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

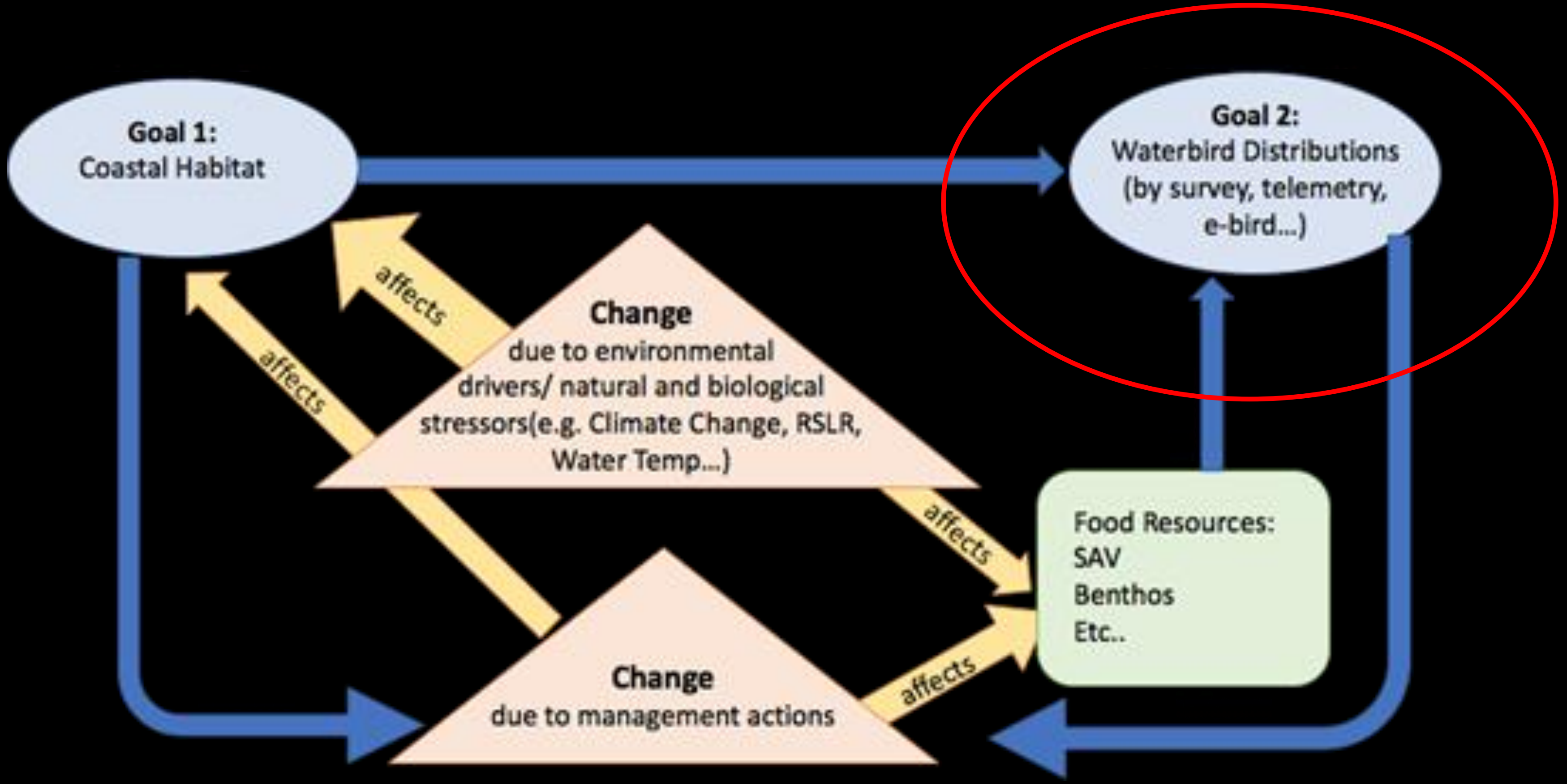
USGS Chesapeake Bay Studies
Coastal Habitats Team (Theme 2)
U.S. Department of the Interior

USGS

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



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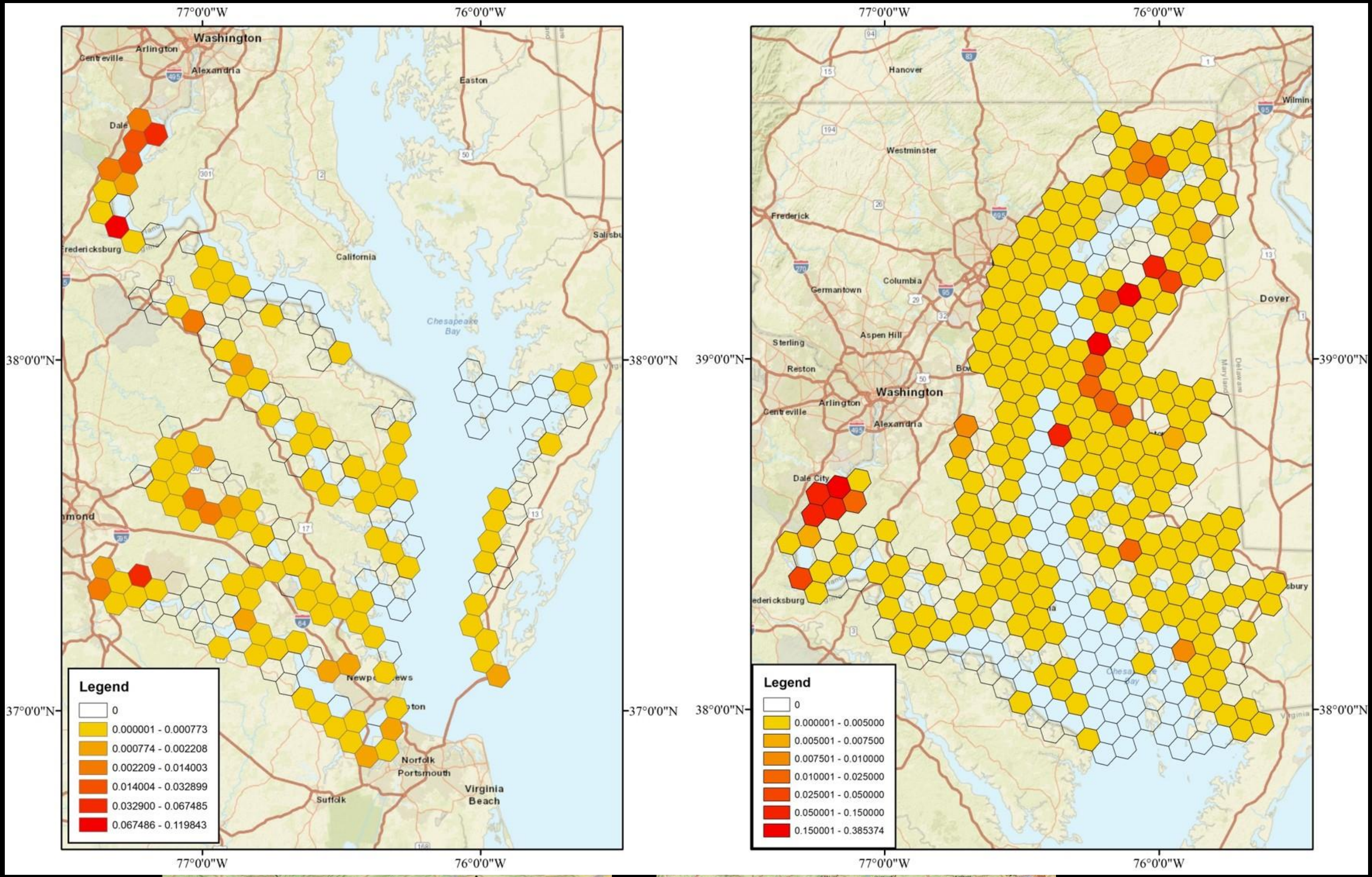
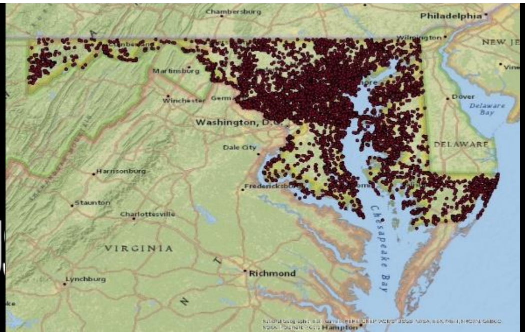
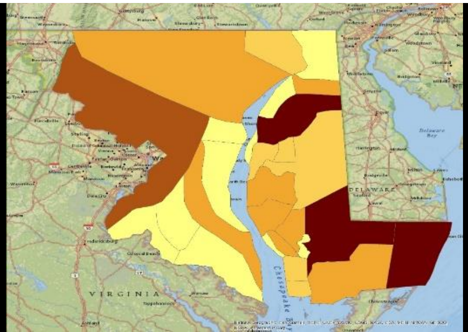
Waterfowl Hotspot Modeling



- 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 just provided GPS routes for survey data
  - New survey area correction to allow comparisons between MD and VA





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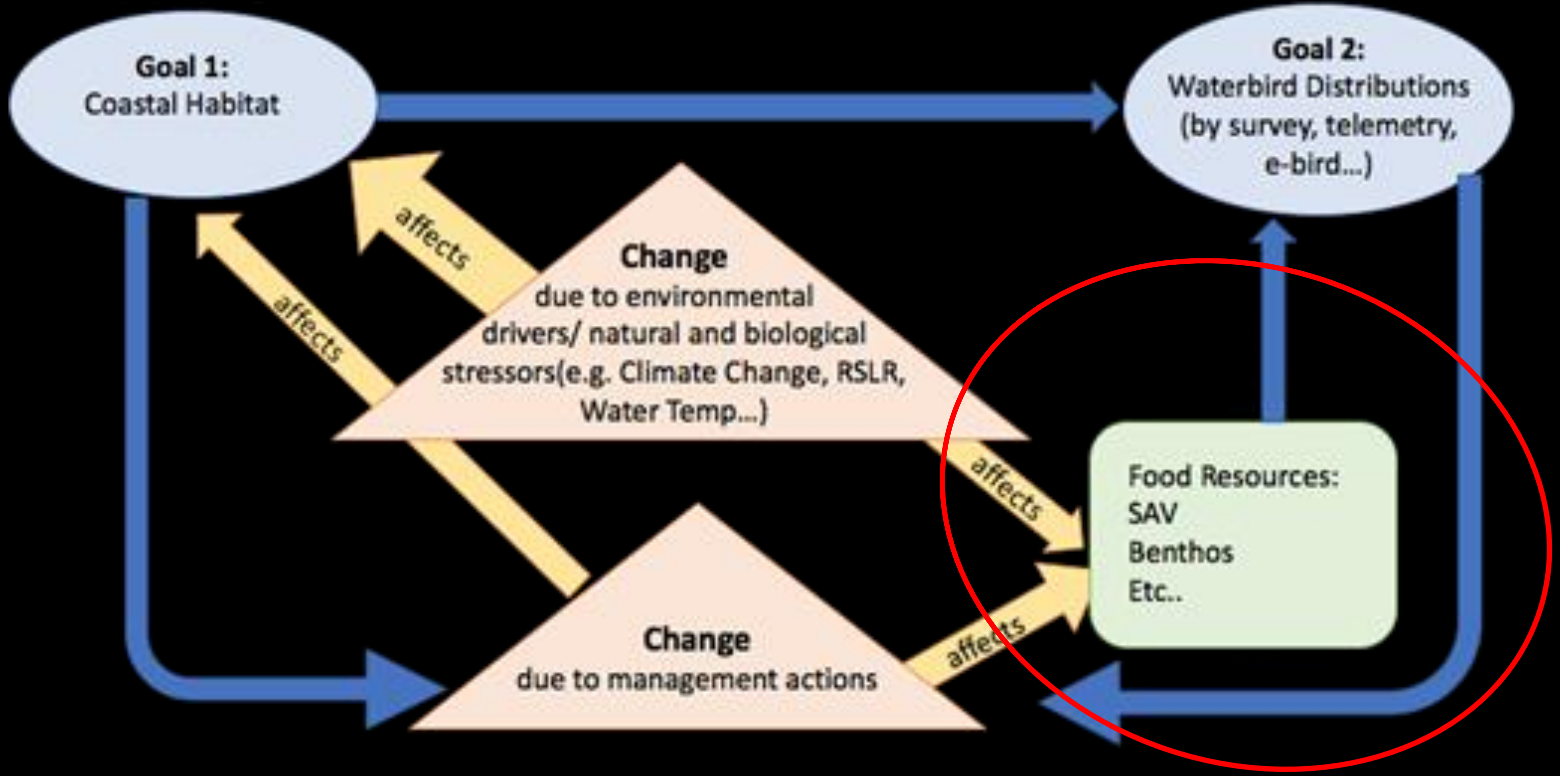

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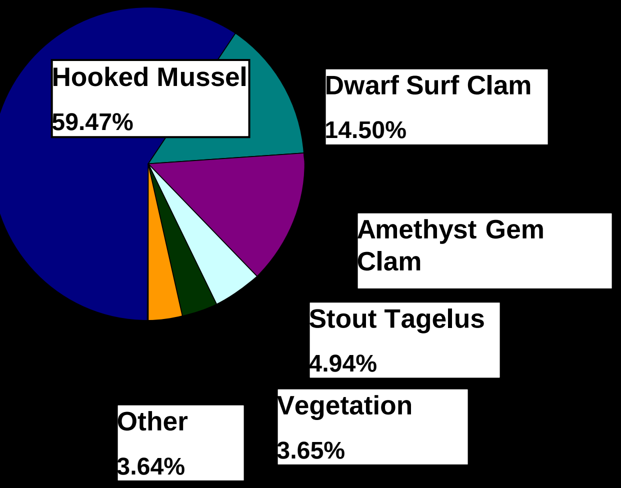
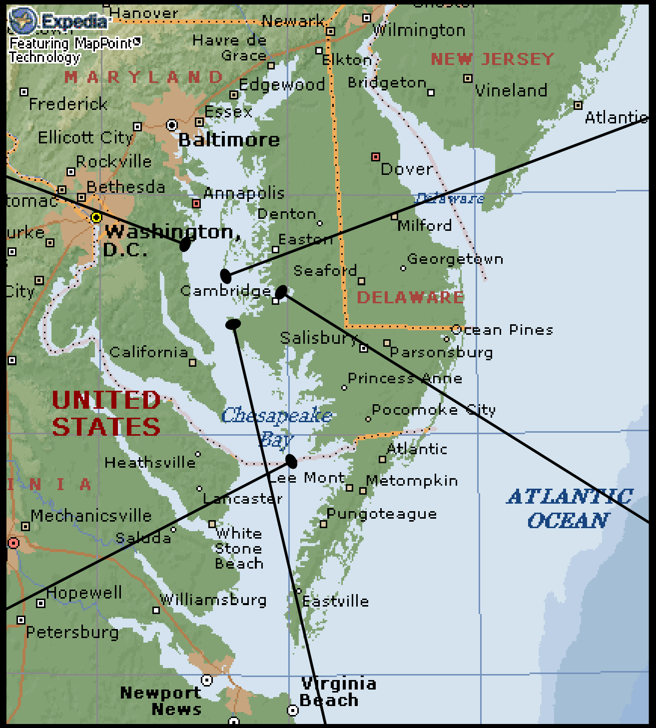
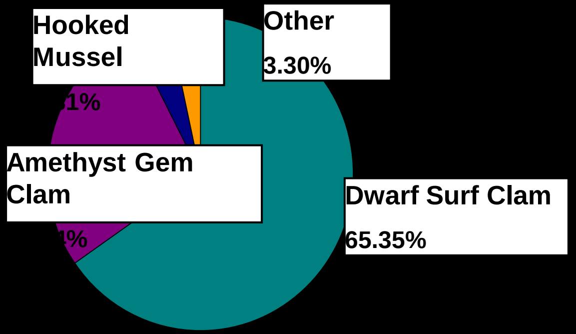
FOOD HABITS IN THE CHESAPEAKE BAY

Herring Bay n=93





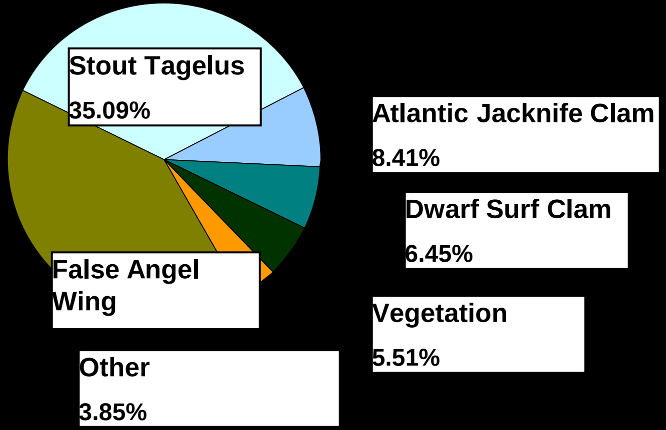
Tilghman Island n=27



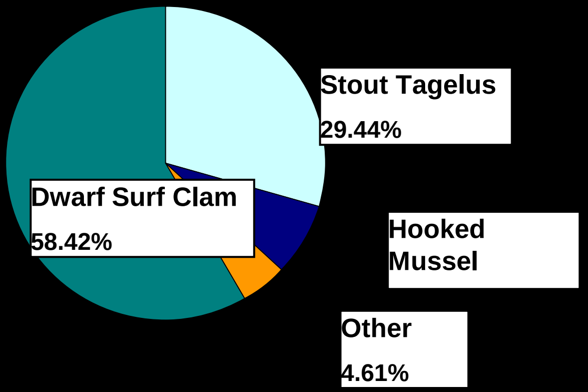
Food Habits Dataset:
32 different species, mainly waterfowl

1953 food habits samples

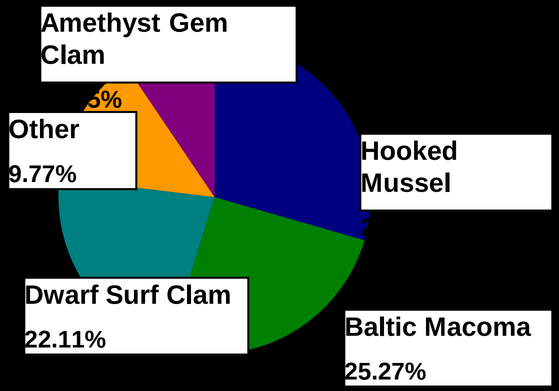
Smith Island n=13

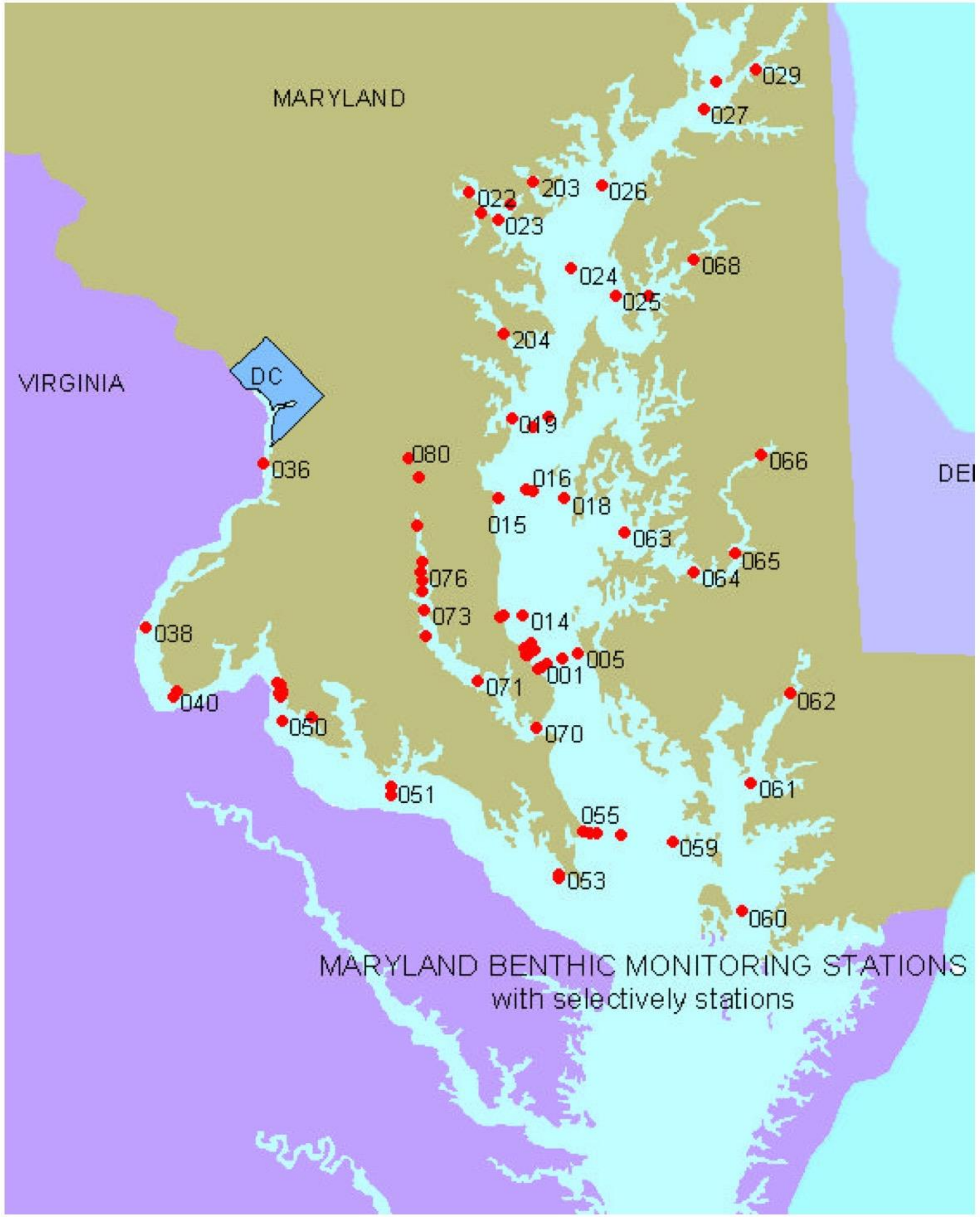


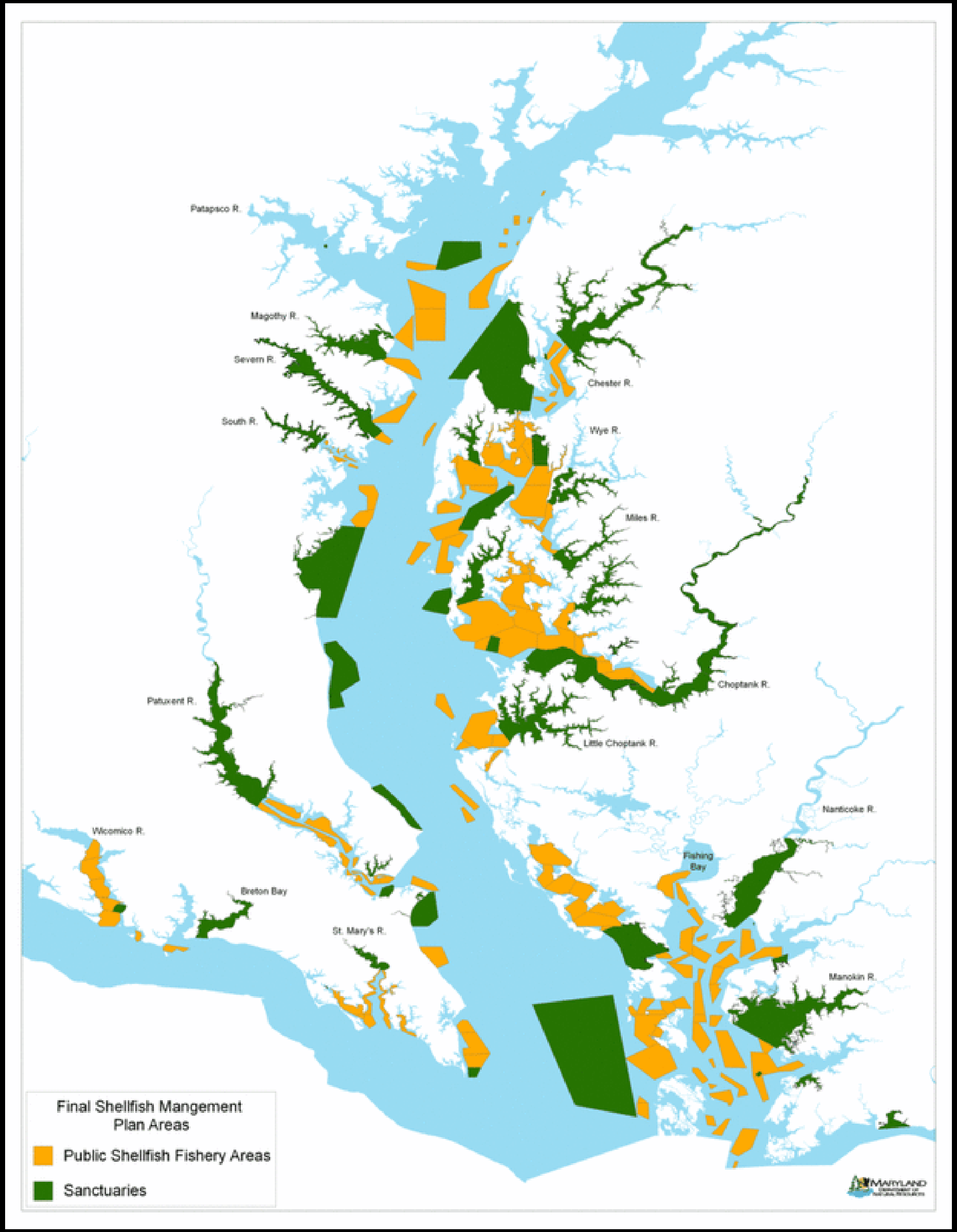
Taylors Island n=38



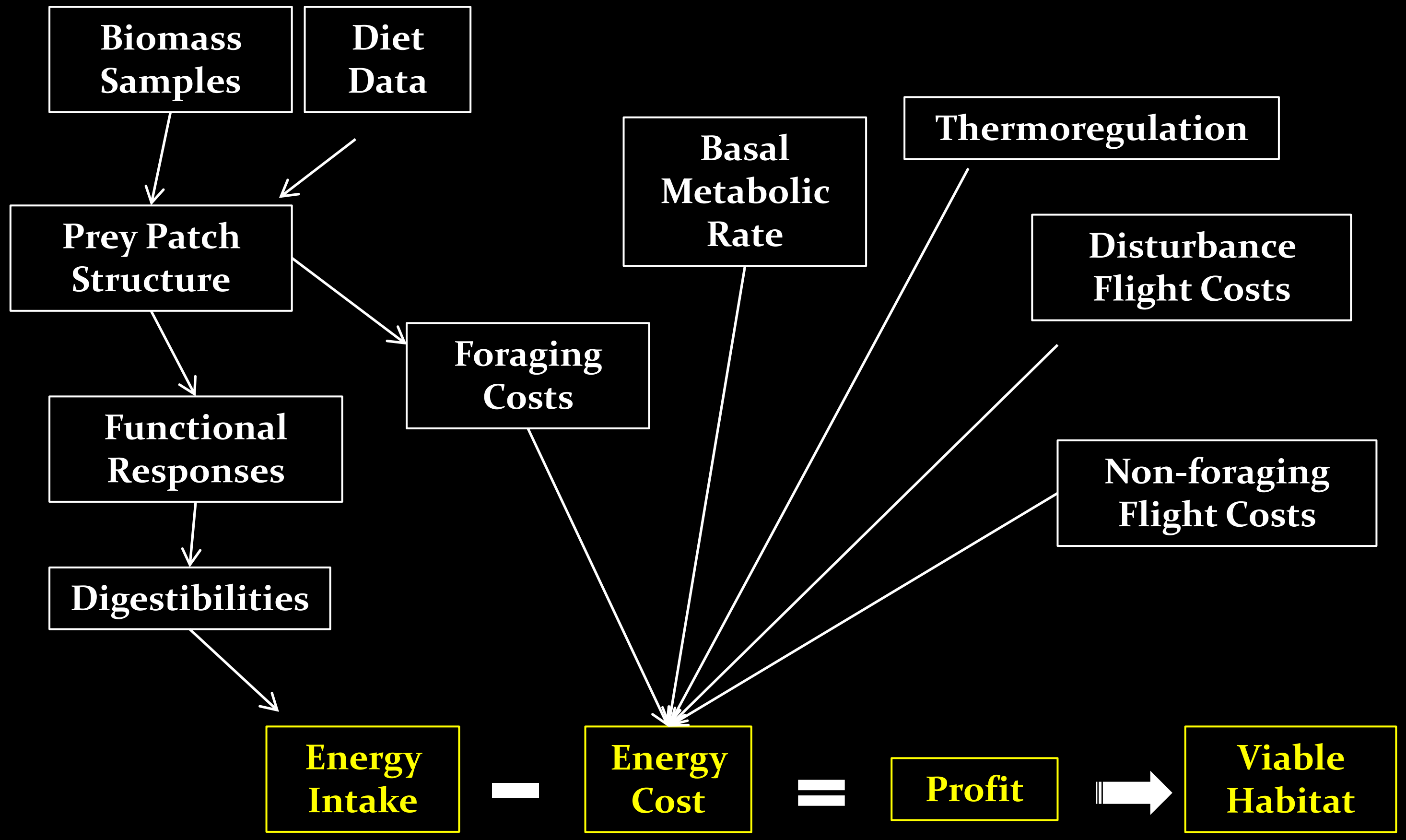
Choptank River n=65







Create a waterbird food layer using SAV and other benthic layers

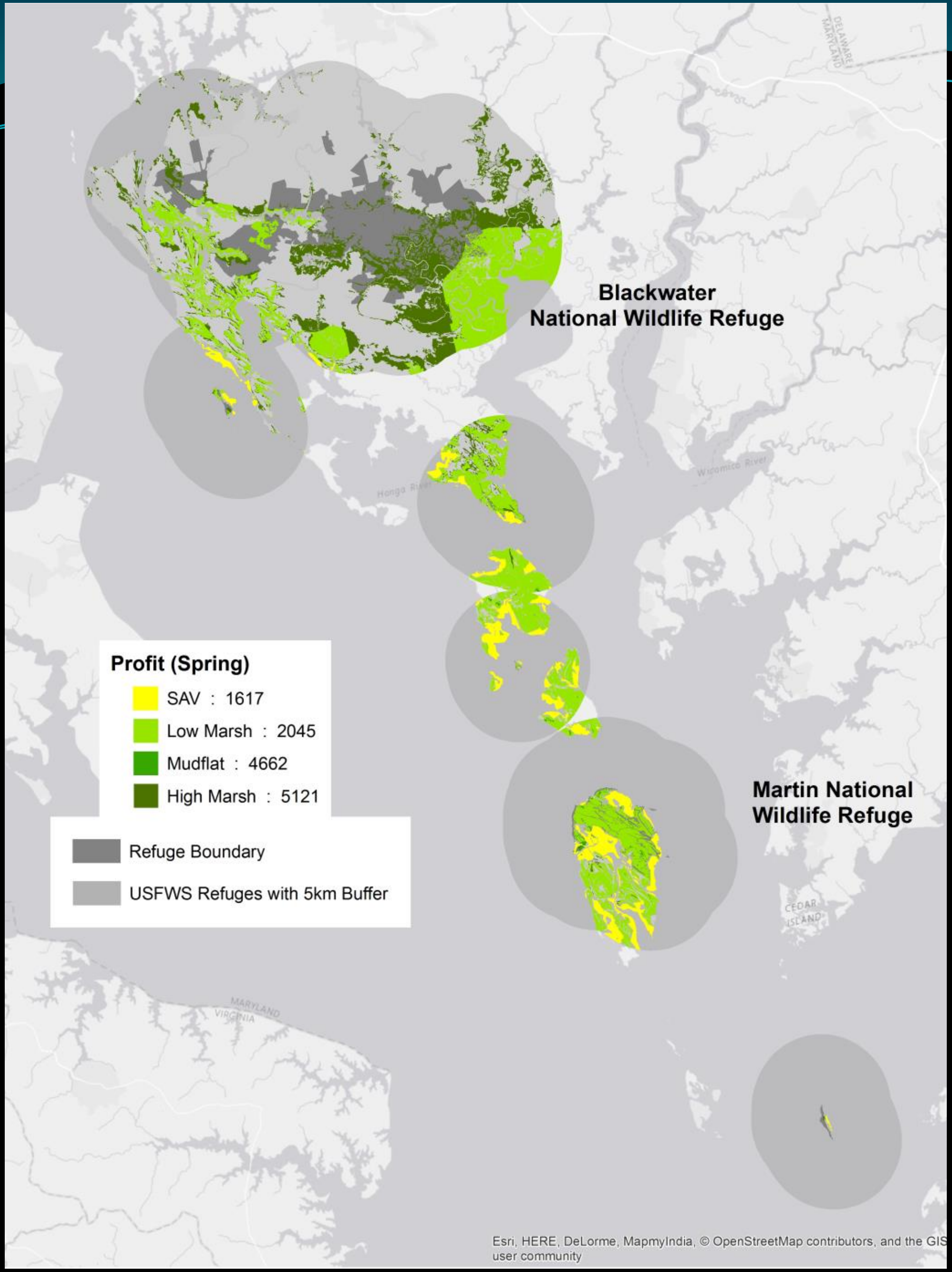


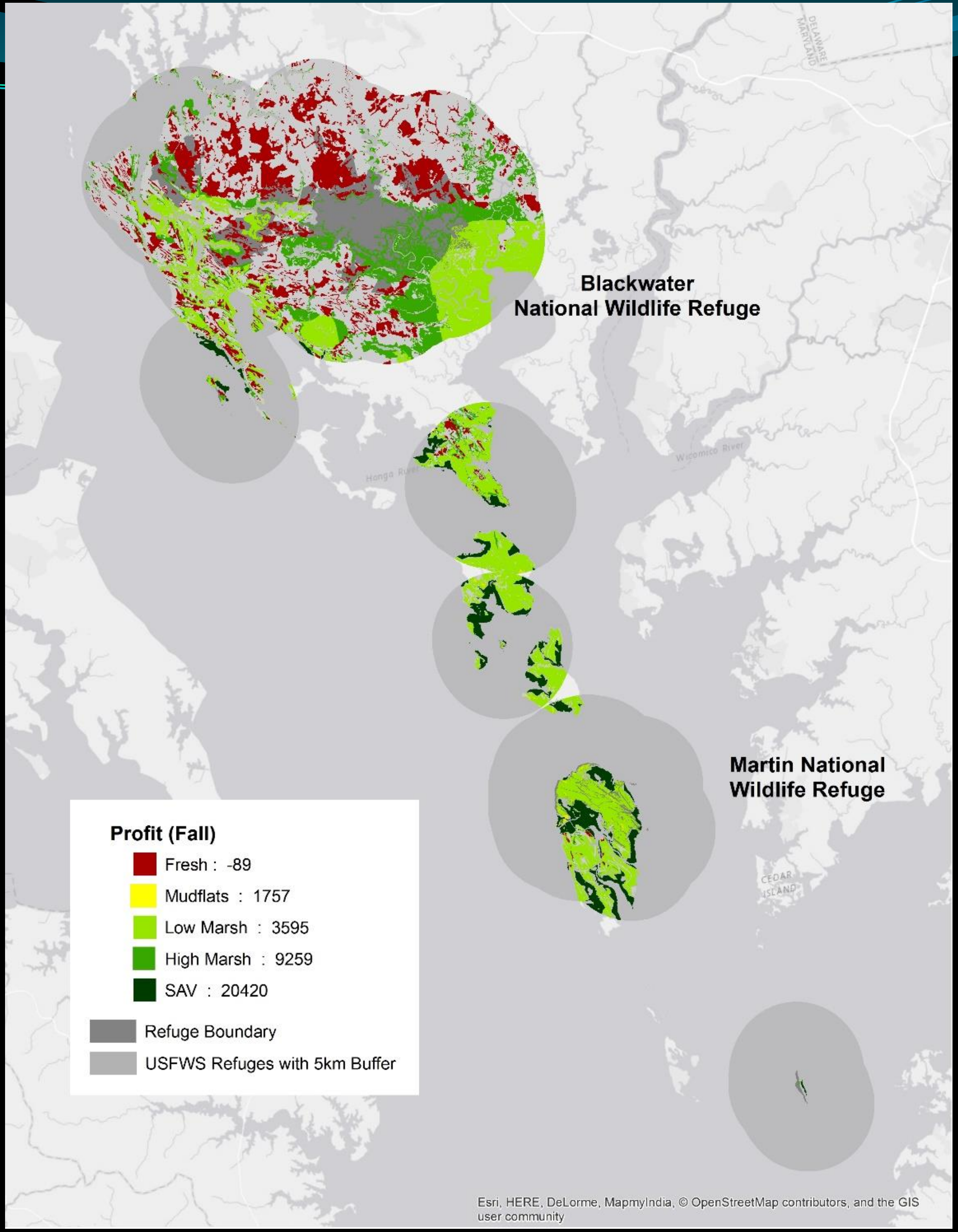
Biomass Samples
Diet Data
Prey Patch Structure
Functional Responses
Digestibilities
Foraging Costs
Basal Metabolic Rate
Thermoregulation
Disturbance Flight Costs
Non-foraging Flight Costs
Energy Intake
Energy Cost
Profit
Viable Habitat

Biomass

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


Blackwater
National Wildlife Refuge
Martin National
Wildlife Refuge
Profit (Spring)
SAV : 1617
Low Marsh : 2045
Mudflat : 4662
High Marsh : 5121
Refuge Boundary
USFWS Refuges with 5km Buffer
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community


Blackwater
National Wildlife Refuge
Martin National
Wildlife Refuge
Profit (Fall)
Fresh : -89
Mudflats : 1757
Low Marsh : 3595
High Marsh : 9259
SAV : 20420
Refuge Boundary
USFWS Refuges with 5km Buffer
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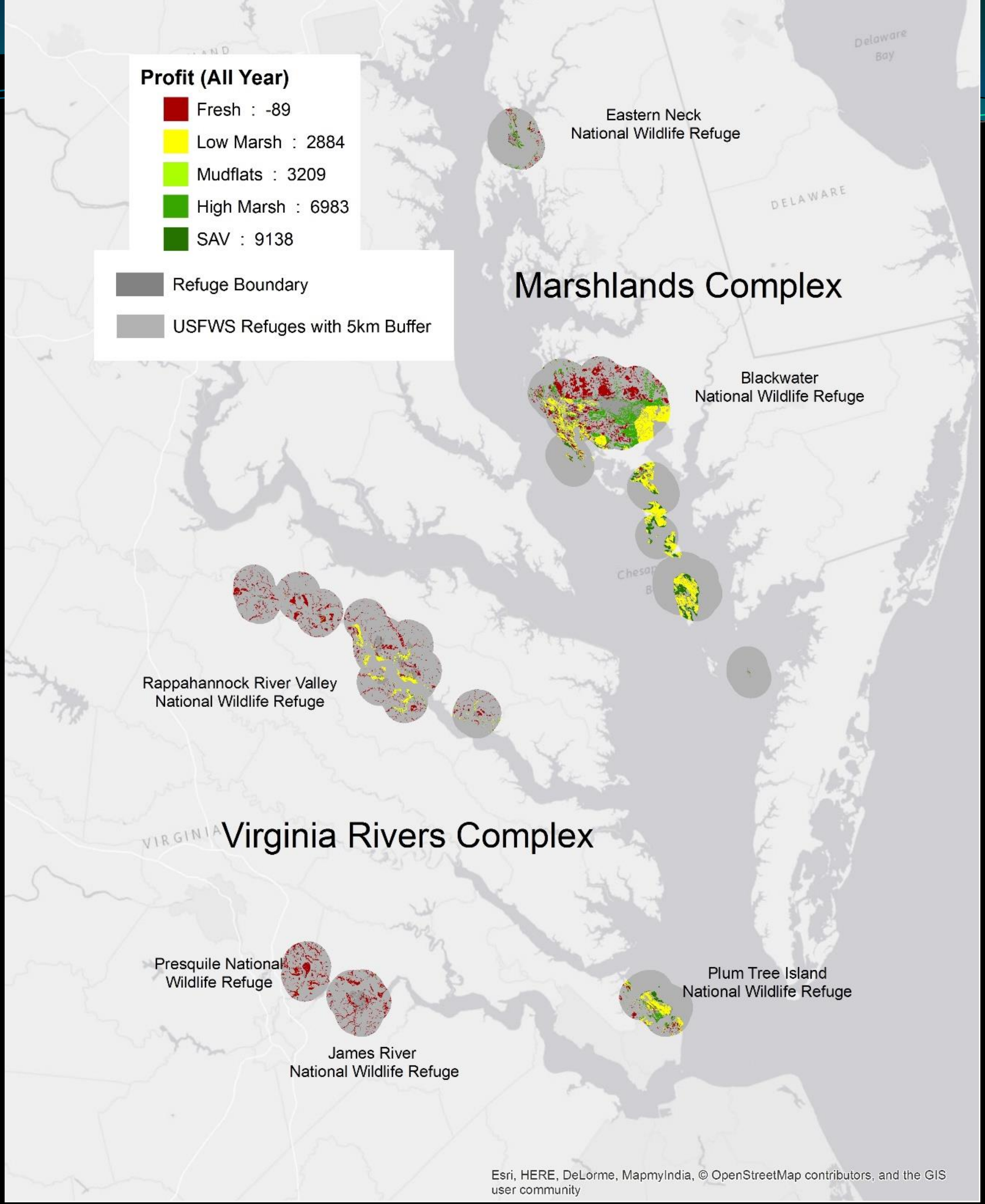
Profit (All Year)
Fresh : -89
Low Marsh : 2884
Mudflats : 3209
High Marsh : 6983
SAV : 9138
Refuge Boundary
USFWS Refuges with 5km Buffer
Eastern Neck
National Wildlife Refuge
DELAWARE
Marshlands Complex
Blackwater
National Wildlife Refuge
Rappahannock River Valley
National Wildlife Refuge
VIRGINIA
Virginia Rivers Complex
Presquile National
Wildlife Refuge
James River
National Wildlife Refuge
Plum Tree Island
National Wildlife Refuge
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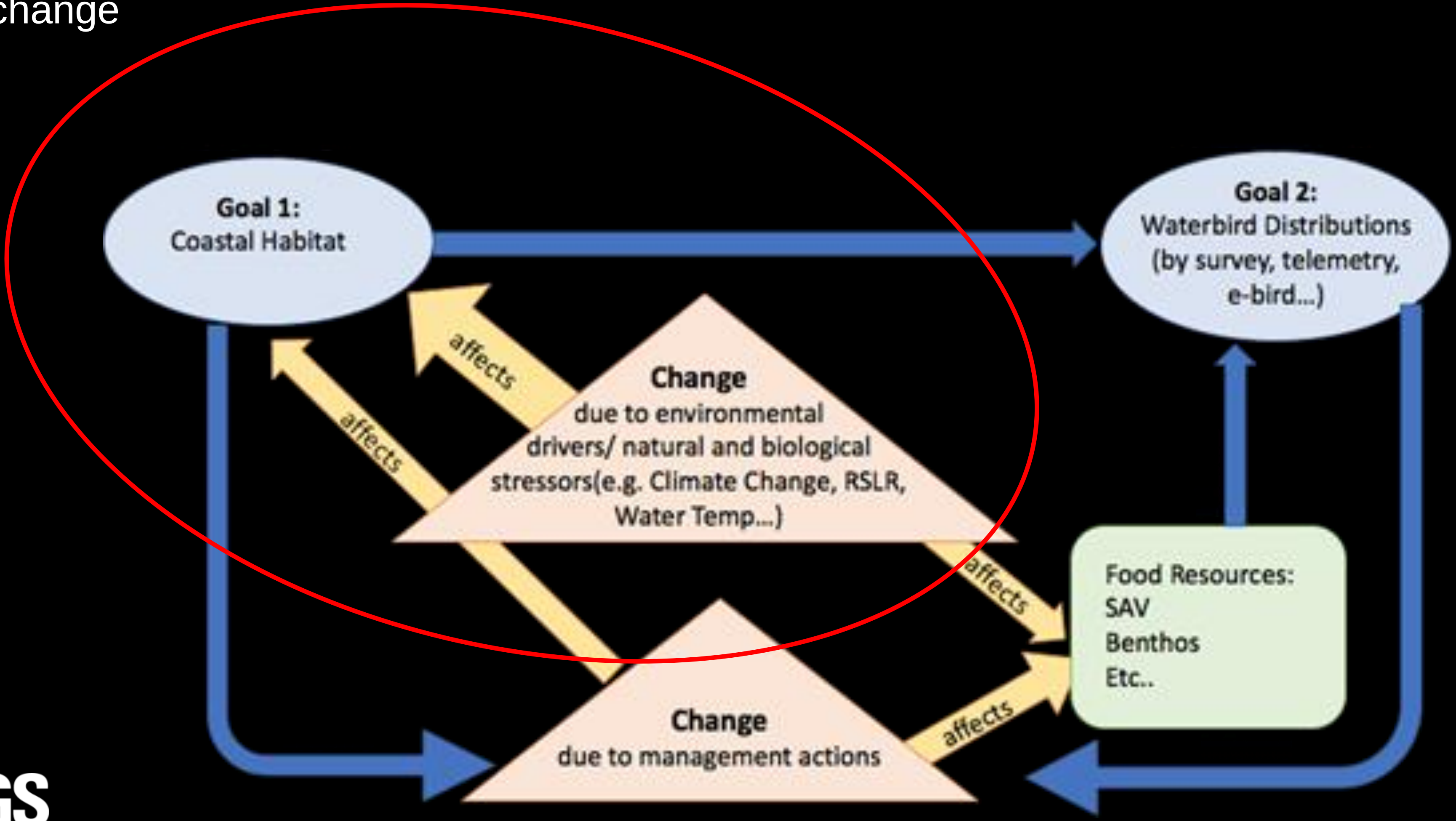
Avian Influenza Transmission in the Chesapeake Bay

- 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).

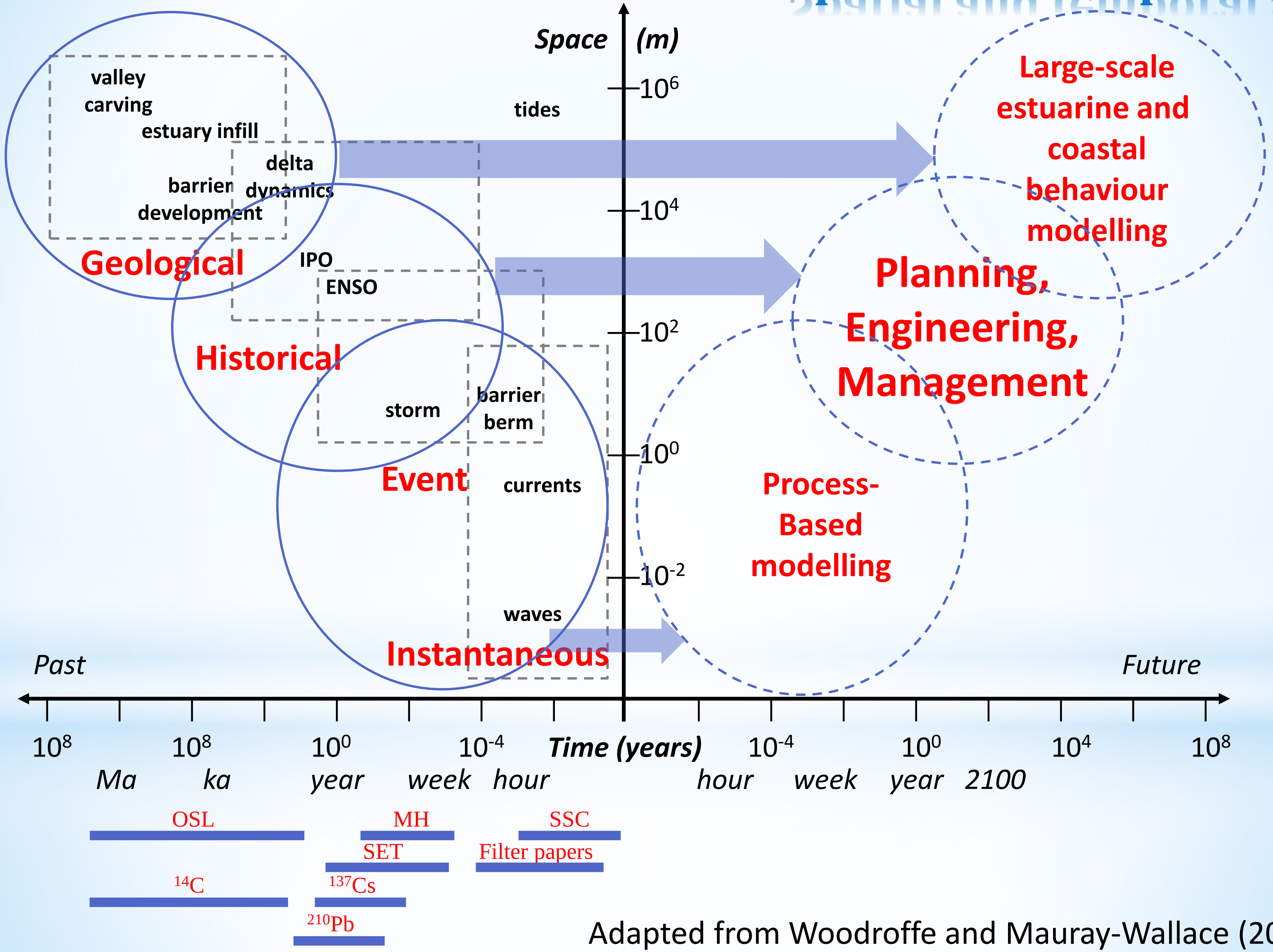
Towards Modeling Habitat Change

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



Adapted from Woodroffe and Mauray-Wallace (2012)

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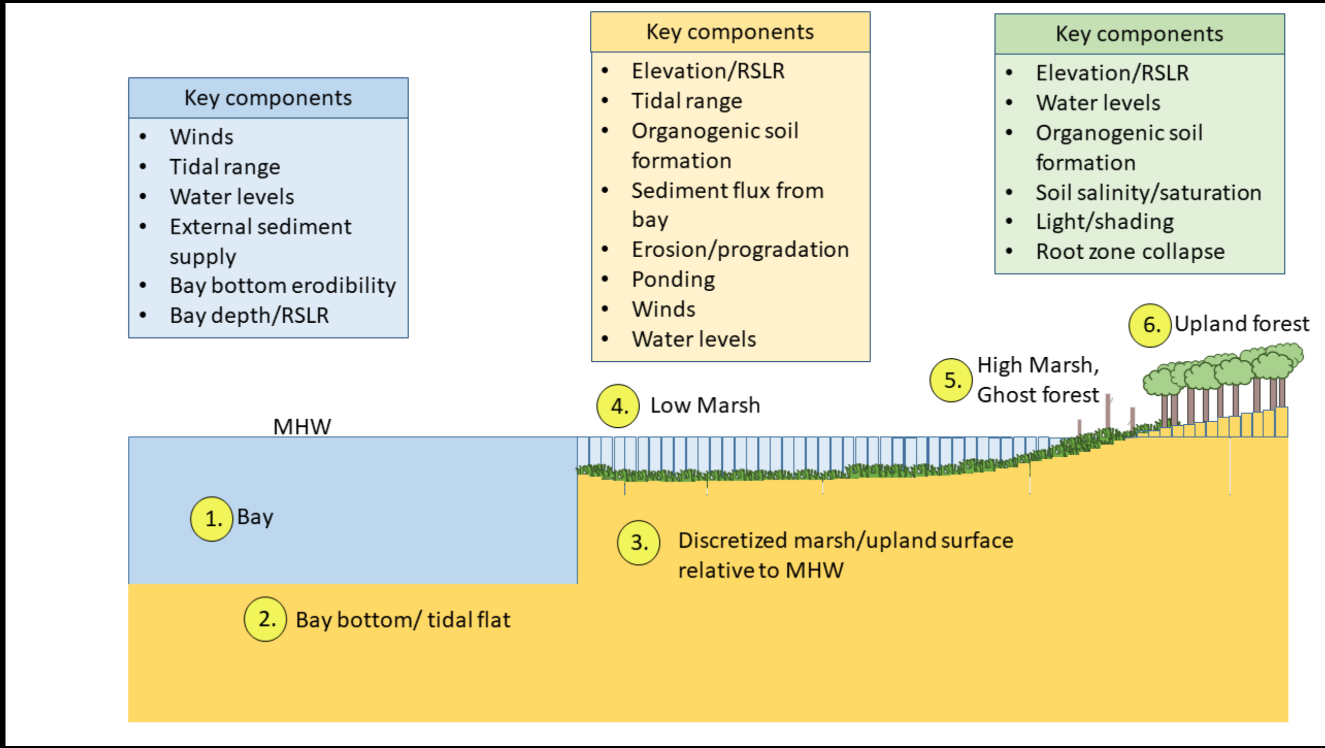
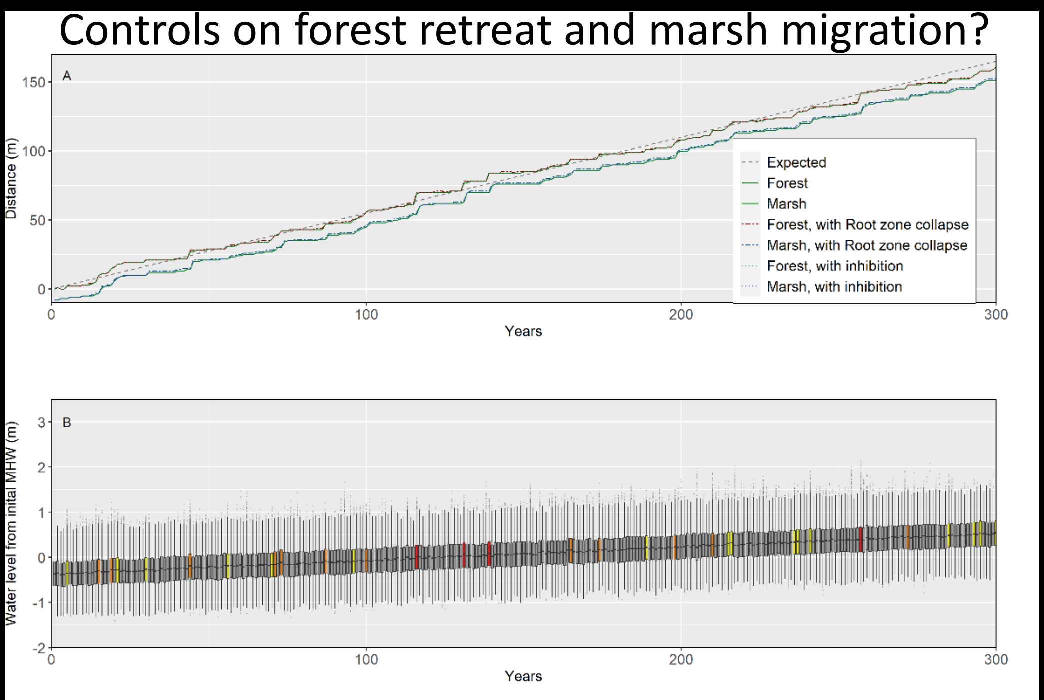
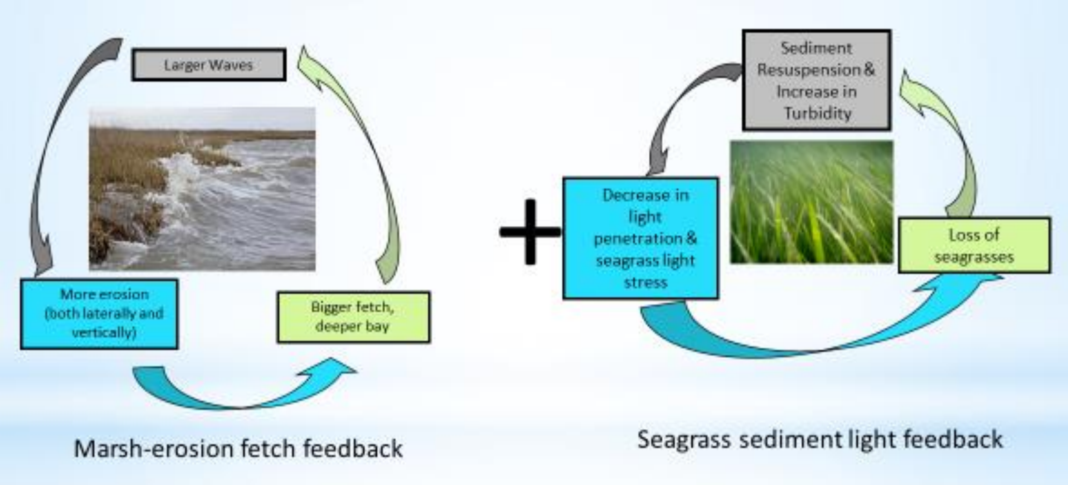
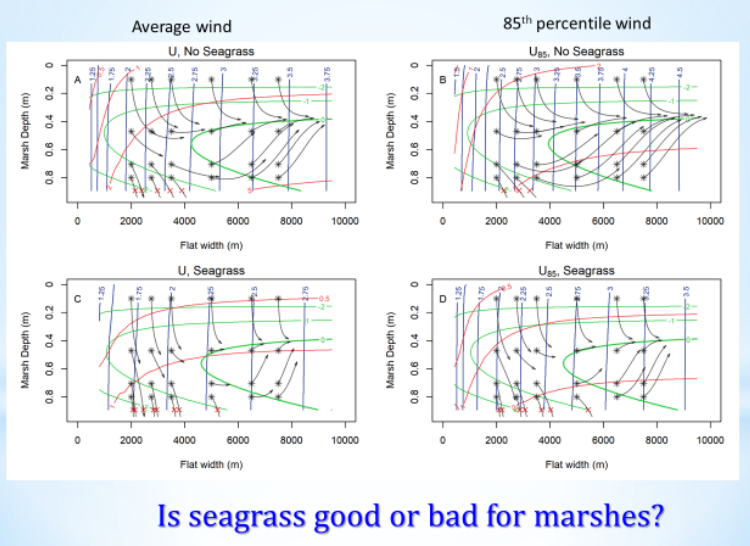
Models to generate hypotheses and understand complex interactions









Habitat expansion into the uplands
What processes and timescales control marsh upland migration?

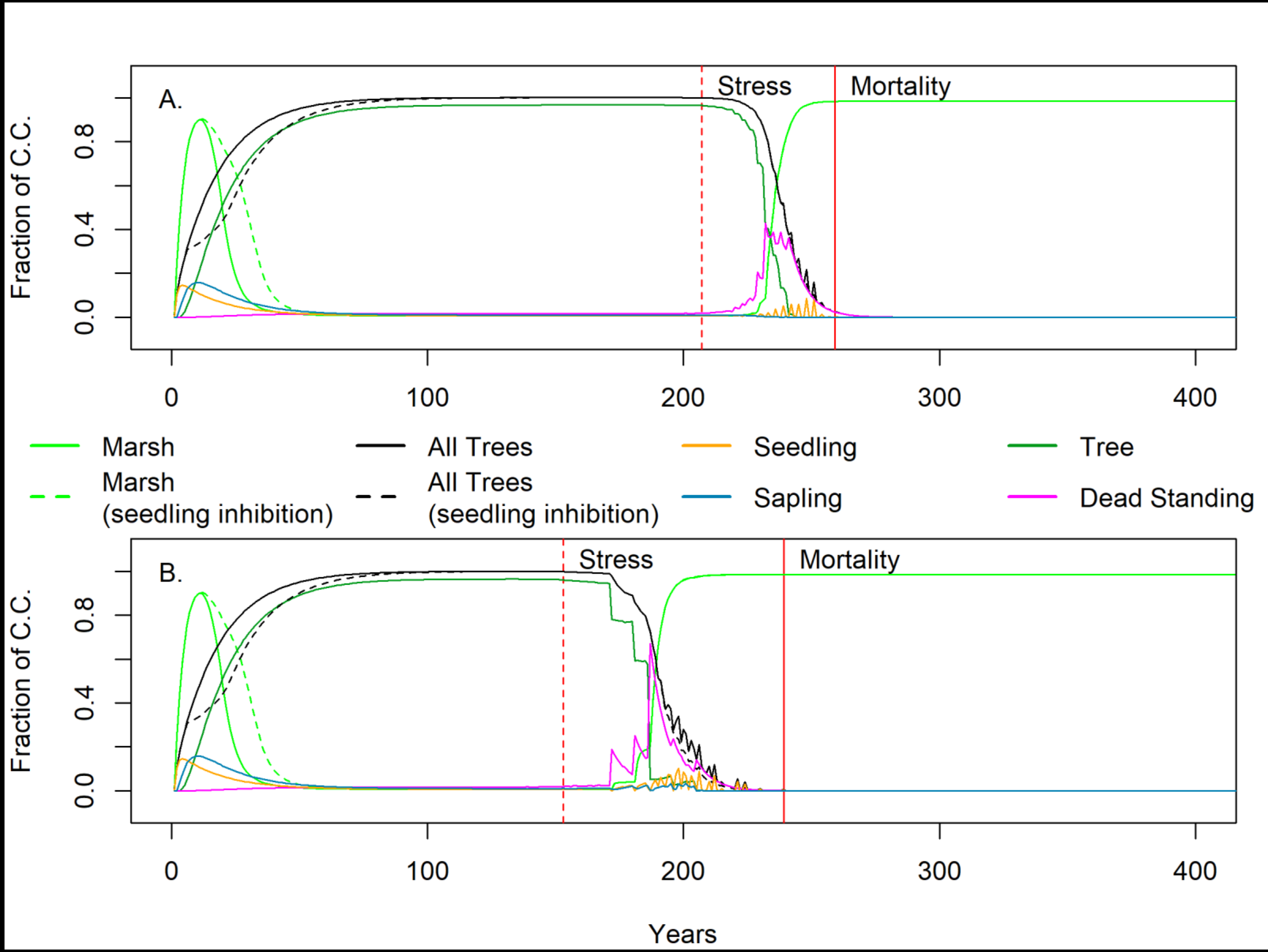
Bare ground at 1m above MHW grows a forest

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

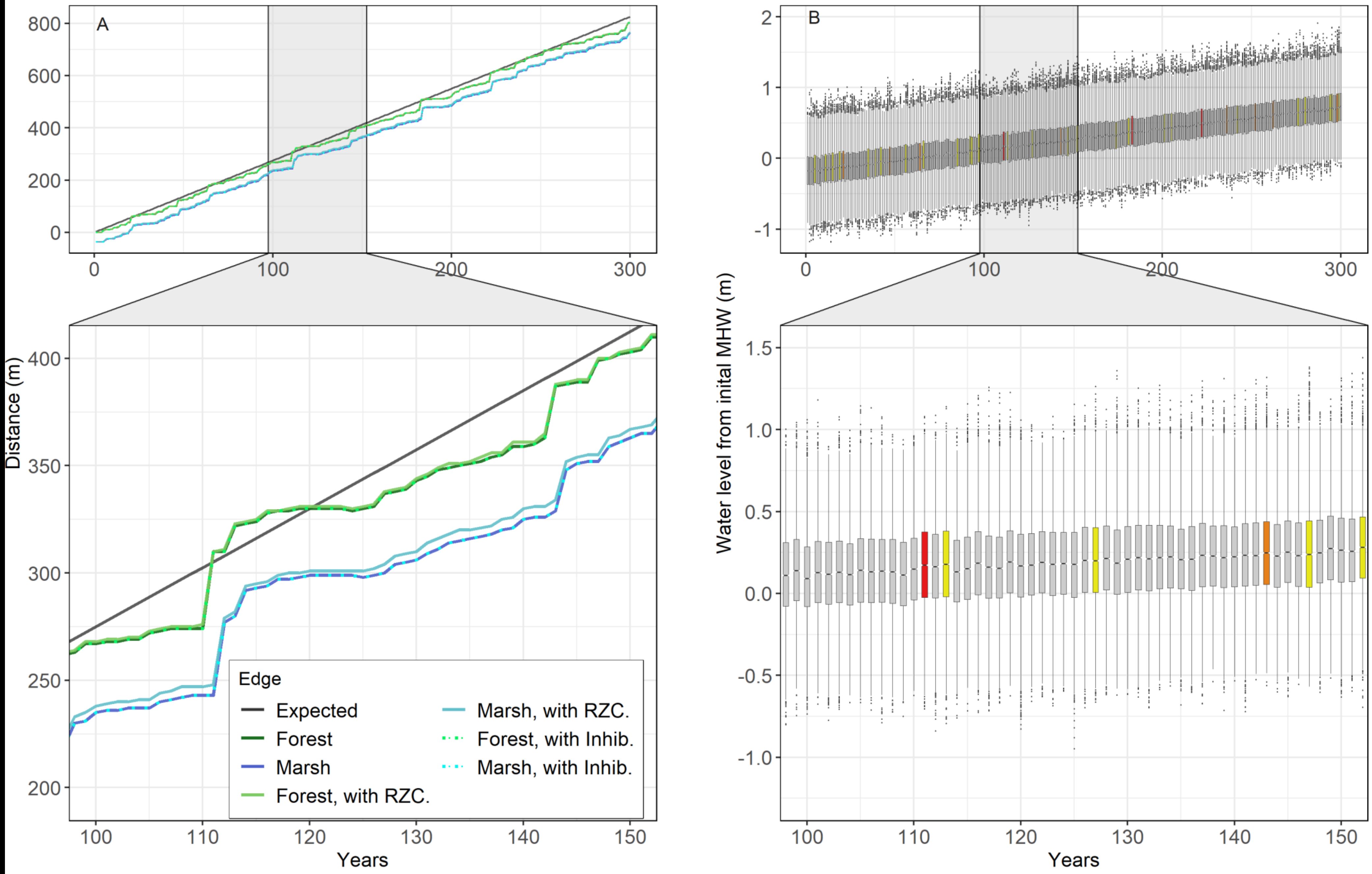
But stochastic events (i.e. storms) transition forest to marsh~50-75 years earlier.

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 seedings
Blue is saplings
Black is saplings+adult trees
Maroon is dead standing



Seedling inhibition, root zone collapse? Limited memory?



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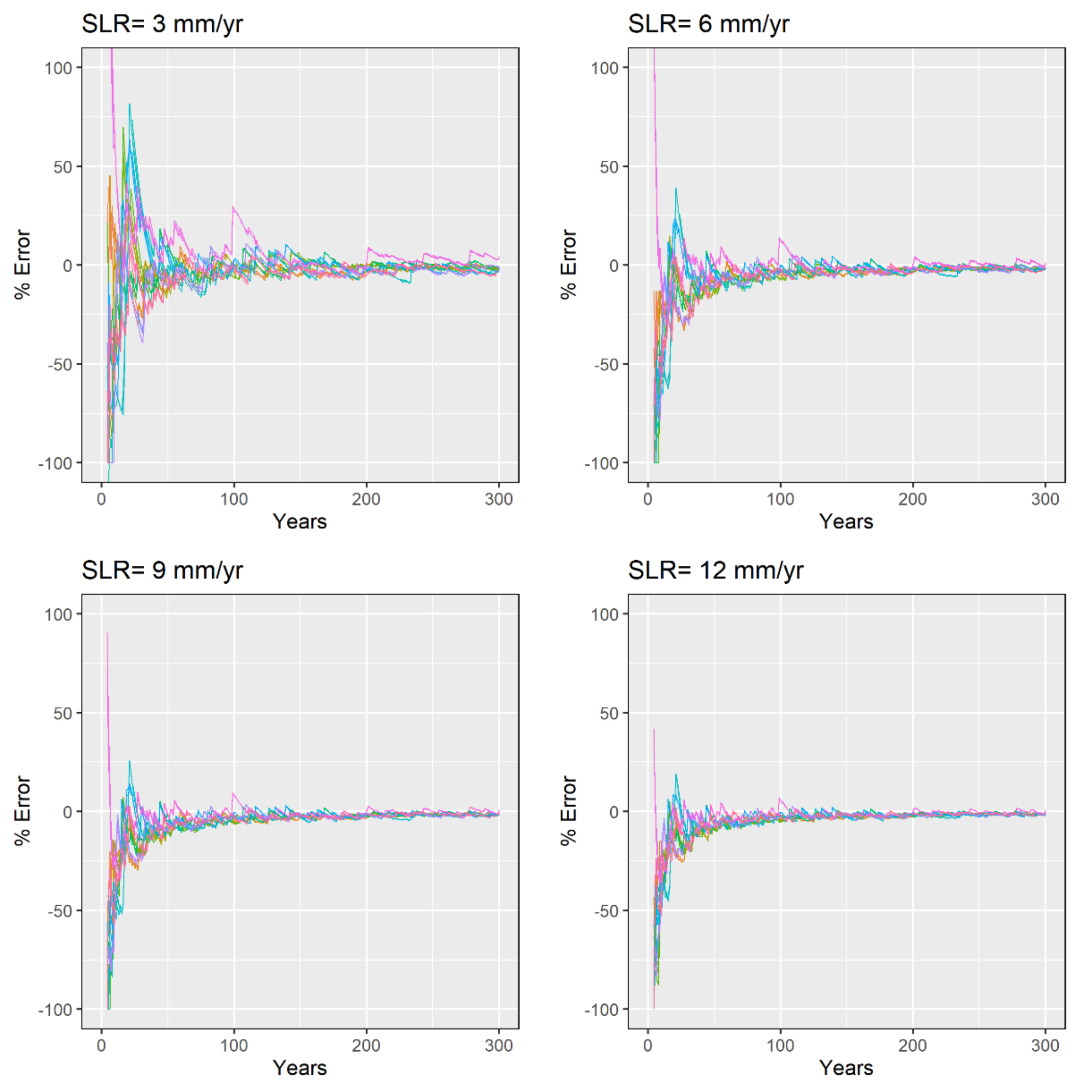
Large errors are likely to remain in estimation of forest retreat and marsh migration rates from remote sensing

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.



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?

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Chesapeake Bay LEAN Corrections

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

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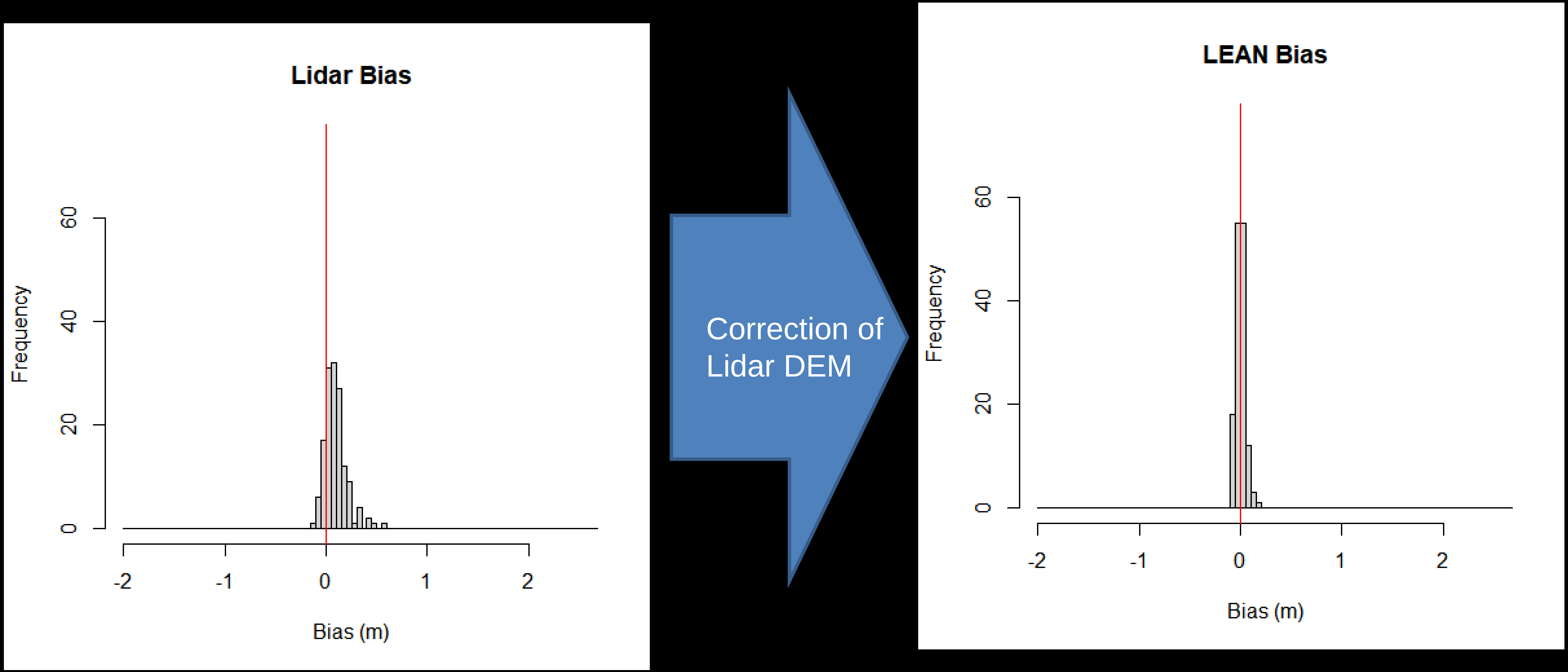
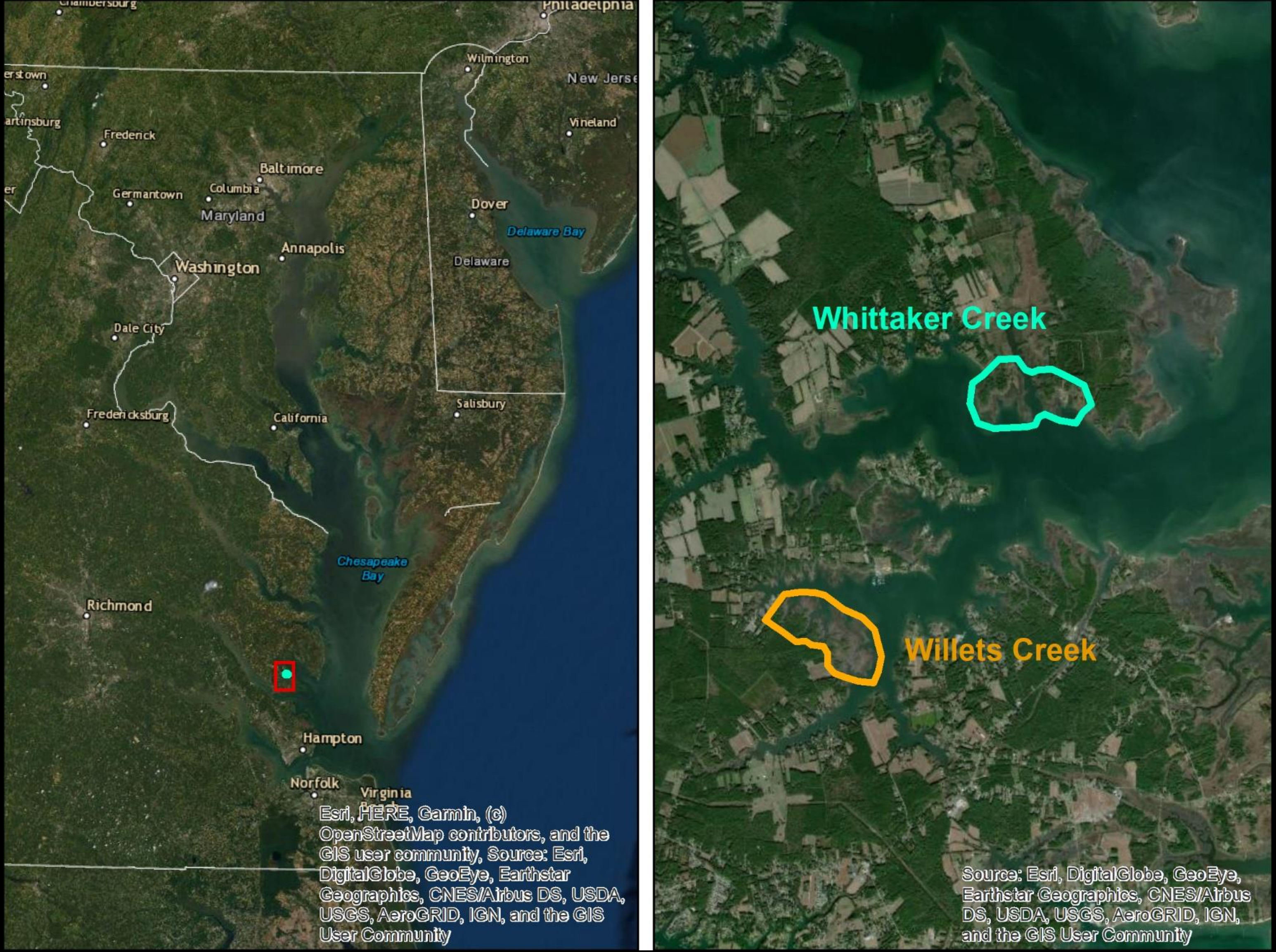
Lidar error and bias, and correction





Available Datasets

LiDAR: April-May 2010

NAIP: May 2012

RTK GPS: 2020 (marsh only)

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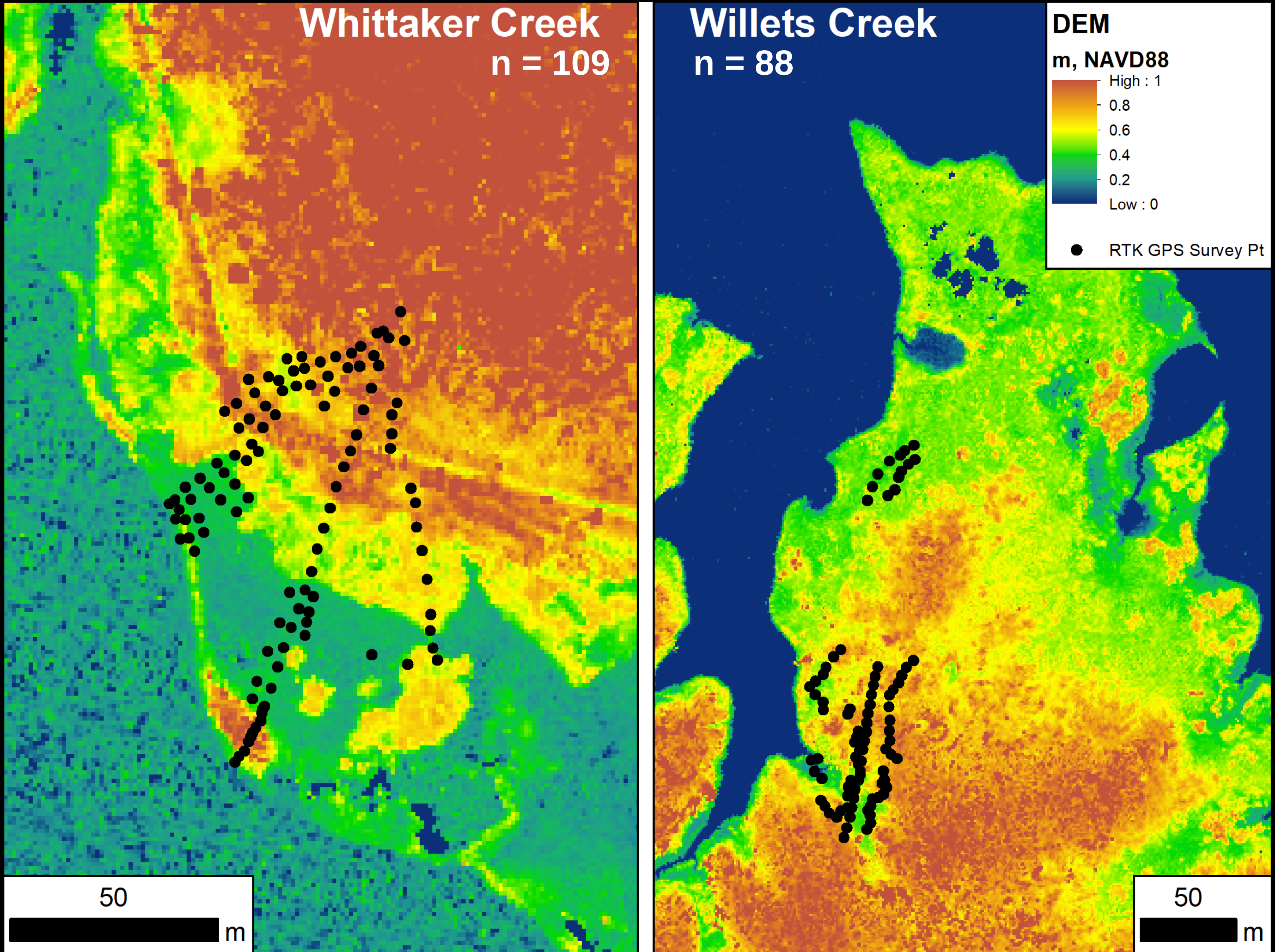
Original

RMSE: 0.277 m
Mean Error: 0.099 m

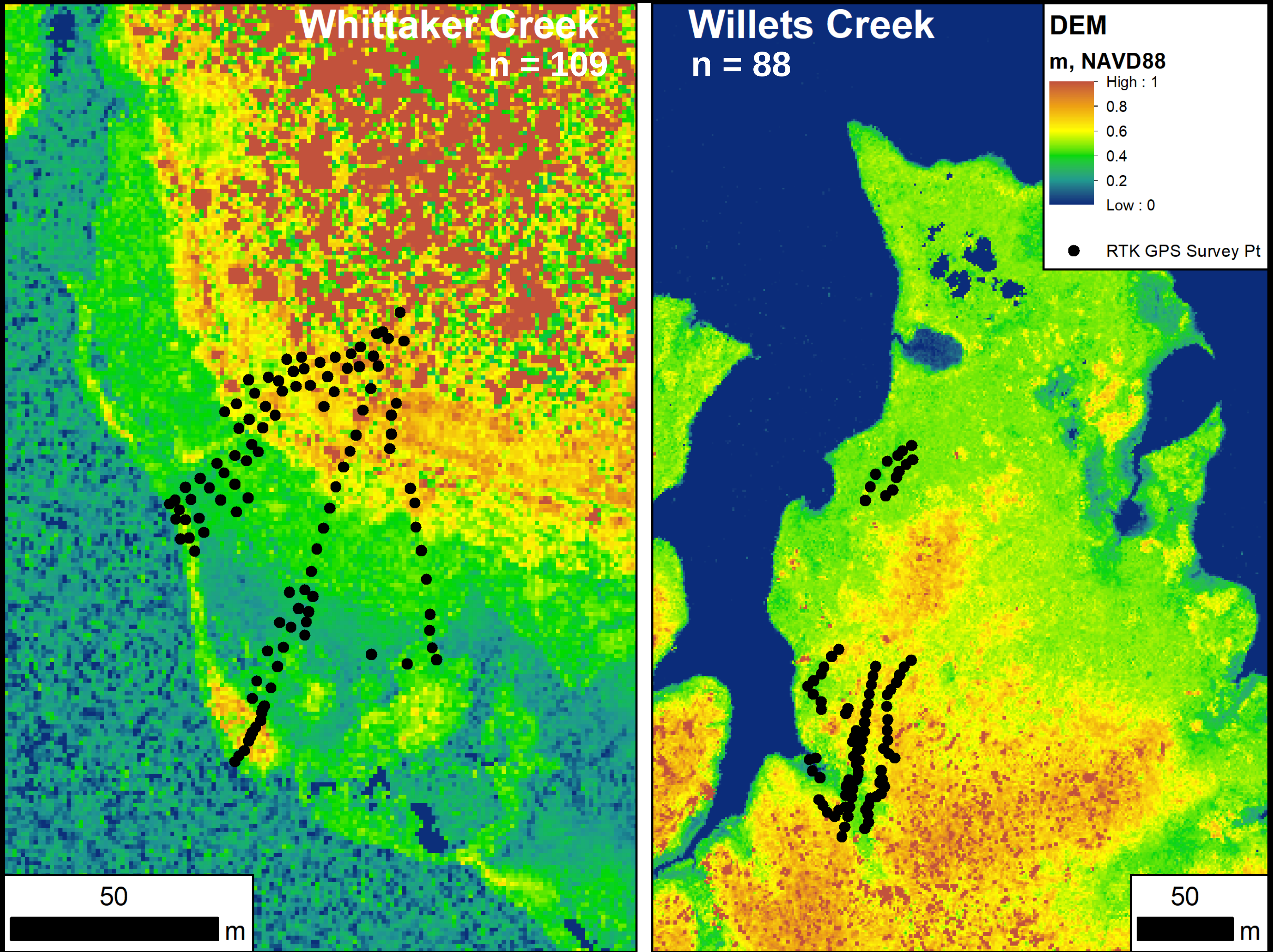
RMSE: 0.341 m
Mean Error: 0.11 m



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



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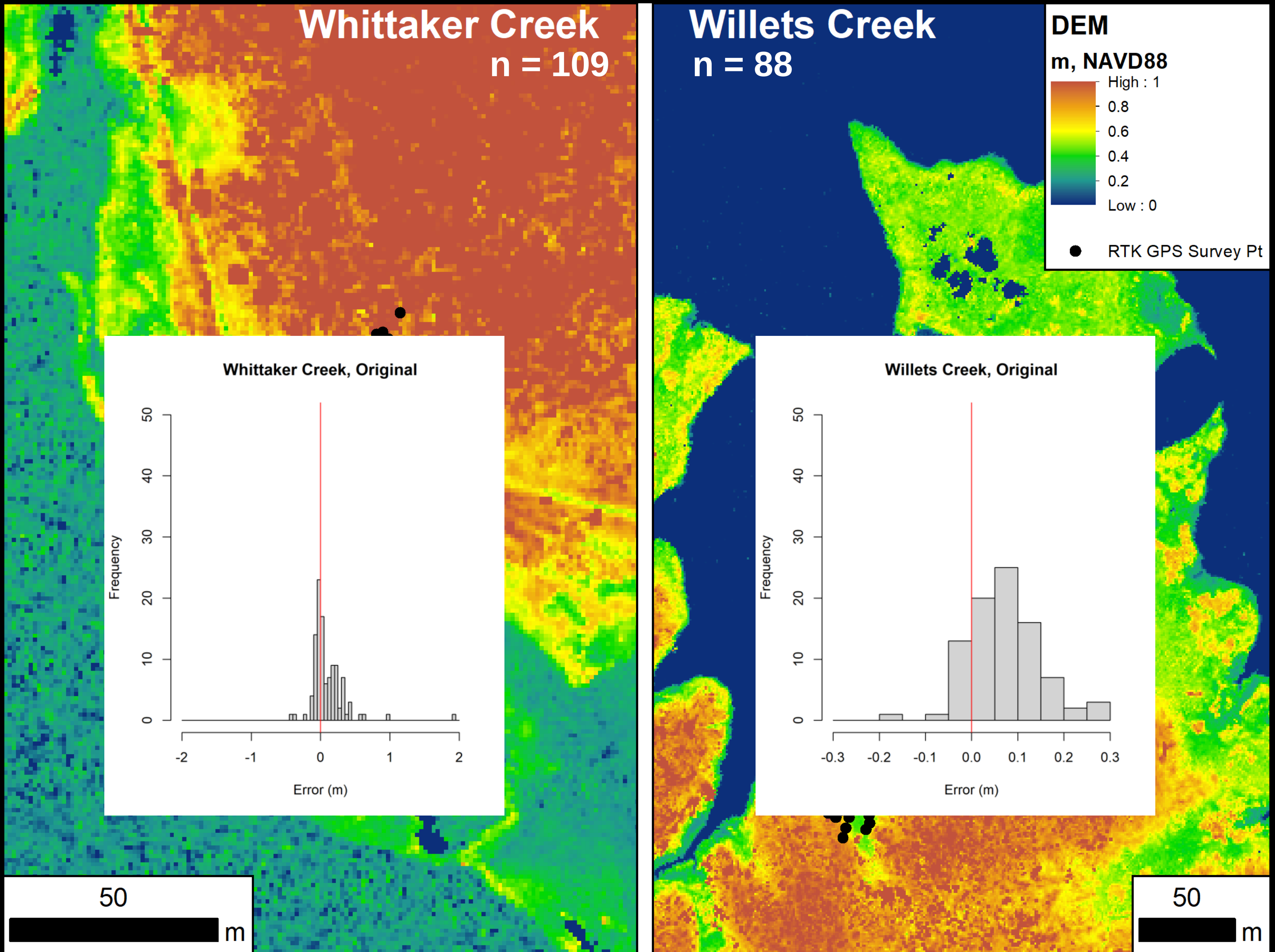

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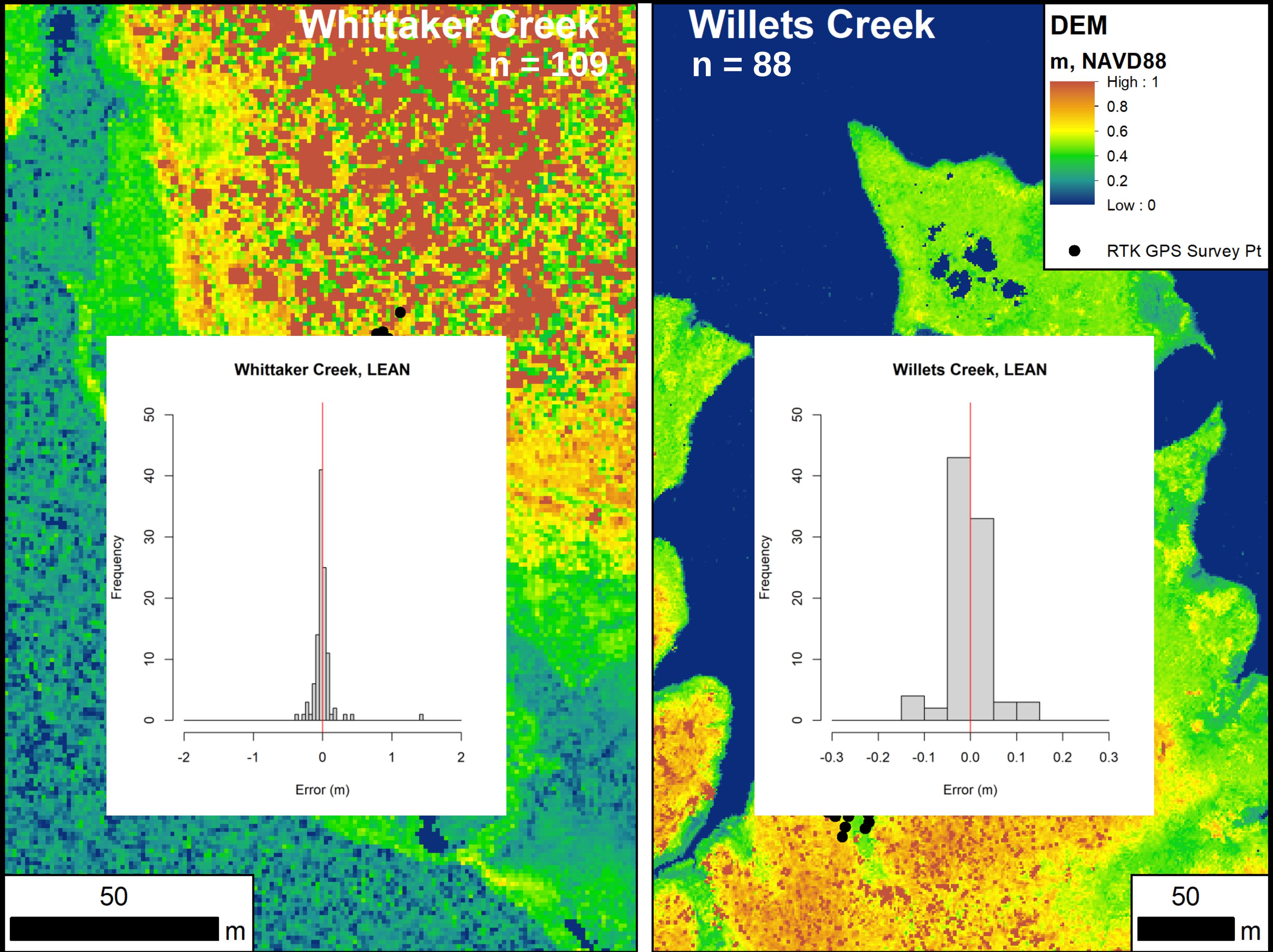

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LiDAR Elevation Adjustment using NDVI (LEAN)

Next steps:

CBNEER VA and CBNEER MD collaboration.

Testing of point cloud methods with extant RTK data sets (Fire Island, Assateague, Gateway etc…)

How do systems change?


Eastern Neck NWR
Waterfowl Hotspot
EN_StratSampleLoc2
Habitat__1
Freshwater ponds/impoundments
High Marsh
Low Marsh
Mudflats
SAV

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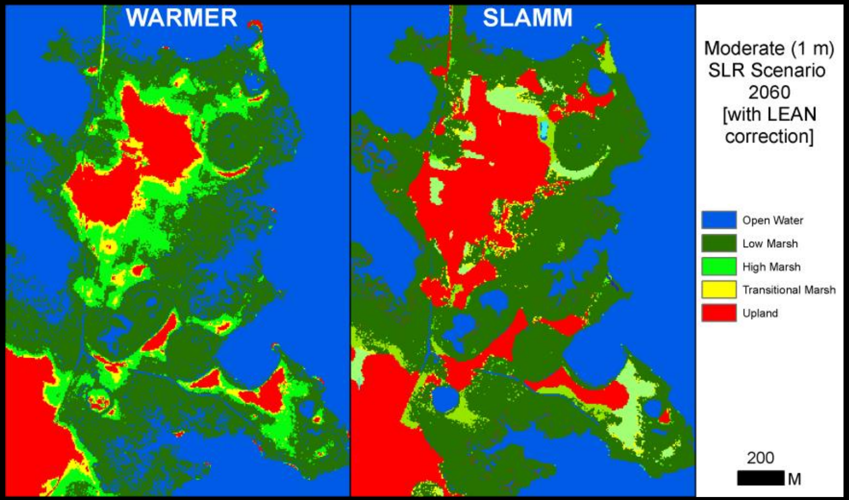
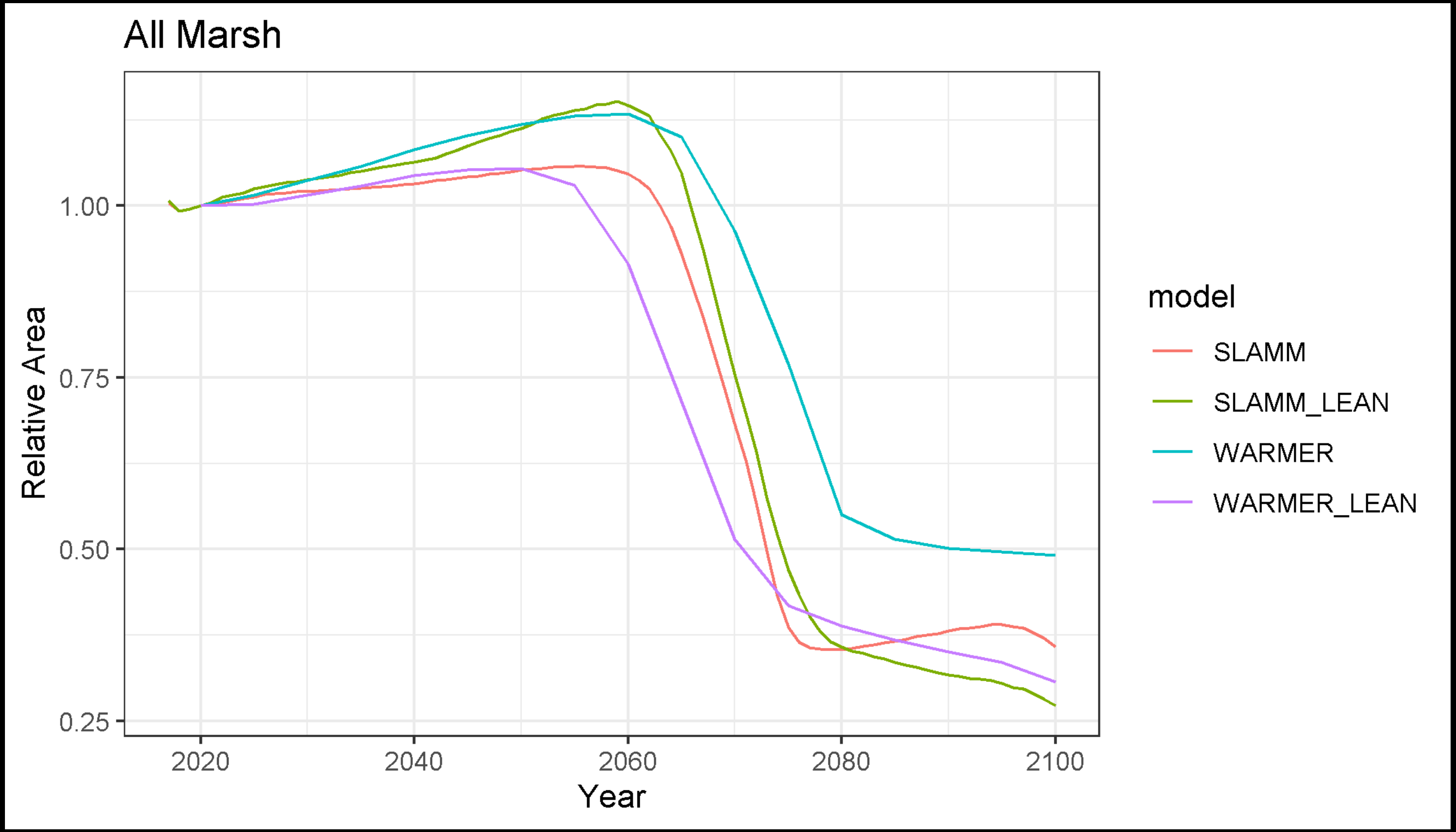
Vertical dynamic models (SLAMM, WARMER), Eastern Neck NWR

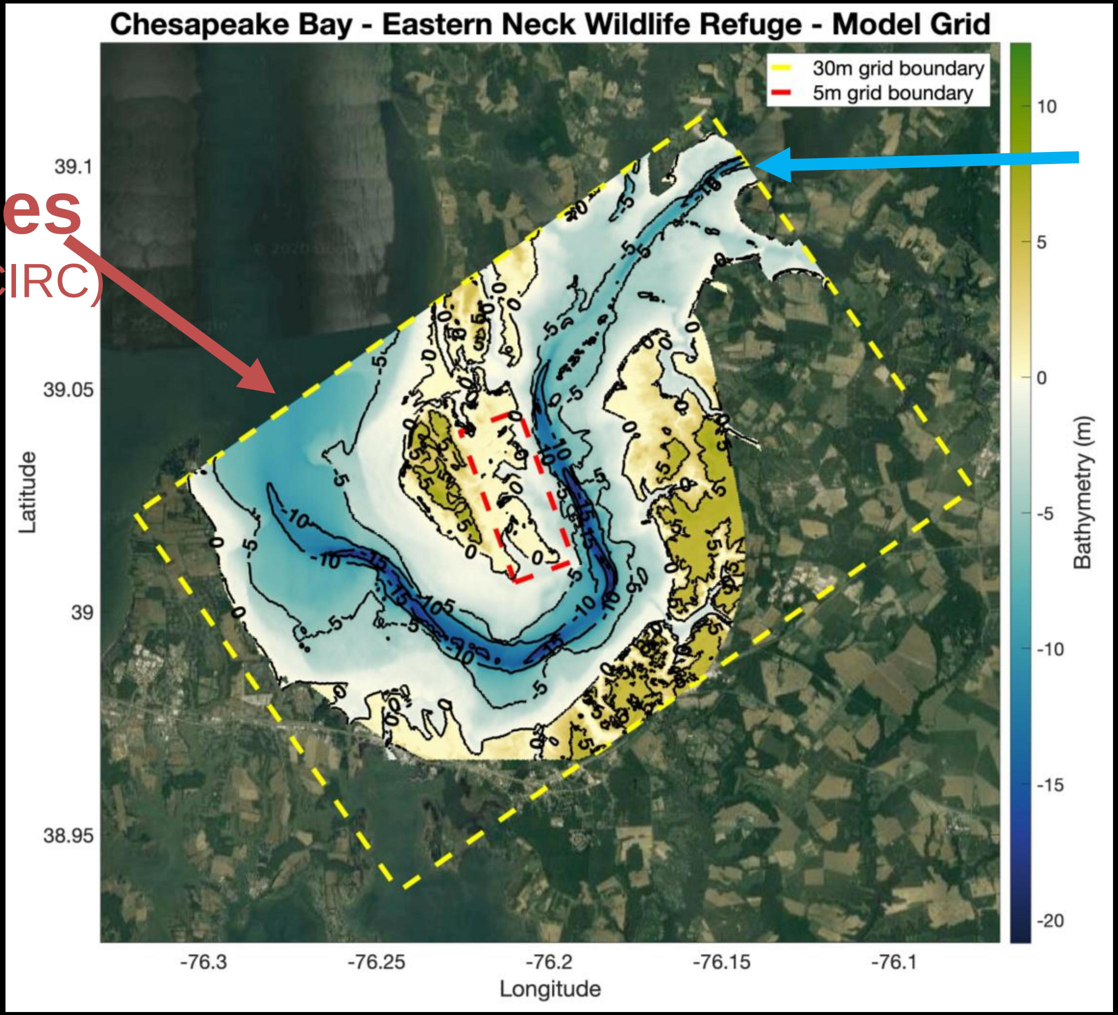


Importance of initial “state” of the system



Hydrodynamic model forcing (COAWST)

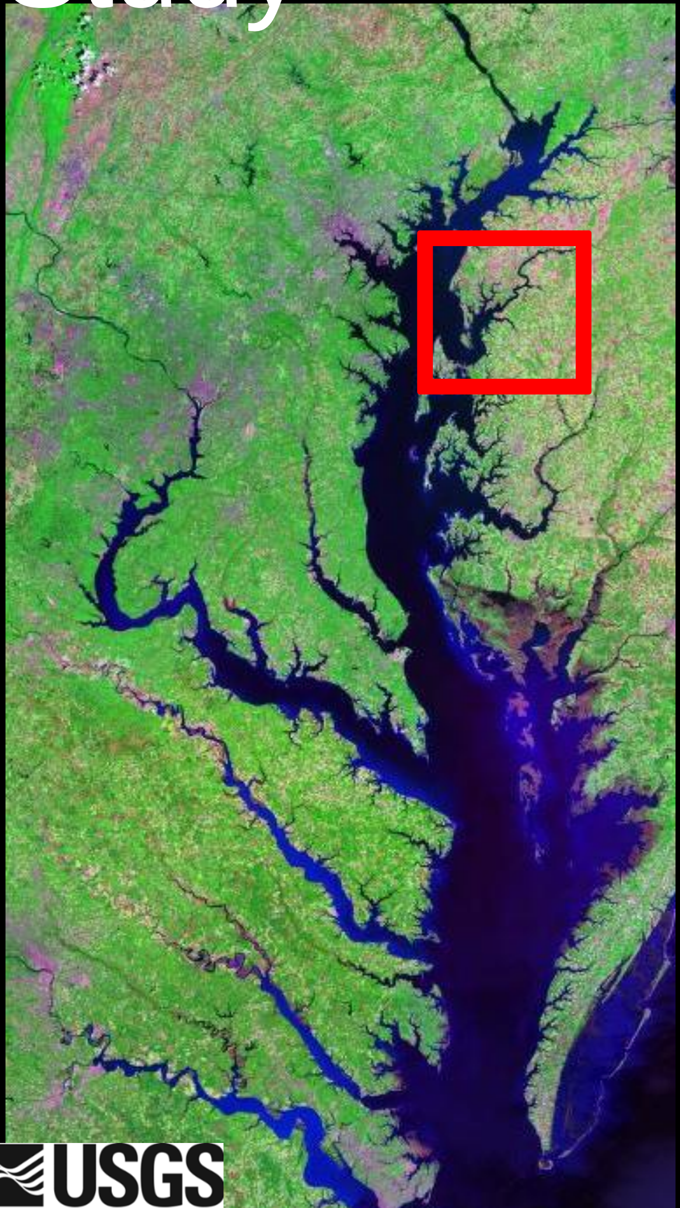
Tides
(ADCIRC)



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:

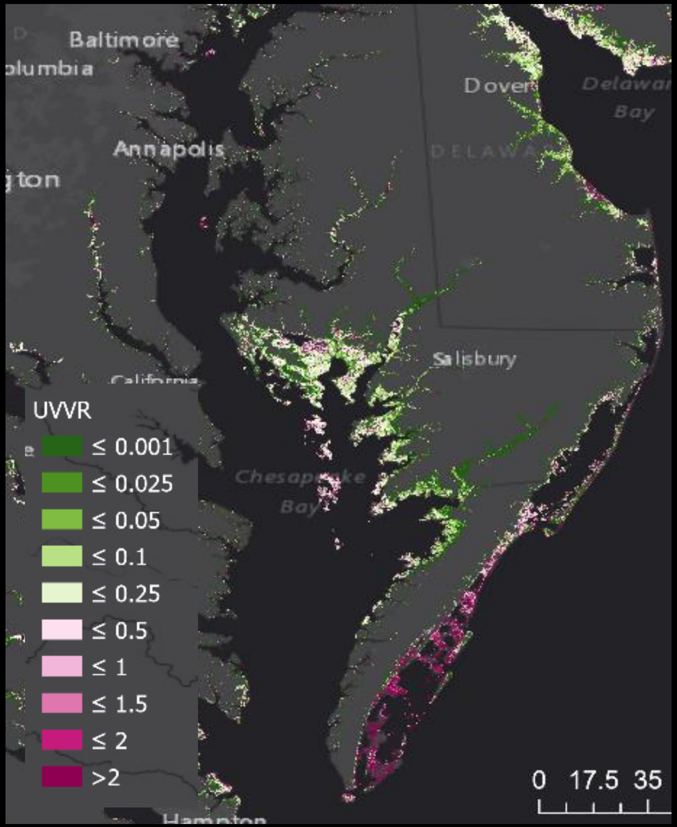
Generate ensemble model outputs of habitat change under key environmental driver projections.

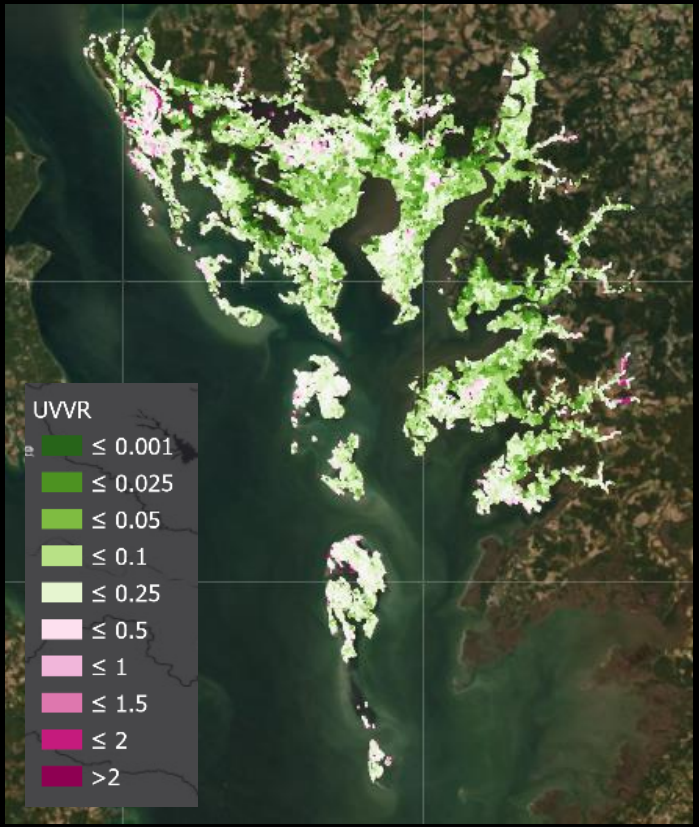
Incorporate those projections/understanding of habitat change into a geospatial synthesis products

Link Habitat change to potential waterfowl distributions

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

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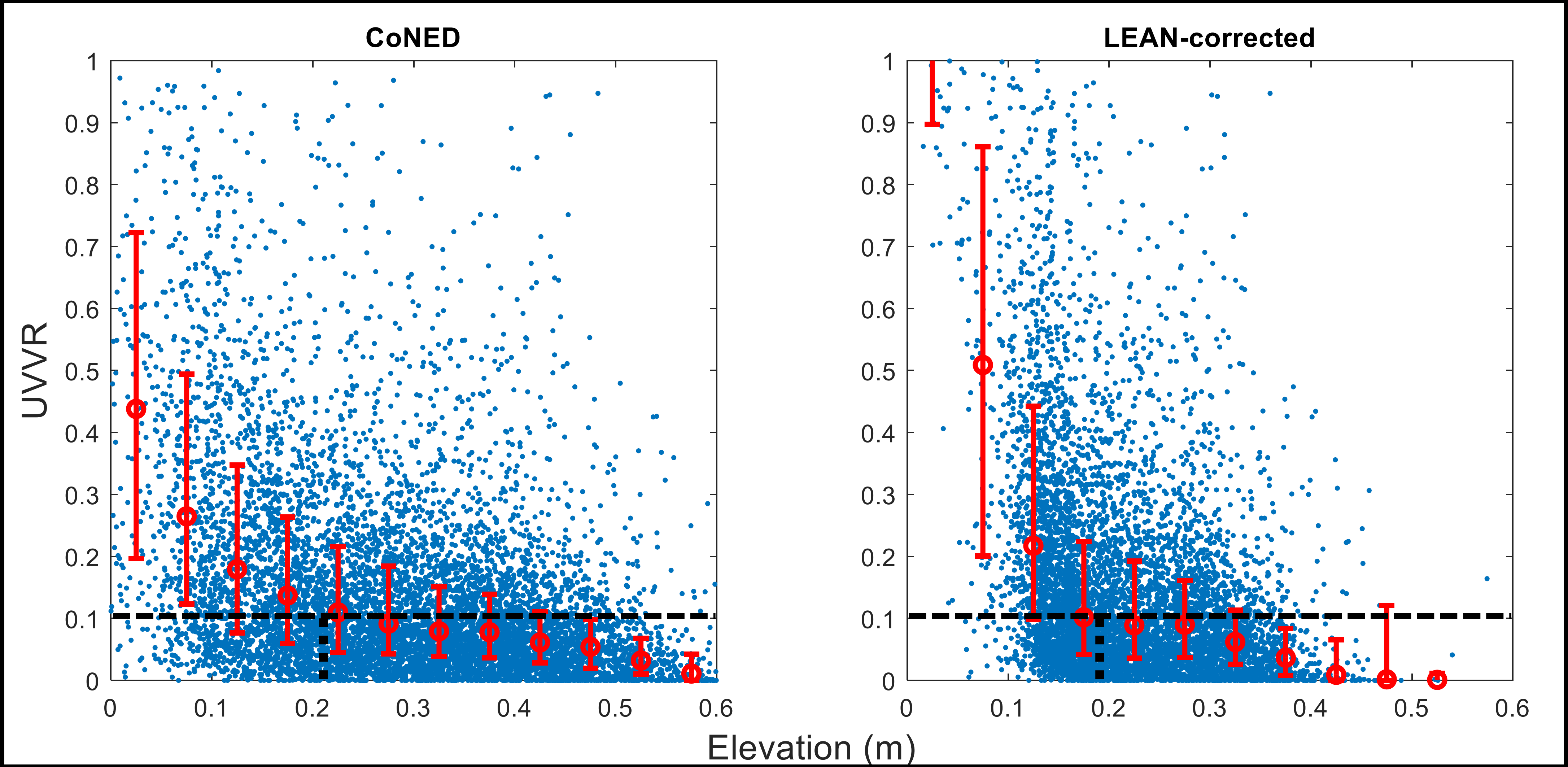
Chesapeake UVVR vs. elevation comparison with LEAN* correction



***LEAN =** Lidar Elevation Adjustment with NDVI

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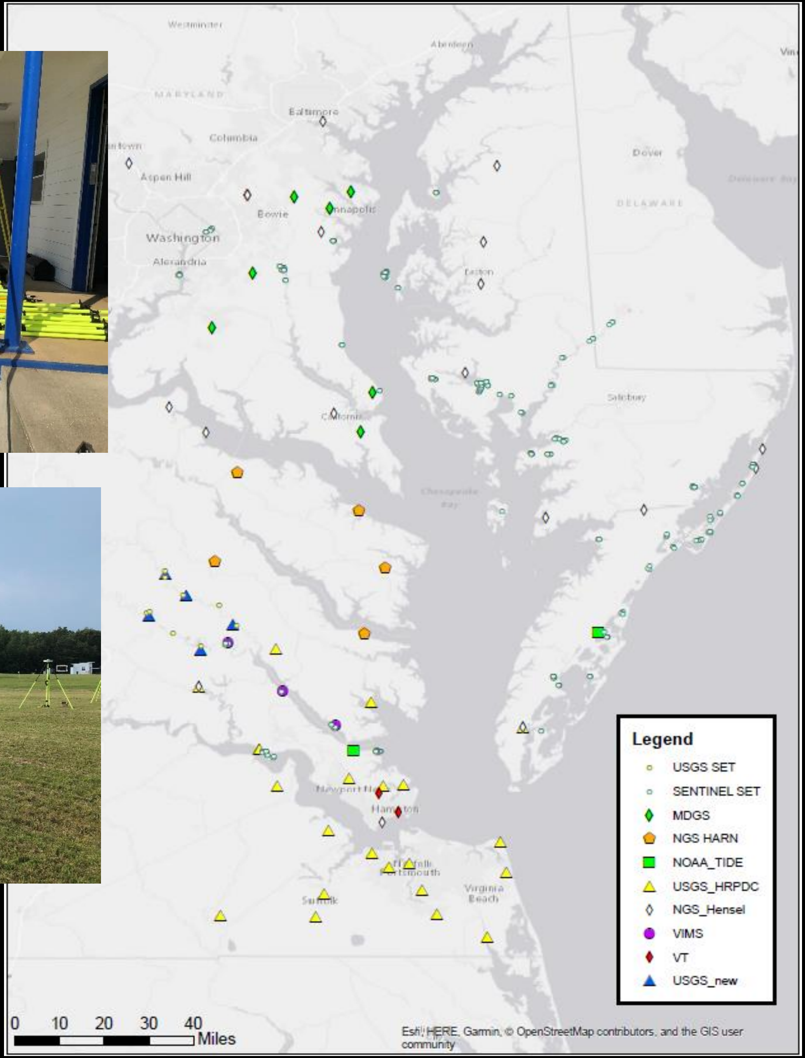
Processes we need to better constrain and understand

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



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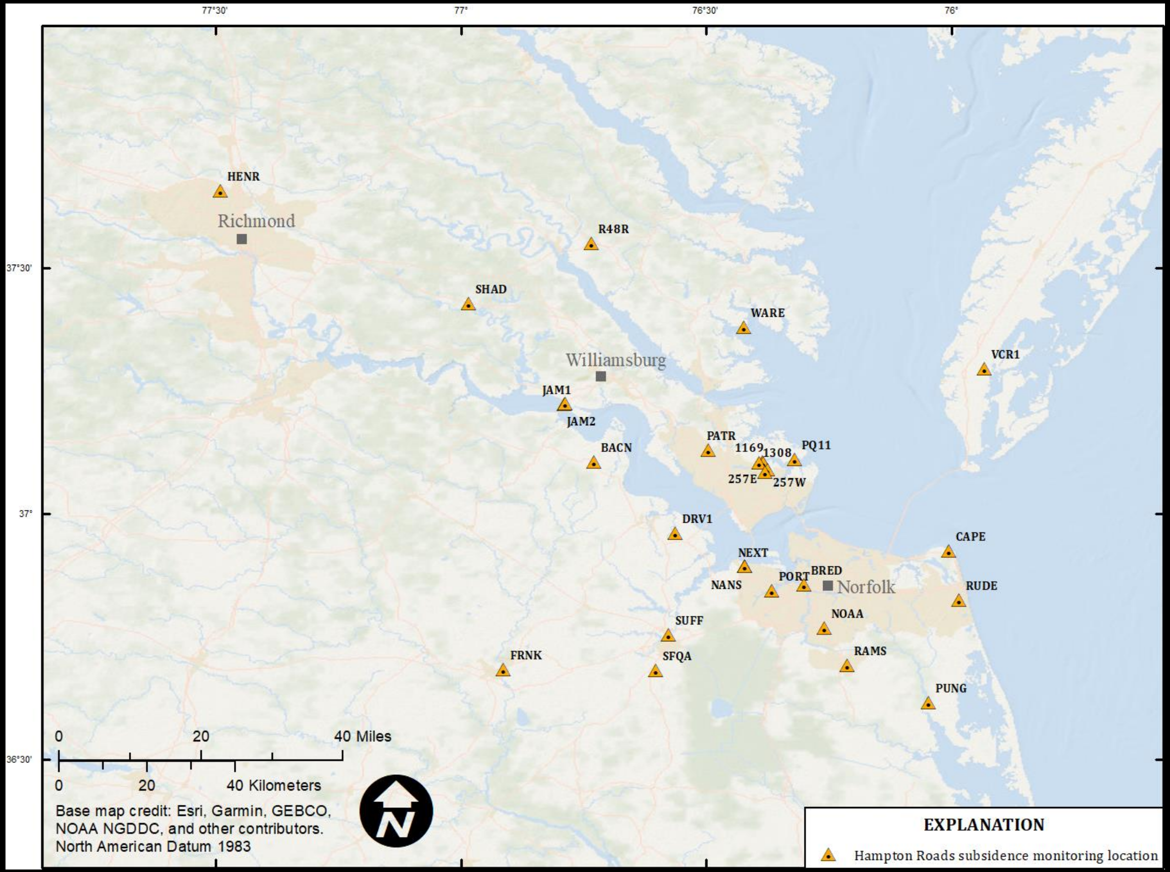
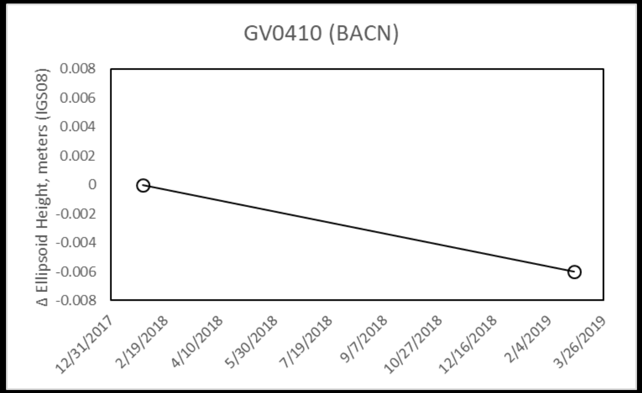
Hampton Roads Benchmark Monitoring Network (2018-2022)

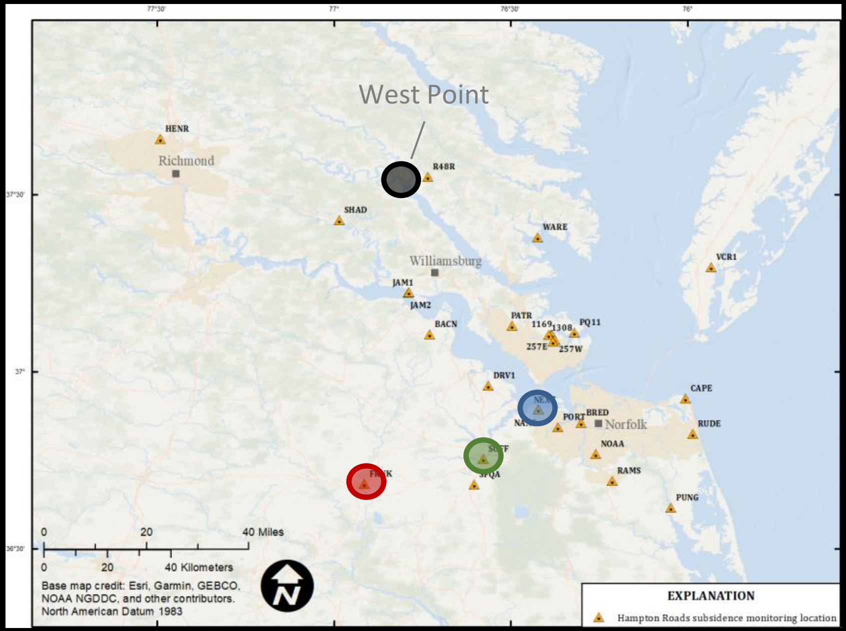
- 2018 -2020 surveys completed
  - 24-hr observations
  - 25 benchmarks
- Data processing and evaluation complete (NGS – OPUS Projects)
- Final 2018-2020 results to be published through ScienceBase

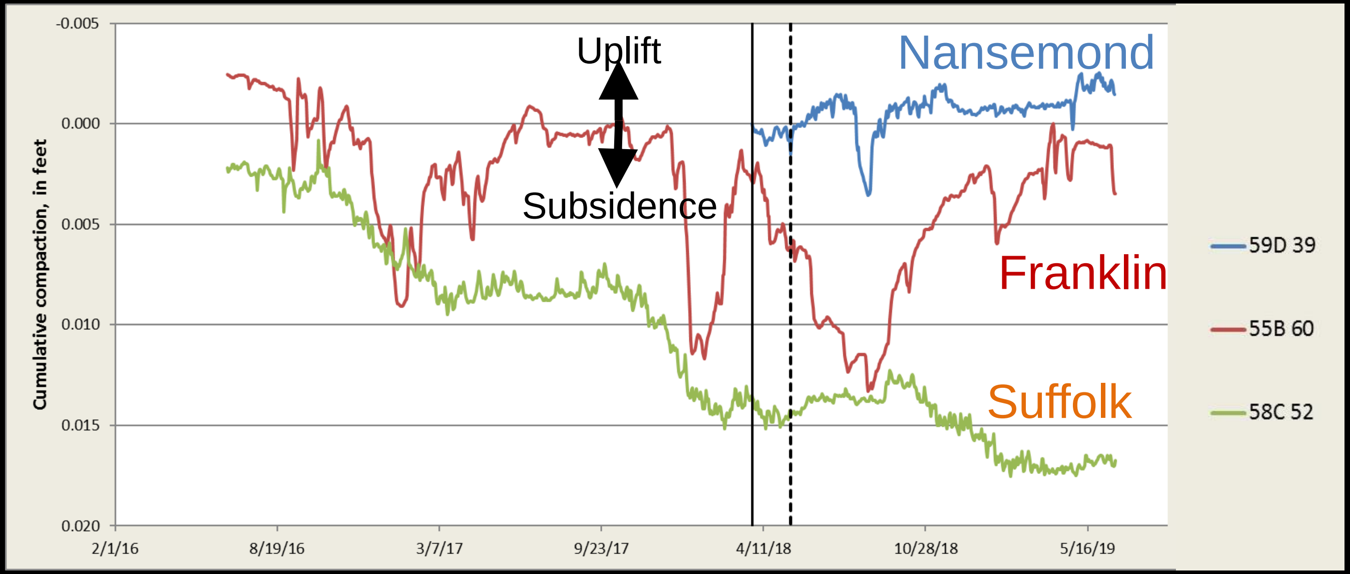




Extensometers

- 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 4th sensor (West Point)





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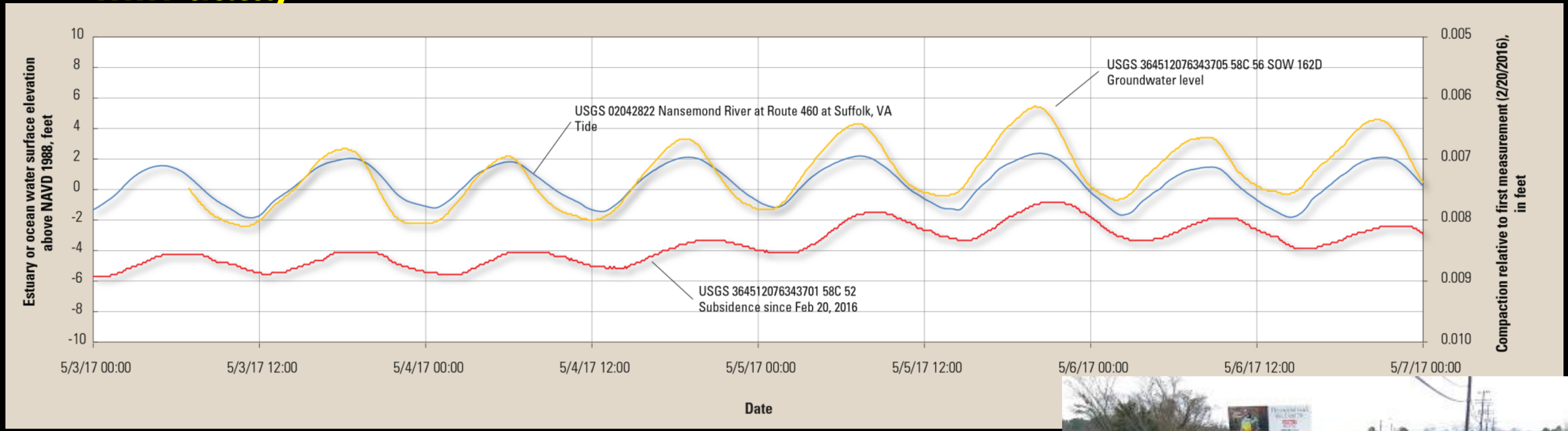
Which Direction does the Ground Move?

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

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

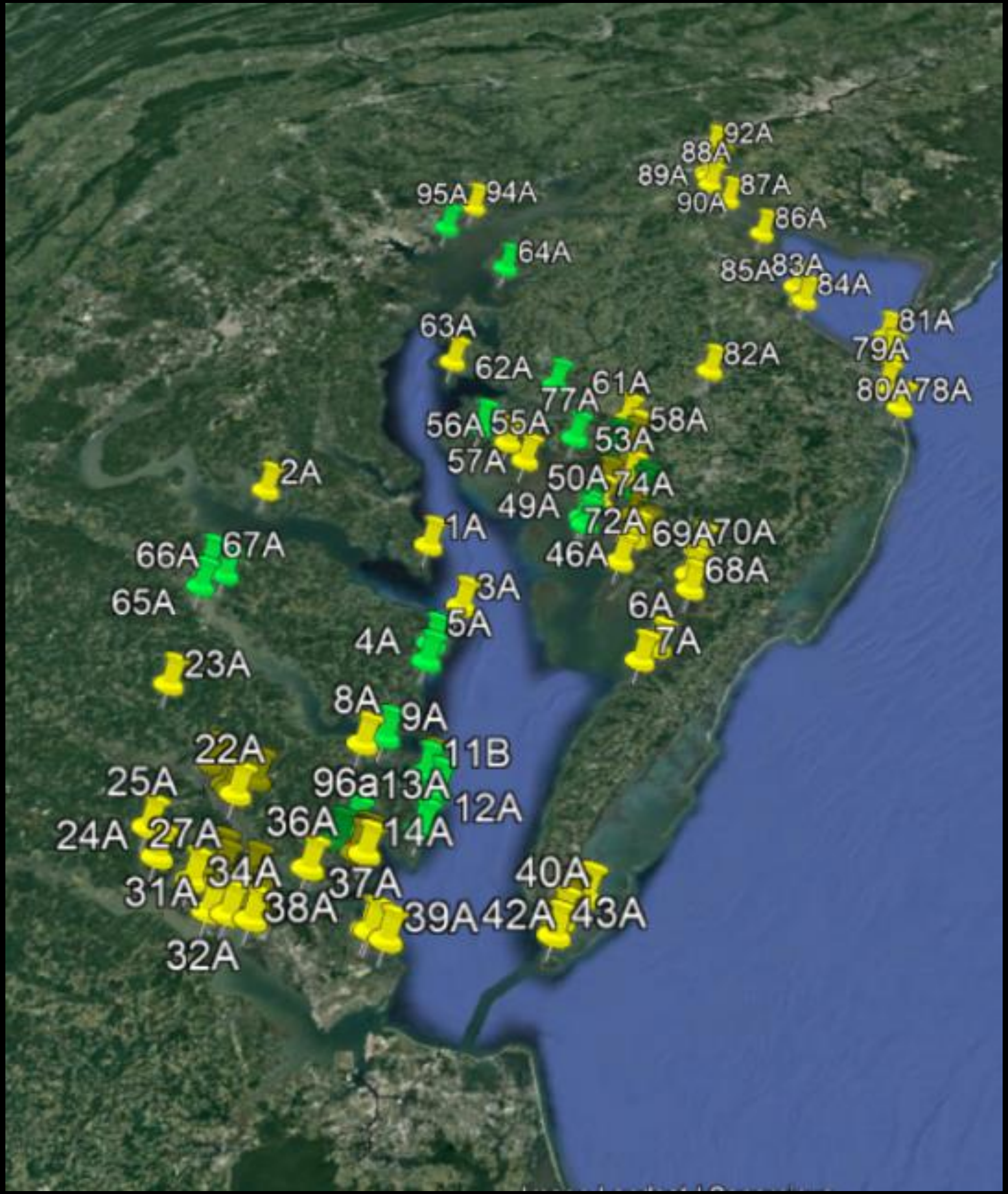


USGS 364512076343701 58C 52
Extensometer 1,620 feet

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

USGS 02042822 Nansemond River at Route 460 at Suffolk, VA

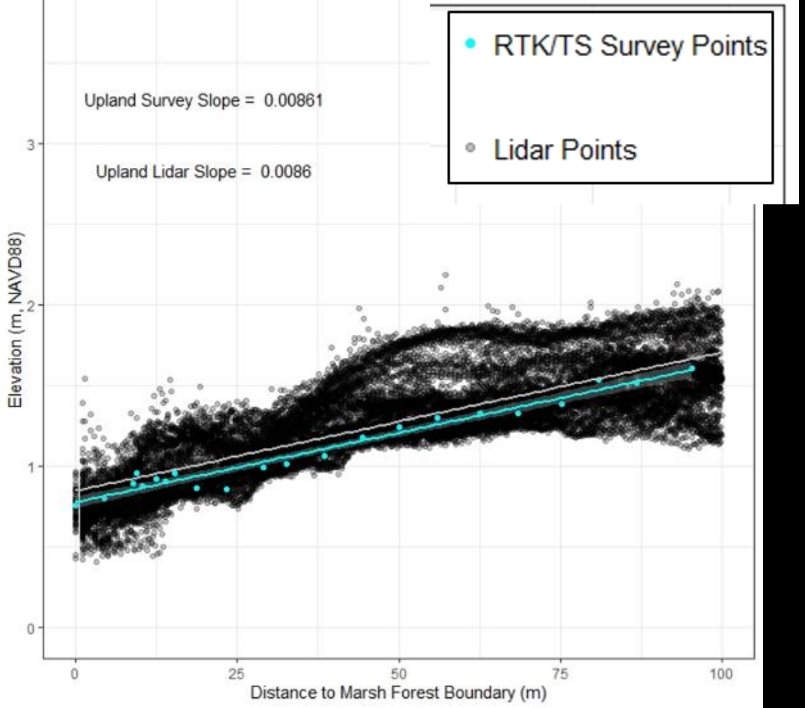
Chesapeake Bay Marsh-Upland Transect Surveys

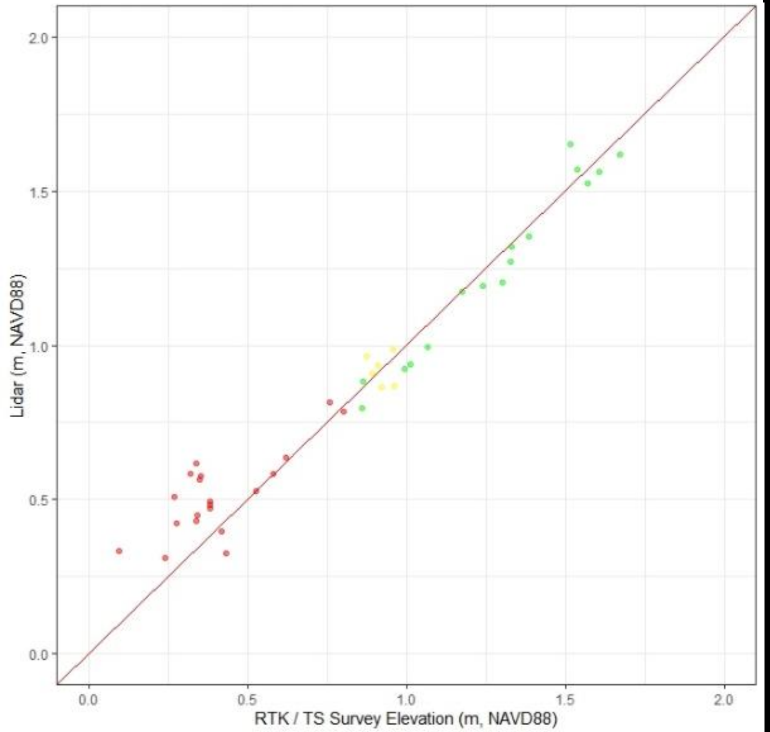


22 sites completed from 2019-2021

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

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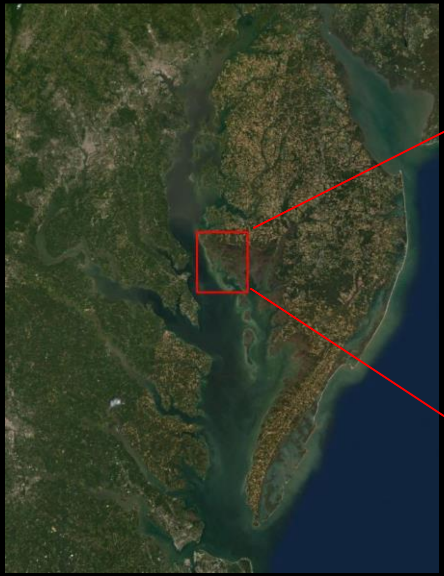
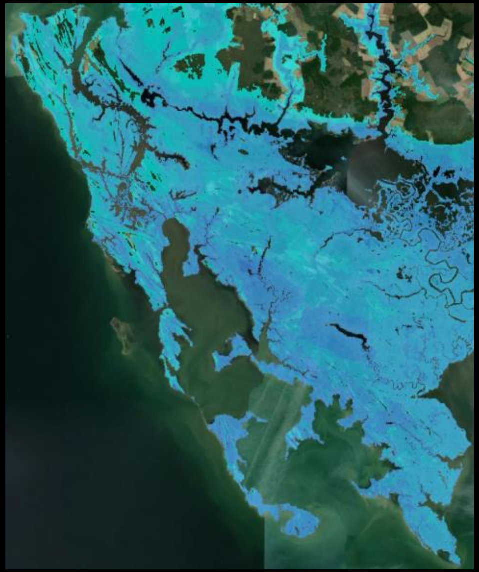
Mapping likelihood of migration into coastal forests:



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

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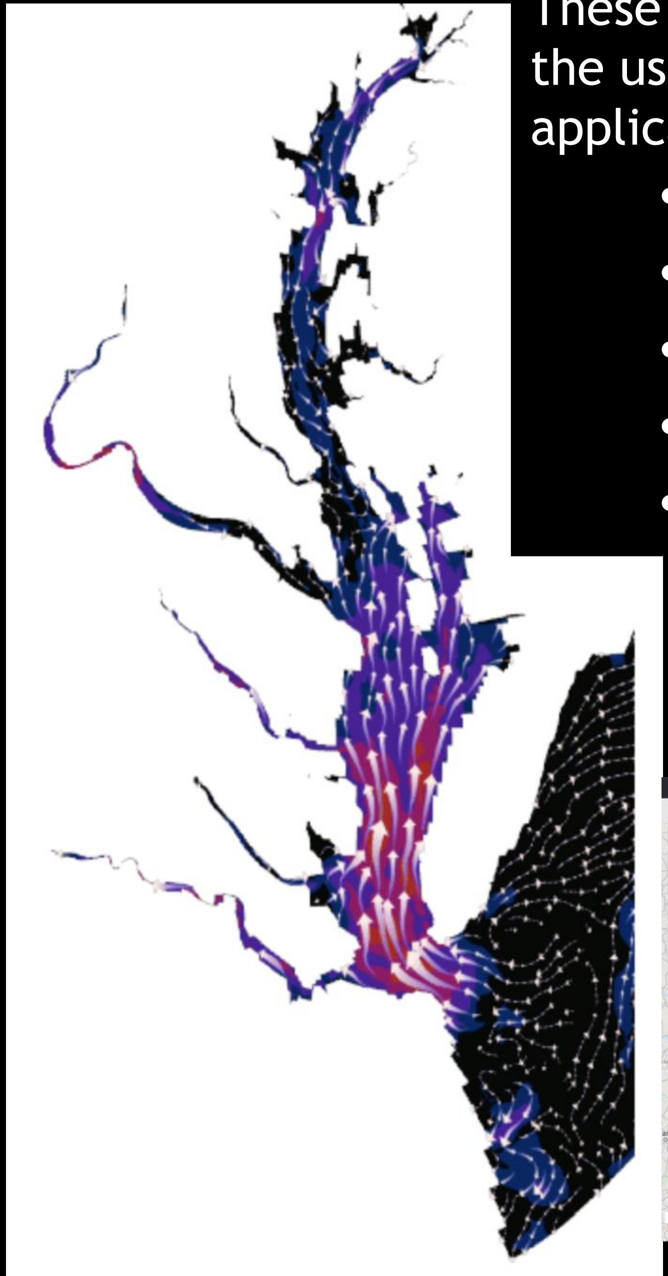
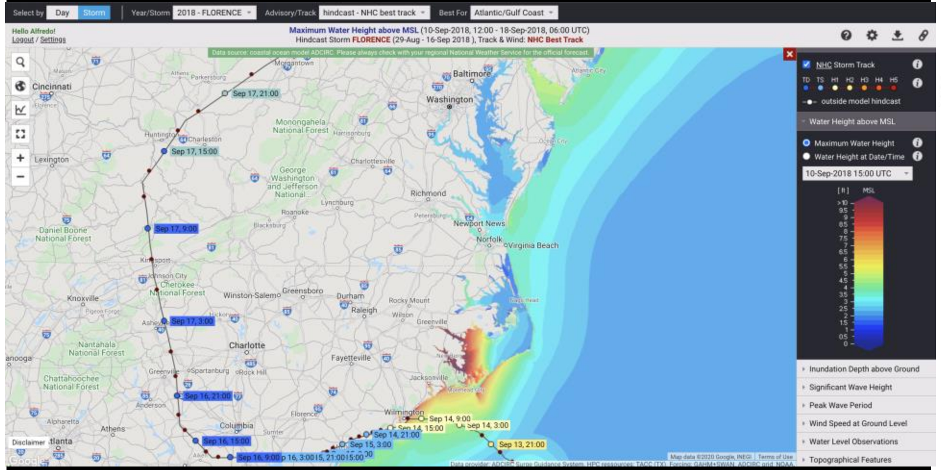
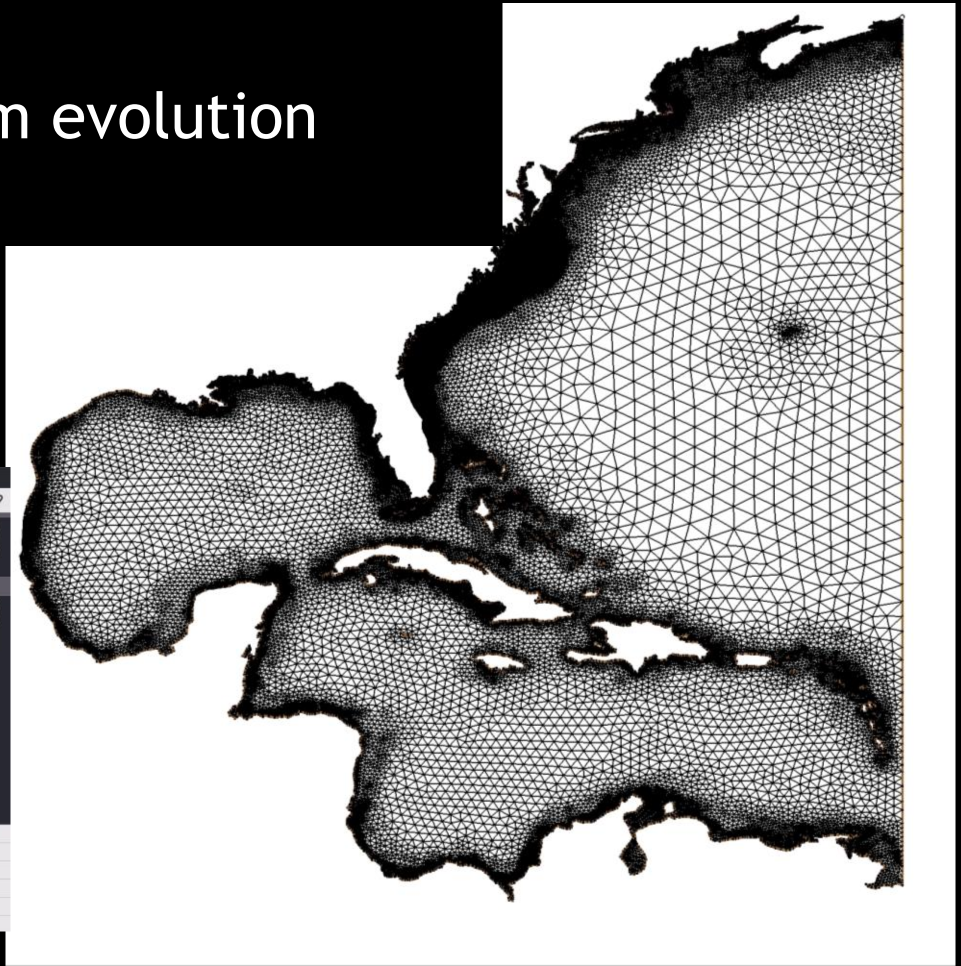
ADCIRC is a system of computer programs for solving time dependent, free surface circulation, wave, and transport problems. These programs utilize the finite element method in space allowing the use of highly flexible, unstructured grids. Typical ADCIRC applications have included:

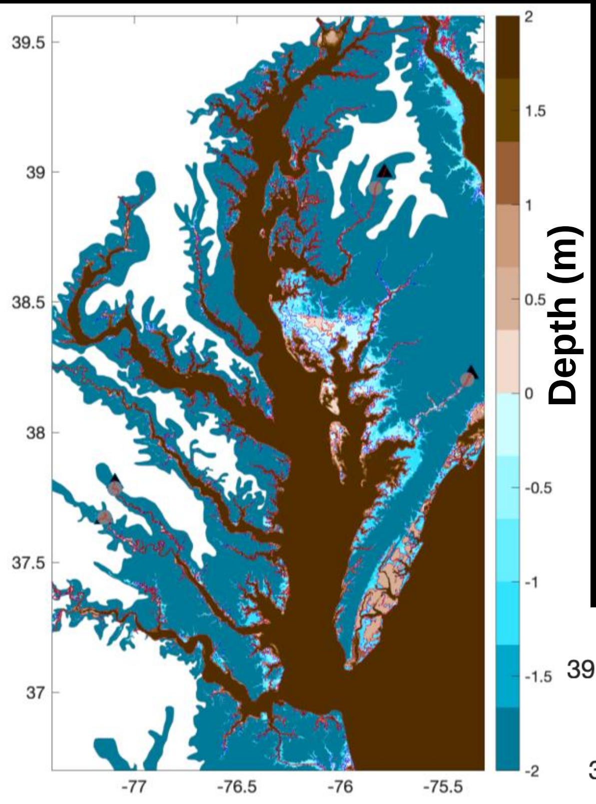
- prediction of storm surge and flooding
- modeling tides and wind driven circulation
- larval transport studies
- physical controls of ecosystem evolution
- near shore marine operations



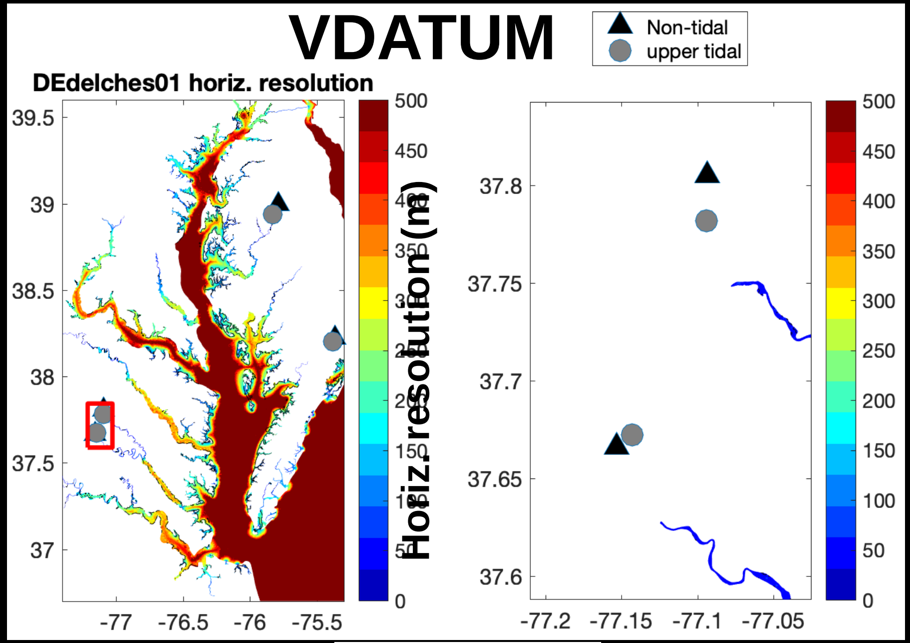


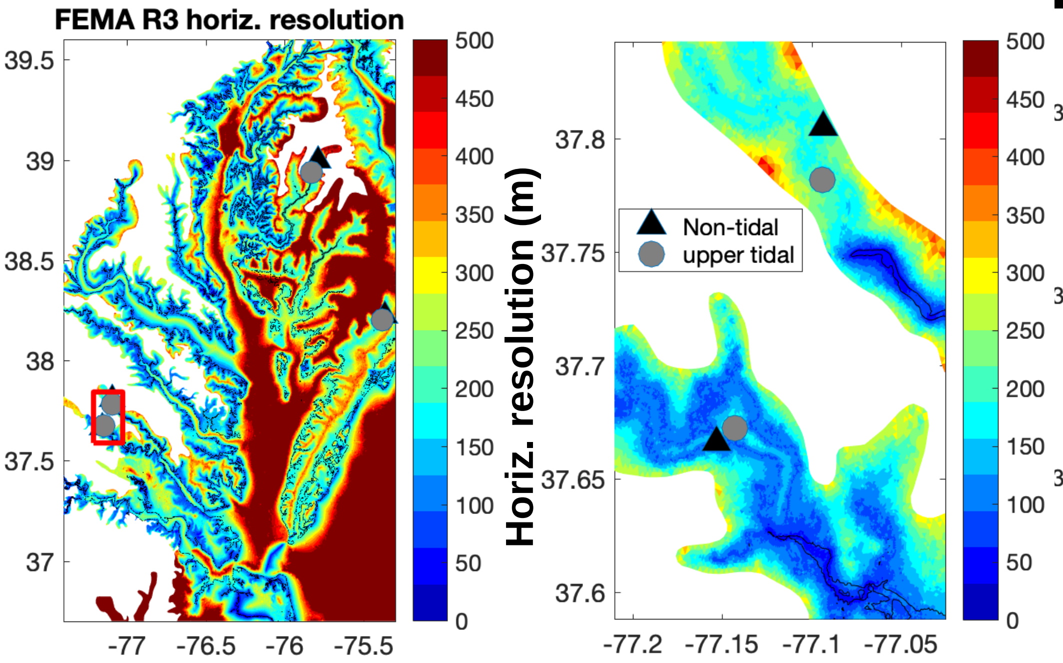


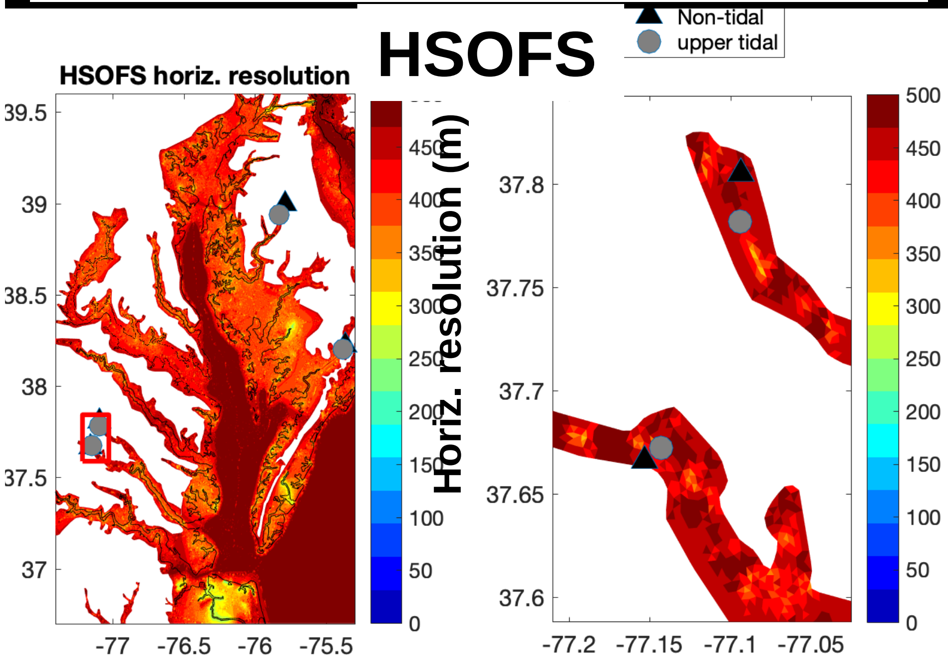
Using ADCIRC high-resolution model for tidal determination



Nuisance flooding, tidal datums and range evaluated using ADCIRC high-resolution FEMA Region 3 grid with horizontal resolutions between 50 and 200m in river areas. Better coverage and better resolved than other products (e.g., VDATUM).







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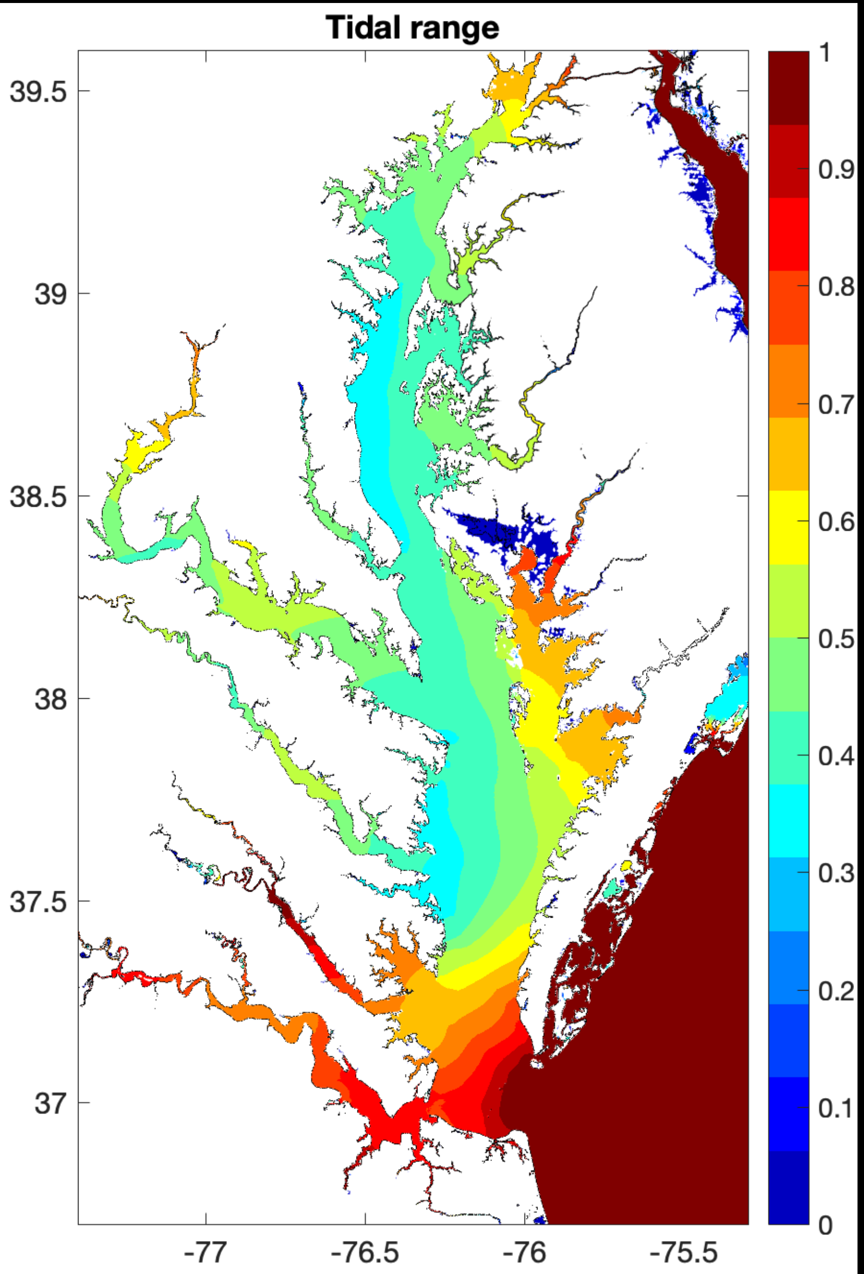
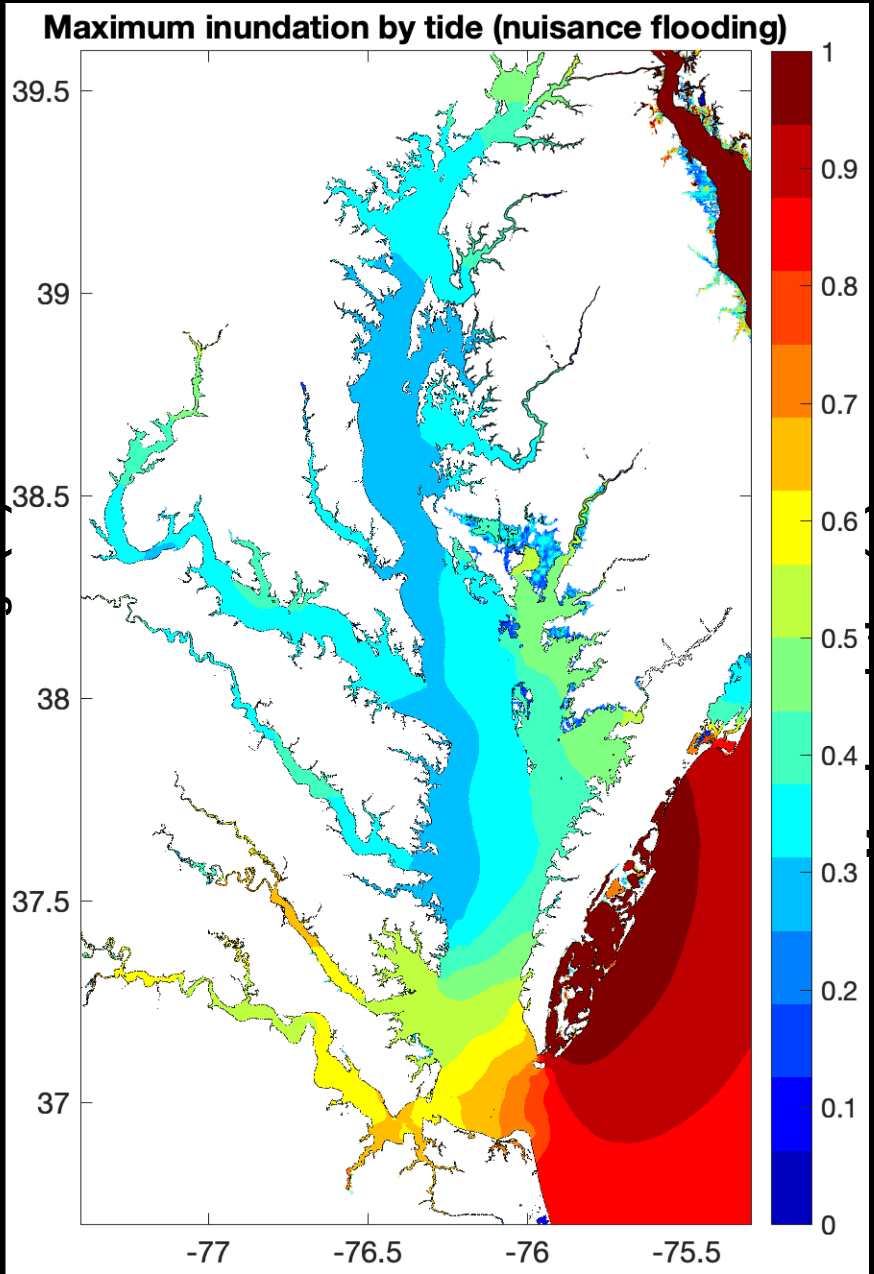
Using ADCIRC high-resolution model for tidal determination

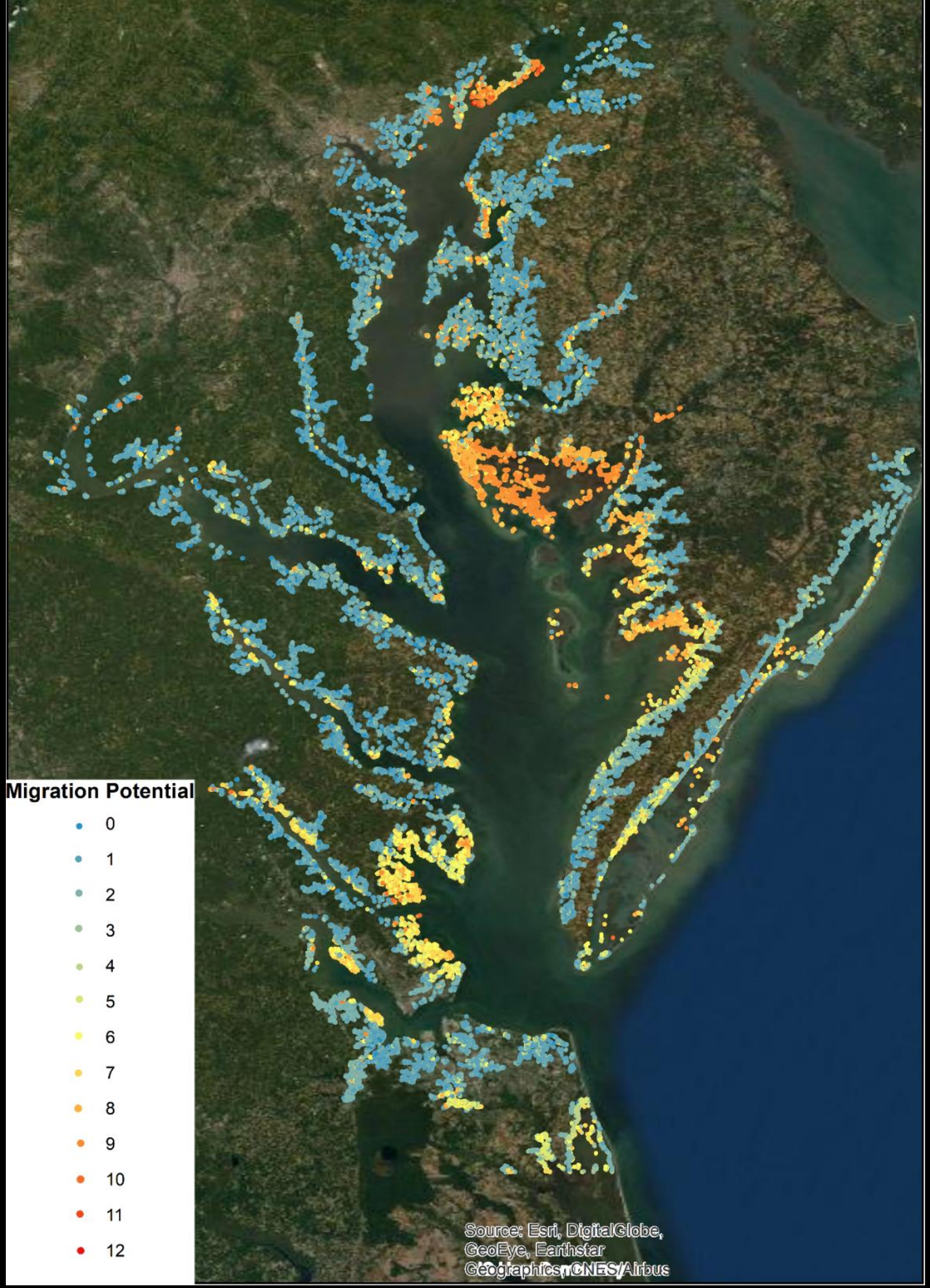




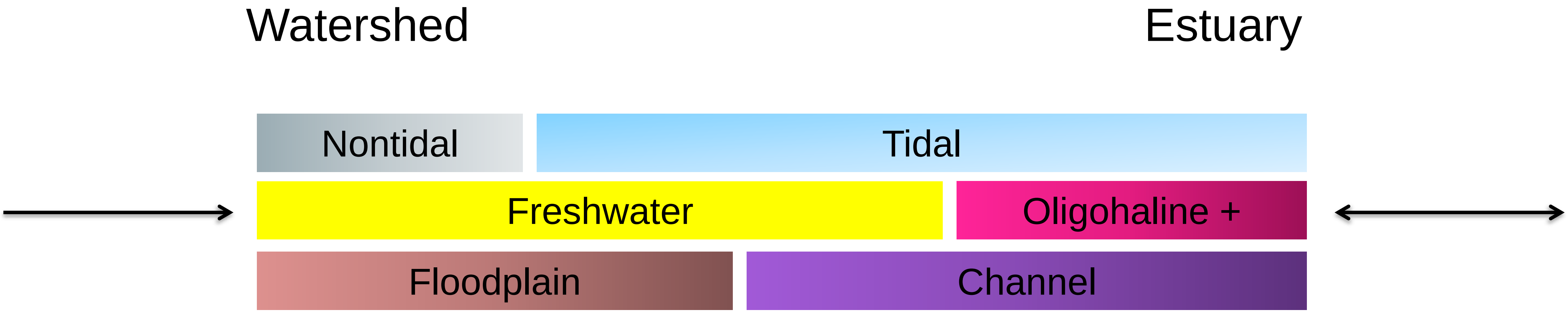
Next steps:

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

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



How do watersheds and estuaries control TFW ecosystems? and their ecogeomorphic responses to SLR?



Tidal river

2,850 km along U.S. Atlantic Coast, median length = 20 km among 127 rivers

(Ensign and Noe 2018)

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Pamunkey and Mattaponi rivers: ecosystem measurements

2 Rivers x 5 Sites/river x hummock/hollow

nontidal

upper tidal fresh

lower tidal fresh

stressed tidal fresh

oligohaline marsh

Sediment/soil change

2 SET

12 feldspar pads

- Eventual coring for chemistry

- Started 2/yr, now annual

Hydrologic

1 SW-GW well with stage and conductivity

- continuous

Geomorphic

Survey of topography in wetland (total station and RTK)

- Once

Longitudinal bathymetry + topography

- Once

Longitudinal susp. Sediment & salinity

- Twice, done

Vegetation

2 plots

- Once

Tree growth and mortality levels

- Mean annual tree basal area increment (BAI) vs. watershed and estuarine controls

Plant community change in canopy trees, understory trees/saplings/shrubs, and herbs

Sediment source fingerprinting

ID watershed, riverbed, vs. estuarine sediment sources along watershed-to-Bay

- Planning and testing

Carbon budget

GHG soil efflux

6 collars

- Quarterly for 2 yr, finished

Soil denitrification

6 plots

- Once, finished

Deep coring

- Pollen, macrofossil, texture, C14, XRD
- Once, finished

- 210Pb and 137Cs
- Planning summer 2020

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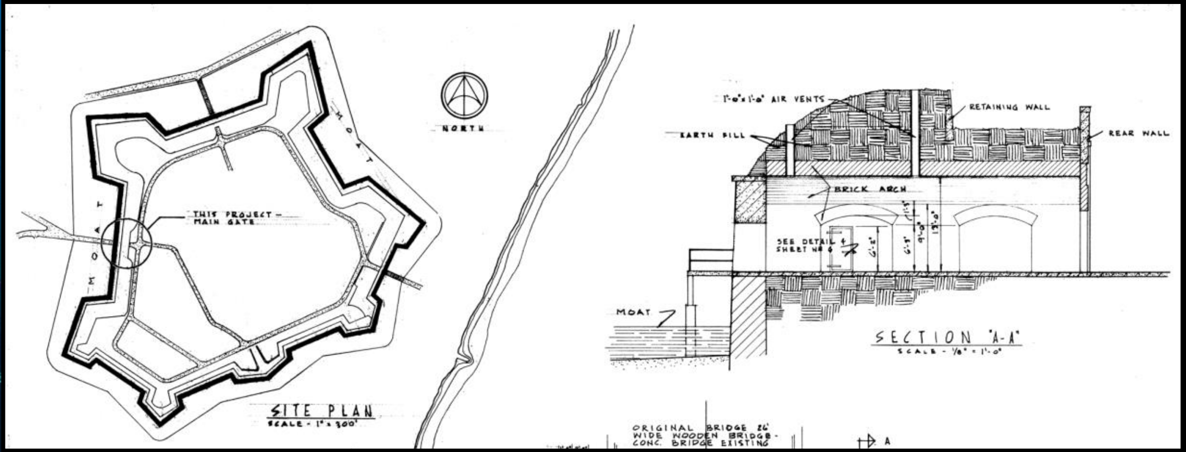
Historic sea-level rise and coastal habitat loss:

Toomey & Cronin (FBGC)

Objective: Extend Chesapeake Bay tide gauges beyond the 20th 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.

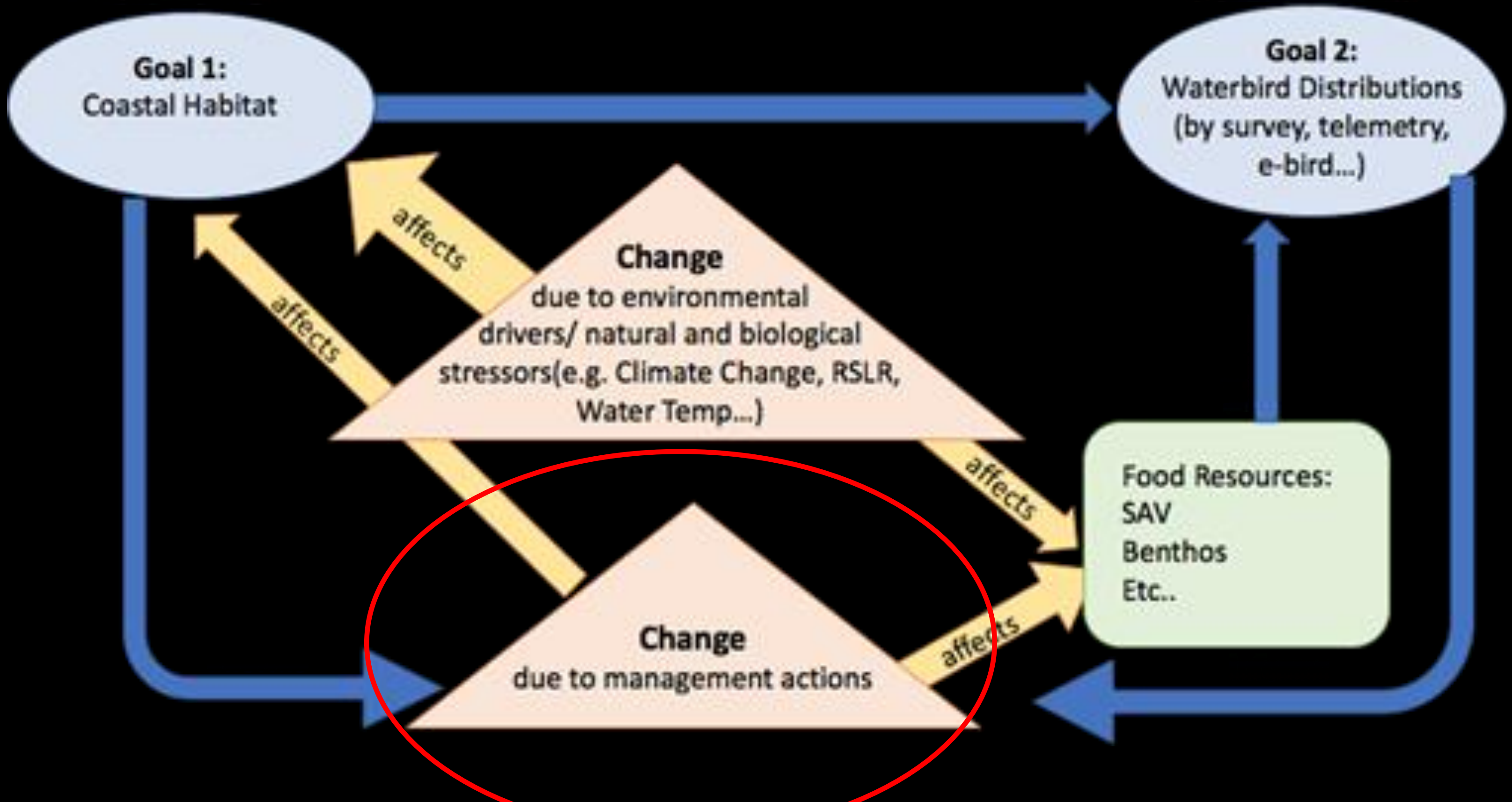
(2) Analyze historic charts to assess the rates and drivers of coastal erosion over the past 150 years.

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

Refs: NPS; Library of Congress

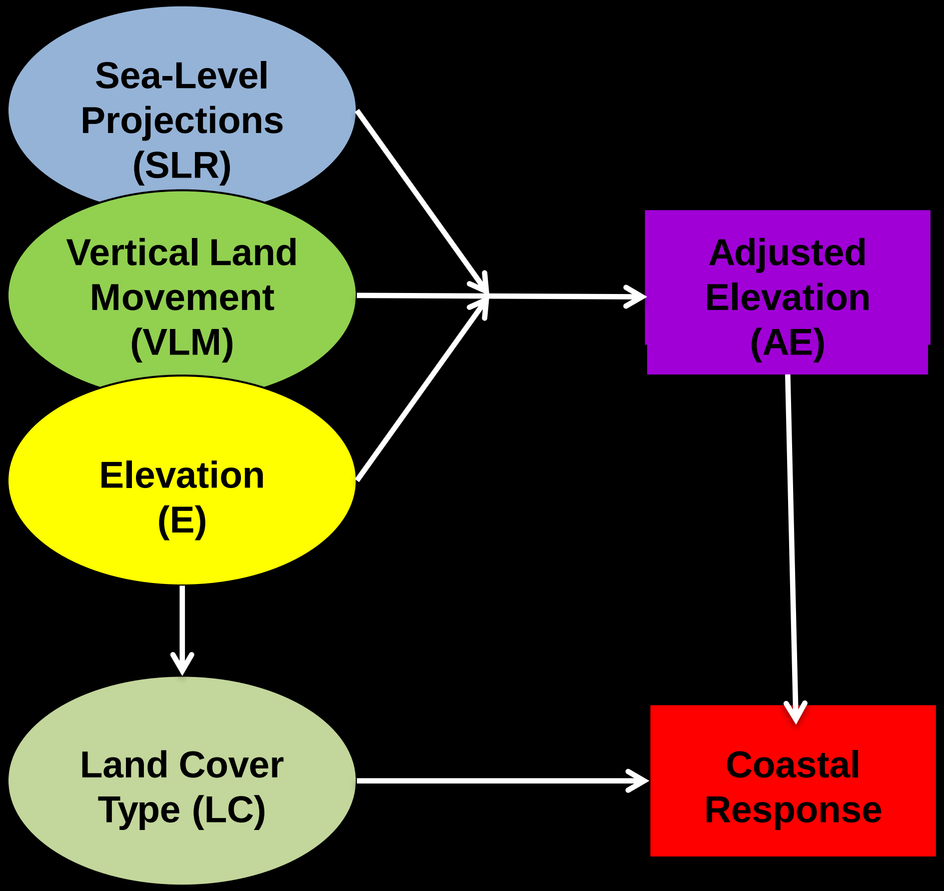
A: Assess risks to coastal habitats and DOI lands, by forecasting vulnerability and resiliency of coastal systems to future change

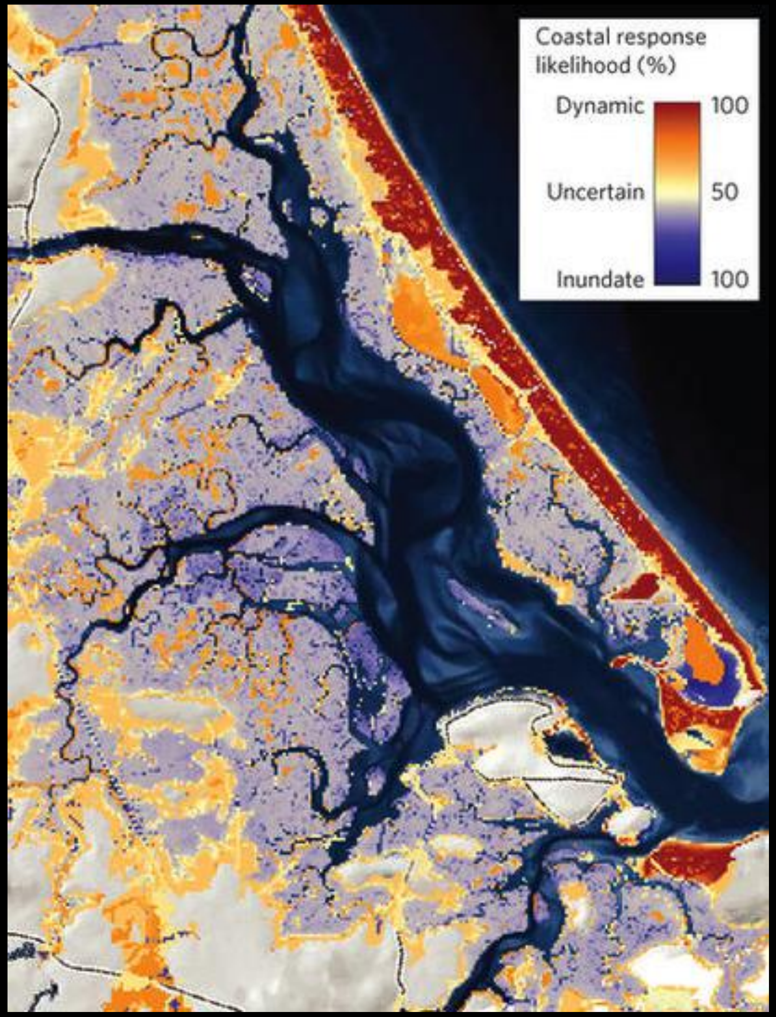
B: Understand the factors affecting waterbirds and their habitats



Coastal Response model: likelihood of vertical response

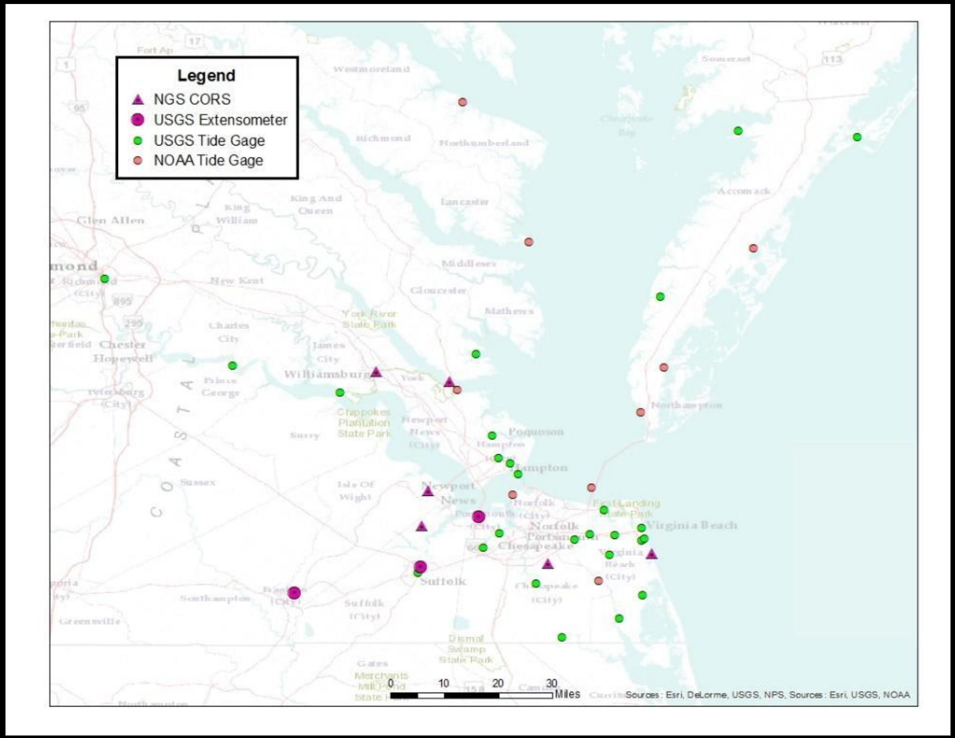
Bayesian network of coastal response





Lentz et al. 2016 Nat. Clim. Change

Enhancing the Coastal Response Model



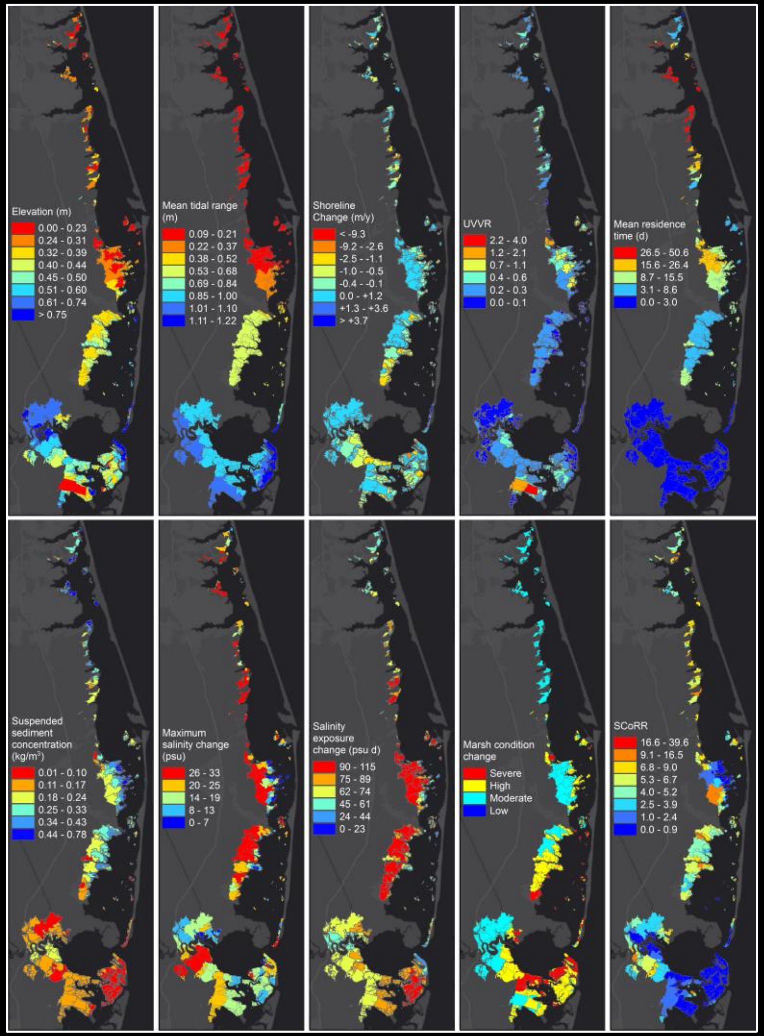
Vertical land movement: expand network of benchmark stations to get updated picture of subsidence

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:

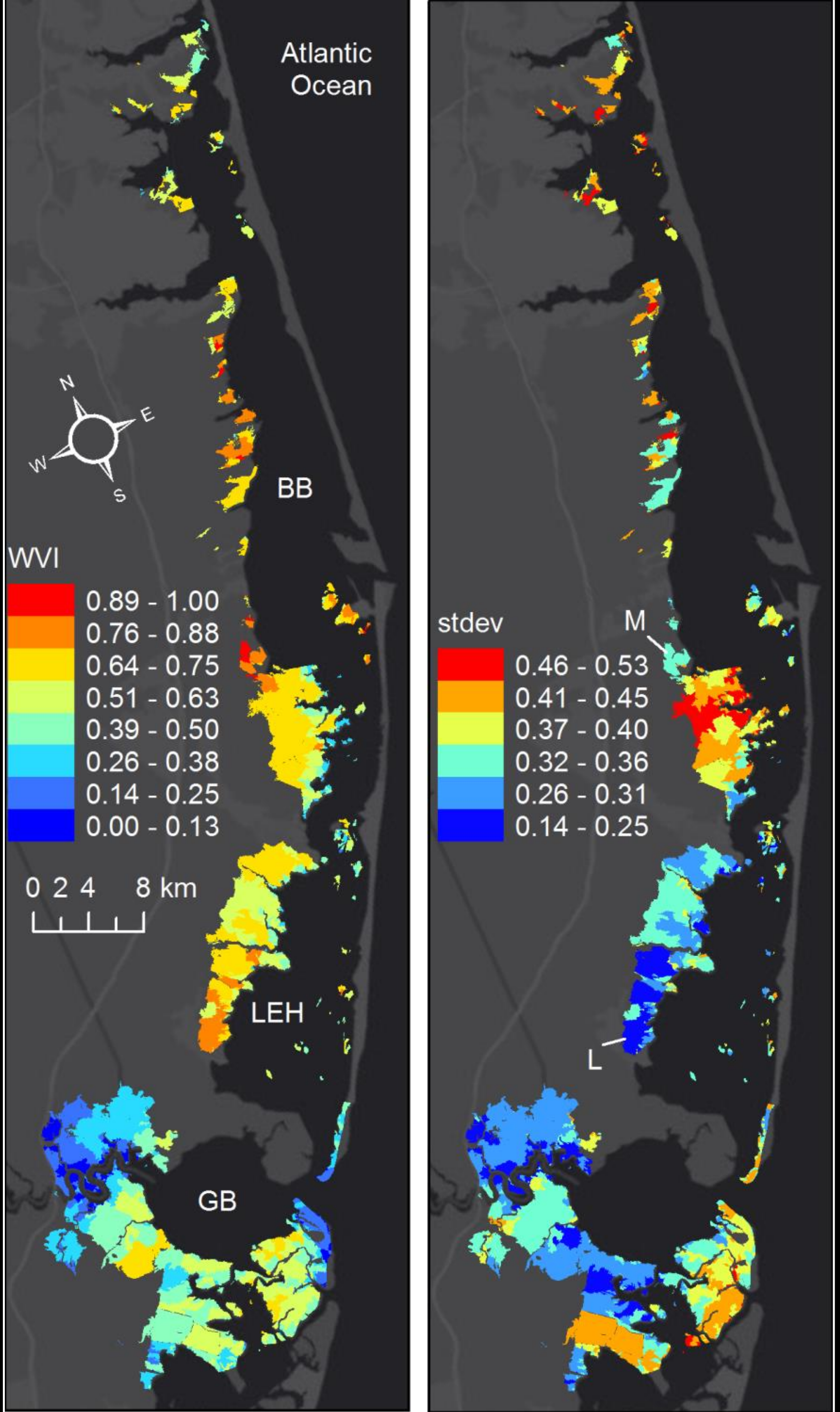


Combine multiple data layers into wetland vulnerability index

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



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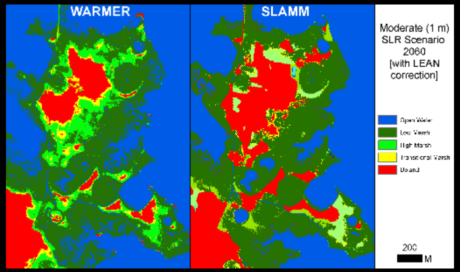
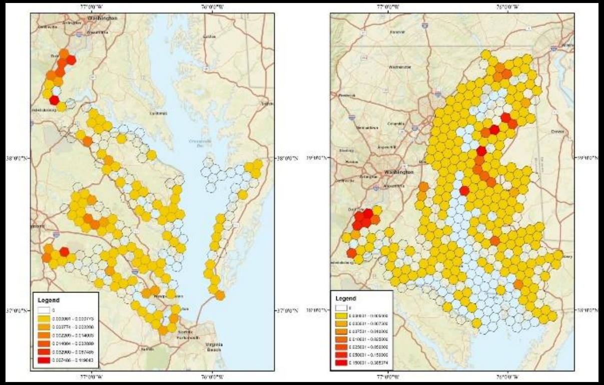
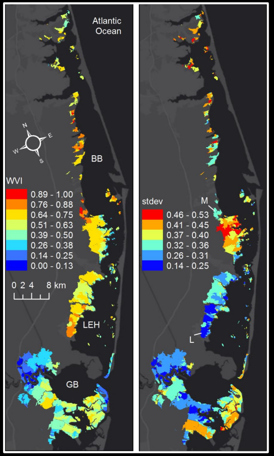
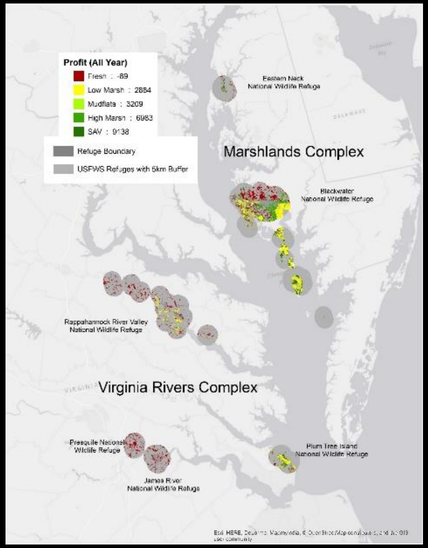
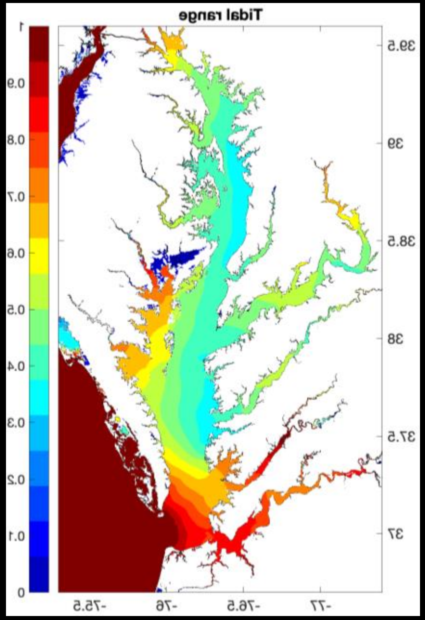
Metrics to guide restoration investments:

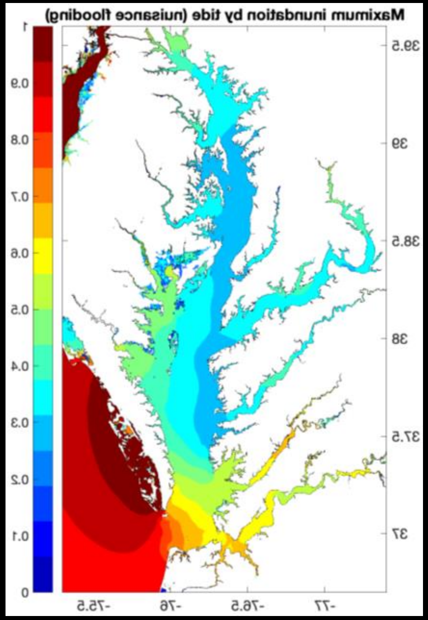


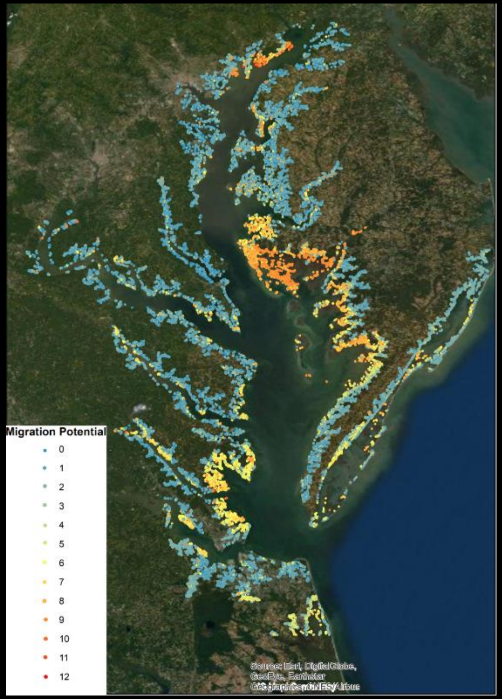


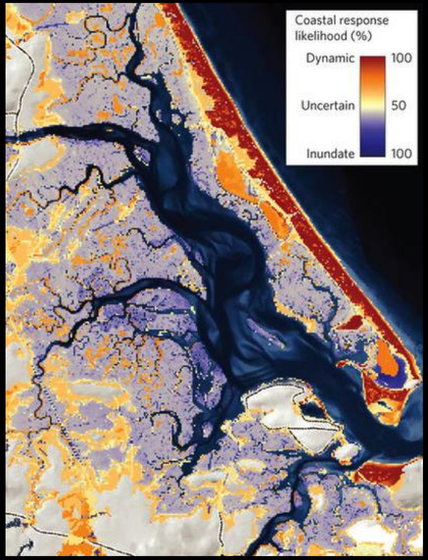












Similarly…

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

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Sediment Addition Experiment

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

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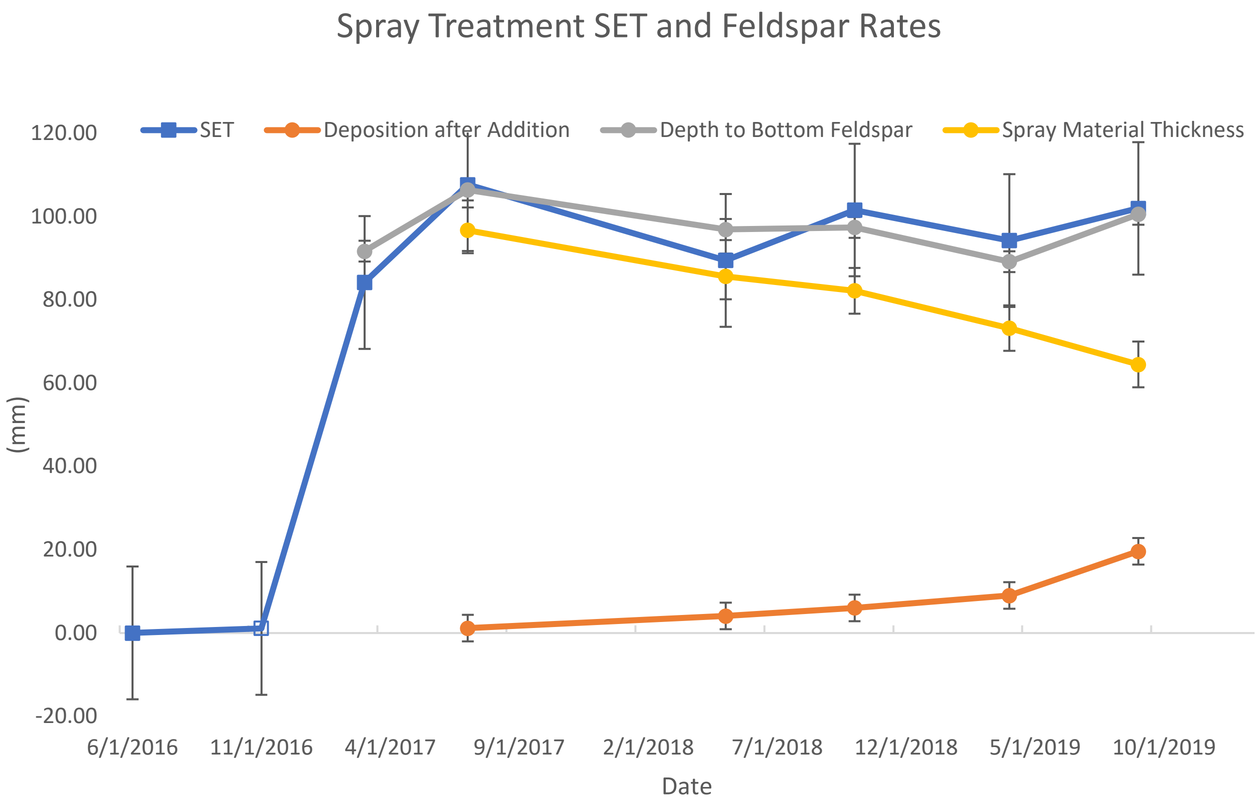
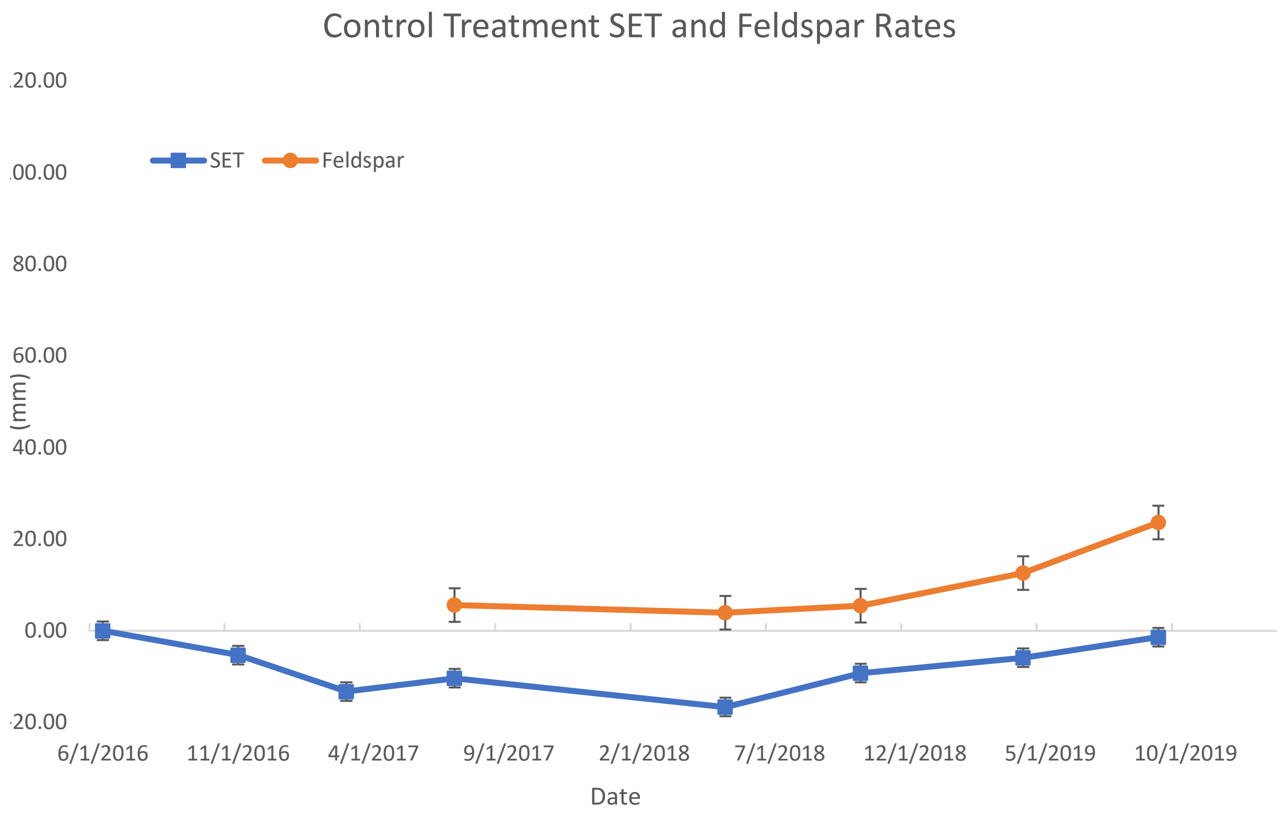
Sediment Addition Experiment





Average sediment addition of ~100mm

No change in elevation of control area over same time frame

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

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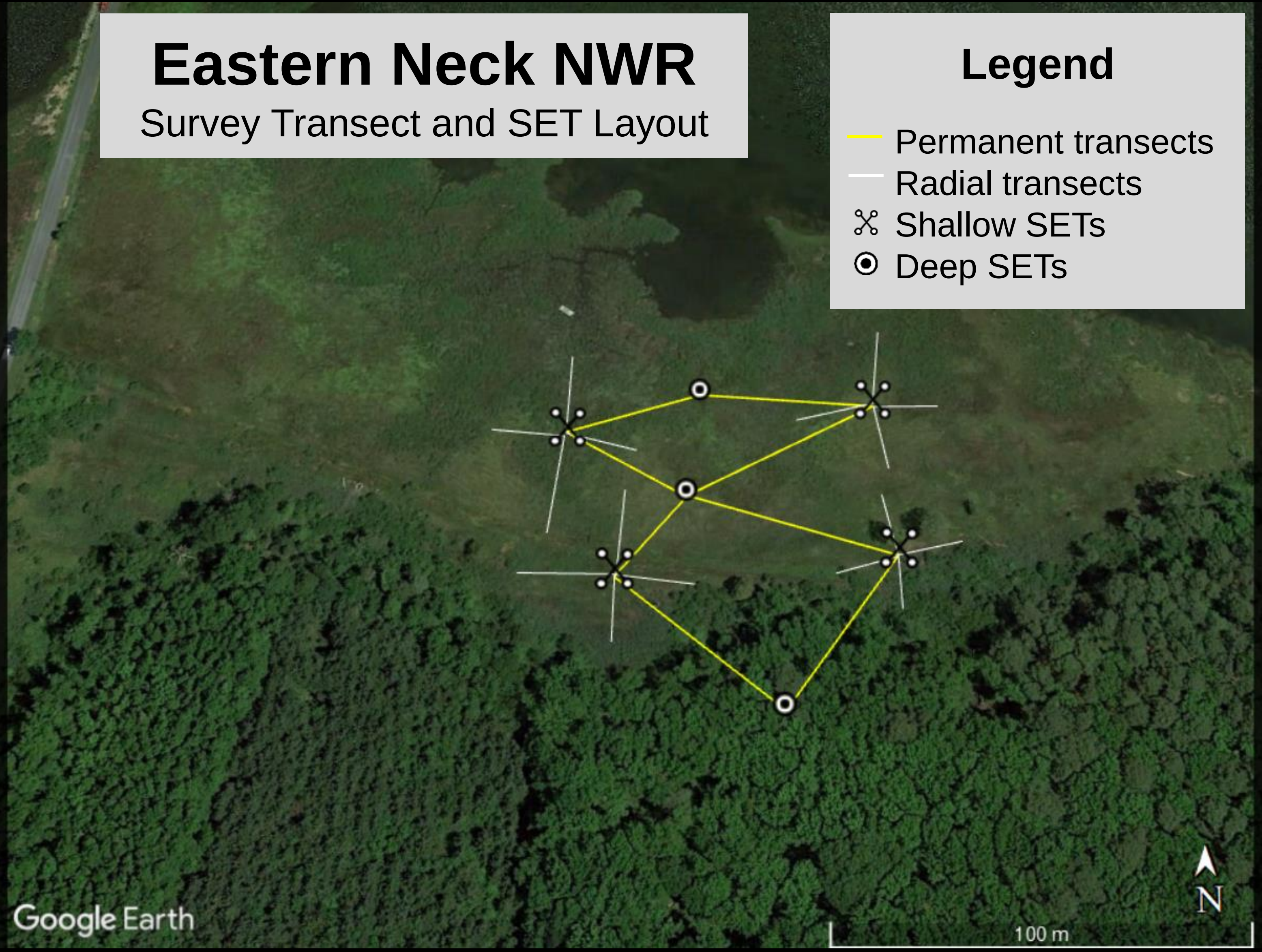

- 3 Deep SETs installed in: low marsh, high marsh, and forest
- 4 shallow SETs installed as reference points between deep SET's
- Topo measurements taken each year along permanent transects that connect Deep and Shallow SETs
- Radial transects originating from Shallow SETs surveyed in a 4 different directions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

USGS science for a changing world

Theme 2

Alicia Berlin, Joel Carr, Glenn Guntenspergen, Diann Prosser

Neil Ganju, Zafer Defne, Alfredo Aretxabaleta, Taran Kalra, Kate Ackerman, Grace Molino, Salme Cook

Kurt McCoy, Russ Lotspeich

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