Direct Climate Effect

Current Condition:

- Range shifts, altered species composition
- ↓ forb communities
- ↓ high marsh
- ↑ die-back
- Declines in salt marsh extent since 1860s; loss rate over 40 yrs = 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)

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

Increase in CO_2:

- No expected change to C4 plants but ↑ biomass in C3 plants (*Scirpus*, *Phrag*)
- Root %N ↓ and C/N ↑ in *Scirpus* could decrease decomposition and increase peat formation

Individual site response does not vary:
Score = 0; Certainty = 4

Increase in Temperature:

- Δ competitive interactions
- ↑ marsh decomposition rates
- ↓ organic matter accretion
- ↓ forb pannes

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.

Individual site response does not vary:
Score = 2; Certainty = 3

Change in Precipitation:

- Seasonal Δ timing/duration influences salinity through salt H_2O intrusion
- Changes in groundwater flow/level can impact marsh elevation
- Δ precip. = ↓ productivity
- C4 better competitors wth freq./more severe drought
- ↓ precip. and drought have no sign. impact on *S. patens*
- Dieback ↑ during drought?

Sites vary based on: relative groundwater levels (potentially, although site specific data is not available); species composition (maybe)

Change in Sea Level:

- Effects species distribution (shift to more salt tolerant sp.)
- ↓ high marsh
- ↓ low sediment marshes
- ↑ inundation reduces below-ground biomass of *S. alterniflora*
- ↑ inundation drives veg. loss (elevation as proxy for inundation accounts for 96% of var. in loss rates); elevation threshold for *S. patens* = 0.51mNAVD88

Sites vary based on: change in tidal range (using relative elevation as proxy)

Increase in Extreme Climate Events:

- ↑ extr. disturbance favors sp. that are 'colonizers'
- Δ upland /marsh interface
- ↑ compression of marsh surface due to weight of storm surges
- Δ plant communities
- ↑ debris

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

Invasive/Nuisance Species

Current Condition:

- Many exotic grazers and predators are present and increasing (interactions with natives vary ±)
- Many anthropogenic impacts making things worse (e.g. eutrophication, overfishing, shoreline development)
- Range expansion by native plants, animals occurring (impacts debated ±)

Sites vary based on: presence/absence/proximity of Phragmites; presence/abundance of crab herbivores (if/when available); others (e.g. perennial pepperweed, purple loosestrife)

Increase in CO_2:

- ↑ could enhance fitness of many marsh invasives (e.g. Phrag) as well as some natives (e.g. poison ivy)
- *Phragmites* does better with salt stress with ↑ CO2 and ↑ temperature
- Reduction in %N of *Scirpus* shoots results in an increase in green tissue C/N (may effect herbivore preferences and feeding rates); not true of C4 grasses (*S. patens, D. spicata*)

Note: Response of *Phragmites* to both elevated CO2 and temperature should only be considered once (do not double-count impact under both stressors).

Individual site response varies only by presence/absence/proximity of invasives species

Increase in Temperature:

- ↑ temp. and CO2 may make Phragmites more tolerant of salt stress
- C4 plants more resistant to Phrag encroachment
- ↑ temp. may encourage range expansion of southern species (animals quicker, plants)
- Impacts of both natural and facilitated expansion debated
- Facilitates Phrag encroachment (with elevated CO2)

Individual site response varies only by presence/absence/proximity of invasives species

Change in Precipitation:

- 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 ↑ precip.

Individual site response varies only by presence/absence/proximity of invasives species

Change in Sea Level:

- Rising SL may accelerate loss of some natives (e.g. salt sensitive species)
- Salt sensitive sp. may move inland if possible
- Multiple stressors may act synergistically with SL ↑
- ↑ salt will kill Phrag
- SLR = ↑ fiddler crabs

Note: Although site specific responses may in fact vary, the relative cost/benefit associated with invasive/nuisance species (e.g reduced *Phrag,* increased crabs) is simply too complex without additional information with which to make that determination.

Individual site response varies only by presence/absence/proximity of invasives species

Increase in Extreme Climate Events:

- Variable impacts on species, disease, vectors, etc.
- Range expansion likely
- More disturbances could ↑ vulnerability to invasion

Individual site response varies only by presence/absence/proximity of invasives species

Nutrients

Current Condition:

- High nutrient levels cause ↑ aboveground and ↓ belowground biomass; accelerates organic matter decomposition; marsh geomorphic stability is lost
- ↑ N bad for high marsh - ↑ N favors *S. alterniflora* and *Phrag* at expense of *S. patens*
- ↑ 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); sp. comp. shift to sp. that produce less below ground biomass)

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

Increase in CO_2:

- Changes to veg. communities (e.g. *Phrag* promotion) affects N pools
- Changes to structure/function of microbial N transformers
- C3 sp. ↑ aboveground prod. with N + CO_2 (but not ea. alone)
- ↑ C4 growth under high N (above- and below-ground) but response ↓ with increasing CO_2

Individual site response does not vary:
Score = 0; Certainty = 0.5

Increase in Temperature:

- Warming ↑ aboveground for *S. alterniflora*, but not high marsh plants
- Stem height ↑ for both low + high marsh with warming
- Warming ↑ decomposition for *S. patens*
- ↑ temp. = ↑ nutrient cycling

Individual site response does not vary:
Score = 0; Certainty = 2

Change in Precipitation:

- Drought decreased decomposition for native high marsh
- Drought ↑ total biomass for *S. alterniflora* and *S. patens*
- Changes in WT levels could influence nutrient availability/circulation
- ↑ in wet deposition of nutrients

Sites vary based on: potential for nutrient input via surface and groundwater (using adjacent land use [and slope] as proxy])

Change in Sea Level:

- 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 conc. (↑ decomposition)

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.

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

Increase in Extreme Climate Events:

- May cause more frequent combined sewer overflows

Note: General knowledge also suggests storm related flooding and run-off as source.

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

Sedimentation

Current Condition:

- Salt marshes in RI are not keeping pace with SLR; low suspended sediment in Narragansett Bay
- ↑ ditching in marshes = ↓ sedimentation
- Height and width of barrier is α̃ to sedimentation rate in back barrier system
- ↓ sed. supply may exacerbate marsh loss but unlikely sole driver
- With ↑ sediment of 1-2 orders of magnitude, marsh can form in < 100 yrs

Sites vary based on: extent of ditching; river/streams inputs (or presence/absence of river/streams as estimator); presence/absence of dunes

Increase in CO_2:

- Sediment trapping ↑ in C3 plants with ↑ N and ↑ CO_2

Individual site response does not vary:
Score = 0; Certainty = 2

Increase in Temperature:

No impact of increase on sediment supply anticipated.
All sites = no score.

Change in Precipitation:

- ↑ precipitation may increase sediment supply from uplands/streams

Sites vary based on: adjacent land use; presence/absence of streams

Change in Sea Level:

- 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

Note: Although the degree of tidal restriction and sediment load may influence sites, it is not possible to predict relative response to these factors.

Individual site response does not vary:
Score = -1; Certainty = 1.5

Increase in Extreme Climate Events:

- Summer storms a major factor in defining short-term variability in sedimentation rates
- Storm events dominate accretion/sedimentation rates at certain marshes. Mostly <u>riverine systems</u> and those subject to storm overwash

Sites vary based on: overwash potential, riverine vs. cove (e.g. geomorphic setting)

Erosion

Current Condition:

- 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)

Sites vary based on: erosion rates (using shoreline change maps as proxy for current rates); evidence of creek widening; soil type; geomorphic setting

Increase in CO_2:

- ↑ soil surface cover from ↑ plant production can reduce erosion rates

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.

Individual site response does not vary:
Score = 0; Certainty = 3

Increase in Temperature:

- ↑ temp = ↑ belowground decomposition = ↑ erosion (maybe)

Individual site response does not vary:
Score = 3.9; Certainty = 3

Change in Precipitation:

- With increased rainfall, there may be an increase in erosion at riverine SM systems

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.

Sites vary based on: proximity of rivers/streams influencing scouring levels

Change in Sea Level:

- 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 sign.)
- Shoreline erosion with ↑ wind wave exposure (associated with ↑ depth, fetch, bottom shear stress)

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

Increase in Extreme Climate Events:

- ↑ 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

Note: Given the somewhat contradictory statements of the two bullets, the choice was made to consider only the second for scoring purposes.

Individual site response does not vary:
Score = 1.7; Certainty = 2

Environmental Contaminants

Current Condition:

- 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

Sites vary based on: proximity and source of exposure to both legacy and emerging contaminants; adjacent land use

Increase in CO_2:

- ↑ CO_2 can alter key ecosystem processes by altering contaminant mobility

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.

Individual site response does not vary:
Score = 0; Certainty = 1

Increase in Temperature:

- May increase contaminant uptake and stress plant/animal community
- May see ↑ use of pesticides / POPs with ↑ temp. ; ↑ temp. may alter uptake and physiological response
- ↑ may favor hardier species (more toxic species) that cause HABs

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.

Individual site response does not vary:
Score = 0; Certainty = 1

Change in Precipitation:

- ↑ precip = ↑ runoff = ↑ contaminants delivered to marshes
- ↑ precip = ↑ wet deposition

*Sites vary based on: slope; presence and amount of stormwater and stream inputs; adjacent land use (*although does assume different score if contaminants present/absent)*

Change in Sea Level:

- Changes to LULC 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

*Sites vary based on: contaminant delivery as function of flooding associated with SLR [potentially using elevation as proxy] (*although does assume a different score if nearby contaminants present/absent)*

Increase in Extreme Climate Events:

- Can cause ↑ flooding of infrastructure / landfills, ↑ contaminant delivery

*Sites vary based on: contaminant delivery as function of coastal flooding potential (*although does assume a different score if nearby contaminants present/absent)*

Degree of Fragmentation

- Many species (esp. plants) decrease with fragmentation
- Fragmentation exacerbates vulnerability as harder to move and ↓ genetic diversity
- Many mutualisms hindered by fragmentation
- Edge effects

Barriers to Migration

- ↑ 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

Recovery/Regeneration

- Speed of recovery / regeneration depends on severity of disturbance
- Must be careful w/ 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

Diversity of Functional Groups

- 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

Management Actions

- Current marsh extent is a relic of historic land-use change; allow return to 'natural state'

Institutional/Human Response

- Decide if assisted migration is valid
- Varied (depends on current/future management agency)