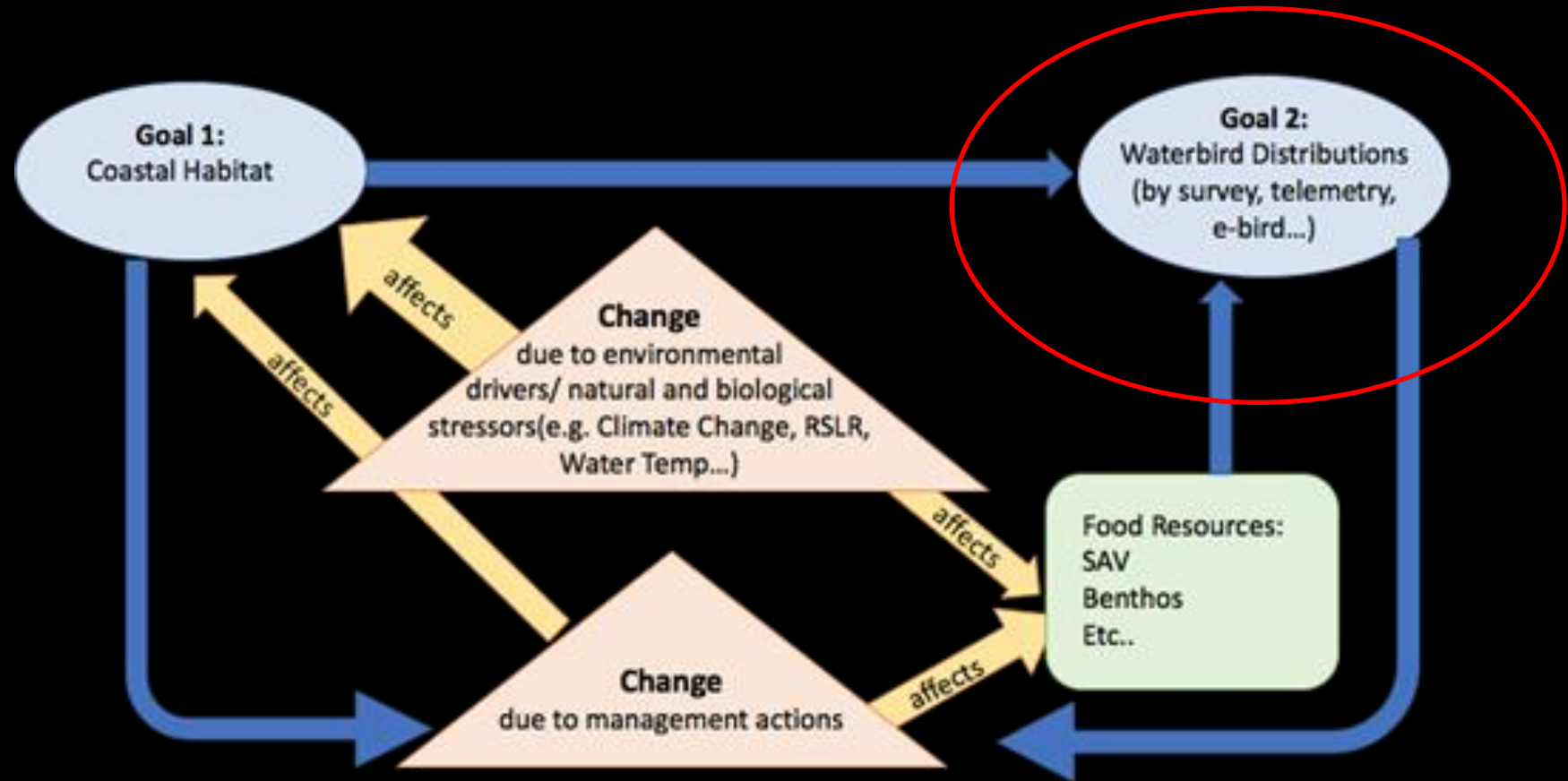


# **Theme 2: Assess the risks to coastal habitats, DOI lands, and migratory waterbirds**

## Theme 2

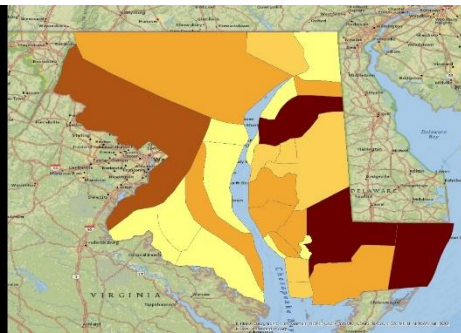
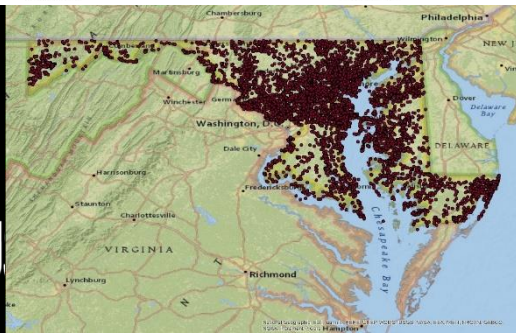
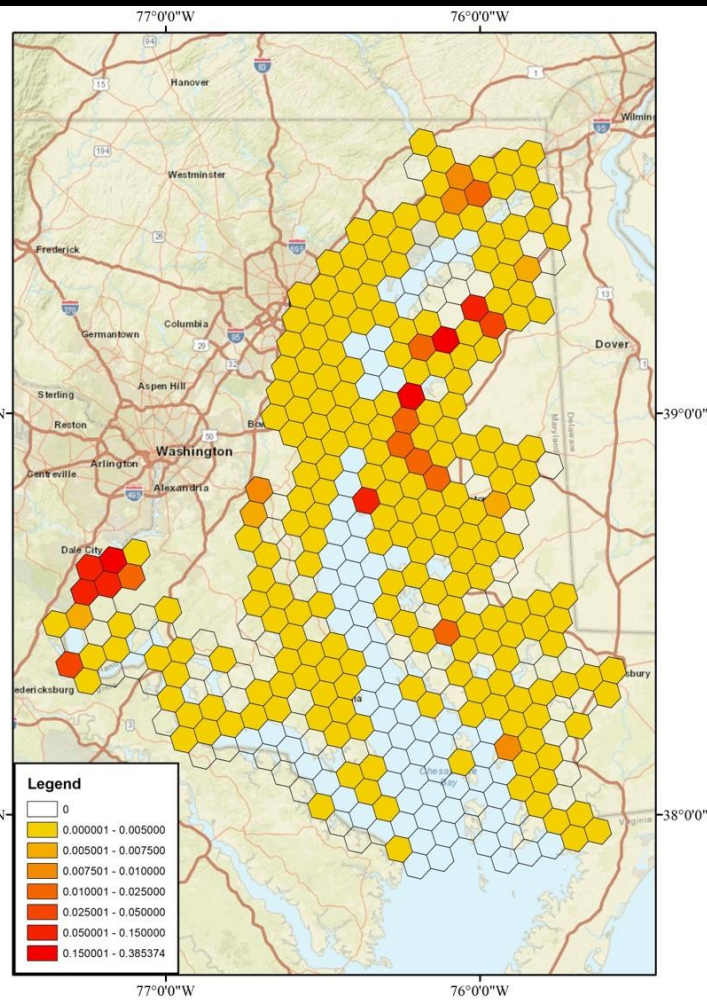
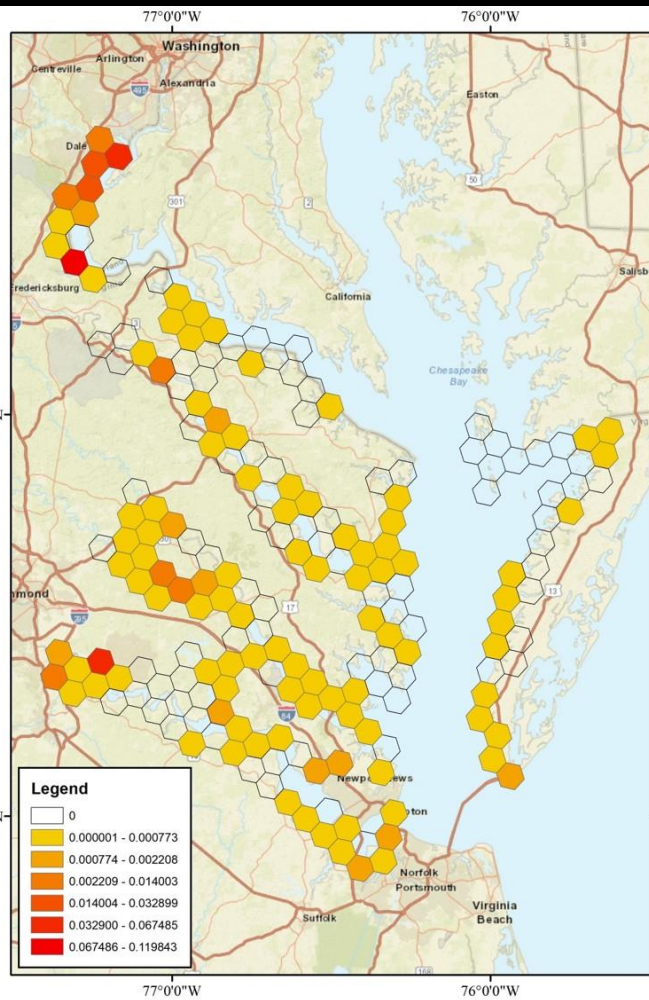
A: Assess risks to coastal habitats and DOI lands, by forecasting vulnerability and resiliency of coastal systems to future change

B: Understand the factors affecting waterbirds and their habitats



# Waterfowl Hotspot Modeling

- Hotspot models of wintering near shore and salt marsh waterfowl to guide site selection for coastal modeling group
  - paired data from scientific surveys (Midwinter Waterfowl Surveys) and citizen science efforts (eBird)
- Currently refining preliminary models with newly acquired data
  - Maryland provided GPS routes for survey data
  - New survey area correction to allow comparisons between MD and VA

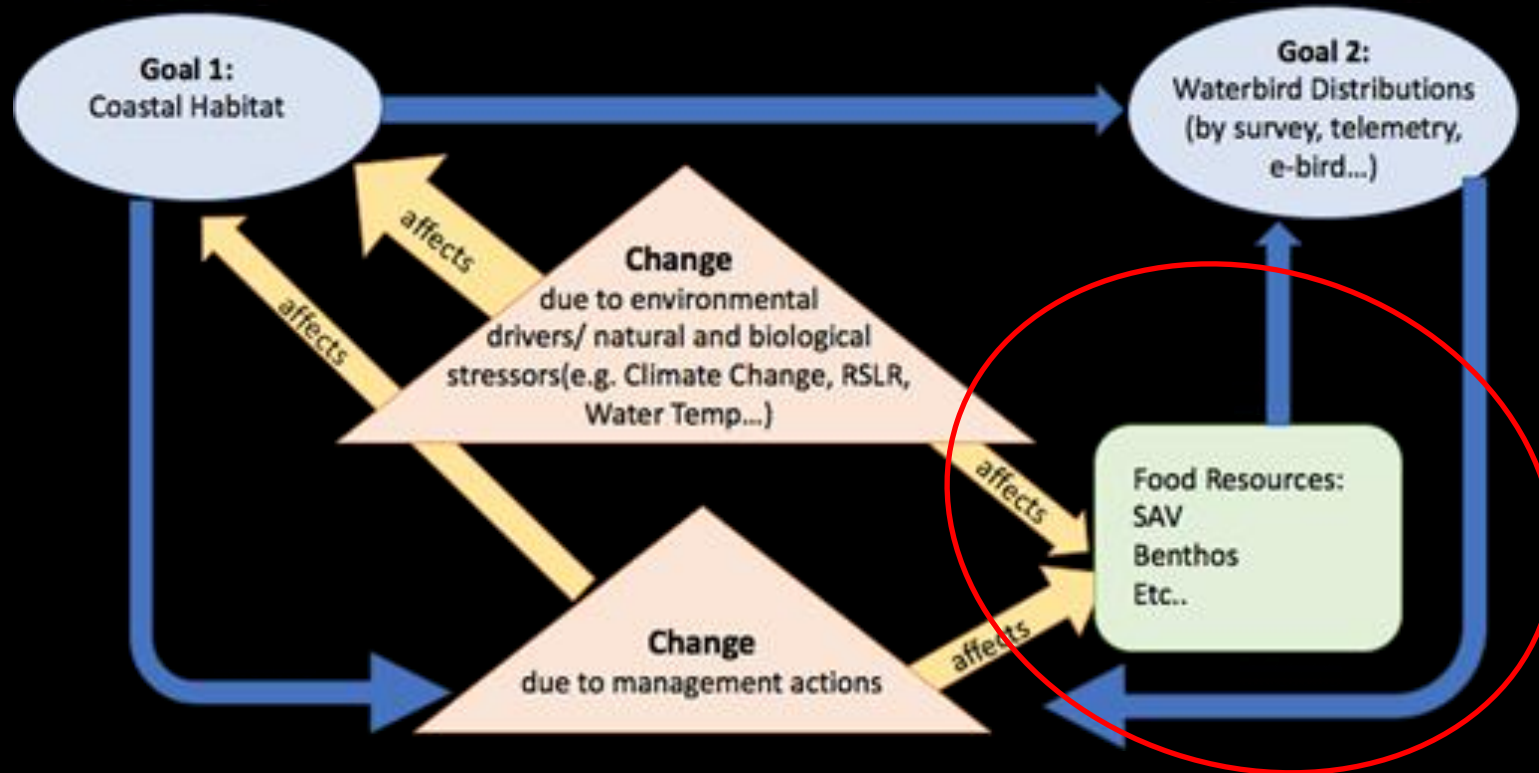




## Theme 2

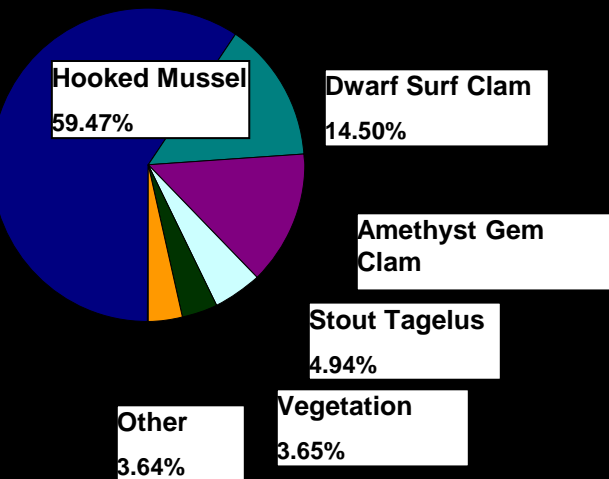
A: Assess risks to coastal habitats and DOI lands, by forecasting vulnerability and resiliency of coastal systems to future change

B: Understand the factors affecting waterbirds and their habitats

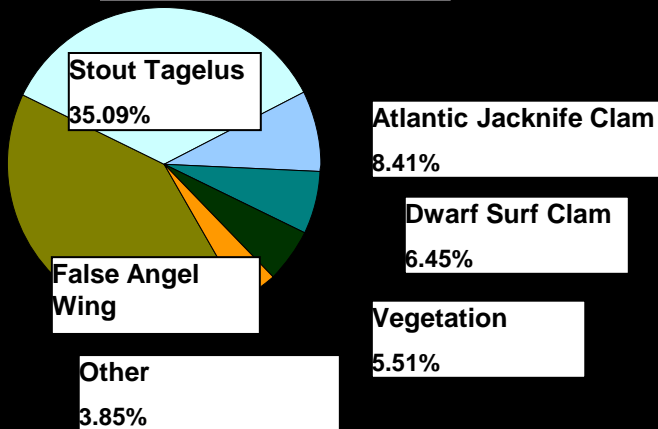


# FOOD HABITS IN THE CHESAPEAKE BAY

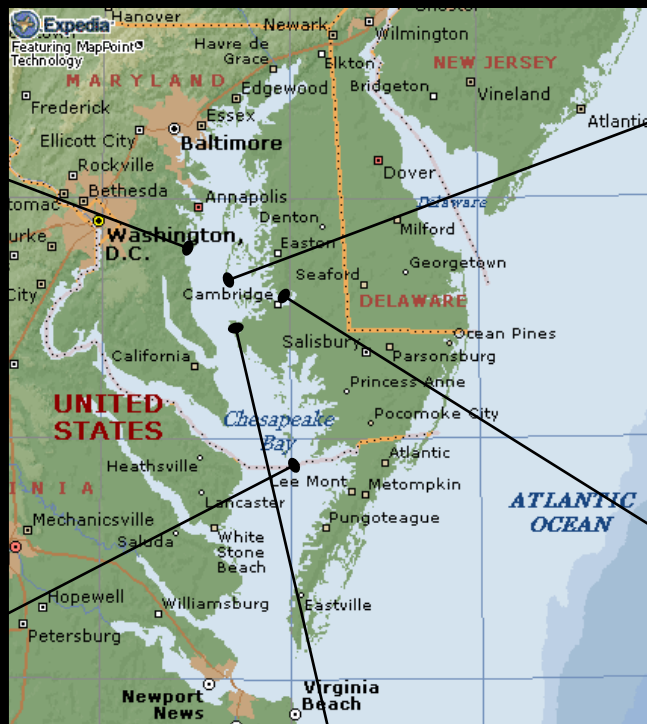
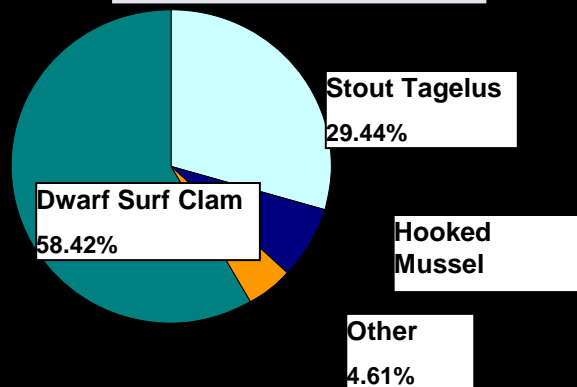
**Herring Bay n=93**



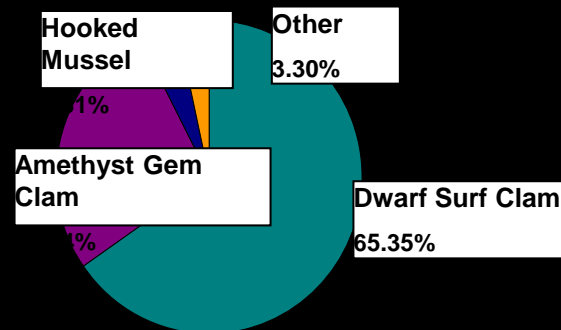
**Smith Island n=13**



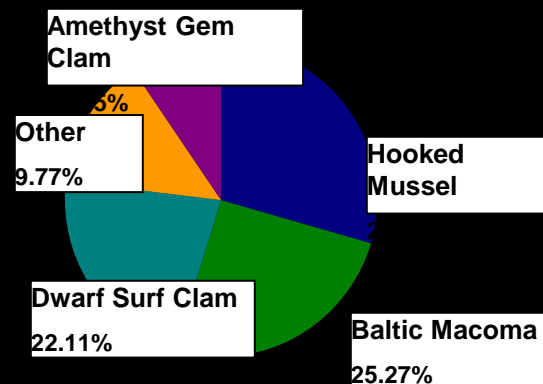
**Taylors Island n=38**



**Tilghman Island n=27**

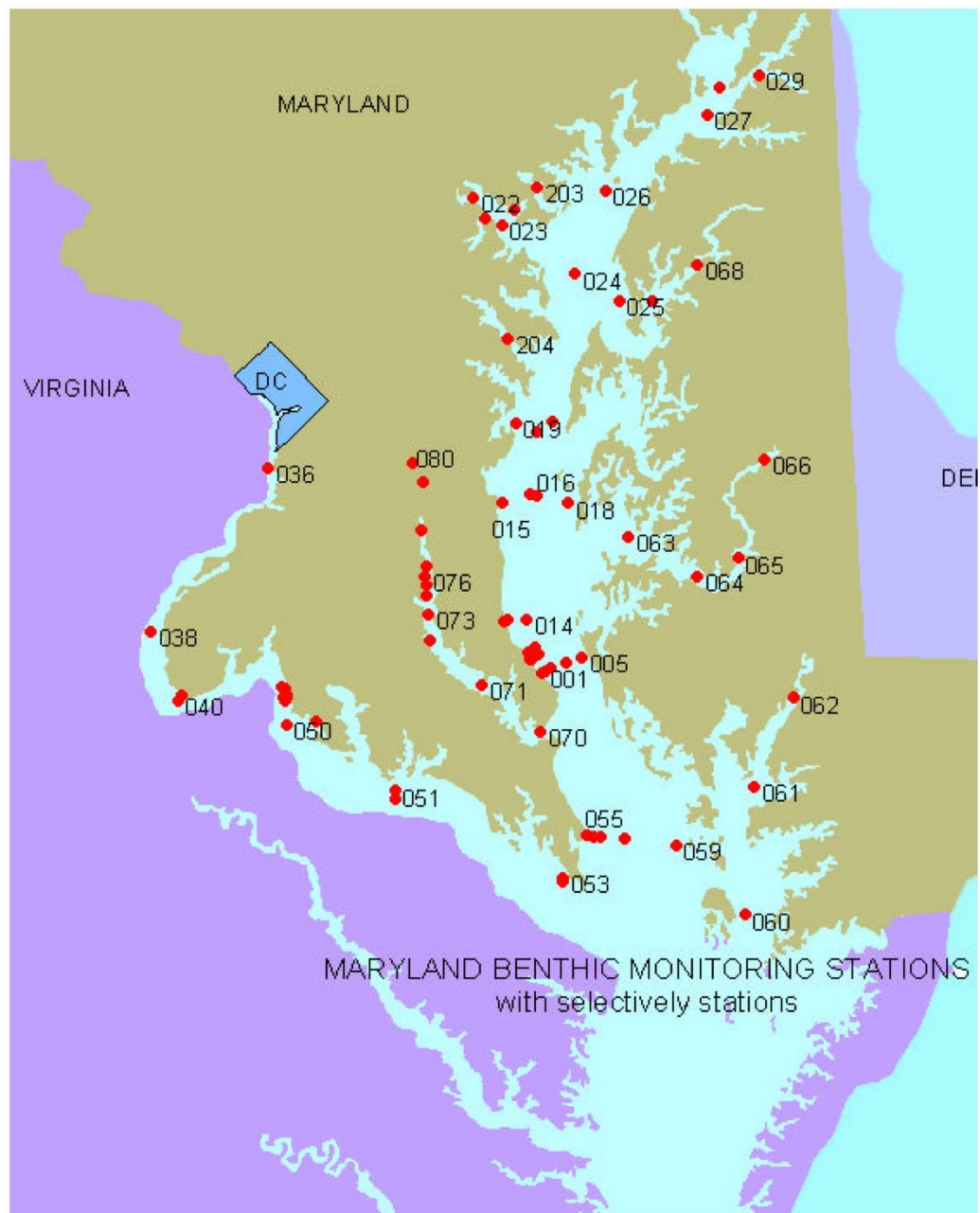


**Choptank River n=65**

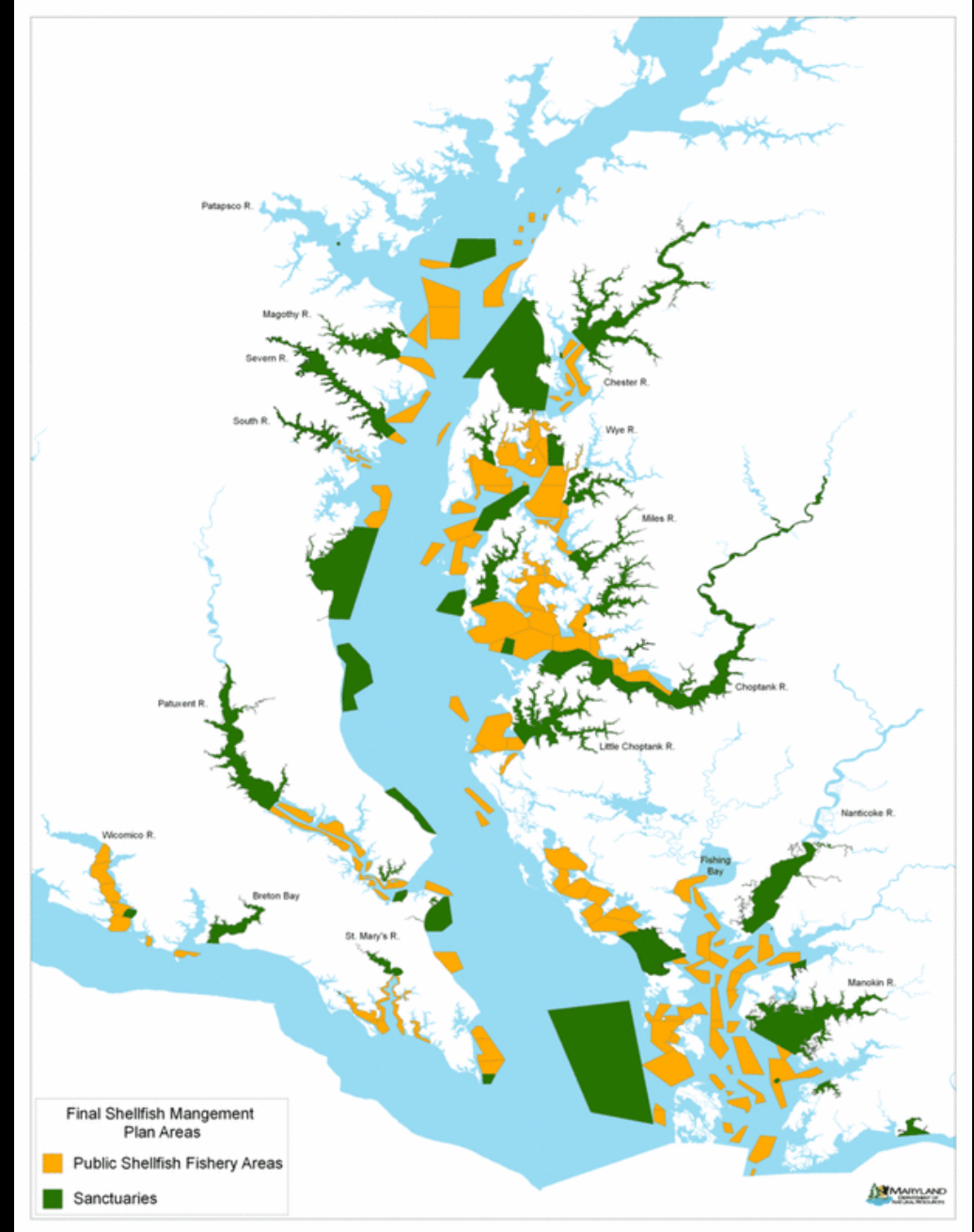


**Food Habits Dataset:**  
32 different species,  
mainly waterfowl

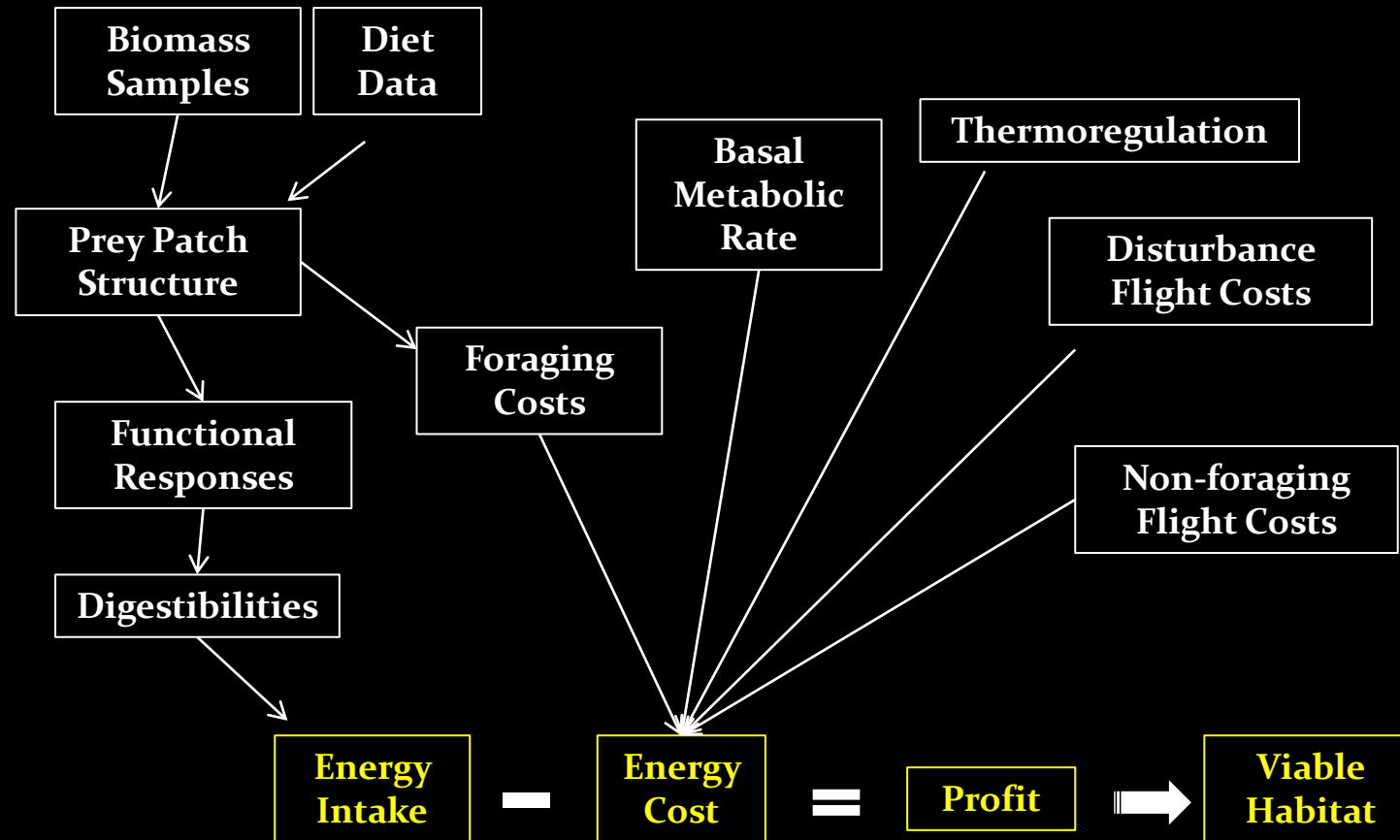
1953 food habits  
samples



Add additional SAV and other benthic layers



# Bioenergetic modeling

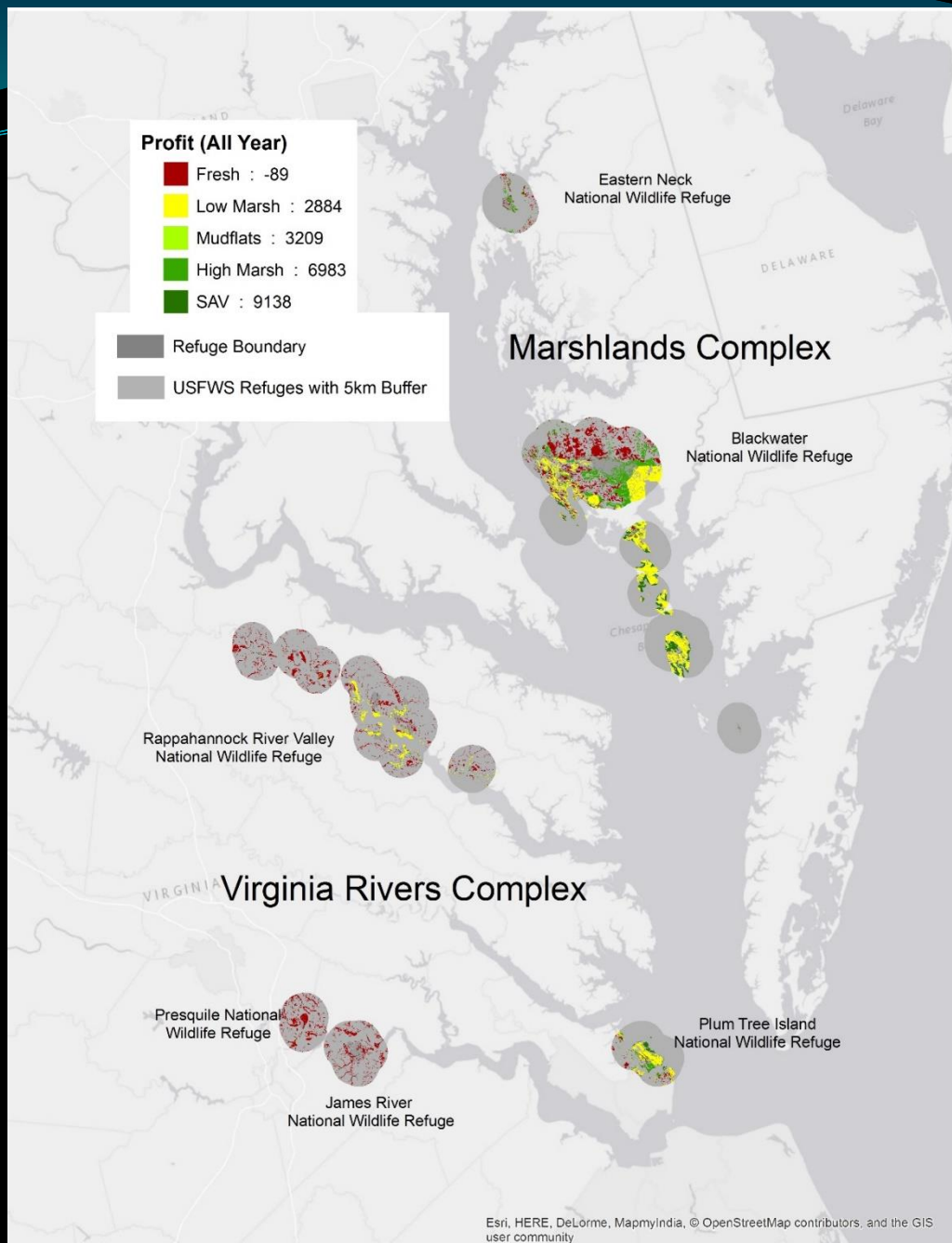


# Bioenergetic modeling: Black duck

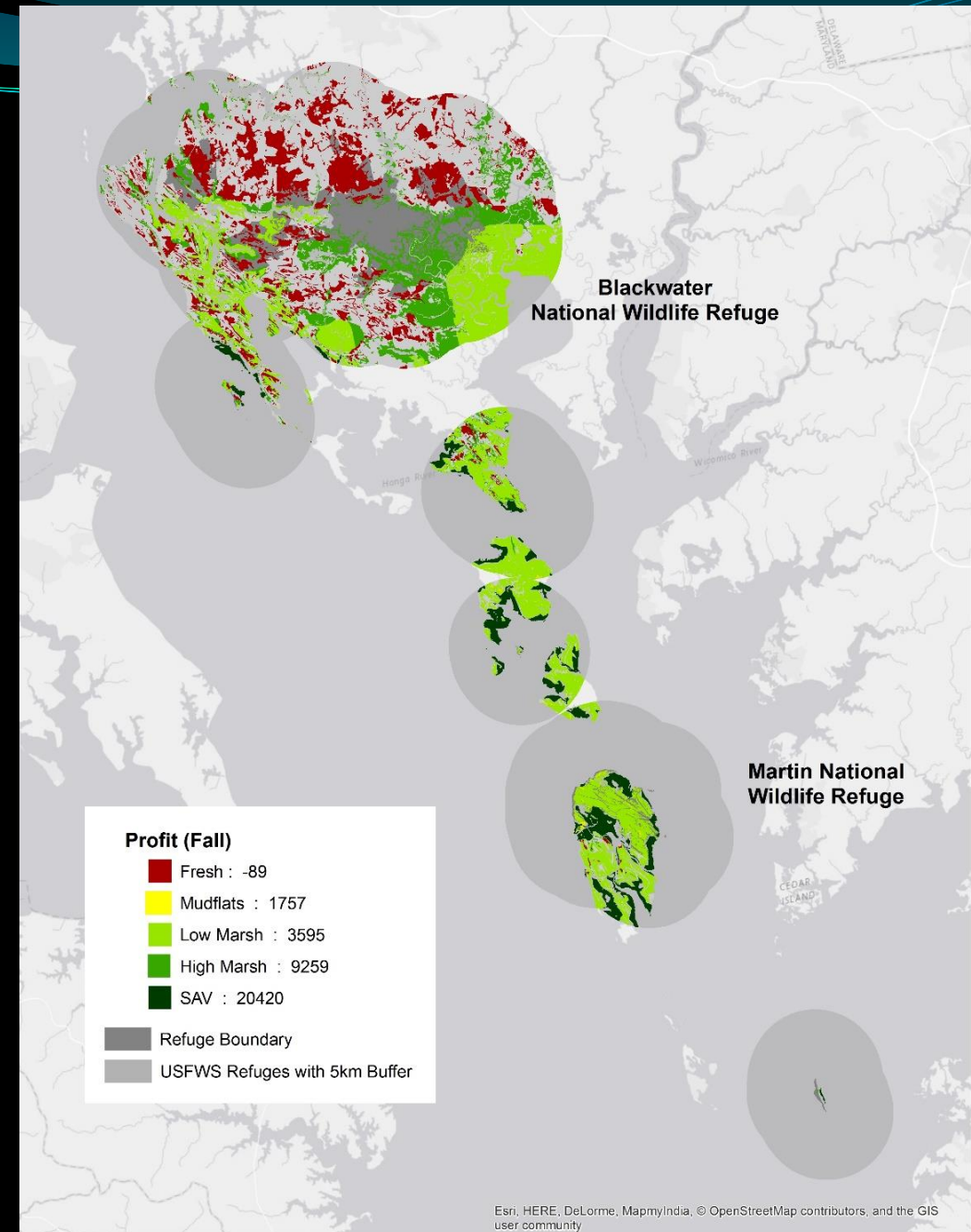
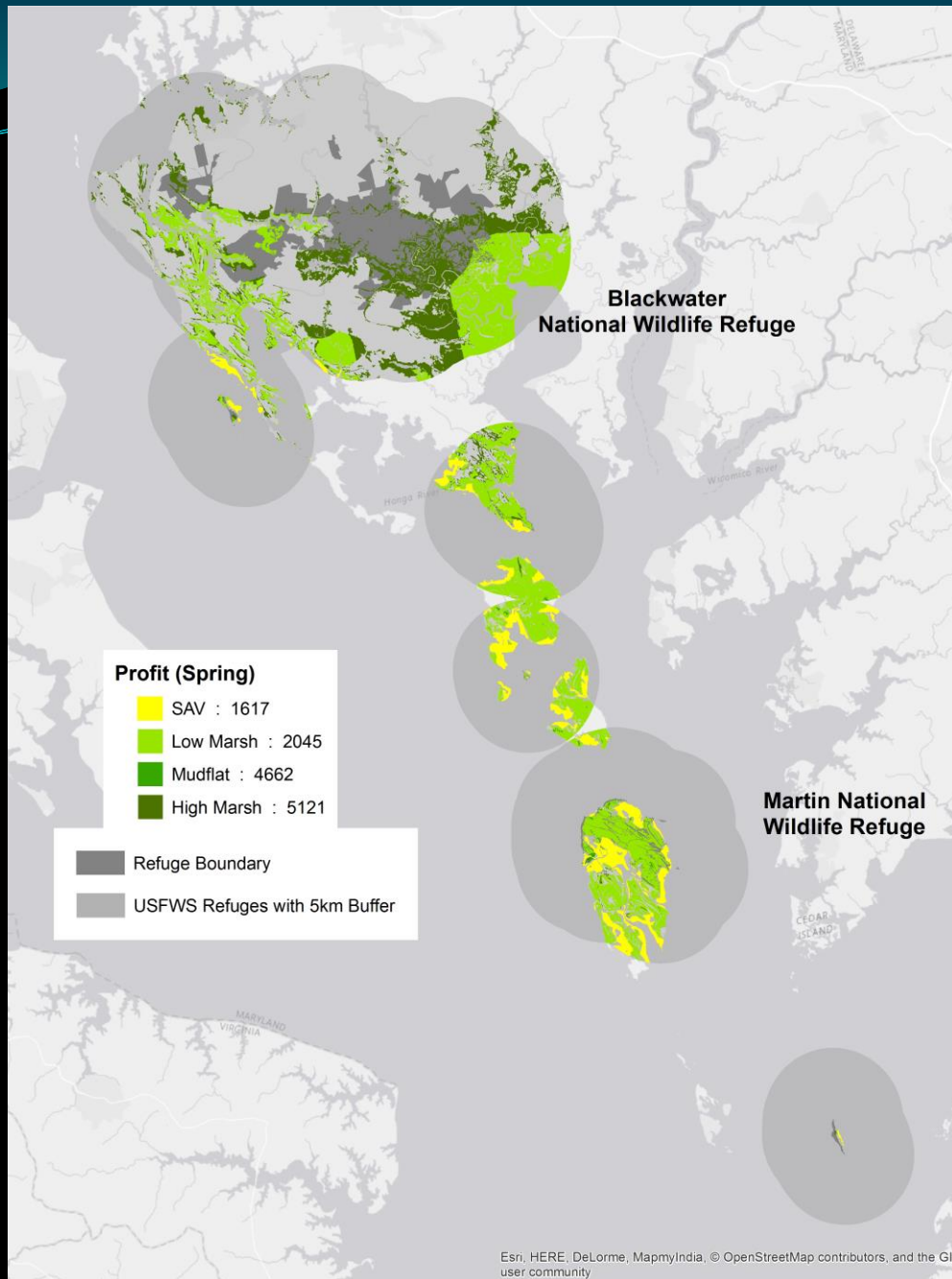
- Low Marsh, SAV, and mudflat appear to be most profitable based on known diet data and biomass data

Freshwater		High Marsh		Low Marsh		Mudflat		SAV	
Winter	kg/ha	Winter	kg/ha	Winter	kg/ha	Winter	kg/ha	Winter	kg/ha
		<i>Scirpus olneyi</i>	9.432	<i>Scirpus validus</i>	3.520	<i>Littoraria irrorata</i>	13.420	<i>Spisula spp.</i>	53.909
		<i>Melampus bidentatus</i>	3.159	<i>Scirpus spp.</i>	1.071	<i>Melampus bidentatus</i>	2.359	<i>Najas guadalupensis</i>	1.762
		<i>Fimbristylis castanea</i>	0.437	<i>Scirpus heterochaetus</i>	0.688	<i>Dalibarda repens</i>	0.181	<i>Tellina modesta</i>	1.055
		<i>Distichlis spicata</i>	0.394	<i>Eleocharis palustris</i>	0.575	<i>Polygonum coccineum</i>	0.174	<i>Ruppia maritima</i>	0.344
		<i>Bromus ciliatus</i>	0.260	<i>Scirpus americanus</i>	0.345	<i>Spartina alterniflora</i>	0.151	<i>Gammarus spp.</i>	0.096
		<i>Panicum spp.</i>	0.225	<i>Scirpus robustus</i>	0.207	<i>Rhus family</i>	0.065	<i>Zannichellia palustris</i>	0.037
		Other	1.242	Other	1.500	Other	0.477	Other	0.121
Fall		Fall		Fall		Fall		Fall	
<i>Hypericum spp.</i>	1.877	<i>Scirpus validus</i>	3.525	<i>Littoraria irrorata</i>	22.019	<i>Littoraria irrorata</i>	15.024	<i>Scirpus americanus</i>	0.075
<i>Ipomoea spp.</i>	1.085	<i>Scirpus acutus</i>	0.418	<i>Mytilopsis leucophaeata</i>	4.695	<i>Melampus bidentatus</i>	3.801	<i>Ruppia (maritima or rostellata)</i>	0.056
<i>Panicum capillare</i>	0.576	<i>Scirpus olneyi</i>	0.202	<i>Spartina alterniflora</i>	1.056	<i>Madia spp.</i>	1.662	<i>Scirpus heterochaetus</i>	0.055
<i>Panicum amarum Ell. var. amarulum</i>	0.138	<i>Hibiscus spp.</i>	0.181	<i>Scirpus spp.</i>	0.408	<i>Zannichellia palustris</i>	1.440	Unidentified SAV	0.049
<i>Decodon verticillatus</i>	0.131	<i>Prunus pensylvanica</i>	0.165	<i>Ruppia maritima</i>	0.394	<i>Potamogeton perfoliatus</i>	1.143	<i>Gemma gemma</i>	0.007
<i>Cyperus spp.</i>	0.109	<i>Scirpus americanus</i>	0.118	<i>Sesarma reticulatum</i>	0.217	<i>Mytilopsis leucophaeata</i>	0.884	<i>Zannichellia palustris</i>	0.006
Other	0.143	Other	0.352	Other	1.127	Other	2.977	Other	0.033

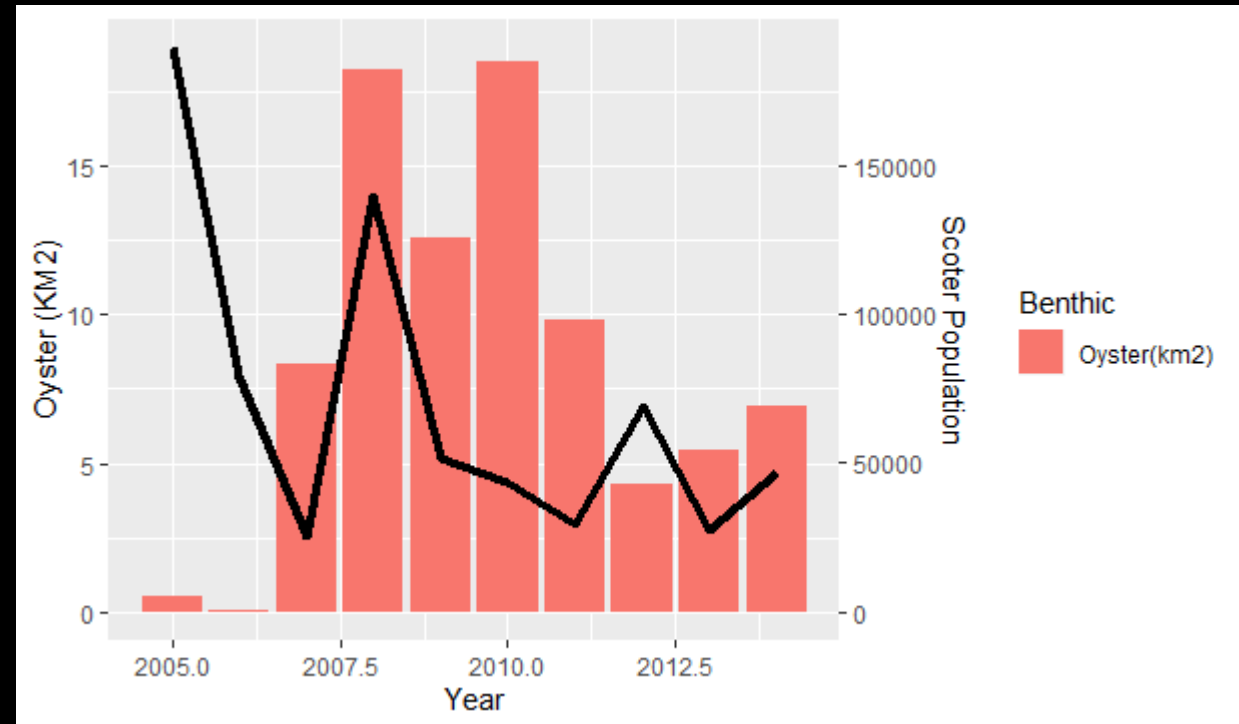
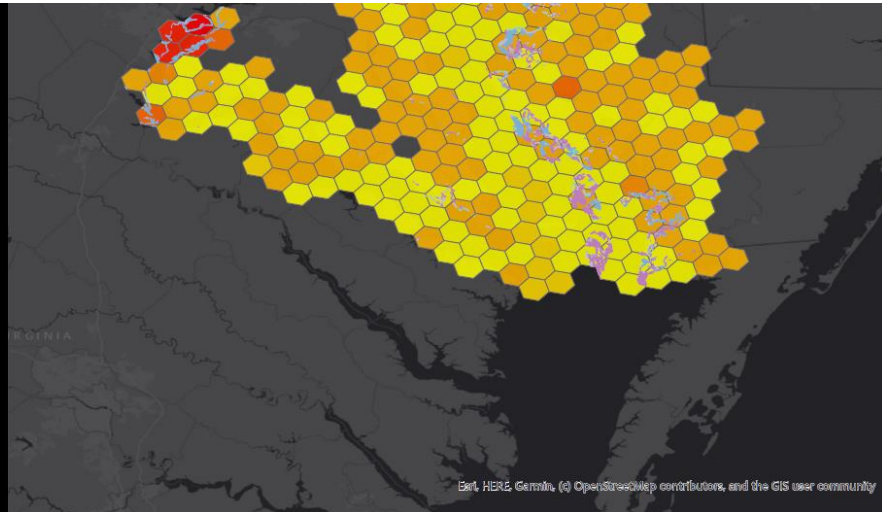
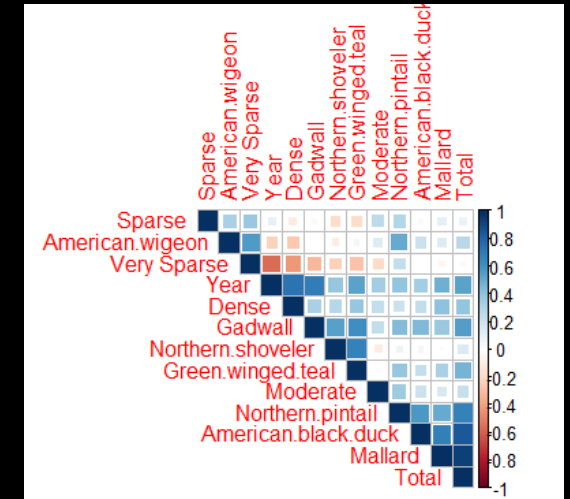
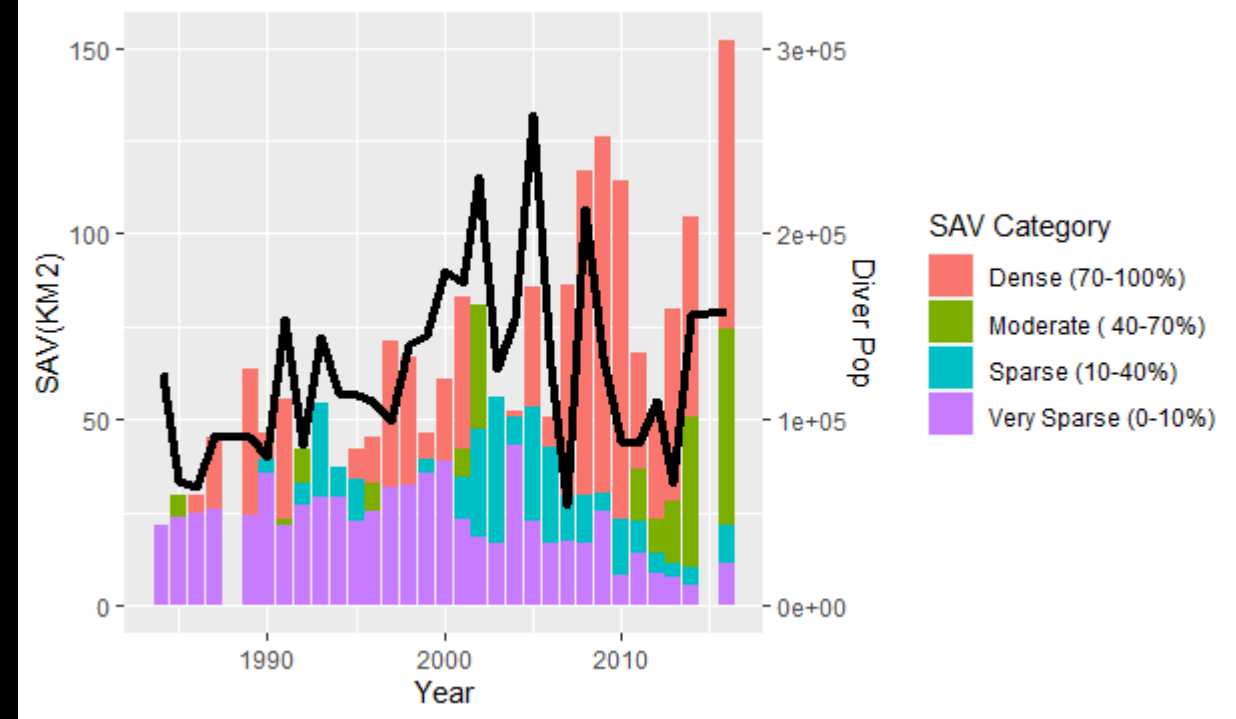




- This type of information allows for estimating per hectare profit based on habitat type and time of year



- Start pairing and exploring relationships between different bird species/guilds population estimates and food resources

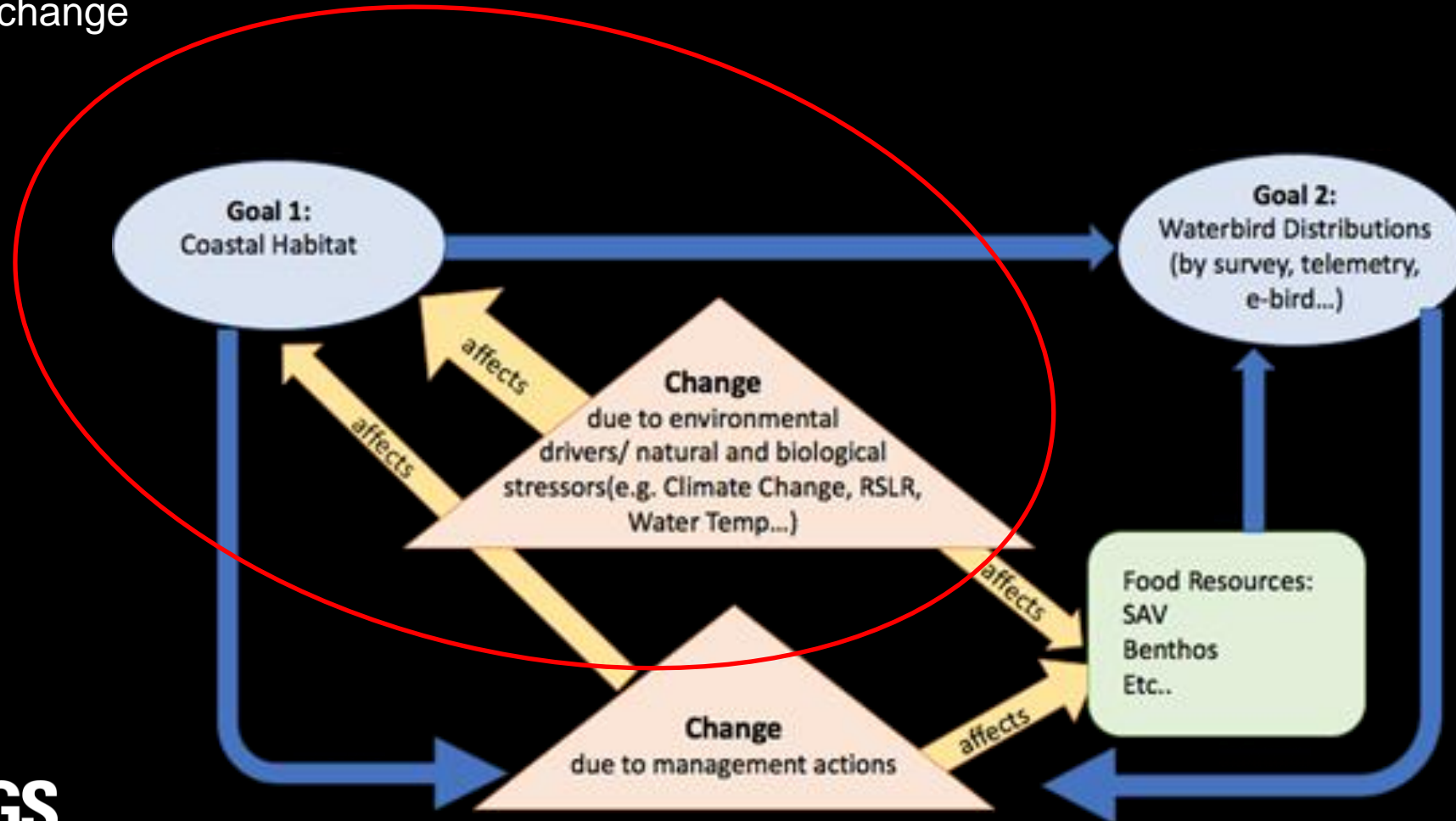


# Towards Modeling Habitat Change

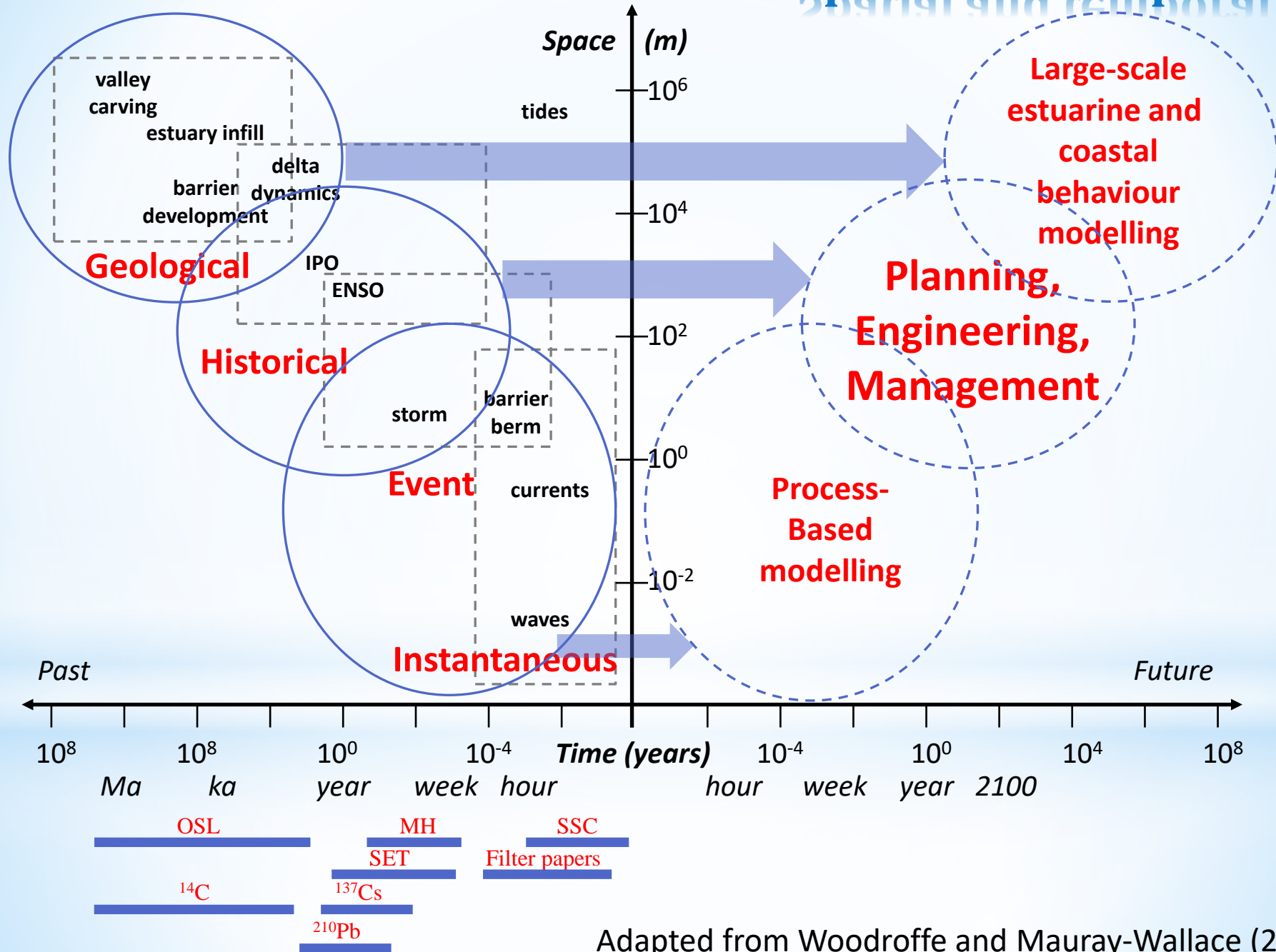


A: Assess risks to coastal habitats and DOI lands, by forecasting vulnerability and resiliency of coastal systems to future change

B: Understand the factors affecting waterbirds and their habitats



# \* Spatial and temporal scales



Eastern Neck NWR

## Waterfowl Hotspot



☆ EN\_StratSampleLoc2

### Habitat\_\_1

- Freshwater ponds/impoundments
- High Marsh
- Low Marsh
- Mudflats
- SAV

## Problem:

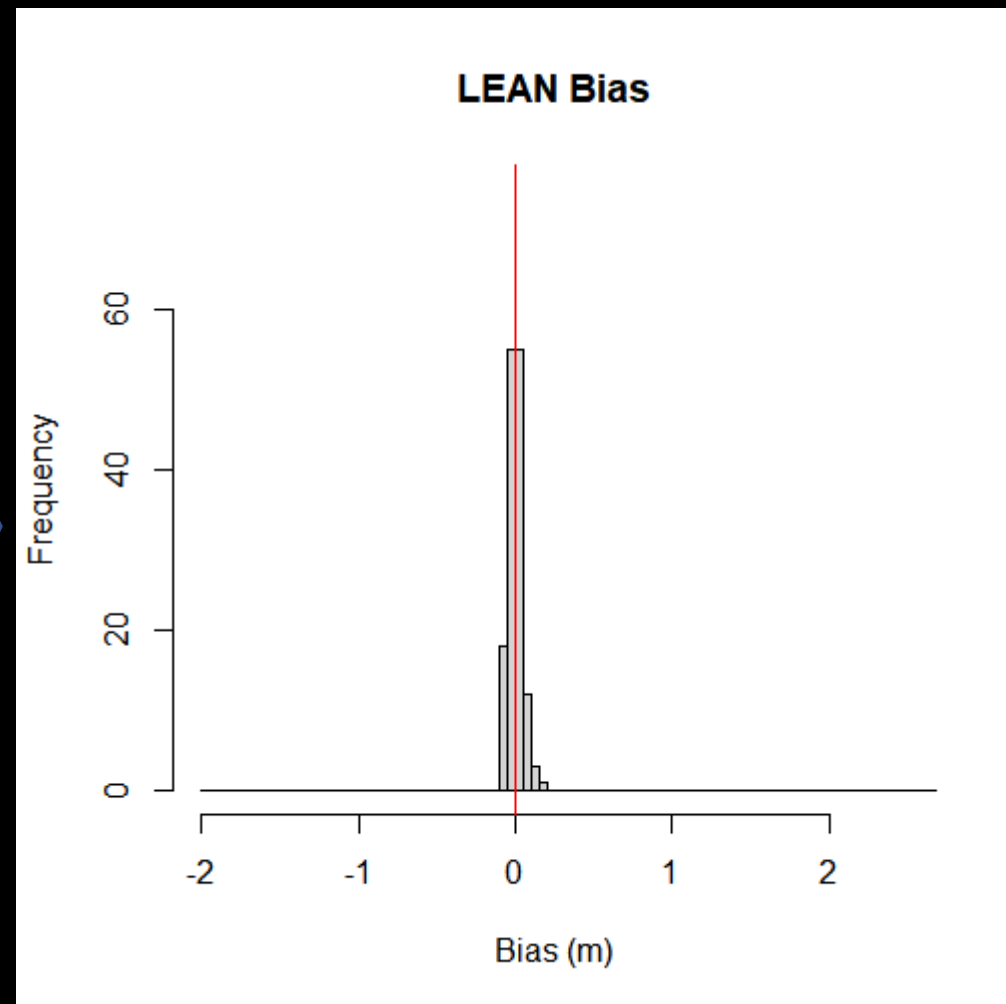
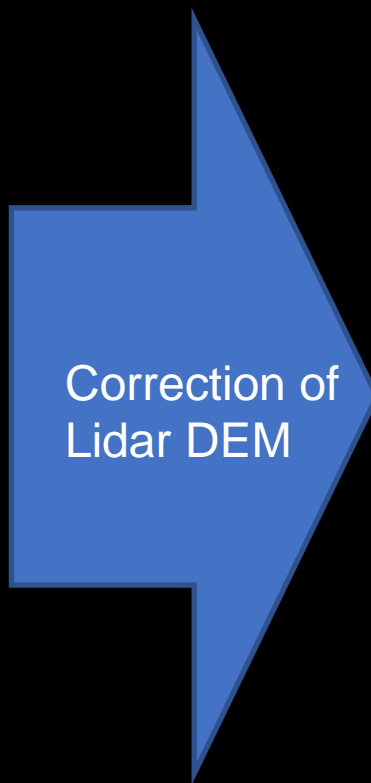
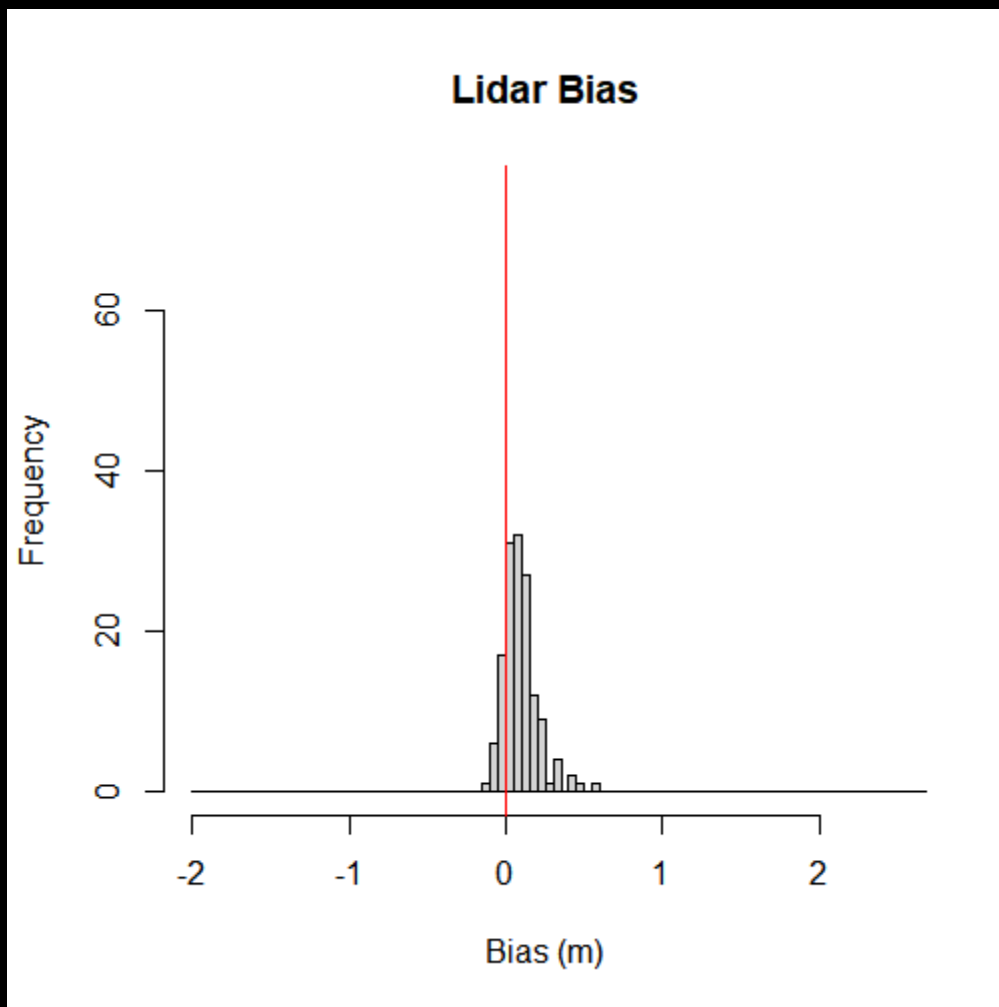
- LiDAR cannot penetrate dense vegetation, causing a positive bias in 'bare earth' DEMs
- Tidal marsh sea-level rise vulnerability analysis & modeling requires accurate DEMs

## Objectives:

1. Use statistical correction model to adjust DEMs  
(LEAN technique, Buffington et al. 2016)
2. Assess scalability of LEAN corrections [how many elevations surveys are required?]
3. Compare LEAN models calibrated with NDVI vs intensity metrics (available in newer LiDAR datasets)
4. Roll procedure into CONED protocols for topobathy



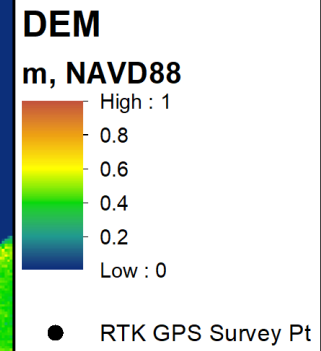
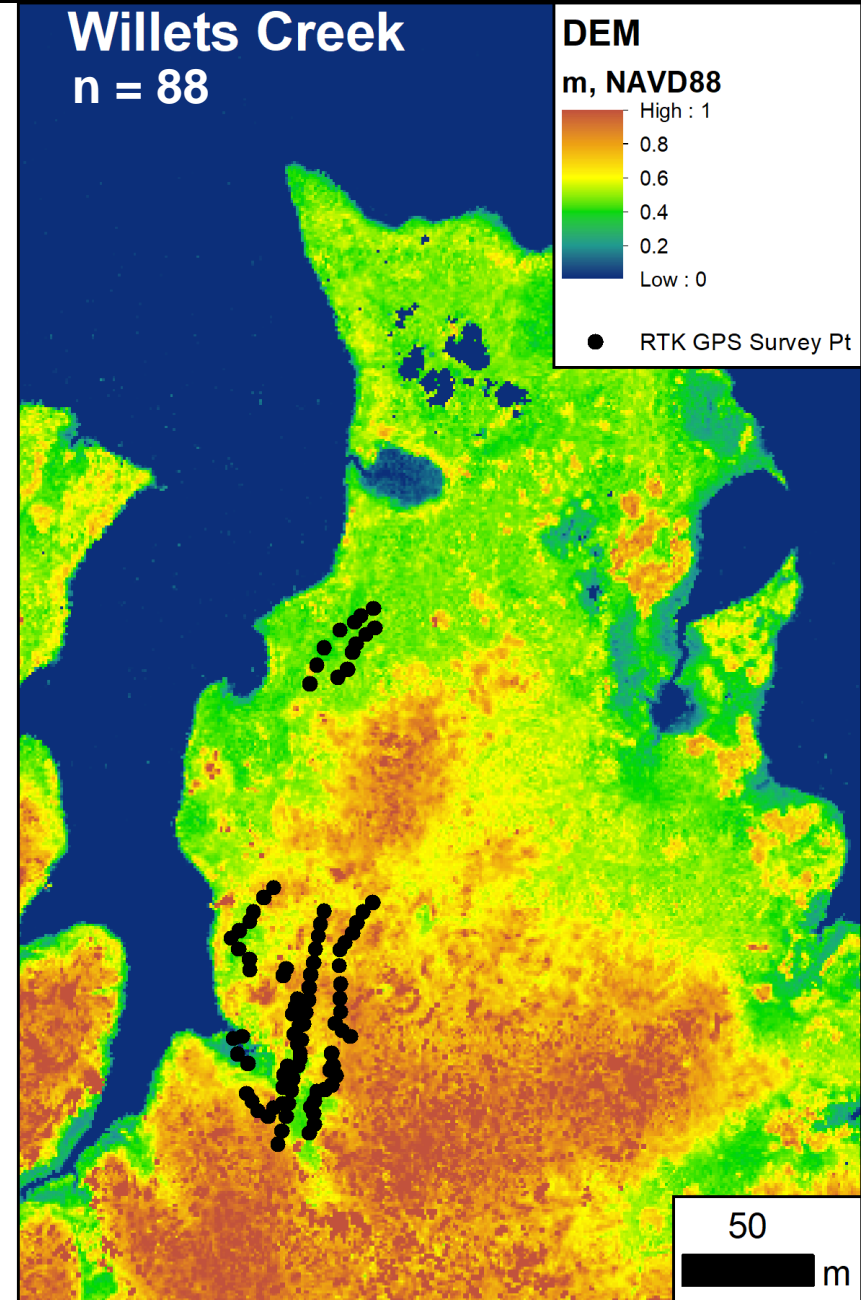
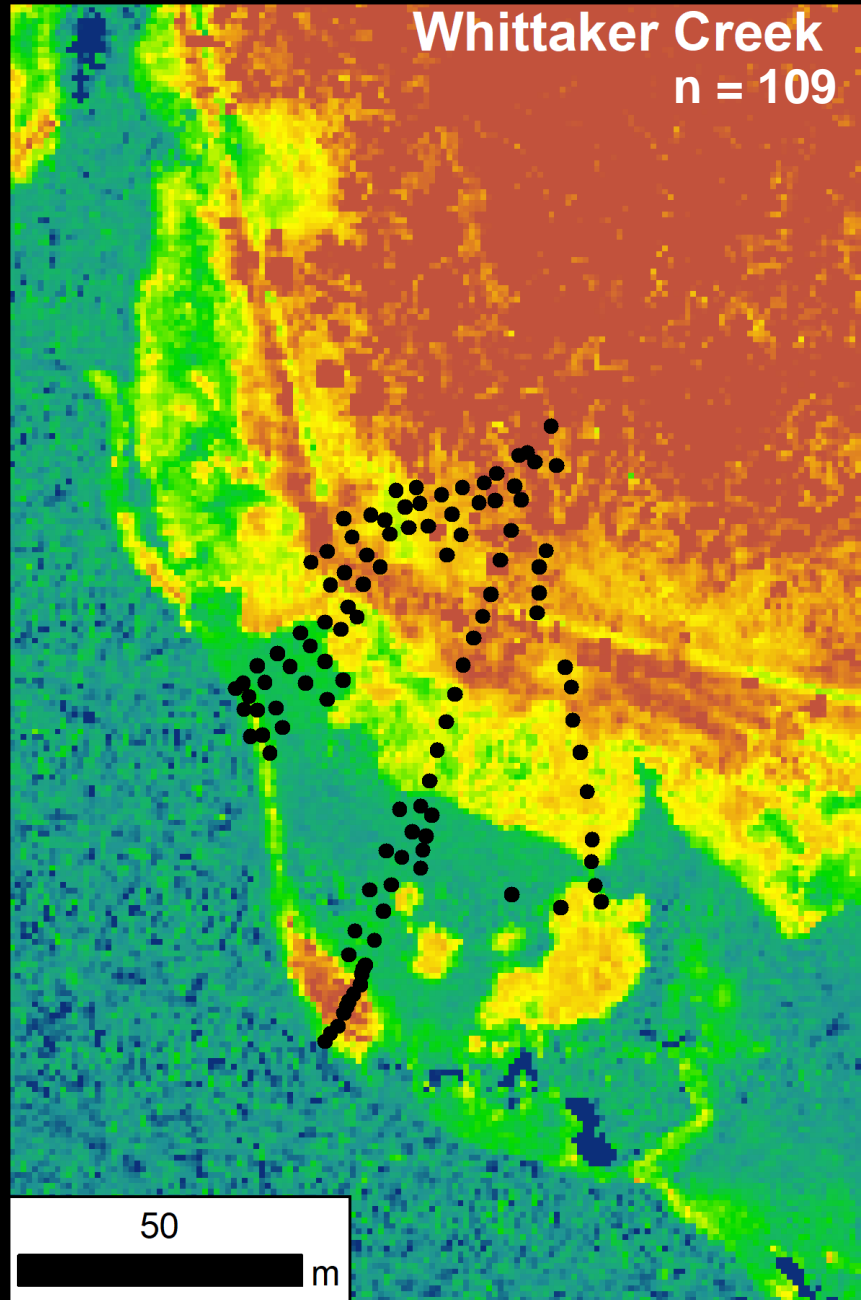
# Lidar error and bias, and correction



Original

RMSE: 0.277 m  
Mean Error: 0.099 m

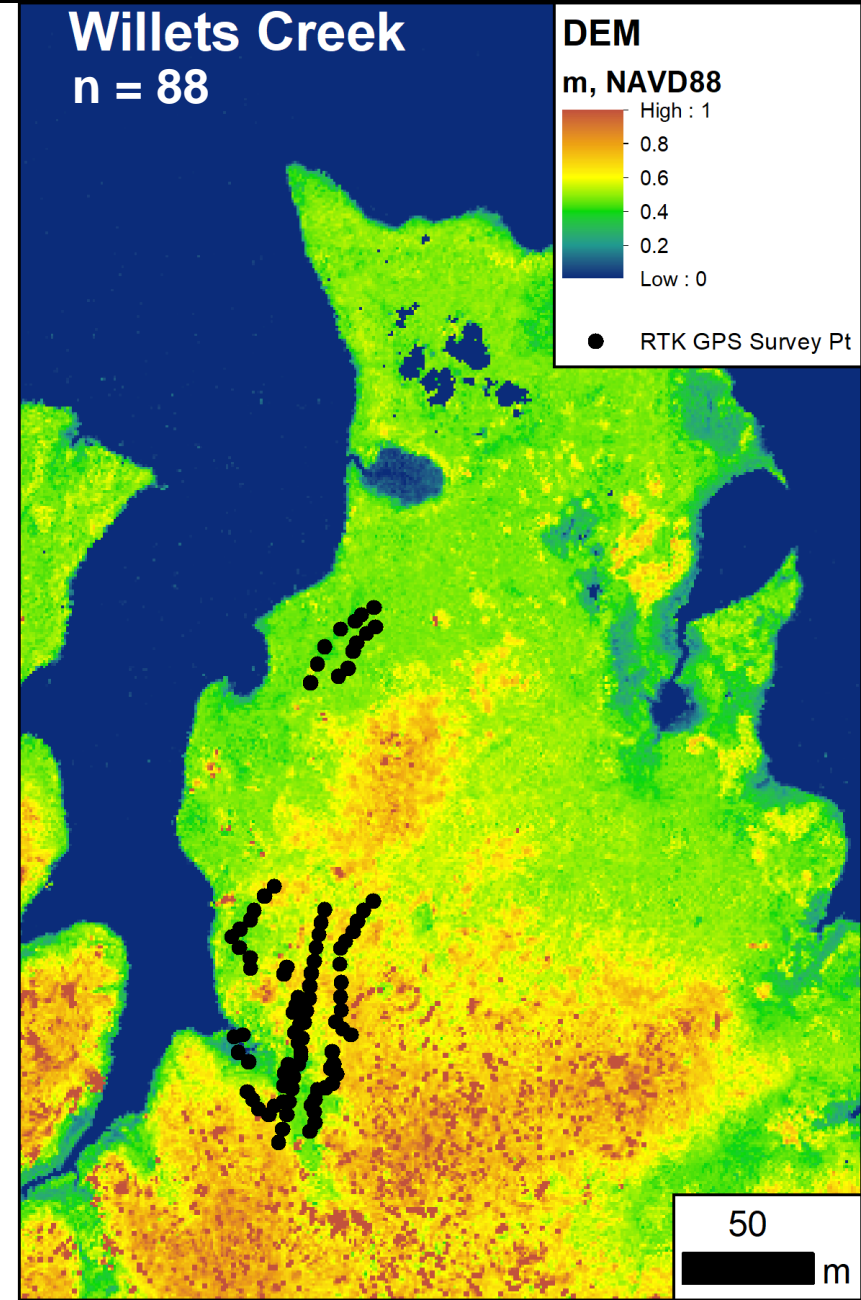
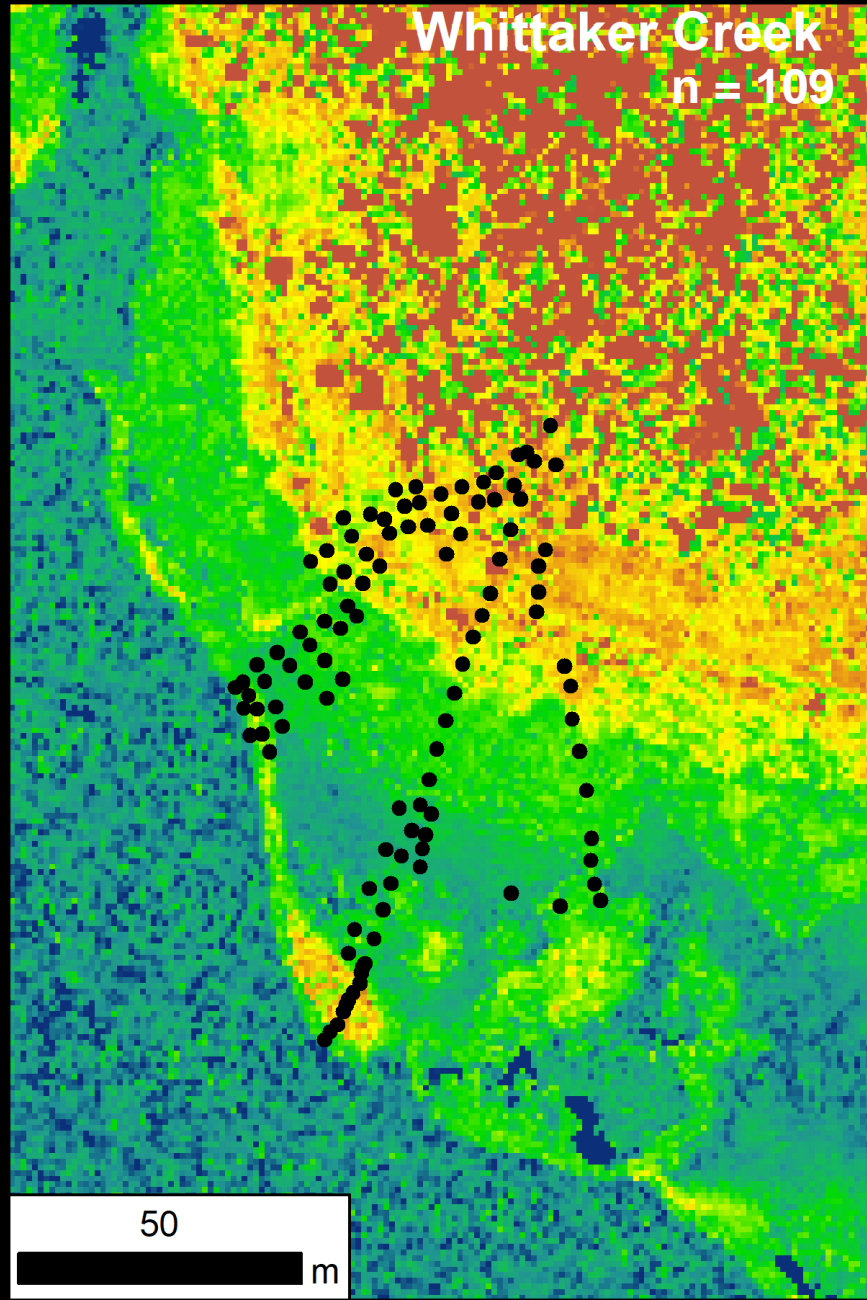
RMSE: 0.341 m  
Mean Error: 0.11 m



**LEAN**

RMSE: 0.154 m, 52.5% improvement  
Mean Error: -0.0012 m

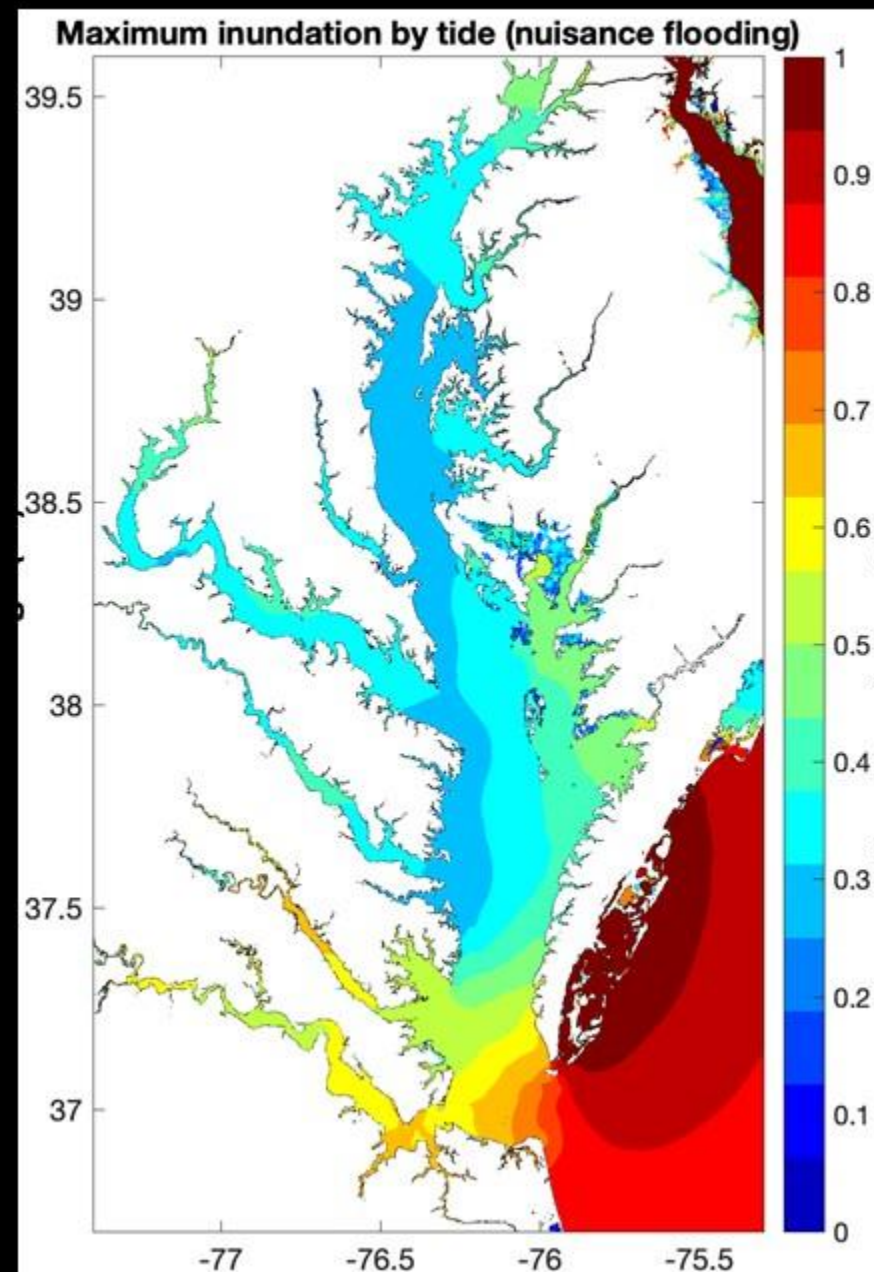
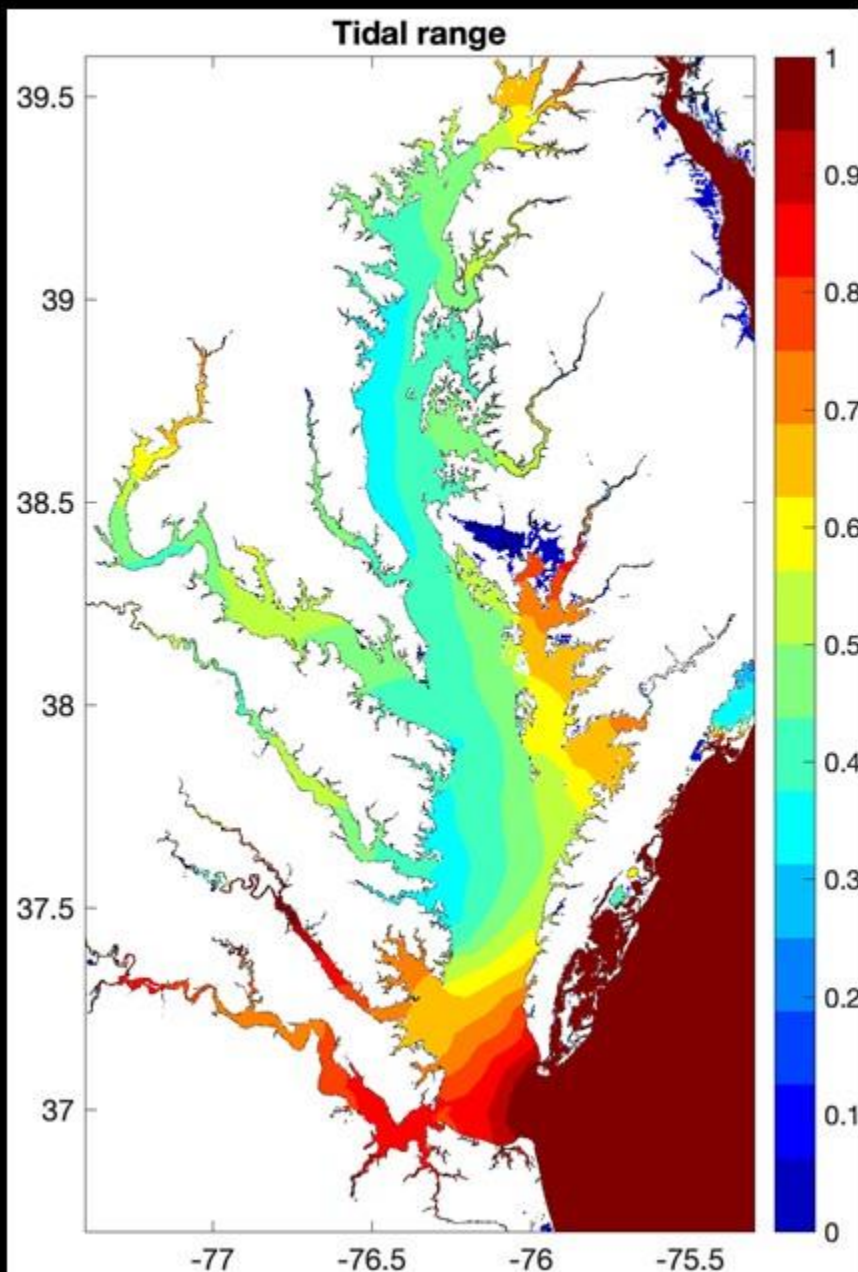
RMSE: 0.042 m, 86.9% improvement  
Mean Error: -0.0063 m





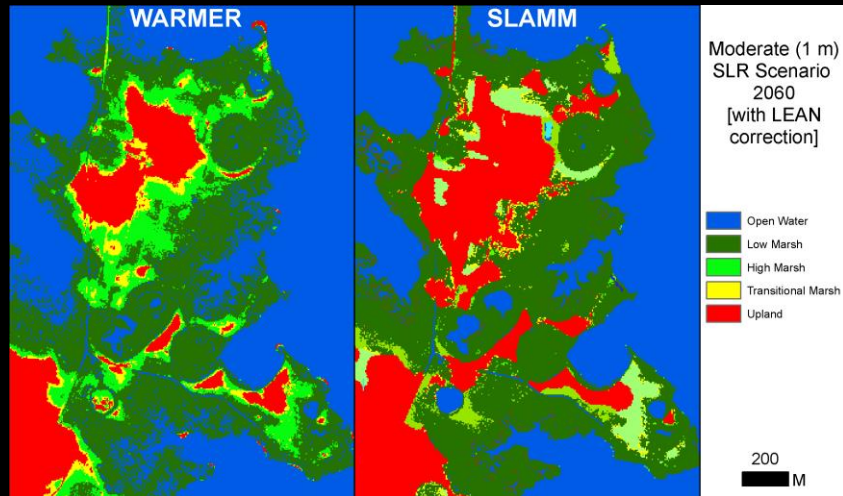
## Next steps:

- Updating bathy/topo with newest CONED
- Correct MSL/NADV88 datum adjustments
- Include river discharge where available

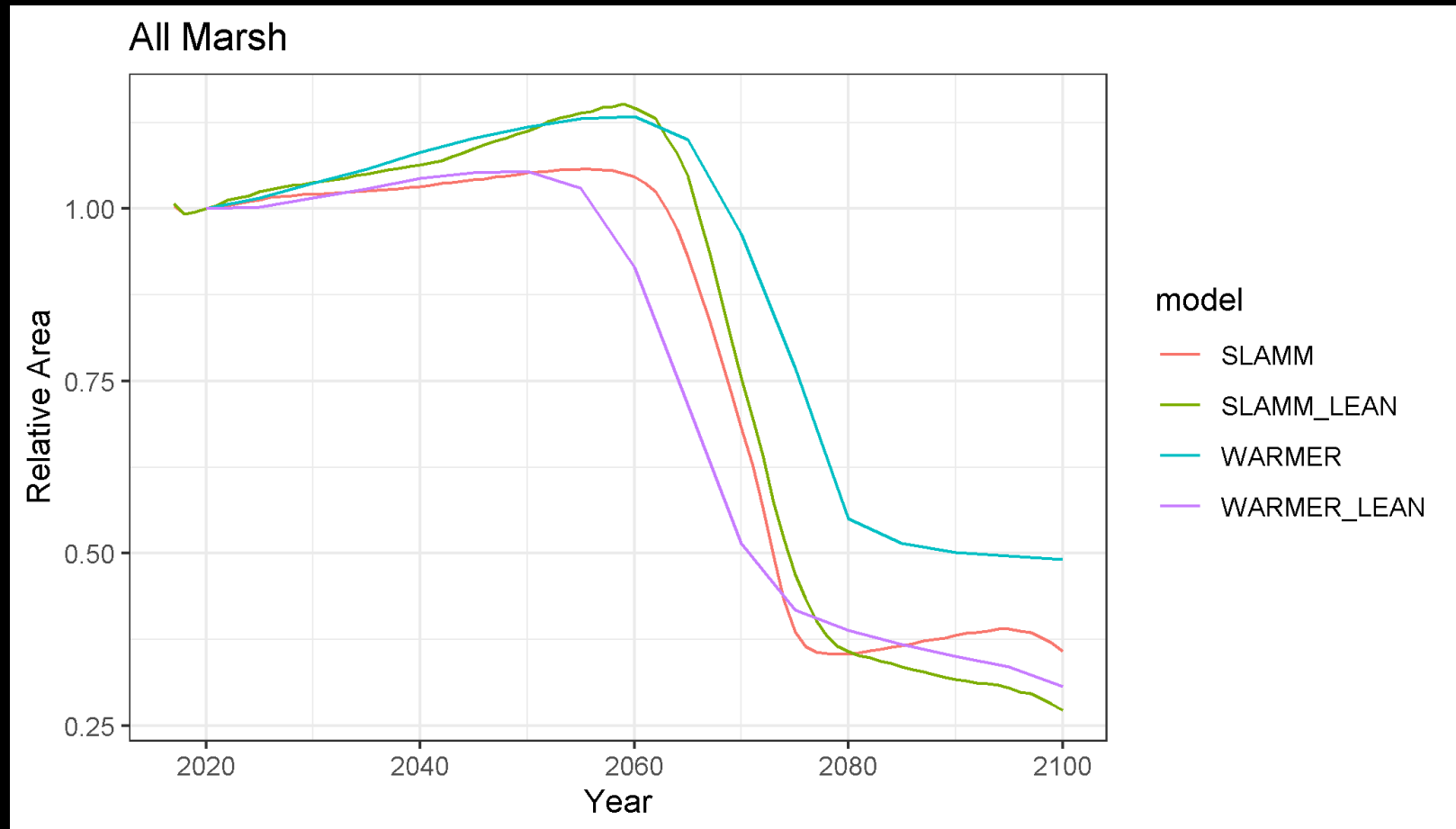




# Vertical dynamic models (SLAMM, WARMER), Eastern Neck NWR



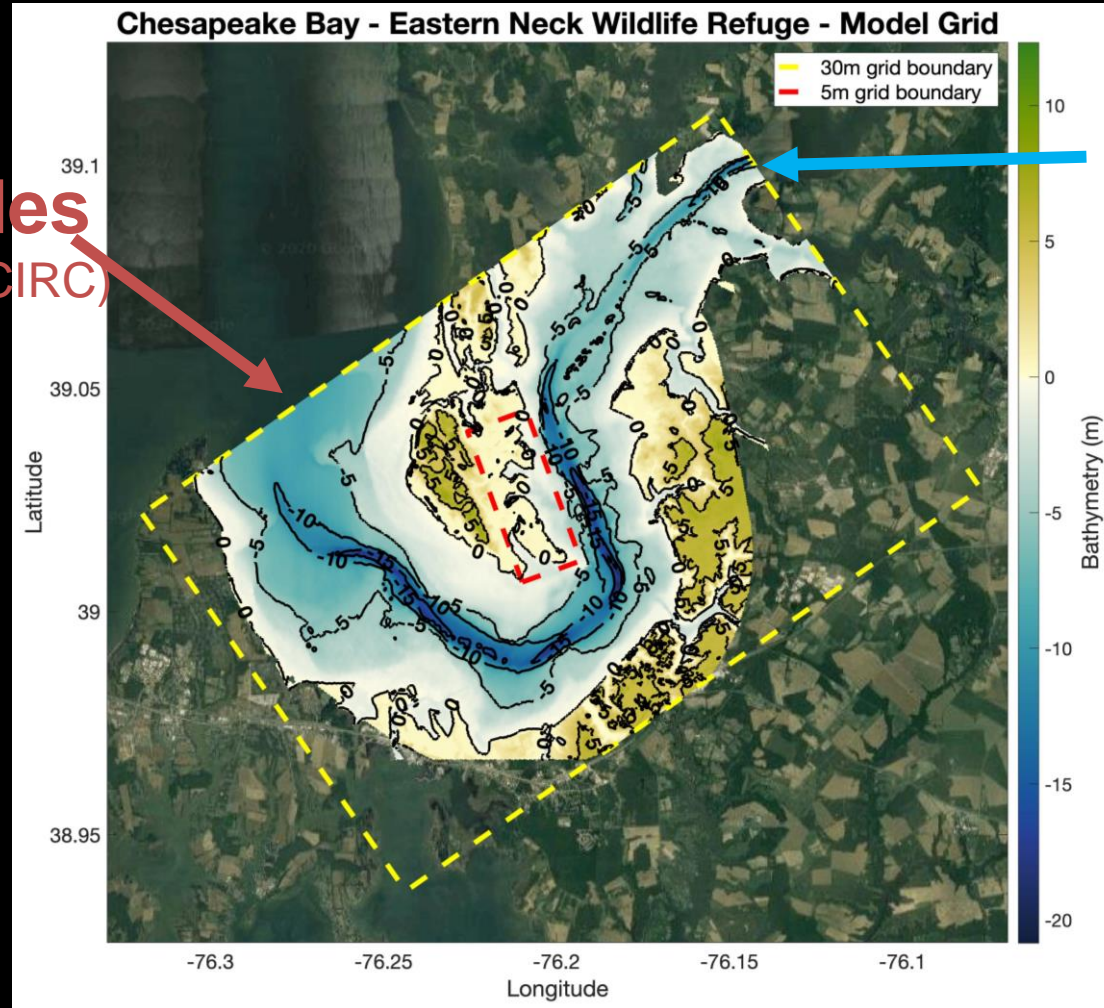
Importance of initial “state” of the system



# Hydrodynamic model forcing (COAWST)



**Tides**  
(ADCIRC)



**River**  
(Chester River  
01493112 USGS gauge)

and,  
**Meteorological  
Forcing**



# Eastern Neck Wildlife Refuge Vegetation Study



The presence of SAV is one of the most significant factors that **determine sustaining waterfowl populations**. Dominant factors of SAV loss is eutrophication through nutrient loading and reduced light availability through epiphytic growth and suspended sediment concentrations.

**Goal:** Use a coupled modeling system to better understand what drives the distribution of waterfowl habitat (SAV growth/die off) given various hydrodynamic and water quality conditions using COAWST and SAV growth model.



Observed Chester River Eelgrass Coverage	
Year	Lower Chester River (CHSMH)
2010	34.04
2011	114.72
2012	70.34
2013	14.86
2014	58.12
2015	154.88
2016	187.4
2017	95.04
2018	154.59
2019	TBD

\* primarily widgeon grass

VIMS dataset:

<http://web.vims.edu/bio/sav/index.html>

# Future steps:

**Generate ensemble model outputs of habitat change under key environmental driver projections.**

**Incorporate those projections/understanding of habitat change into a geospatial synthesis products**

**Link Habitat change to potential waterfowl distributions**



# End-user applications

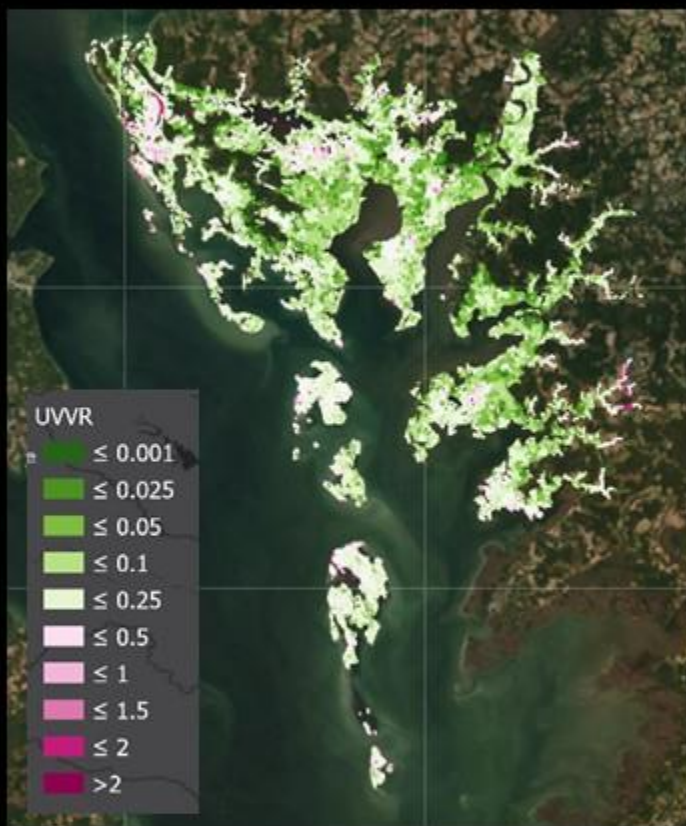
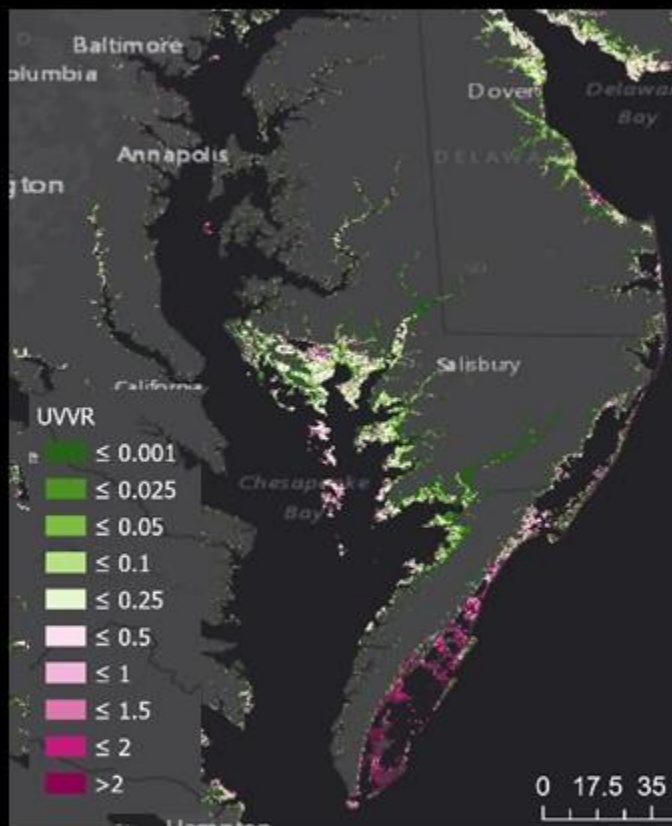
Can we:

- Identify critical system parameters that determine rates of change (for example : marsh migration, marsh loss?)
- Extract these parameters from remote sensing/model output in Ches. Bay?
- Deliver maps of change likelihood (example: migration likelihood?)
- Use those maps to guide management, acquisition, and restoration?



# Geospatial studies and likelihood of habitat change

# Marsh vulnerability: marsh-unit and UVVR using Landsat



UnVegetated-Vegetated marsh ratio

Vulnerability metric that integrates sediment budgets and sea-level rise

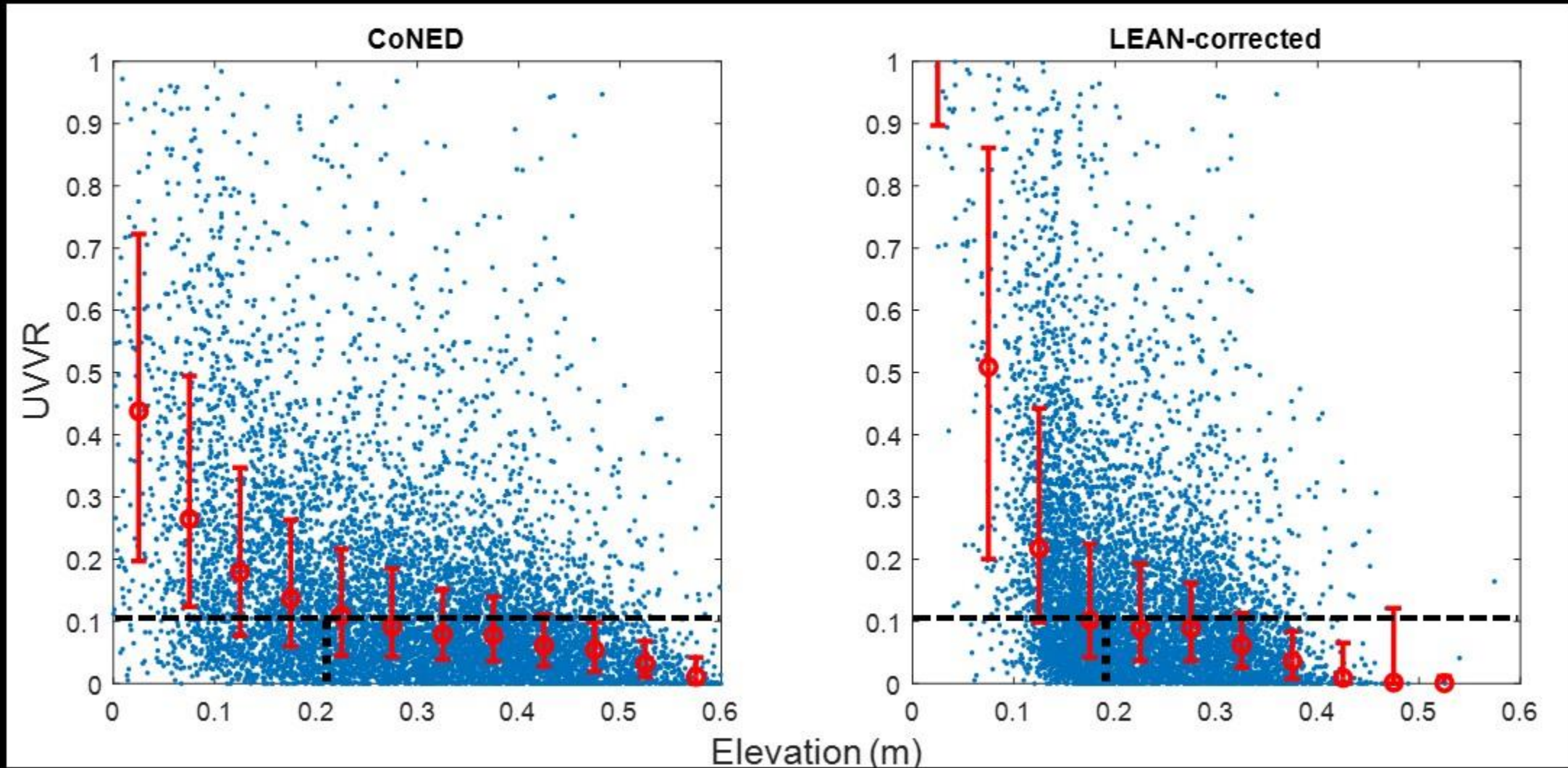
Landsat-based product complete

Detailed “marsh-unit” version 50% complete

Includes mapping of elevation, tide range



# Chesapeake UVVR vs. elevation comparison with LEAN\* correction

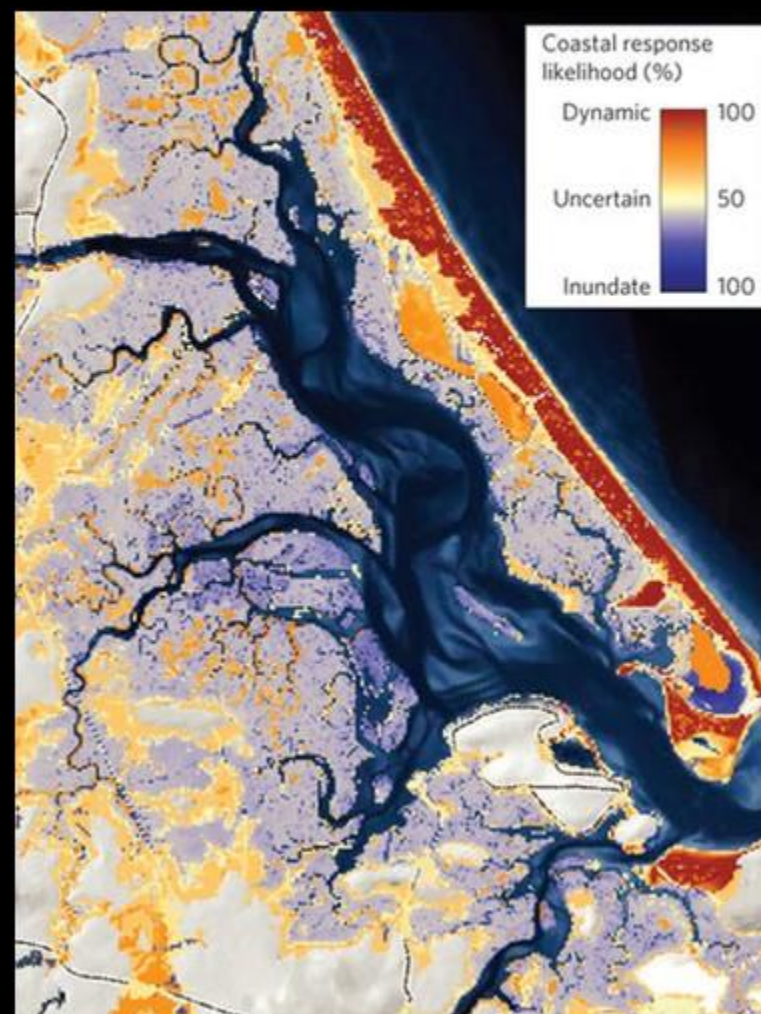
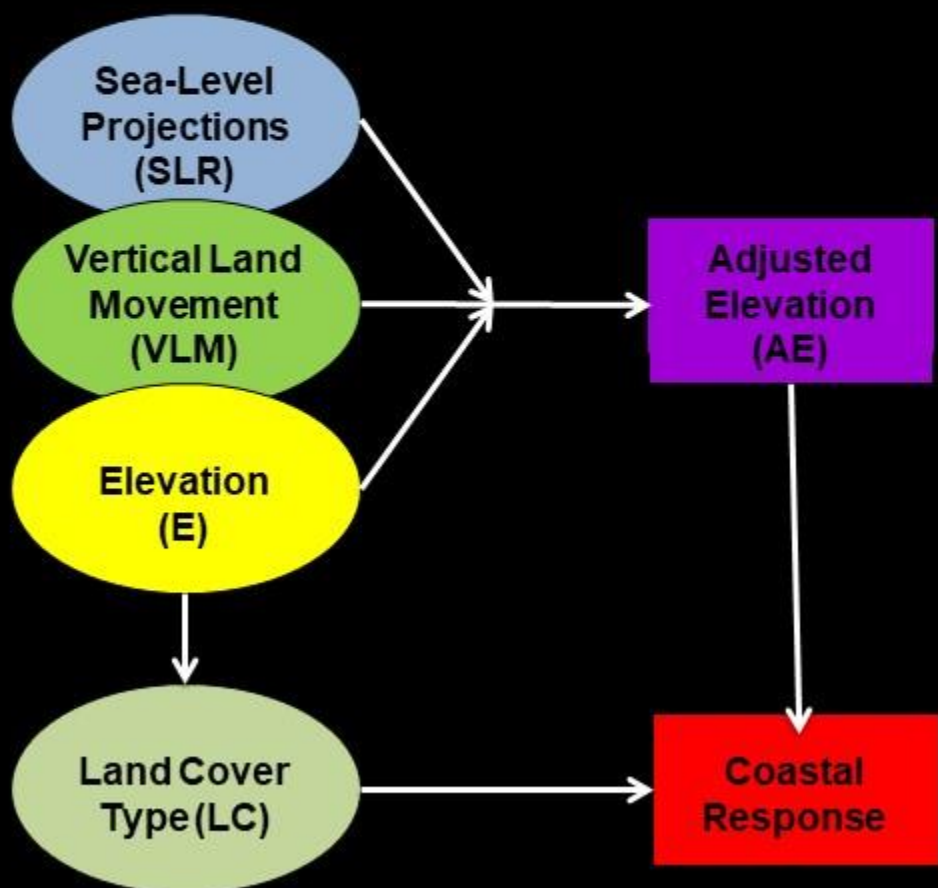


\*LEAN = Lidar Elevation Adjustment with NDVI



# Coastal Response model: likelihood of vertical response

## Bayesian network of coastal response



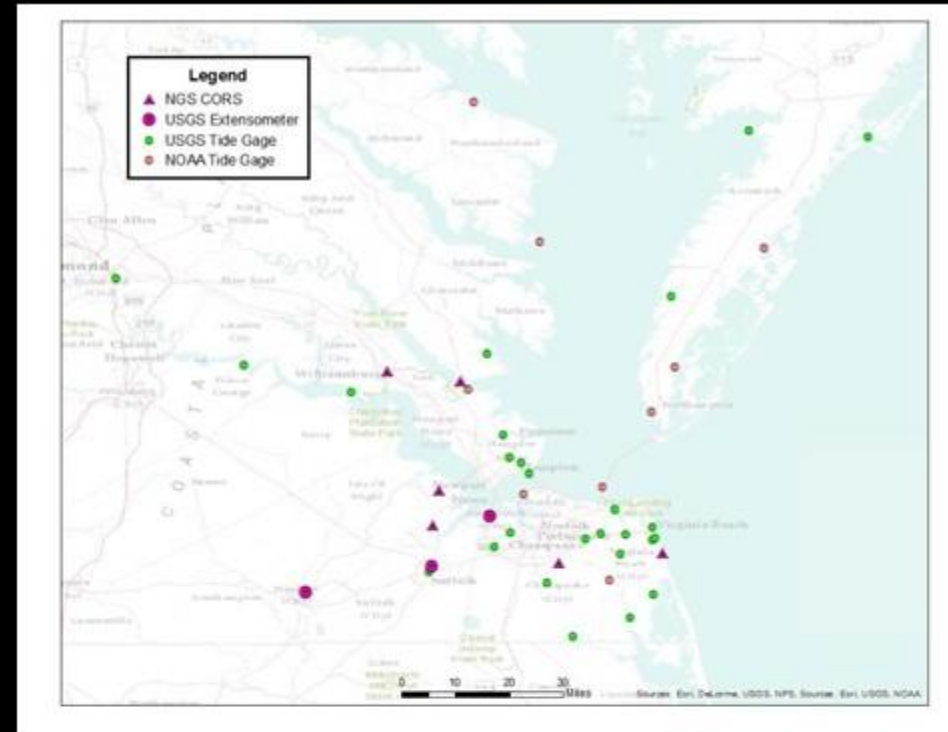
# Enhancing the Coastal Response Model

Vertical land movement: expand network of benchmark stations to get updated picture of subsidence

Vertical response of marshes: incorporate representation of tide-dependent processes (biomass→vertical growth)

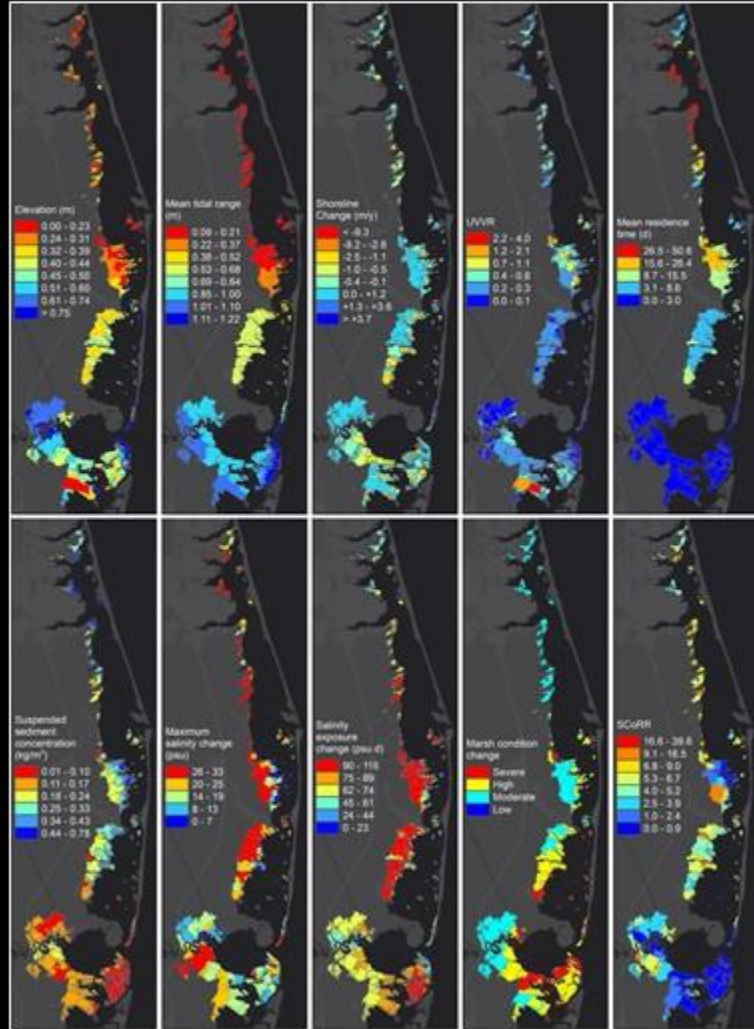
Lateral response of coasts: incorporate probabilistic wave climate into sandy and marsh coastlines

Internal response of marshes: use remote-sensing metrics to estimate likelihood of internal deterioration (UVVR)





# Metrics to guide restoration investments:

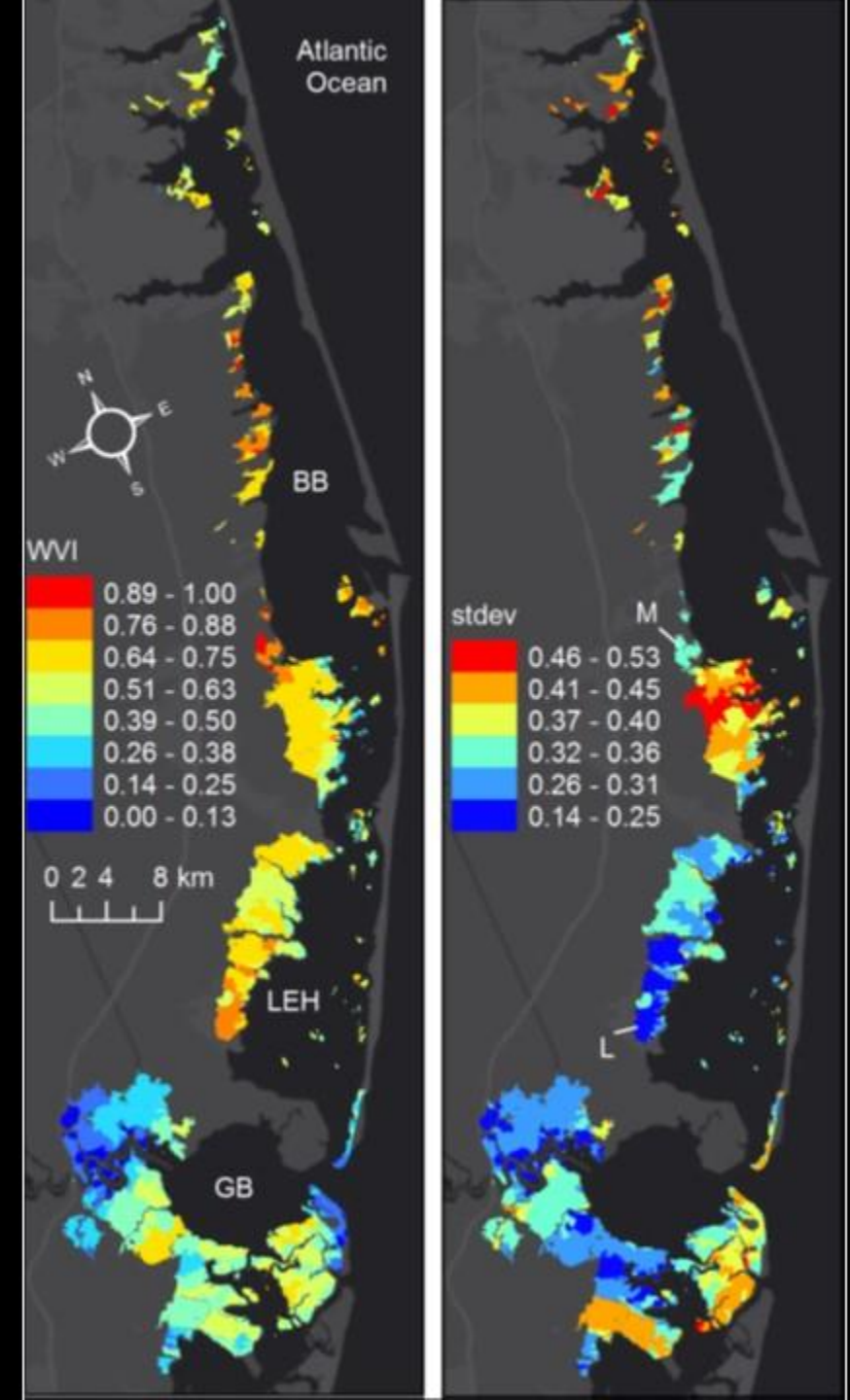


Combine multiple data layers into wetland vulnerability index

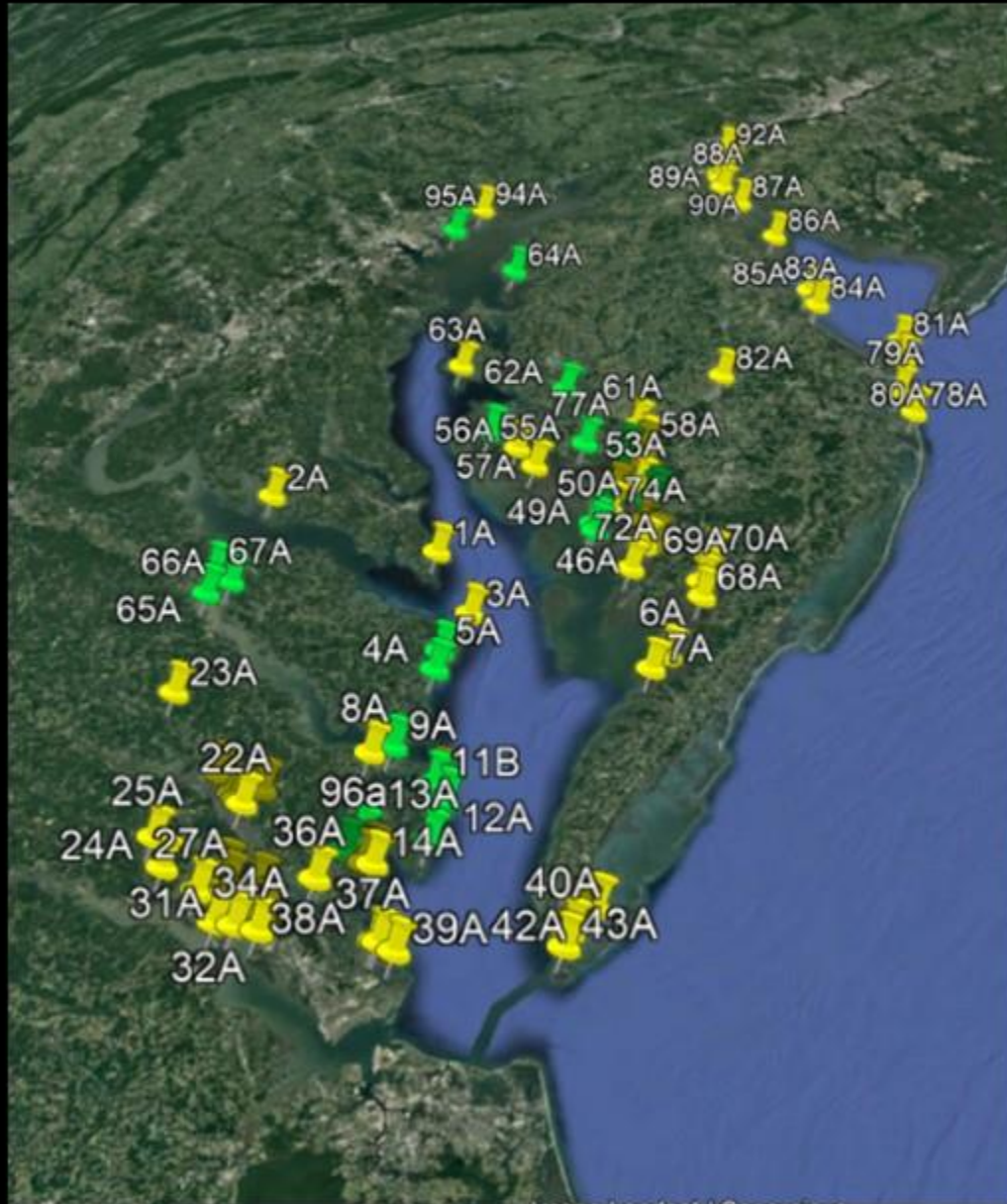
Deliver WVI through portals

Map can be explored unit-by-unit to identify parameters causing most vulnerability

Products can be updated regularly to get time-series of vulnerability



# Chesapeake Bay Marsh-Upland Transect Surveys



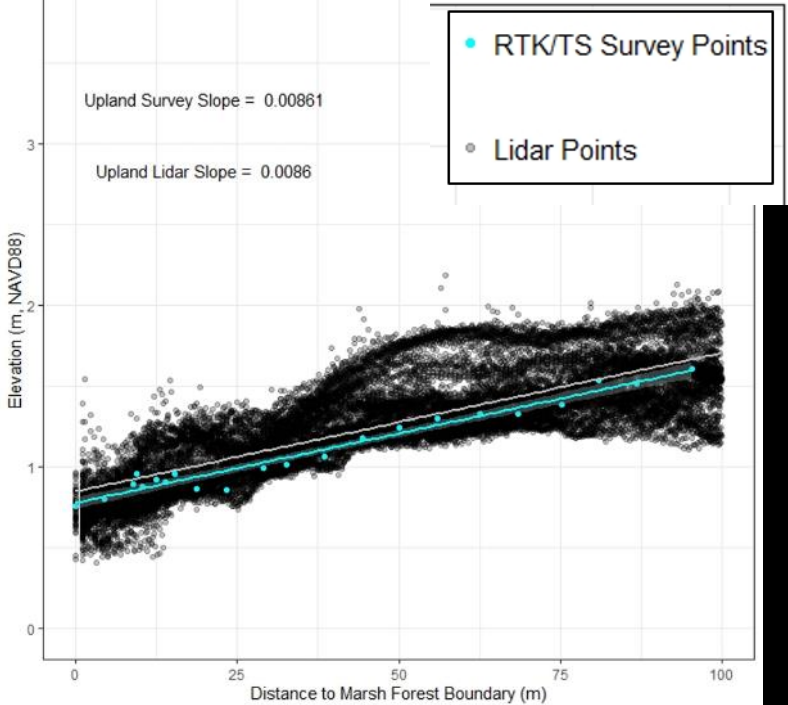
22 sites completed from 2019-2021

Sites Identified via ArcGIS based on criteria:

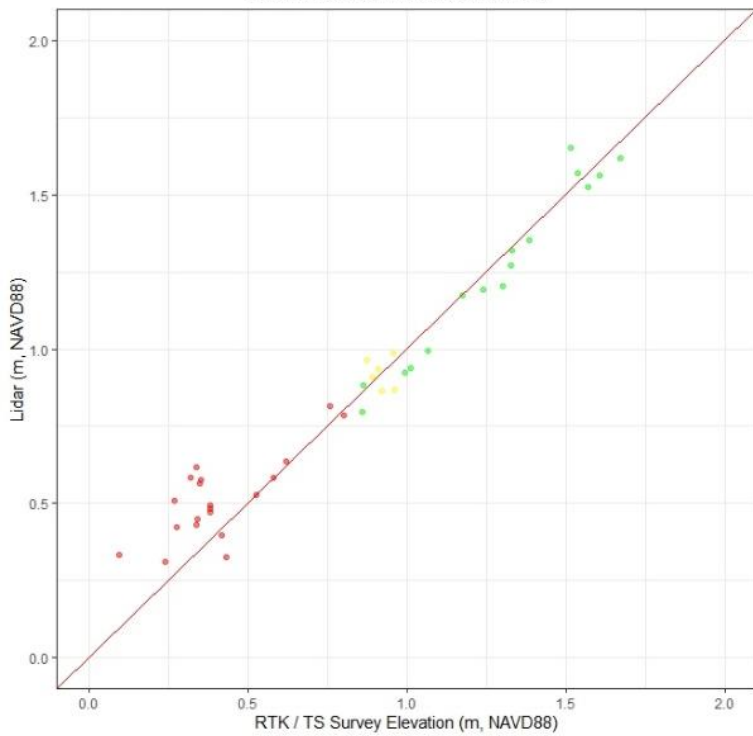
1. Contains forested dry land adjacent to existing wetland (from NWI)
2. Is on public lands (eg, MD DNR, NWR, NERR, State Parks, etc.)
3. Overlap with NOAA t-sheet maps from 1850-1920 where possible



# Comparing LiDAR to RTK-Total Station Survey Results



-LiDAR-derived upland slopes tend to broadly match survey-derived slopes



-Greatest discrepancy occurs in the wetland, where the LiDAR elevation tends to over-estimate elevation

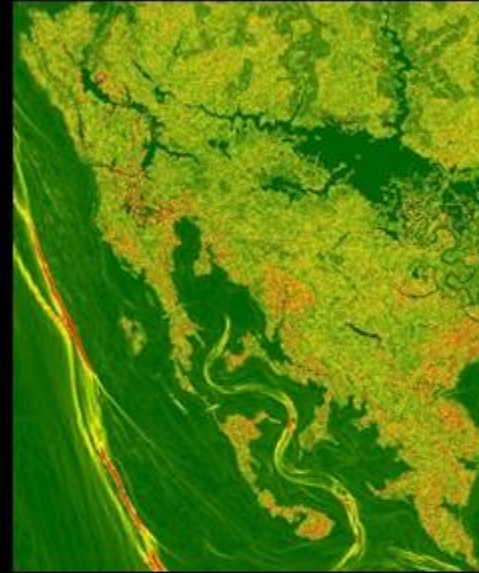
# Mapping likelihood of migration into coastal forests:



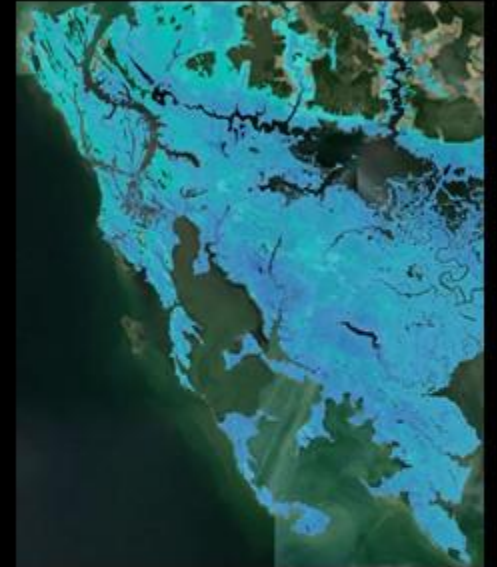
*Example: Dorchester  
County*



*1) Coastal forest (red)  
adjacent to tidal wetland*



*2) Slope  
(green-low, red-high)*

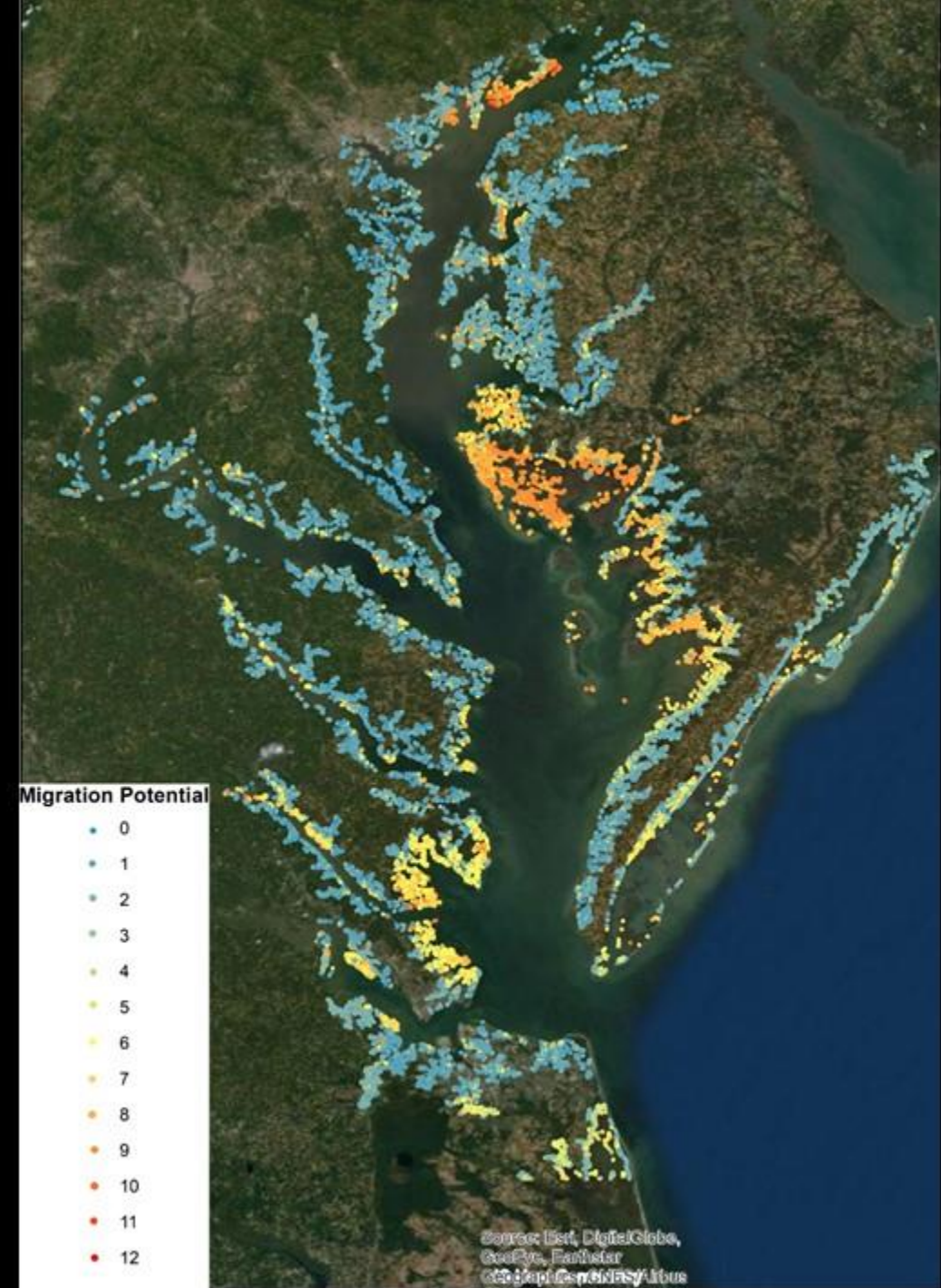


*3) Max inundation from  
Cat1 hurricane*

- 1) Isolate coastal forests adjacent to tidal wetlands using land cover/land use datasets
- 2) Determine geomorphic slope at the marsh-forest boundary
- 3) Use hydrodynamic models of real and synthetic storms to determine maximum extent of saltwater
- 4) Overlay these data and compare with observed migration areas

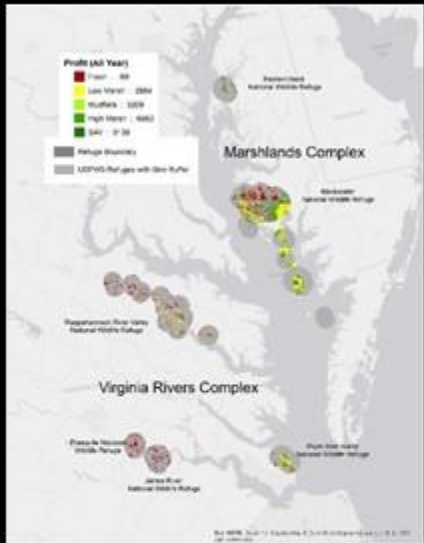
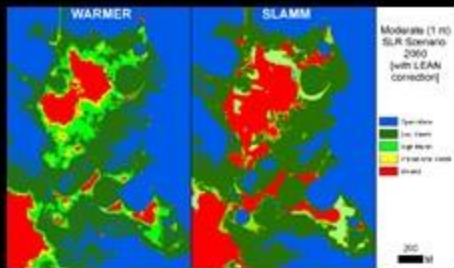
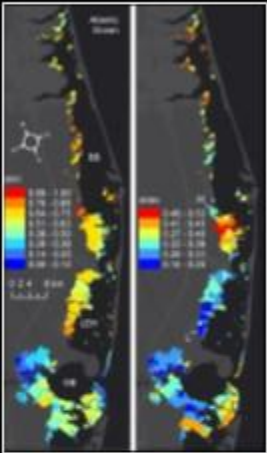
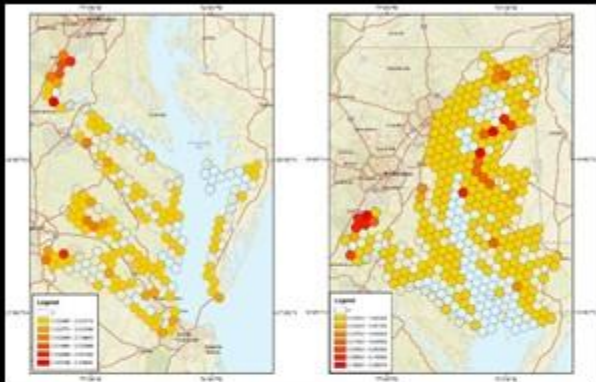


Combine slope and storm likelihood and inundation  
inundation to provide one estimate of migration potential

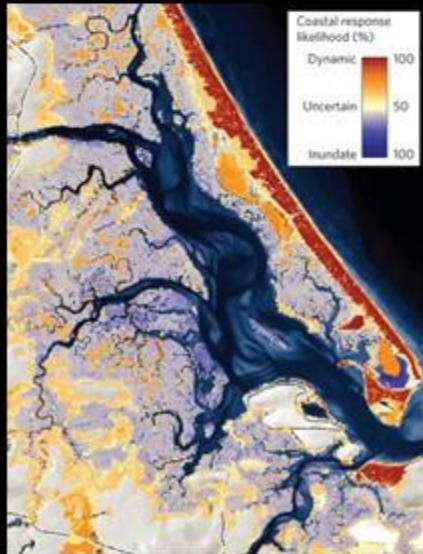
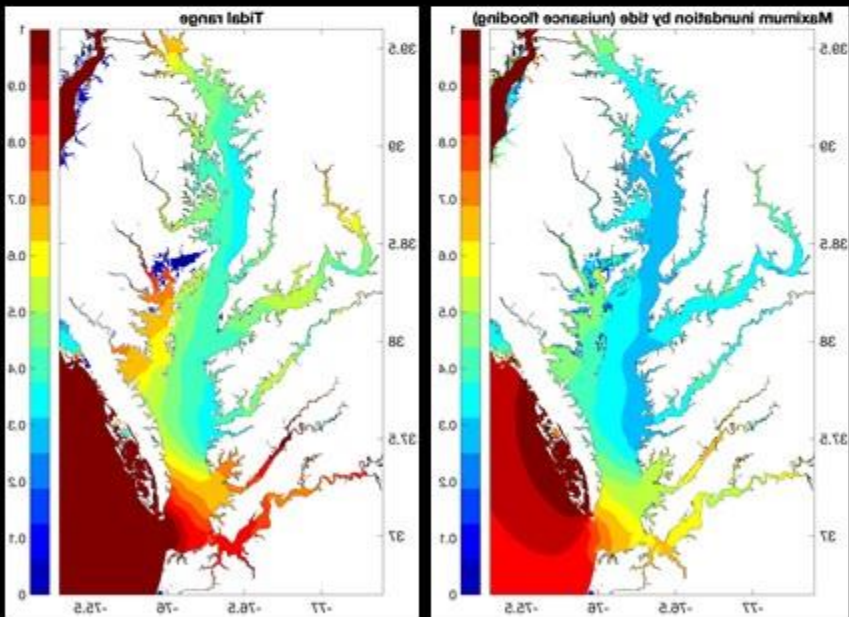




# Metrics to guide restoration investments:



Similarly...  
combine multiple data  
layers and modeling  
output into waterfowl  
habitat change index



Processes we need to  
better constrain and  
understand

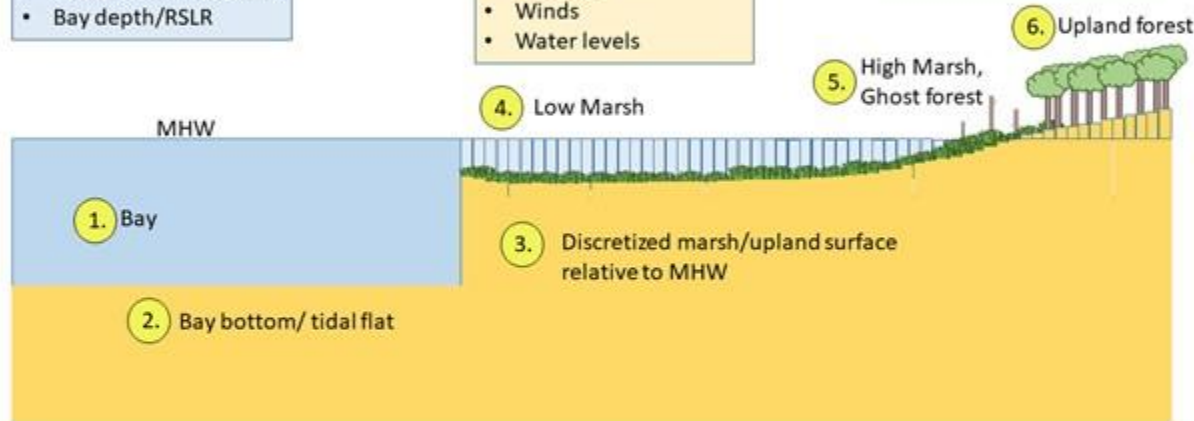


# Models to generate hypotheses and understand complex interactions

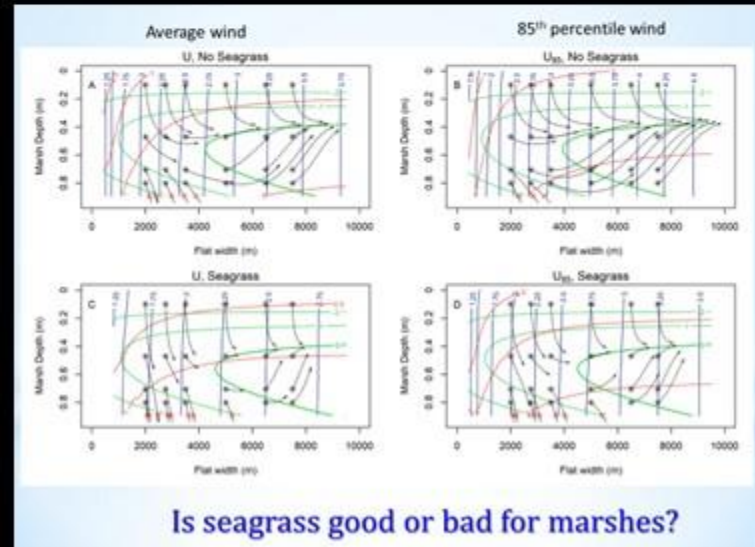
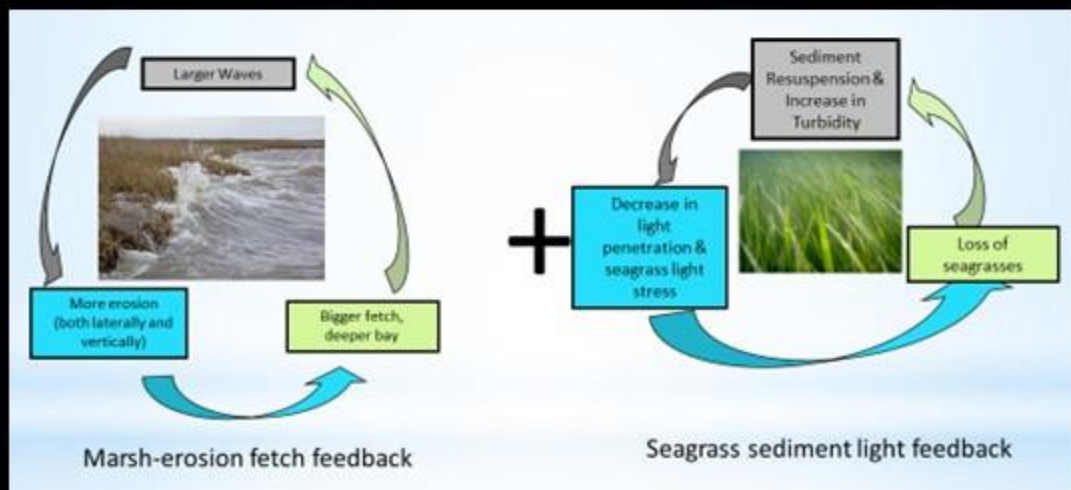
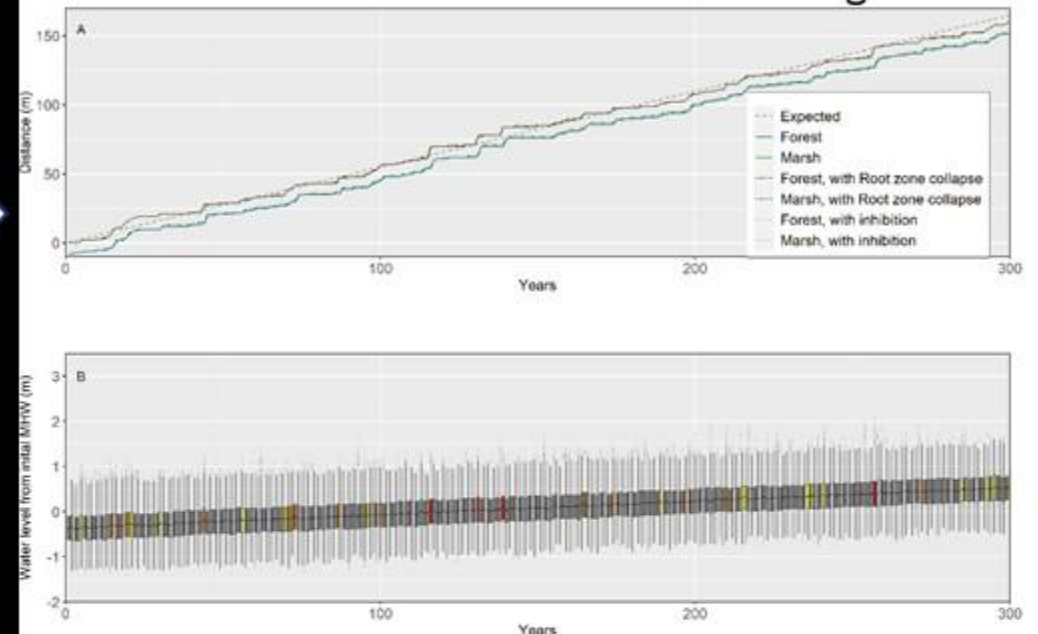
- Key components**
- Winds
  - Tidal range
  - Water levels
  - External sediment supply
  - Bay bottom erodibility
  - Bay depth/RSLR

- Key components**
- Elevation/RSLR
  - Tidal range
  - Organogenic soil formation
  - Sediment flux from bay
  - Erosion/progradation
  - Ponding
  - Winds
  - Water levels

- Key components**
- Elevation/RSLR
  - Water levels
  - Organogenic soil formation
  - Soil salinity/saturation
  - Light/shading
  - Root zone collapse



## Controls on forest retreat and marsh migration?



Is seagrass good or bad for marshes?

# Habitat expansion into the uplands

## What processes and timescales control marsh upland migration?

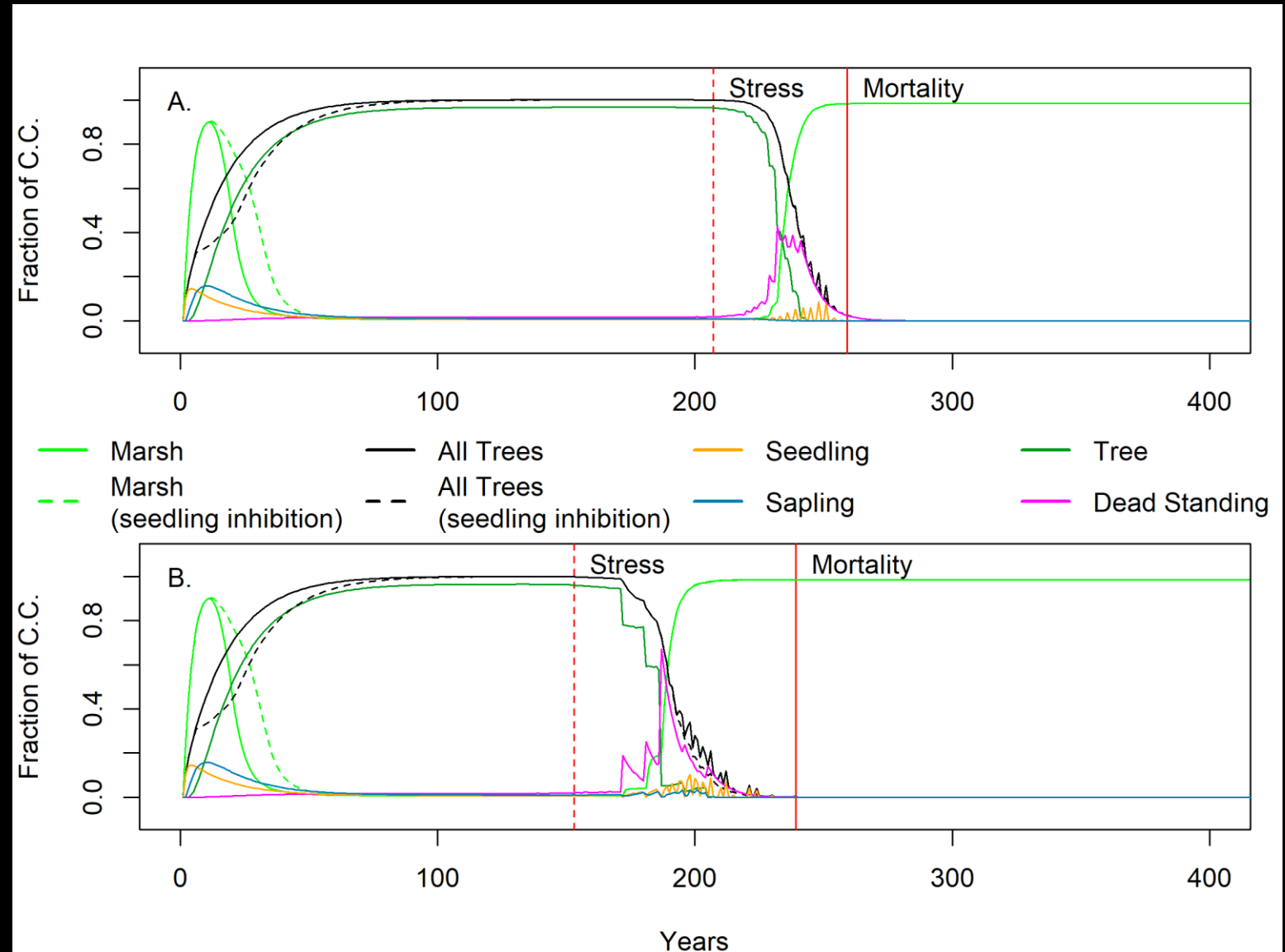
Bare ground at 1m above MHW grows a forest

Expected inundation from bathtub style model with 4mm/yr RSLR to occur at year: 250 for MHW, 225 for MHHW

But stochastic events (i.e. storms) transition forest to marsh~50-75 years earlier.

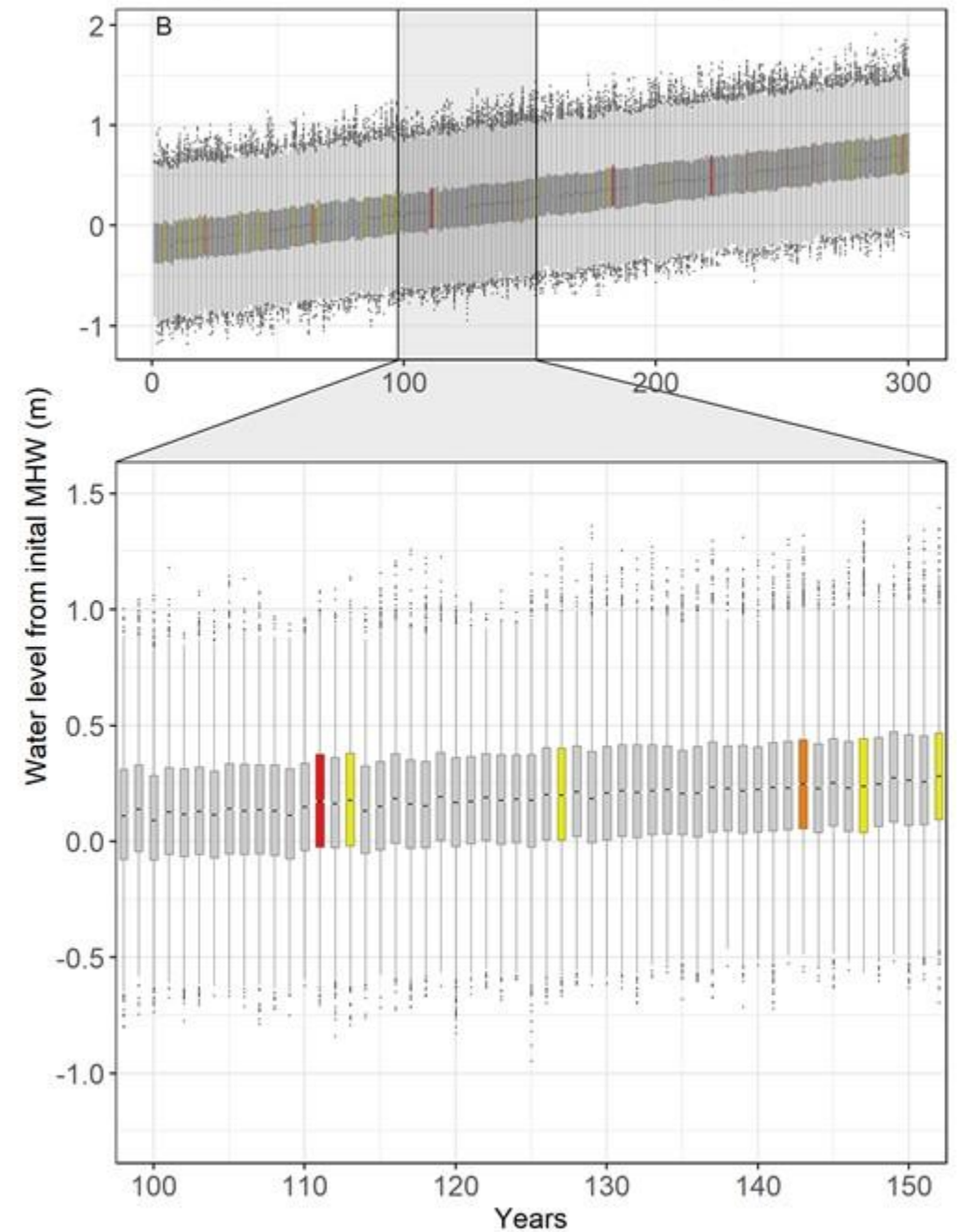
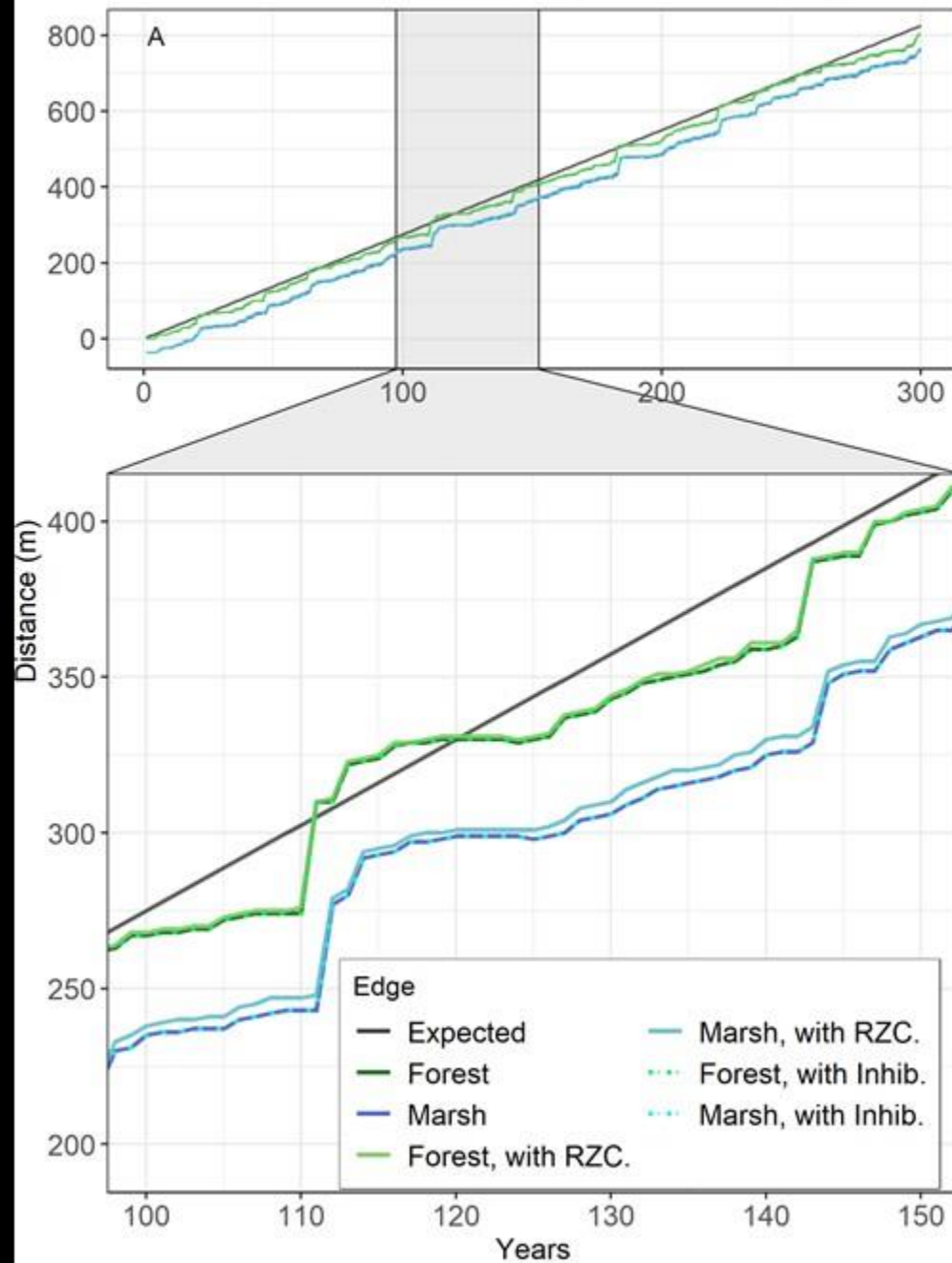
Overall long-term migration rates still tend toward slope RSLR dominated process

CC is carrying capacity  
Light green is grass  
Dark green adult trees  
Orange is seedlings  
Blue is saplings  
Black is saplings+adult trees  
Maroon is dead standing





# Seedling inhibition, root zone collapse? Limited memory?

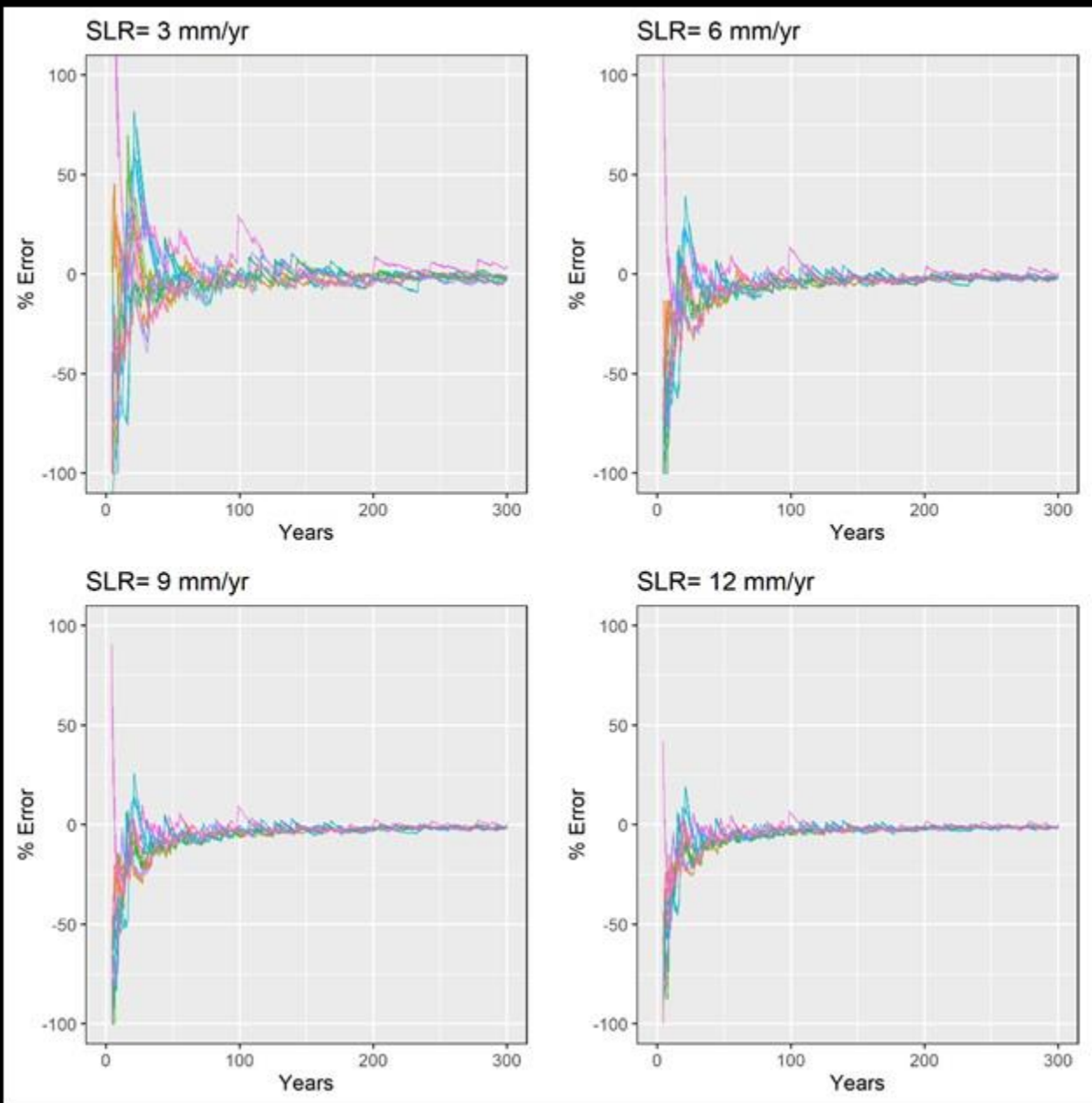


Large errors are likely to remain in estimation of forest retreat and marsh migration rates from remote sensing

Overall long-term migration rates still tend toward slope RSLR dominated process

Errors in rate estimation diminish in longer records, and as SLR increases.

Reinforcing the concept that the location of the landward boundary is controlled by stochastic (storm) events.



# Marsh Migration

- Establish network of vertical control points in two SLR-threatened marsh systems
  - Deep rod benchmarks installed
  - Included in VLM regional surveys
- Use GPS and total station survey techniques to measure grid of ground elevations tied to control points
- Compile annual grid surveys of elevation and vegetation type and evaluate change over time
- Compare results to model predictions



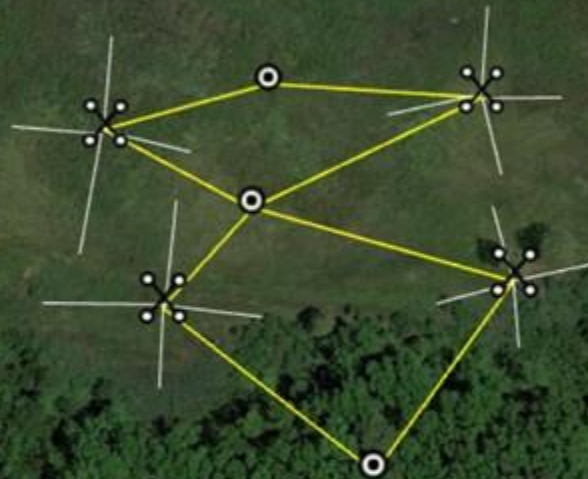


# Eastern Neck NWR

## Survey Transect and SET Layout

### Legend

- Permanent transects
- Radial transects
- Shallow SETs
- Deep SETs



- 3 Deep SETs installed in: low marsh, high marsh, and forest
- 4 shallow SETs installed as reference points between deep SET's
- Topo measurements taken each year along permanent transects that connect Deep and Shallow SETs
- Radial transects originating from Shallow SETs surveyed in a 4 different directions randomly each year
- Second site at Peter's Neck a new land purchase at BW NWR

Google Earth

100 m

N



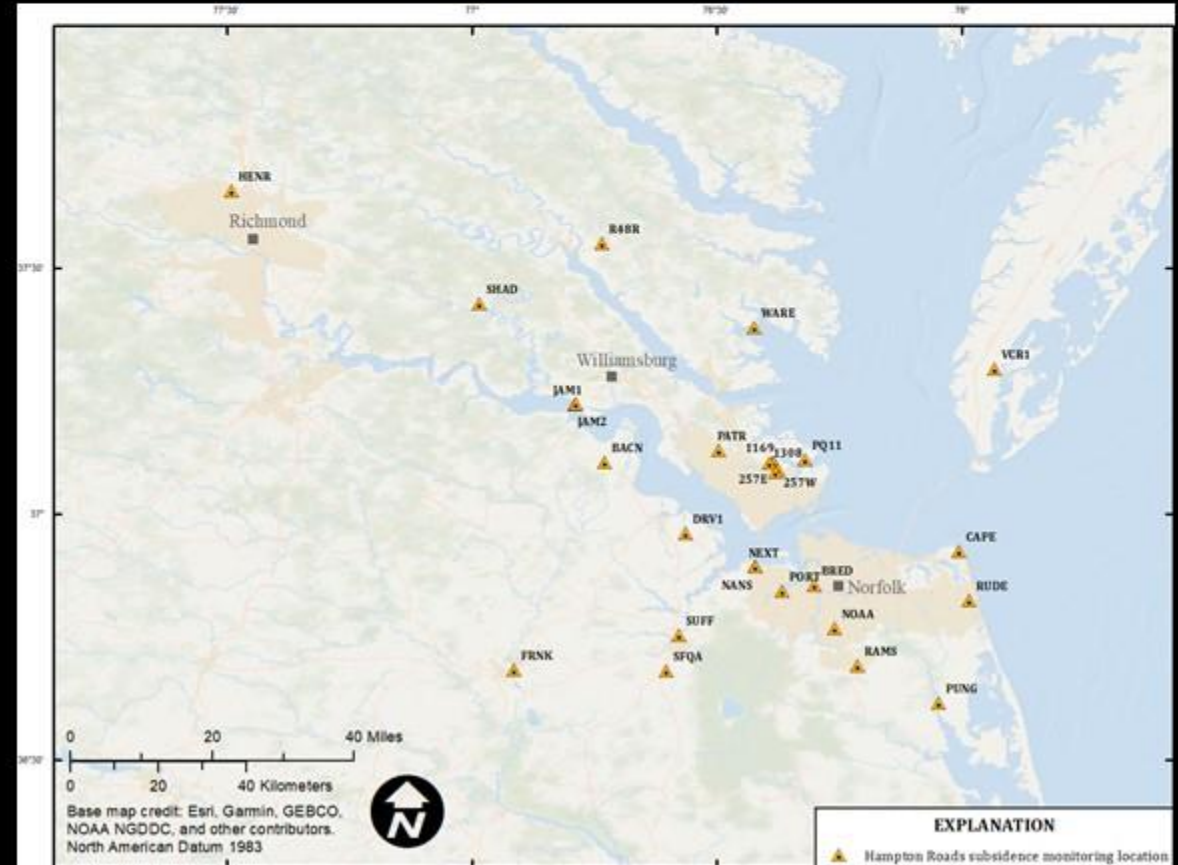
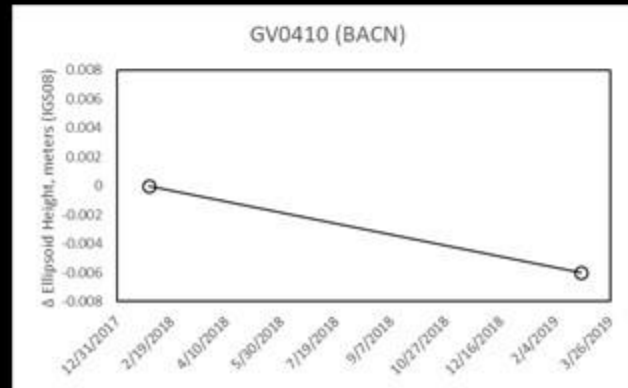
# Chesapeake Bay Regional Benchmark Monitoring Network (2019-2023)

- 2019-2020 surveys completed
  - 72-hour observations
  - 55 benchmarks
- Partners:
  - NGS
  - Maryland Geologic Survey
  - VIMS
  - Virginia Tech
- Data processing ongoing (VT)
- Data to be published through UNAVCO



# Hampton Roads Benchmark Monitoring Network (2018-2022)

- 2018 -2020 surveys completed
  - 24-hr observations
  - 25 benchmarks
- Data processing and evaluation complete (NGS – OPUS Projects)
- Final 2018-2020 results to be published through ScienceBase





# Extensometers

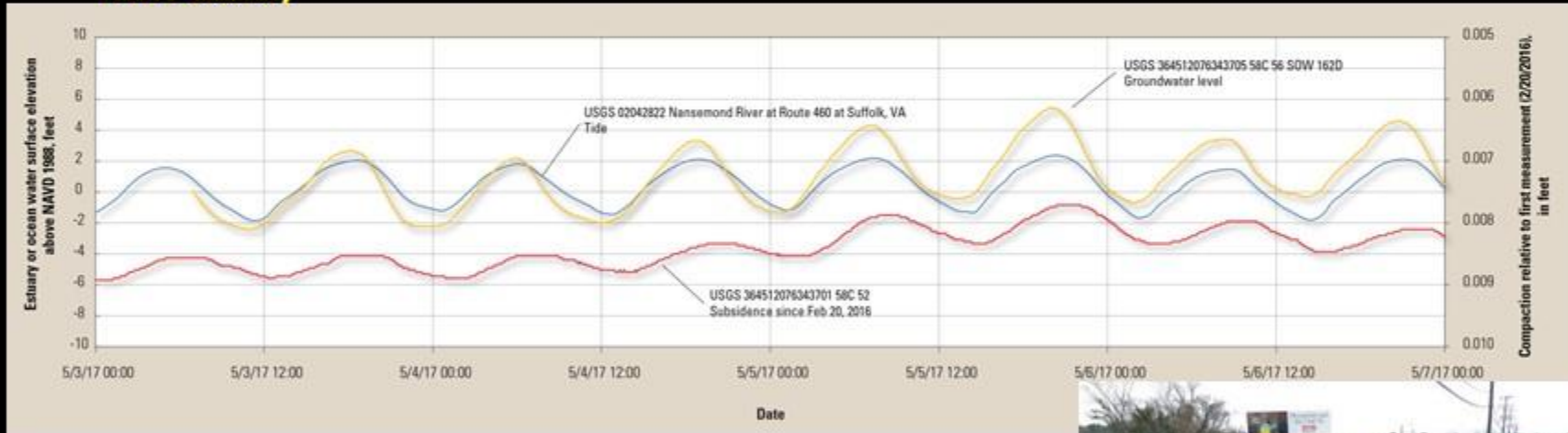
- Measure aquifer compaction
- Reactivated two sensors (2016):
  - Franklin
  - Suffolk
- Historic data recovered (late 1970s – mid 1990s)
- Installed new sensor (2018):
  - Nansemond
  - Co-located at HRSD SWIFT facility
  - CORS tied to bedrock
- Planning for 4<sup>th</sup> sensor (West Point)



# Which Direction does the Ground Move?

Synthesis of multiple data sets explain which direction the ground moves, and why.

**Suffolk Extensometer—Tidal Loading and Groundwater (6-min data)**



USGS 364512076343701 58C 52  
Extensometer 1,620 feet



USGS 364512076343705 58C 56 SOW 162D  
Observation well 567 feet



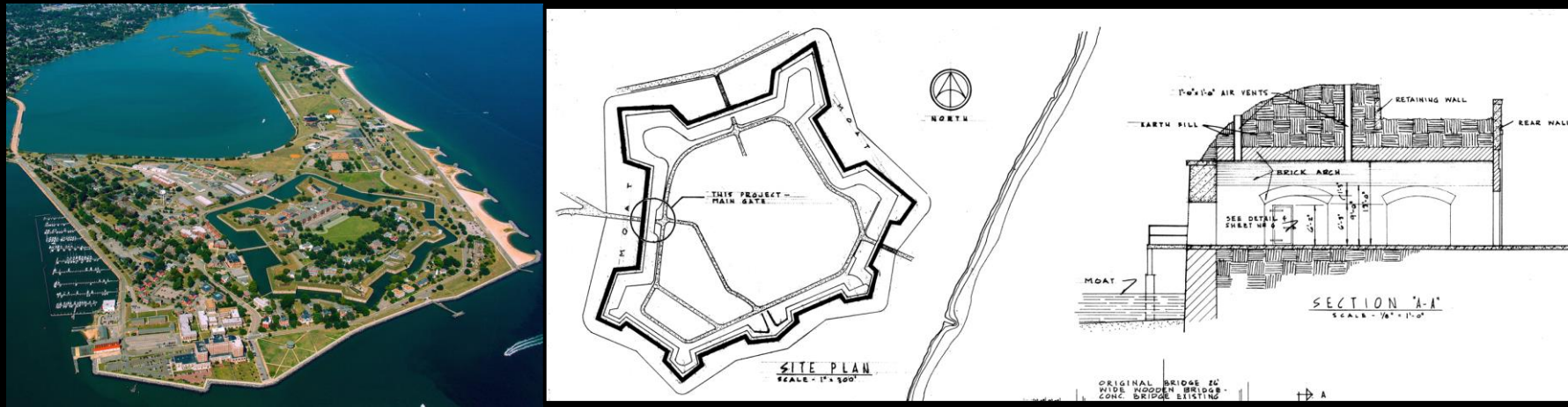
USGS 02042822 Nansemond River at Route 460 at Suffolk, VA



# Historic sea-level rise and coastal habitat loss:

Toomey & Cronin (FBGC)

**Objective:** Extend Chesapeake Bay tide gauges beyond the 20<sup>th</sup> century and identify drivers of coastal land loss (e.g., storms, sea-level rise).



**Approach:** (1) Resurvey historic structures designed relative to sea level—for example, Fortress Monroe (built 1819-1834 CE), above.

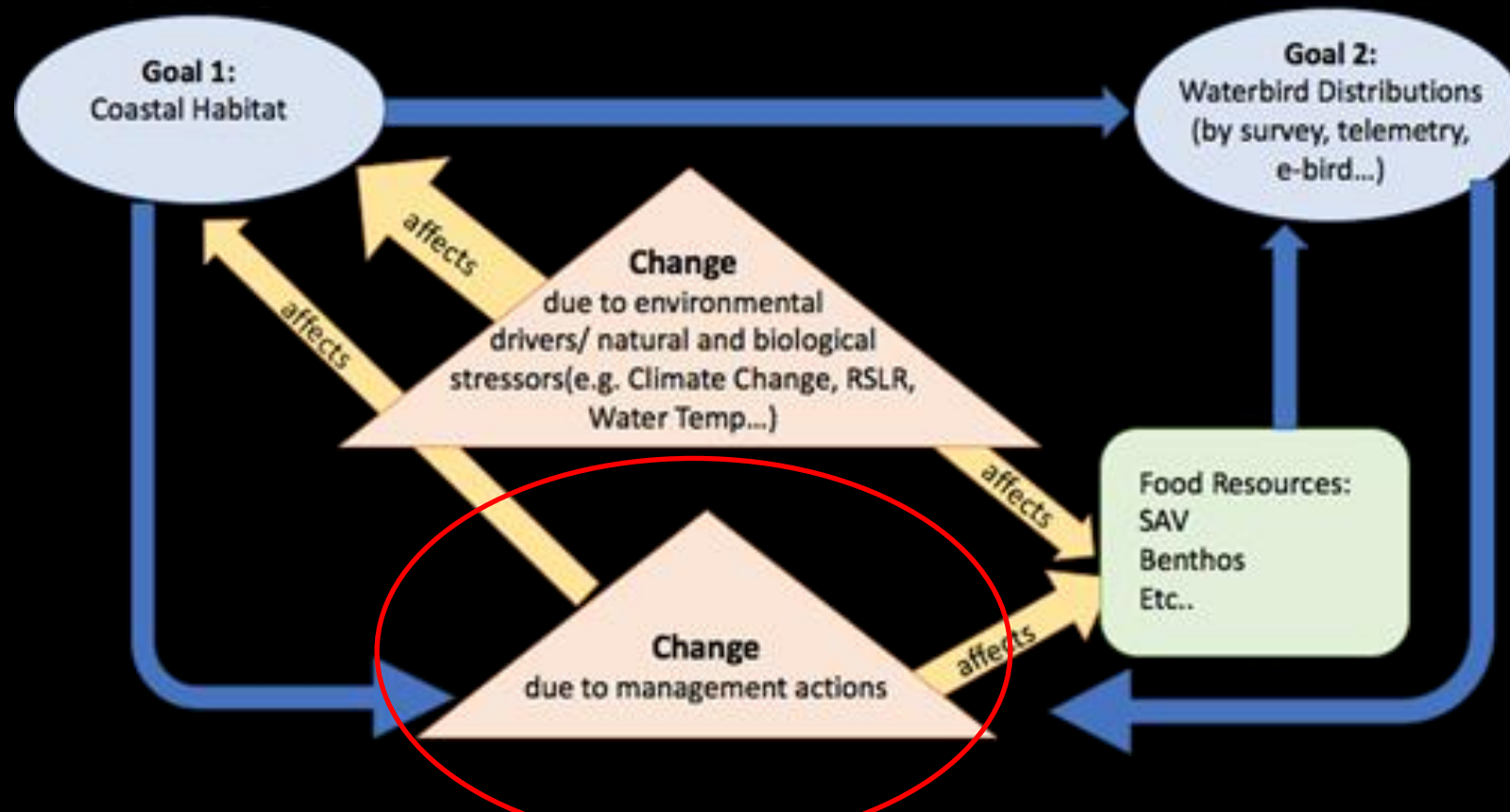
(2) Analyze historic charts to assess the rates and drivers of coastal erosion over the past 150 years.

(3) Develop proxy records from sediment cores to reconstruct marsh loss and storm frequency over the last millennium.



A: Assess risks to coastal habitats and DOI lands, by forecasting vulnerability and resiliency of coastal systems to future change

B: Understand the factors affecting waterbirds and their habitats



# Sediment Addition Experiment



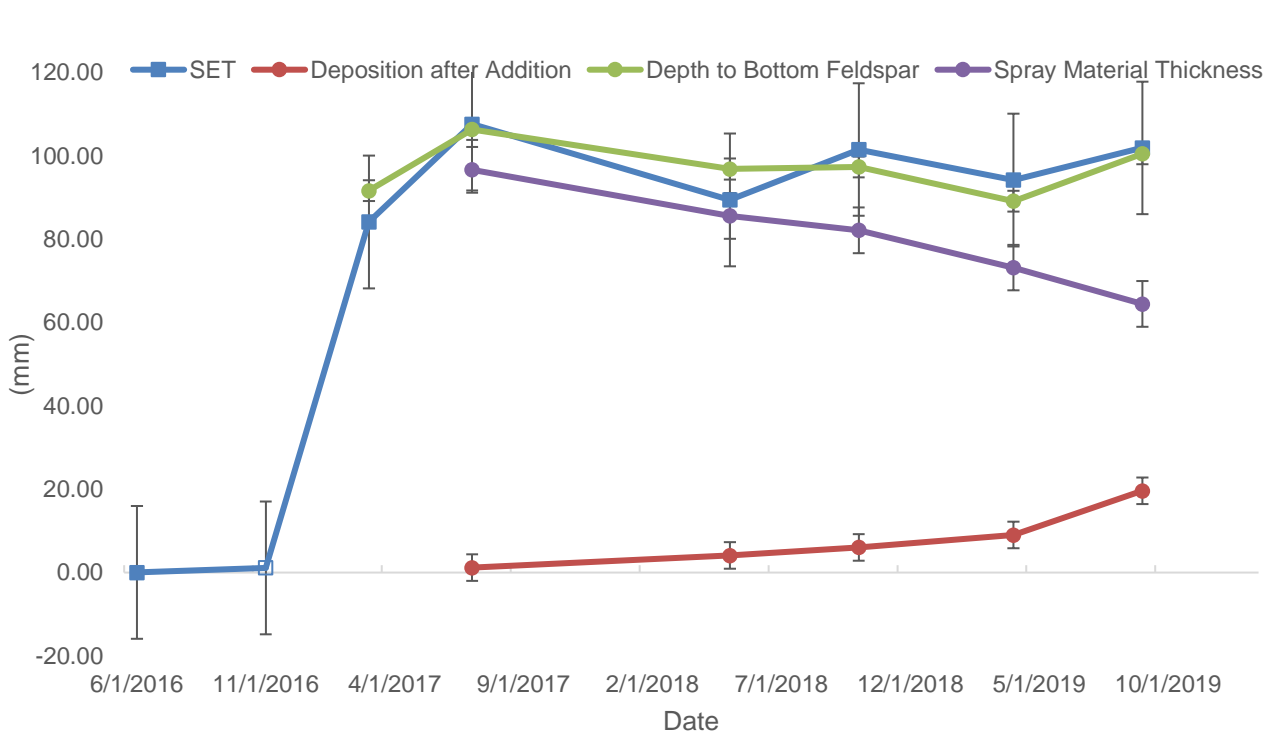
- Sprayed in 2016
- SET's monitor change in marsh surface elevation



# Sediment Addition Experiment

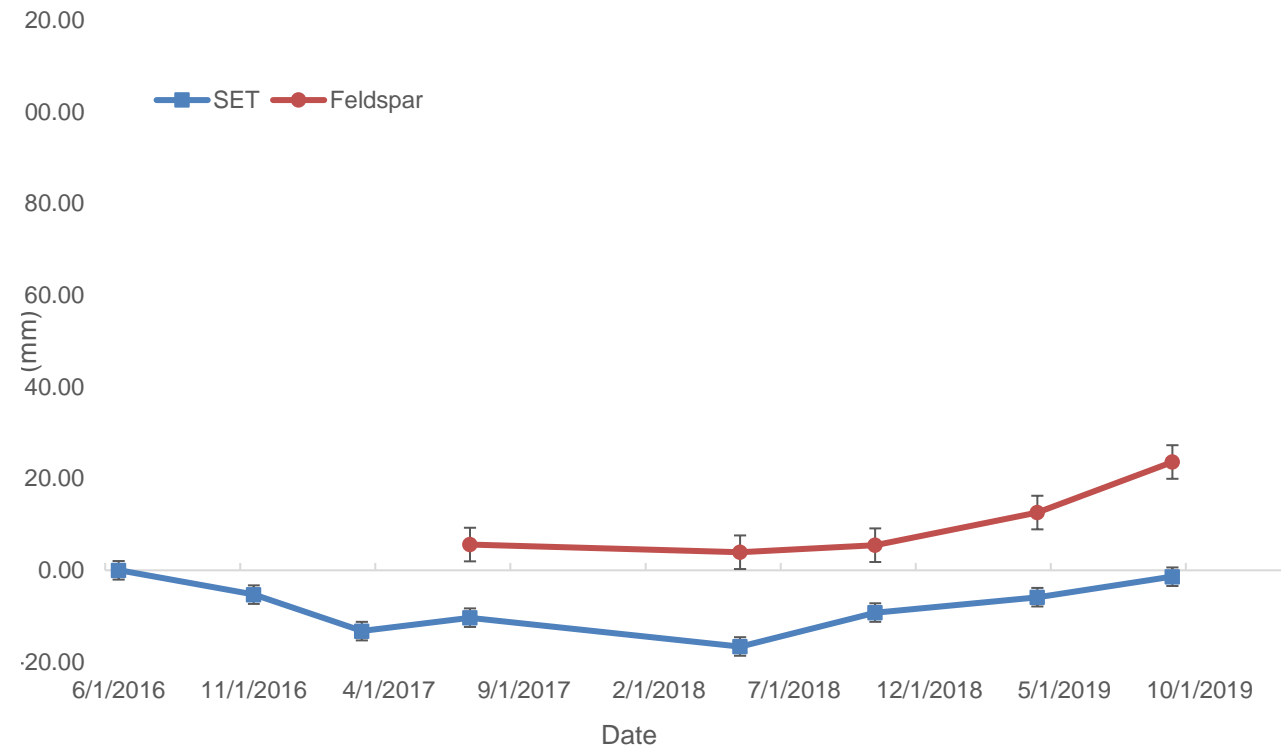


Spray Treatment SET and Feldspar Rates



Average sediment addition of ~100mm

Control Treatment SET and Feldspar Rates



No change in elevation of control area over same time frame



# Avian Influenza Transmission in the Chesapeake Bay



- Continued meeting with stakeholder groups including the Delmarva Avian Influenza Taskforce (wildlife, agriculture, and public health groups)
- Continued communications regarding potential to leverage funds for additional waterfowl telemetry work in the Delmarva region
- Future work will include monitoring of waterfowl use of small water bodies associated with commercial poultry facilities (i.e. farm ponds).

# Theme 2

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Greg Noe, Michael Toomey

Ken Hyer, Scott Phillips

Results and figures shown are preliminary and subject to revision...  
Please do not distribute without consulting theme 2 team