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)

Increase in CO_2:

- No expected change to C4 plants
- Root %N ↓ and C/N ↑ in *Scirpus* could decrease decomposition and increase peat formation

Increase in Temperature:

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

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?

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

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

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 ±)

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
- 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*)

Increase in Temperature:

- ↑ temp. may make Phragmites more tolerant of salt stress
- C4 plants more resistant to Phrag encroachment
- ↑ temp. may encourage range expansion of southern species (animals <u>quicker</u>, plants)
    - impacts of both natural and facilitated expansion debated
- Facilitates Phrag encroachment

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.

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

Increase in Extreme Climate Events:

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

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)

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

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

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

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)

Increase in Extreme Climate Events:

- May cause more frequent combined sewer overflows

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

Increase in CO_2:

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

Increase in Temperature:

Change in Precipitation:

- ↑ precipitation may increase sediment supply from uplands/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

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

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)

Increase in CO_2:

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

Increase in Temperature:

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

Change in Precipitation:

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

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 by 50%
- Shoreline erosion with ↑ wind wave exposure (associated with ↑ depth, fetch, bottom shear stress)

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

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

Increase in CO_2:

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

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

Change in Precipitation:

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

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

Increase in Extreme Climate Events:

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

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)