could exacerbate ponding and result in greater shifts in vegetation. There is potentially greater elevation capital at this site as a whole and its orientation relative to dominant wind directions makes this area less susceptible to extreme climate events. However, present degradation across the southern component of the marsh and anticipated degradation of the northern portion in future as the result of limited sediment supply, elevated nutrient input, and accelerated erosion rates associated with crab borrowing supports a high score for sensitivity-exposure.

The moderate adaptive capacity score reflects this site’s protected status and some limited capacity to migrate into adjacent protected areas (based primarily on the occurrence of forest cover which may impede migration and a modest elevation gradient which may permit migration along much of its boundary) as well as the institutional capacity to address changing conditions as necessary. However the score also reflects the lack of potential management actions possible given the isolated location and access constraints for many potential manipulations.

The overall vulnerability score is based on the relationship table above in which high scores for exposure-sensitivity and moderate scores for adaptive capacity place this site in one of two possible bins for high vulnerability. The overall high vulnerability score suggests that this site is highly susceptible to future climate and climate / non-climate stressor interactions but adaptive capacity components may mitigate some of the anticipated effects. Current limited to moderate degradation occurring at this site is expected to be further exacerbated by the anticipated change in environmental condition and, although adaptive capacity components may slow the progression, the Chase Cove salt marsh will likely experience a continued decline and/or displacement of habitat.

Assigned Scores

The assessment team collaborated to create and review a list of reference materials which they incorporated into a resource document designed to capture relevant information from assorted data sets, white papers and published journal articles. To simplify the scoring process, this resource document was then converted into a bulleted list of anticipated species and/or habitat responses to the anticipated change in condition. The notes provided below reflect both general discussion content from the bulleted list which, together with the original resource document and the CCVATCH Guidance document as necessary were used as the primary source of considerations when discussing score assignment (at left) as well as more specific discussion points and considerations related to this site, if applicable (at right). Inserted grey boxes reflect the outcome of early team discussions regarding specific site characteristics that would influence score assignment; if none exist, then scores were assigned consistently for all sites.

Direct Climate Effects	
<p>Current Condition:</p> <ul style="list-style-type: none"> • Range shifts, altered species composition • ↓ forb communities • ↓ high marsh • ↑ die-back • Declines in salt marsh extent since 1860s; loss rate over 40 years = 17.3% • Loss through: shoreline erosion, reduced bay head region (back-barrier lagoons & estuaries), widening & headward expansion of tidal channels (+ formation/expansion of interior ponds) <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p><i>Sites vary based on: presence/absence or extent of die-back areas; ratio of high/low marsh (or percent of transitional marsh communities); and/or extent of vegetation loss</i></p> </div>	<ul style="list-style-type: none"> • Increased erosion along bank • Vegetation shifts and some ponding in south; some vegetation shift north as well (↓ in high marsh, ↑ in dieback) <p style="text-align: right;">Assigned Score: 5 Certainty: 2.5</p>
<p>Increase in CO₂:</p> <ul style="list-style-type: none"> • No expected change to C4 plants but ↑ biomass in C3 plants (<i>Scirpus</i>, <i>Phrag</i>) • Root %N ↓ and C/N ↑ in <i>Scirpus</i> could decrease decomposition and increase peat formation <div style="border: 1px solid black; padding: 5px; margin-top: 10px; text-align: center;"> <p><i>Individual site response does not vary: Score = 0; Certainty = 4</i></p> </div>	<p style="text-align: right;">Assigned Score: 0 Certainty: 4</p>
<p>Increase in Temperature:</p> <ul style="list-style-type: none"> • Δ competitive interactions • ↑ marsh decomposition rates • ↓ organic matter accretion • ↓ forb pannes <div style="margin-left: 20px;"> <p>Note: Although it was agreed that vegetation community composition (specifically the presence/absence and extent of forb panne communities) could be reflected in a differential response between sites, the variation in marsh communities across the state is very modest and would likely not support different scoring.</p> </div>	<ul style="list-style-type: none"> • Soil compaction

<p style="text-align: center;"><i>Individual site response does not vary: Score = 2; Certainty = 3</i></p>	<p>Assigned Score: 2 Certainty: 3</p>
<p>Change in Precipitation:</p> <ul style="list-style-type: none"> • Seasonal Δ timing/duration influences salinity through salt H₂O intrusion • Changes in groundwater flow/level can impact marsh elevation • Δ precipitation = \downarrow productivity • C4 better competitors with frequent/more severe drought • \downarrow precipitation and drought have no significant impact on <i>S. patens</i> • Dieback \uparrow during drought? <p style="text-align: center;"><i>Sites vary based on: relative groundwater levels (potentially, although site specific data is not available); species composition (maybe)</i></p>	<ul style="list-style-type: none"> • Could exacerbate ponding • Tidal restriction (overland flow being restricted?) <p>Assigned Score: 3.4 Certainty: 2</p>
<p>Change in Sea Level:</p> <ul style="list-style-type: none"> • Effects species distribution (shift to more salt tolerant species) • \downarrow high marsh • \downarrow low sediment marshes • \uparrow inundation reduces below-ground biomass of <i>S. alterniflora</i> • \uparrow inundation drives vegetation loss (elevation as proxy for inundation accounts for 96% of var. in loss rates); elevation threshold for <i>S. patens</i> = 0.51mNAVD88 <p style="text-align: center;"><i>Sites vary based on: change in tidal range (using relative elevation as proxy)</i></p>	<ul style="list-style-type: none"> • Tidal restriction (could be a benefit in the short-term) • Potentially higher elevation capital • Not a major riverine system <p>Assigned Score: 7 Certainty: 3.5</p>
<p>Change in Extreme Climate Events:</p> <ul style="list-style-type: none"> • \uparrow extreme disturbance favors species that are 'colonizers' • Δ upland/marsh interface • \uparrow compression of marsh surface due to weight of storm surges • Δ plant communities • \uparrow debris <p style="text-align: center;"><i>Sites vary based on: differences in geomorphology (e.g. presence/absence of dunes, orientation relative to dominant wind direction, degree of fetch); proximity to rivers prone to flooding; adjacent land use</i></p>	<ul style="list-style-type: none"> • Orientation results in less susceptibility to extreme events <p>Assigned Score: 2 Certainty: 1.2</p>

Invasive / Nuisance Species	
<p>Current Condition:</p> <ul style="list-style-type: none"> • Many exotic grazers and predators are present and increasing (interactions with natives vary \pm) • Many anthropogenic impacts making things worse (e.g. eutrophication, overfishing, shoreline development) 	<ul style="list-style-type: none"> • Many fiddler crabs • Some <i>Phragmites australis</i>

<ul style="list-style-type: none"> • Range expansion by native plants, animals occurring (impacts debated ±) <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p><i>Sites vary based on: presence/absence/proximity of Phragmites; presence/abundance of crab herbivores (if/when data available); presence/absence/proximity of others (e.g. perennial pepperweed, purple loosestrife)</i></p> </div>	<ul style="list-style-type: none"> • Little bit of geese grazing <p>Assigned Score: 2 Certainty: 2</p>
<p>Increase in CO₂:</p> <ul style="list-style-type: none"> • ↑ could enhance fitness of many marsh invasives (e.g. <i>Phragmites</i>) as well as some natives (e.g. poison ivy) • <i>Phragmites</i> does better with salt stress with ↑ CO₂ and ↑ temperature • Reduction in %N of <i>Scirpus</i> shoots results in an increase in green tissue C/N (may effect herbivore preferences and feeding rates); not true of C4 grasses (<i>S. patens</i>, <i>D. spicata</i>) <p>Note: Response of <i>Phragmites</i> to both elevated CO₂ and temperature should only be considered once (do not double-count impact under both stressors)</p> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p><i>Individual site response varies only by presence/absence/proximity of invasives: If absent – Score = 0; Certainty = 1</i></p> </div>	<ul style="list-style-type: none"> • Not much <i>Phragmites</i>, isn't currently increasing <p>Assigned Score: 1.6 Certainty: 2.2</p>
<p>Increase in Temperature:</p> <ul style="list-style-type: none"> • ↑ temperature and CO₂ may make <i>Phragmites</i> more tolerant of salt stress • C4 plants more resistant to <i>Phragmites</i> encroachment • ↑ temperature may encourage range expansion of southern species (animals <u>quicker</u>, plants) • Impacts of both natural and facilitated expansion debated • Facilitates <i>Phragmites</i> encroachment (with elevated CO₂) <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p><i>Individual site response varies only by presence/absence/proximity of invasives: If absent – Score = 0; Certainty = 1</i></p> </div>	<p>Assigned Score: 1 Certainty: 1</p>
<p>Change in Precipitation:</p> <ul style="list-style-type: none"> • May cause species, currently limited by seasonal flooding, to spread • Plants and animals vulnerable to flooding may experience negative impacts • Multiple stressors (abiotic + biotic) may act synergistically with ↑ precipitation <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p><i>Individual site response varies only by presence/absence/proximity of invasives: If absent – Score = 0; Certainty = 1</i></p> </div>	<ul style="list-style-type: none"> • <i>Phragmites</i>, behind tidal restriction (potential for significant increase) <p>Assigned Score: 1 Certainty: 1</p>
<p>Change in Sea Level:</p> <ul style="list-style-type: none"> • Rising SL may accelerate loss of some natives (e.g. salt sensitive species) • Salt sensitive species may move inland if possible • Multiple stressors may act synergistically with SL ↑ • ↑ salt will kill <i>Phragmites</i> 	

<ul style="list-style-type: none"> SLR = ↑ fiddler crabs <p>Note: Although site specific responses may in fact vary, the relative cost/benefit associated with invasive/nuisance species (e.g. reduced <i>Phragmites</i>, increased crabs) is simply too complex without additional information with which to make that determination.</p> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p><i>Individual site response varies only by presence/absence/proximity of invasives: If absent – Score = 0; Certainty = 1</i></p> </div>	<p>Assigned Score: 3.9 Certainty: 2</p>
<p>Increase in Extreme Climate Events:</p> <ul style="list-style-type: none"> Variable impacts on species, disease, vectors, etc. Range expansion likely More disturbances could ↑ vulnerability to invasion <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p><i>Individual site response varies only by presence/absence/proximity of invasives: If absent – Score = 0; Certainty = 1</i></p> </div>	<p>Assigned Score: 0.2 Certainty: 1.4</p>

Nutrients	
<p>Current Condition:</p> <ul style="list-style-type: none"> High nutrient levels cause ↑ aboveground and ↓ belowground biomass; accelerates organic matter decomposition; marsh geomorphic stability is lost ↑ N bad for high marsh - ↑ N favors <i>S. alterniflora</i> and <i>Phragmites</i> at expense of <i>S. patens</i> ↑ N may allow marshes to accrete faster than sea level rise N loading may reduce soil accretion in highly organic marshes (by ↓ allocation to roots); species composition shift to species that produce less below ground biomass <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p><i>Sites vary based on: nutrient input source/levels (use adjacent land use as proxy / estimator); vegetation composition; relative position in Bay (upper vs lower); other nutrient sources</i></p> </div>	<ul style="list-style-type: none"> Significant wetland buffer Area not sewerred (probably still some cesspools) Lack of significant development <p>Assigned Score: 2 Certainty: 2</p>
<p>Increase in CO₂:</p> <ul style="list-style-type: none"> Changes to vegetation communities (e.g. <i>Phragmites</i> promotion) affects N pools Changes to structure/function of microbial N transformers C3 species ↑ aboveground prod. with N + CO₂ (but not each alone) ↑ C4 growth under high N (above- and below-ground) but response ↓ with increasing CO₂ <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p><i>Individual site response does not vary: Score = 0; Certainty = 0.5</i></p> </div>	<p>Assigned Score: 0 Certainty: 0.5</p>
<p>Increase in Temperature:</p> <ul style="list-style-type: none"> Warming ↑ aboveground for <i>S. alterniflora</i>, but not high marsh plants 	

<ul style="list-style-type: none"> • Stem height ↑ for both low + high marsh with warming • Warming ↑ decomposition for <i>S. patens</i> • ↑ temperature = ↑ nutrient cycling <div style="border: 1px solid black; padding: 5px; margin-top: 10px; text-align: center;"> <p><i>Individual site response does not vary: Score = 0; Certainty = 2</i></p> </div>	<p>Assigned Score: 0 Certainty: 2</p>
<p>Change in Precipitation:</p> <ul style="list-style-type: none"> • Drought decreased decomposition for native high marsh • Drought ↑ total biomass for <i>S. alterniflora</i> and <i>S. patens</i> • Changes in water levels could influence nutrient availability/circulation • ↑ in wet deposition of nutrients <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p><i>Sites vary based on: potential for nutrient input via surface and groundwater (using adjacent land use [and slope] as proxy)</i></p> </div>	<ul style="list-style-type: none"> • Red maple swamp = denitrification • Unsewered area (dense development) <p>Assigned Score: 1.7 Certainty: 1</p>
<p>Change in Sea Level:</p> <ul style="list-style-type: none"> • With ↑ N, marshes may keep up with sea level rise • Other factors (like climate, nutrients, predation) impact marshes abilities to survive SLR • SLR and high N load may degrade marshes by cooperatively contributing to ↑ hydrogen sulfide concentration (↑ decomposition) <p>Note: Reference documents are not as definitive as the first and third bullets suggest. All factors that influence growth rate may influence ability to survive SLR. Fertilization may alter community composition and increase turf building capacity. Negative feedback associated with increased decomposition (and lower accretion rates) may result in greater drowning potential.</p> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p><i>Sites vary based on: frequency/duration of inundation (with elevation as proxy) if nutrient sources (i.e. from adjacent land use, relative position in Bay) are thought to influence site</i></p> </div>	<ul style="list-style-type: none"> • Well-buffered • Low nutrient input <p>Assigned Score: 3.7 Certainty: 1</p>
<p>Increase in Extreme Climate Events:</p> <ul style="list-style-type: none"> • May cause more frequent combined sewer overflows <p>Note: General knowledge also suggests storm related flooding and run-off as source.</p> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p><i>Sites vary based on: expected influence and proximity of overflow locations (e.g. upper vs. lower Bay); other sources (using adjacent land use as proxy); slope; geomorphology</i></p> </div>	<p>Assigned Score: 0.2 Certainty: 2</p>

Sedimentation	
<p>Current Condition:</p> <ul style="list-style-type: none"> • Salt marshes in RI are not keeping pace with SLR; low suspended sediment in Narragansett Bay • ↑ ditching in marshes = ↓ sedimentation 	<ul style="list-style-type: none"> • Not a back barrier system • Not on a major river system

<ul style="list-style-type: none"> • Height and width of barrier is related to sedimentation rate in back barrier system • ↓ sediment supply may exacerbate marsh loss but unlikely sole driver • With ↑ sediment of 1-2 orders of magnitude, marsh can form in < 100 years <p style="border: 1px solid black; padding: 5px; margin: 10px 0;"><i>Sites vary based on: extent of ditching; river/streams inputs (or presence/absence of river/streams as estimator); presence/absence of dunes</i></p>	<ul style="list-style-type: none"> • No sand bars, etc. <p>Assigned Score: 4.6 Certainty: 3</p>
<p>Increase in CO₂:</p> <ul style="list-style-type: none"> • Sediment trapping ↑ in C3 plants with ↑ N and ↑ CO₂ <p style="border: 1px solid black; padding: 5px; margin: 10px 0;"><i>Individual site response does not vary: Score = 0; Certainty = 2</i></p>	<p>Assigned Score: 0 Certainty: 2</p>
<p>Increase in Temperature:</p> <p style="border: 1px solid black; padding: 5px; margin: 10px 0;"><i>No impact of increase on sediment supply anticipated. All sites = no score.</i></p>	<p>Assigned Score: - Certainty: -</p>
<p>Change in Precipitation:</p> <ul style="list-style-type: none"> • ↑ precipitation may increase sediment supply from uplands/streams <p style="border: 1px solid black; padding: 5px; margin: 10px 0;"><i>Sites vary based on: adjacent land use; presence/absence of streams</i></p>	<ul style="list-style-type: none"> • Buffered • Decreasing agriculture • Many lawns <p>Assigned Score: -1 Certainty: 3</p>
<p>Change in Sea Level:</p> <ul style="list-style-type: none"> • Accretion rates across Narragansett Bay are not keeping pace with SLR • ↑ inundation period may increase sediment deposition • In vegetated marshes with high sediment loads, marshes may sustain elevation with SLR • Narragansett Bay marshes rely primarily on <u>organic</u> accretion – ratios are site-specific • Non-tidally restricted marshes may <u>not</u> drown <p>Note: Although the degree of tidal restriction and sediment load may influence sites, it is not possible to predict relative response to these factors.</p> <p style="border: 1px solid black; padding: 5px; margin: 10px 0;"><i>Individual site response does not vary: Score = -1; Certainty = 1.5</i></p>	<ul style="list-style-type: none"> • Not a back barrier system <p>Assigned Score: -1 Certainty: 1.5</p>
<p>Increase in Extreme Climate Events:</p> <ul style="list-style-type: none"> • Summer storms a major factor in defining short-term variability in sedimentation rates 	<ul style="list-style-type: none"> • Not a back barrier system

<ul style="list-style-type: none"> Storm events dominate accretion/sedimentation rates at certain marshes. Mostly <u>riverine systems</u> and those subject to storm overwash <div style="border: 1px solid gray; padding: 5px; margin-top: 10px;"> <p><i>Sites vary based on: expected influence and proximity of overflow locations (e.g. upper vs. lower Bay); other sources (using adjacent land use as proxy); slope;</i></p> </div>	<p>Assigned Score: 0 Certainty: 2.5</p>
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Erosion

<p>Current Condition:</p> <ul style="list-style-type: none"> Look up annual erosion rates from CRMC for each marsh (http://crmr.ri.gov/maps/) Edge vegetation has been denuded by overabundant marsh crabs Vegetation loss leads to widening of creek banks and loss of marsh edge/area Soil type and geographical setting are most important factors when comparing erosion rates among sites Erosion continuously occurs (no critical threshold below which there is none) <div style="border: 1px solid gray; padding: 5px; margin-top: 10px;"> <p><i>Sites vary based on: erosion rates (using shoreline change maps as proxy for current rates); evidence of creek widening; soil type; geomorphic setting</i></p> </div>	<ul style="list-style-type: none"> Edges denuded by crabs <p>Assigned Score: 5 Certainty: 3</p>
<p>Increase in CO₂:</p> <ul style="list-style-type: none"> ↑ soil surface cover from ↑ plant production can reduce erosion rates <p>Note: Although the decomposition of peat (and potential for increased erosion) could also be exacerbated by CO₂, levels of CO₂ across the state are assumed to be basically a constant and therefore no site specific variation in score for this impact is possible either.</p> <div style="border: 1px solid gray; padding: 5px; margin-top: 10px; text-align: center;"> <p><i>Individual site response does not vary: Score = 3.9; Certainty = 3</i></p> </div>	<p>Assigned Score: 0 Certainty: 3</p>
<p>Increase in Temperature:</p> <ul style="list-style-type: none"> ↑ temperature = ↑ belowground decomposition = ↑ erosion (maybe) <div style="border: 1px solid gray; padding: 5px; margin-top: 10px; text-align: center;"> <p><i>Individual site response does not vary: Score = 3.9; Certainty = 3</i></p> </div>	<p>Assigned Score: 3.9 Certainty: 3</p>
<p>Change in Precipitation:</p> <ul style="list-style-type: none"> With increased rainfall, there may be an increase in erosion at riverine salt marsh systems <p>Note: Acknowledging that variation between sites is possible, this metric presents a challenge as differences in stream flow rate, channel width/depth etc. are generally not known.</p>	<p>Assigned Score: 2 Certainty: 3</p>

<p><i>Sites vary based on: proximity of rivers/streams influencing scouring levels</i></p>	
<p>Change in Sea Level:</p> <ul style="list-style-type: none"> • As marshes drown, wind-driven waves will erode unvegetated platforms • Platform marshes are more susceptible than ramp (fringe) marshes because they are expected to drown at once • ↑ SL of 30 cm will ↑ potential erosion on marsh surface by 50% (considered by authors as not significant) • Shoreline erosion with ↑ wind wave exposure (associated with ↑ depth, fetch, bottom shear stress) <p><i>Sites vary based on: type (e.g. platform, fringe); orientation to dominant wind direction; relative elevation; measured erosion rates (e.g. from shoreline change maps); percent vegetated cover</i></p>	<p>Assigned Score: 5 Certainty: 3.5</p>
<p>Increase in Extreme Climate Events:</p> <ul style="list-style-type: none"> • ↑ storms = more erosion of barrier beaches = ↑ threat to back barrier marshes • Violent storms and hurricanes contribute less than 1% to long-term salt marsh erosion rates <p>Note: Given the somewhat contradictory statements of the two bullets, the choice was made to consider only the second for scoring purposes.</p> <p><i>Individual site response does not vary: Score = 1.7; Certainty = 2</i></p>	<p>Assigned Score: 1.7 Certainty: 2</p>

Environmental Contaminants	
<p>Current Condition:</p> <ul style="list-style-type: none"> • There is a presumed tolerance to historic and persistent levels of exposure; however “cost” may be reduced ability to tolerate climatic stress • Certain legacy pollutants are decreasing, but other emerging contaminants are increasing and it is unknown how these ‘new’ contaminants will affect marsh growth • CC will stress communities through shifting them into non-optimal areas, ↓ resiliency, ↓ diversity, ↑ stress <p><i>Sites vary based on: proximity and source of exposure to both legacy and emerging contaminants; adjacent land use</i></p>	<p>Assigned Score: 0 Certainty: 1</p>
<p>Increase in CO₂:</p> <ul style="list-style-type: none"> • ↑ CO₂ can alter key ecosystem processes by altering contaminant mobility 	

<p>Note: There is insufficient information to determine the degree to which contaminant mobility is affected by CO₂ (and the degree to which contaminant uptake will alter ecosystem processes). No variation in score possible unless new information becomes available.</p> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <p><i>Individual site response does not vary: Score = 0; Certainty = 1</i></p> </div>	<p>Assigned Score: 0 Certainty: 1</p>
<p>Increase in Temperature:</p> <ul style="list-style-type: none"> • May increase contaminant uptake and stress plant/animal community • May see ↑ use of pesticides / persistent organic pollutants (POPs) with ↑ temperature; ↑ temperature may alter uptake and physiological response • ↑ may favor hardier species (more toxic species) that cause harmful algal blooms (HABs) <p>Note: Although temperature is assumed to have some effect, there is no data available to determine if a 2° change is a sufficient trigger. No variation in score possible unless new information becomes available.</p> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <p><i>Individual site response does not vary: Score = 0; Certainty = 1</i></p> </div>	<p>Assigned Score: 0 Certainty: 1</p>
<p>Change in Precipitation:</p> <ul style="list-style-type: none"> • ↑ precipitation = ↑ runoff = ↑ contaminants delivered to marshes • ↑ precipitation = ↑ wet deposition <div style="border: 1px solid black; padding: 5px;"> <p><i>Sites vary based on: presence/absence of contaminants; slope; presence and amount of stormwater and stream inputs; adjacent land use</i></p> </div>	<p>Assigned Score: 0 Certainty: 1</p>
<p>Change in Sea Level:</p> <ul style="list-style-type: none"> • Changes to land use/land cover will alter runoff / flooding and delivery of contaminants • Changes bioavailability based on changes in salinity • Sea level affects infrastructure which alters contaminant delivery if infrastructure fails or is flooded <div style="border: 1px solid black; padding: 5px;"> <p><i>Sites vary based on: presence/absence of contaminants; contaminant delivery as function of flooding associated with SLR [potentially using elevation as proxy]</i></p> </div>	<p>Assigned Score: 0 Certainty: 1</p>
<p>Increase in Extreme Climate Events:</p> <ul style="list-style-type: none"> • Can cause ↑ flooding of infrastructure / landfills, ↑ contaminant delivery <div style="border: 1px solid black; padding: 5px;"> <p><i>Sites vary based on: presence/absence of contaminants; contaminant delivery as function of coastal flooding potential</i></p> </div>	<p>Assigned Score: 0 Certainty: 2</p>

Degree of Fragmentation	
<ul style="list-style-type: none"> • Many species (particularly plants) decrease with fragmentation • Fragmentation exacerbates vulnerability as harder to move and ↓ genetic diversity • Many mutualisms hindered by fragmentation • Edge effects 	Assigned Score: 2 Certainty: 3
Barriers to Migration	
<ul style="list-style-type: none"> • ↑ permeability = ↑ adaptability (through migration/range shift) • Relatively flat topography may result in ↑ shifts if barriers are at a greater distance (or absent) • Steep natural topography, but may still allow fringe marsh if erodable • Hardened, developed shoreline, more of an impediment • # and size of structures may ↑ in response to SLR 	<ul style="list-style-type: none"> • Relatively flat • Forest may slow down migration Assigned Score: 2 Certainty: 2.6
Recovery / Regeneration	
<ul style="list-style-type: none"> • Speed of recovery / regeneration depends on severity of disturbance • Must be careful with restoration targets (i.e. is it likely that historic targets not going to be possible in future) • Where tidal exchange occurs through narrow inlets, tidal range restricted (and converse is true); may influence response 	Assigned Score: 2 Certainty: 3
Diversity of Functional Groups	
<ul style="list-style-type: none"> • Dependent on disturbance level / stress • Biogeographical shifts of community already occurring and will continue • Changes to growing season will affect which species/groups are active when 	Assigned Score: 0 Certainty: 4
Management Actions	
<ul style="list-style-type: none"> • Current marsh extent is a relic of historic land-use change; allow return to 'natural state' 	<ul style="list-style-type: none"> • 'Fix' tidal restriction Assigned Score: 2 Certainty: 3
Institutional / Human Response	
<ul style="list-style-type: none"> • Decide if assisted migration is valid • Varied (depends on current/future management agency) 	Assigned Score: 2 Certainty: 3

Research Needs

Certainty scores reflect the source of information considered when assigning sensitivity-exposure and adaptive capacity scores and ranges from zero (0; no direct or anecdotal evidence) to four (4; strong evidence, high consensus). Across all assessed sites within the state, overall certainty tended to be moderately higher at individual sites where local data sources were available or active management was being planned or applied.

Certainty score assignment associated with specific stressors (or stressor interactions) that are assigned an average score of less than two across sites indicates a general lack of evidence or consensus regarding habitat response. In the table below, circles indicate stressor / stressor interactions that fall within that category. Closed circles (●) indicate specific instances in which Chase Cove also received low scores for those stressors and open circles (○) indicate higher than average certainty scores since more information about this specific site is known. X's indicate instances where the available information related to Chase Cove was considered lacking and therefore were assigned less than the average certainty score. Cells in the table marked with ● or X's generally suggest that more research is needed to better understand habitat response at Chase Cove.

	Current Condition	CO₂	Temp.	Precip.	Sea Level	Extreme Climate
Direct Effects						●
Invasive /Nuisance Sp.			X	X		X
Nutrients		●		●	●	○
Sedimentation					X	
Erosion						
Env. Contaminants	●	●	●	●	●	○
	Habitat Fragment.	Barriers	Recovery /Regen.	Functional Groups	Management Actions	Inst./Human Response
Adaptive Capacity						

Process and Facilitation

Numerous meetings were conducted over the course of a year to implement CCVATCH in the State of RI. The assessment team members varied somewhat, but a core group representing numerous state agencies (e.g. RI Coastal Resources Management Council, US Environmental Protection Agency, US Fish and Wildlife Service, Narragansett Bay National Estuarine Research Reserve, Audubon Society of RI, and Save The Bay) have consistently participated throughout the process. The process of applying CCVATCH in RI required the following general steps:

- Overview of tool & habitat selection
- Identification of experts, resources (e.g. published literature, available data sets, etc.) available
- Outreach to experts to solicit additional resource material
- Review of reference material & generation of resource document

- Create bulleted list from resource document to assist with scoring
- CCVATCH score assignment to selected sites

Team members were originally invited from a master list of attendees at a salt marsh conference recently held in the state. While this may have biased habitat selection toward salt marsh, specifically those marshes for which monitoring data were available, other habitats were identified as priorities for assessment such as tidal river/stream and submerged aquatic vegetation (SAV) for future efforts. Additional applications of CCVATCH to these habitats may take place in future, particularly if on-going efforts in other New England states develop resource documents that would aid in the process (see <http://graham.umich.edu/activity/32984> for a project overview).

Climate Forecast

Temperatures in the Northeast increased by almost 2°F between 1895 and 2011 (0.16°F per decade) and precipitation increased more than 10%, approximately 5 inches (0.4 inches per decade; Horton et al, 2014). For the State of Rhode Island, a change in annual mean temperature of +3.6°F is expected by 2050 with comparable increases in annual precipitation levels, predominantly in the winter months (RCP8.5 scenario; Alder and Hostetler, 2013). Increased winter precipitation would mean more water available for runoff and evaporation. Rising temperatures would melt snow faster and earlier, likely increasing runoff and soil moisture in winter and early spring followed by reductions in soil moisture in the late summer and early fall, since warmer temperatures drive higher evaporation rates. The Northeast has experienced a greater recent increase in extreme precipitation than any other region in the United States, more than 70% increase in the amount of precipitation falling in very heavy events (defined as the heaviest 1% of all daily events) between 1958 and 2010 (Horton et al, 2014). Long-term rates of sea-level rise are 2.74 mm year-1 from 1930 to 2013 at the Newport, RI tide station; rates calculated from more current data over a shorter time scale suggest 4 mm year-1 increase in mean high water (MHW) from 1993 to 2014 (Boyd & Freedman, 2015). A two foot increase in sea level for 2050 and five foot increase by 2100 predicted using the NOAA High Rate sea level rise curve for this area has been adopted by the state to govern policy and management.

	Current (1950-2005) Temp (°C)		Predicted 2025-2049 Δ Temp (°C)		Current (1950-2005) Precip (mm/day)	Predicted 2025-2049 Δ Precip (mm/day)	Change in Evap. Deficit 2025-2049 (mm/mo)	Change in Runoff 2025-2049 (mm/mo)
	min	max	min	max				
Winter	-5.1	4.5	2.2	1.8	3.3	0.4	0.0	22.7
Spring	8.0	19.0	1.8	1.8	3.0	0.2	0.7	-12.6
Summer	14.7	25.3	2.1	2.2	3.0	0.2	7.1	-2.9
Fall	1.0	10.9	2.3	2.1	3.5	0.1	0.1	-0.5
Annual	4.6	14.9	2.1	2.0	3.2	0.3	2.0	1.7

*Data from USGS National Climate Change Viewer (RCP8.5 scenario; Mean Model output available Jan. 2016)

References

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