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

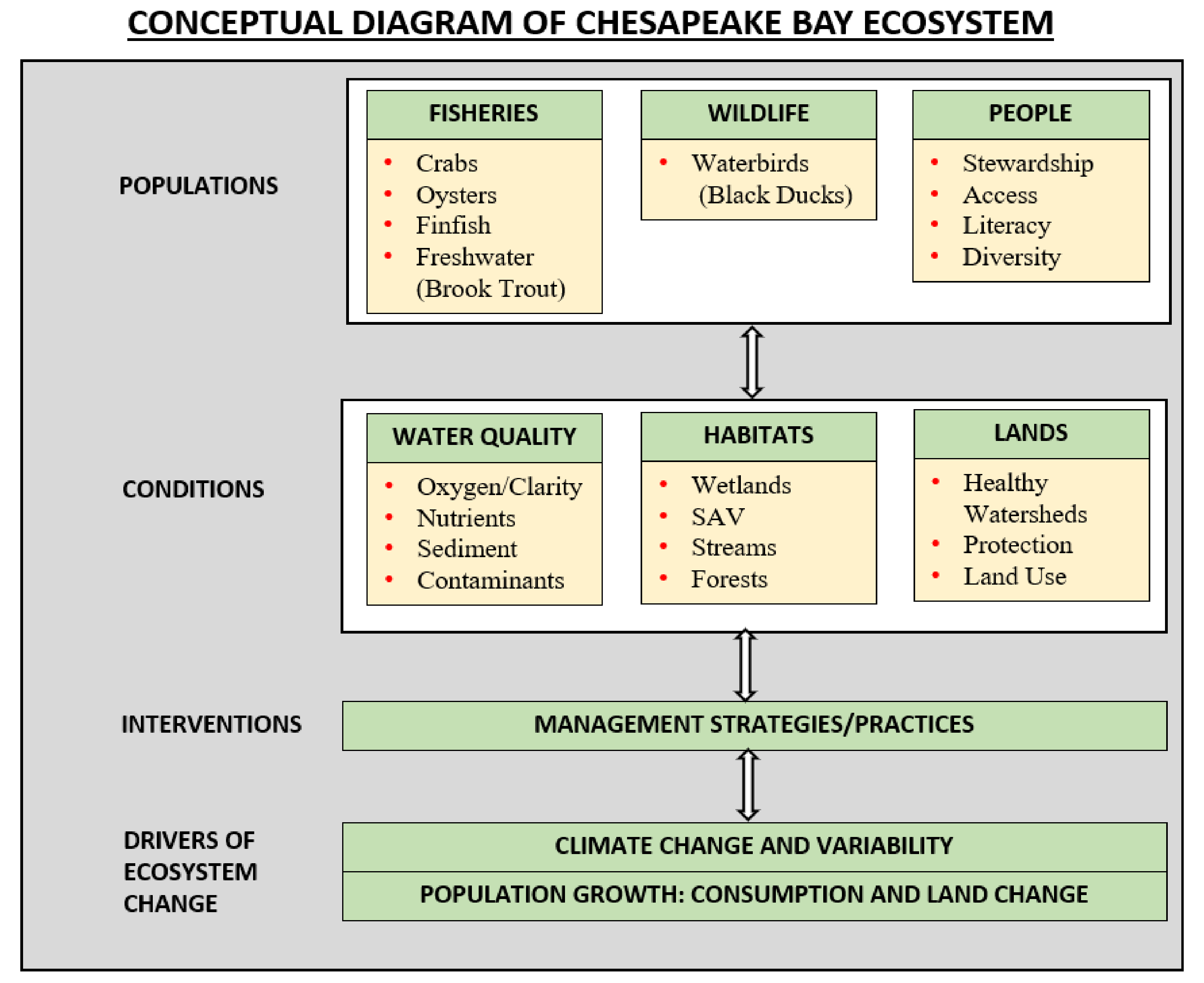
USGS Chesapeake Bay Studies
Coastal Habitats Team (Theme 2)
U.S. Department of the Interior

USGS Chesapeake Science Themes

Integrated science to inform decisions

USGS Themes:

1. Stream health, fish habitat and aquatic conditions
2. Coastal habitats and waterbirds
3. Land change and watersheds
4. Integrate science and inform decisions



CONCEPTUAL DIAGRAM OF CHESAPEAKE BAY ECOSYSTEM

POPULATIONS

FISHERIES
- Crabs
- Oysters
- Finfish
- Freshwater (Brook Trout)

WILDLIFE
- Waterbirds (Black Ducks)

PEOPLE
- Stewardship
- Access
- Literacy
- Diversity

CONDITIONS

WATER QUALITY
- Oxygen/Clarity
- Nutrients
- Sediment
- Contaminants

HABITATS
- Wetlands
- SAV
- Streams
- Forests

LANDS
- Healthy Watersheds
- Protection
- Land Use

INTERVENTIONS

MANAGEMENT STRATEGIES/PRACTICES

DRIVERS OF ECOSYSTEM CHANGE

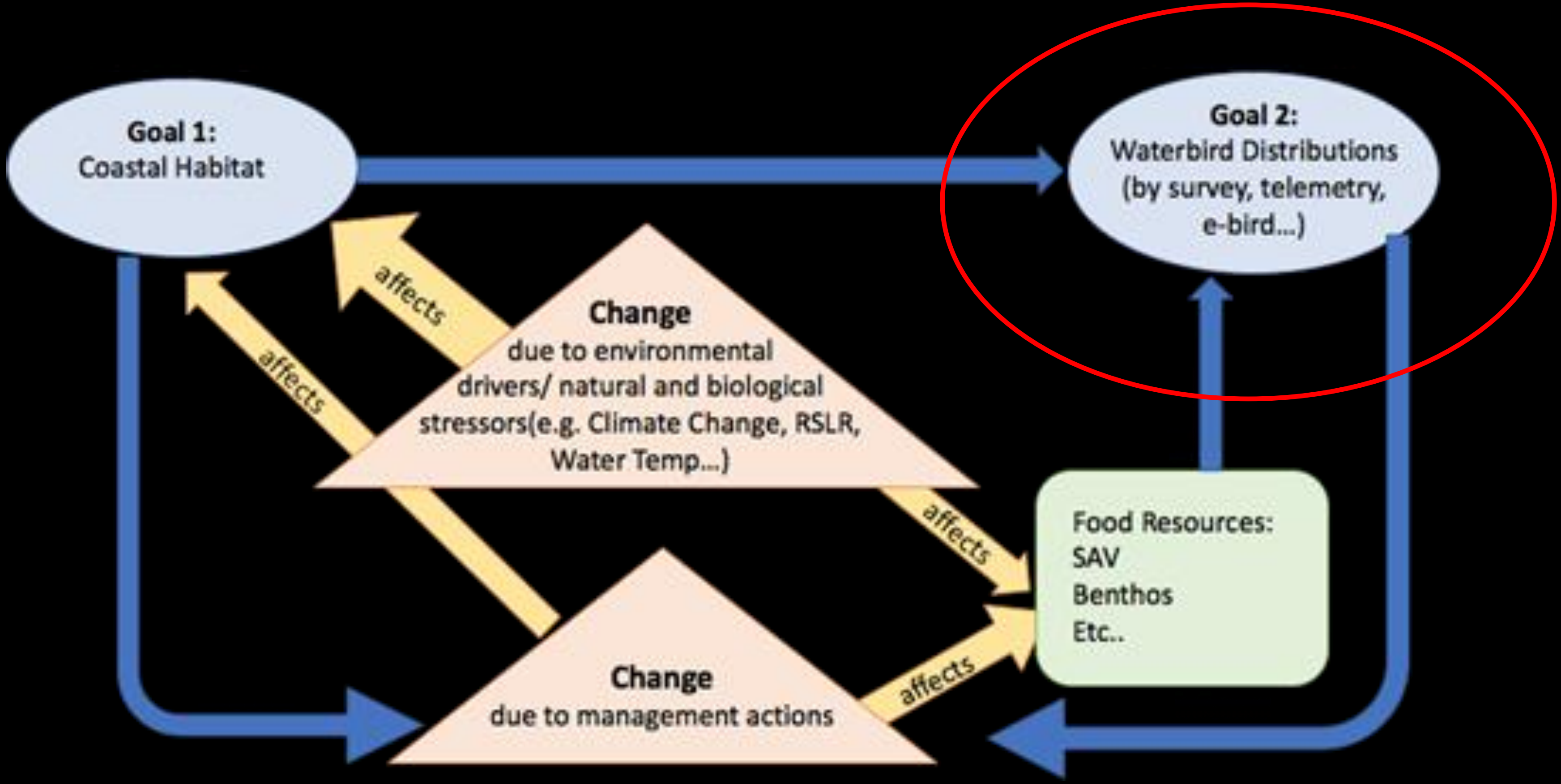
CLIMATE CHANGE AND VARIABILITY

POPULATION GROWTH: CONSUMPTION AND LAND CHANGE

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



Goal 1:
Coastal Habitat

Goal 2:
Waterbird Distributions
(by survey, telemetry,
e-bird…)

Change
due to environmental
drivers/ natural and biological
stressors(e.g. Climate Change, RSLR,
Water Temp…)

affects

affects

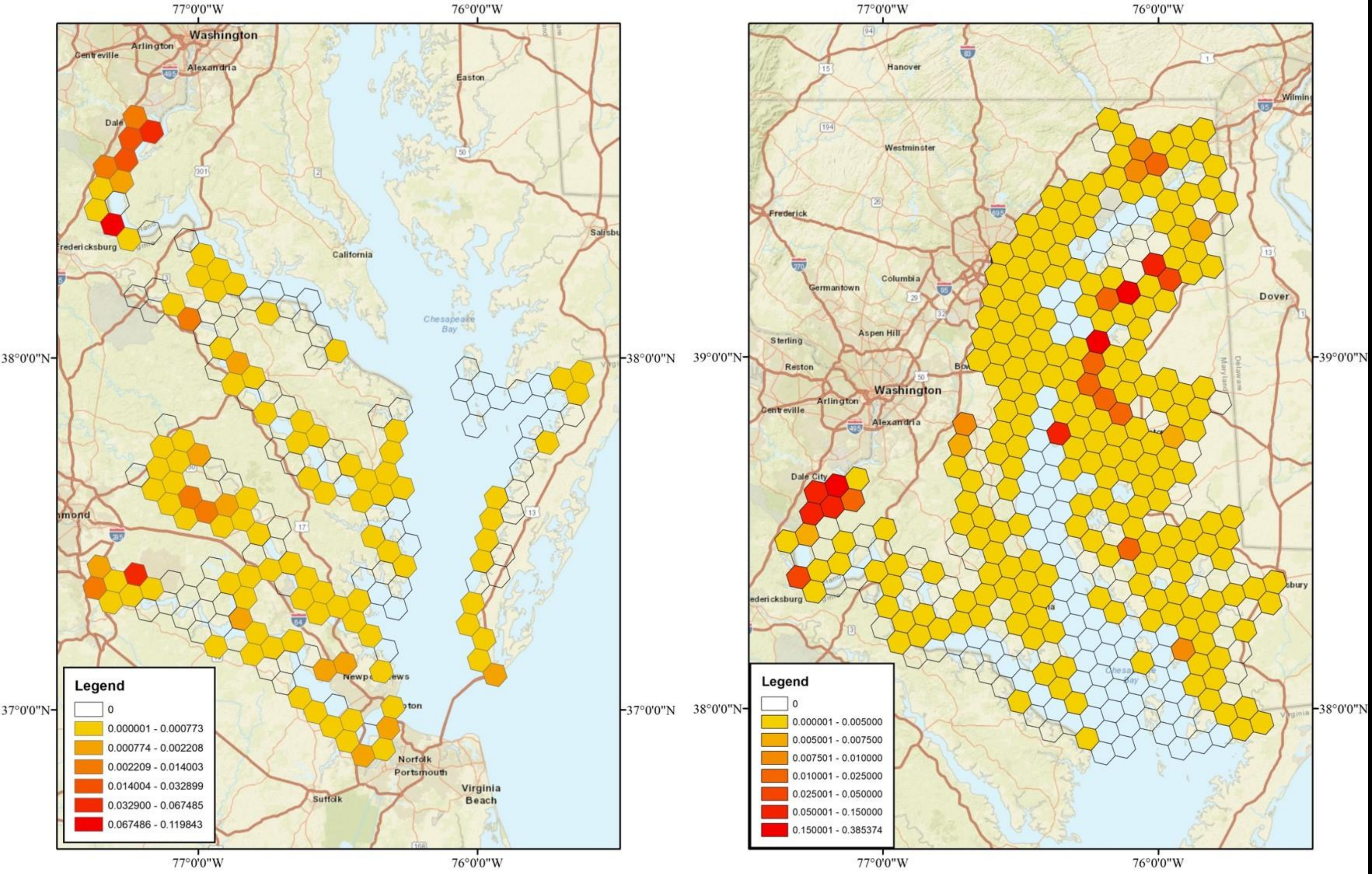
affects

affects

Food Resources:
SAV
Benthos
Etc..

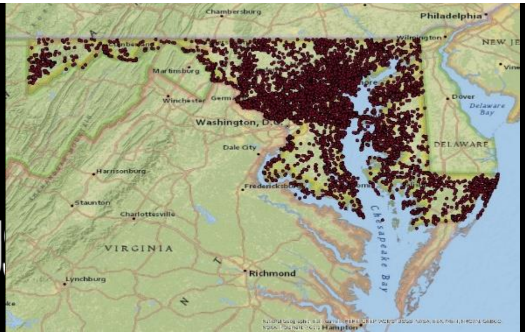
Change
due to management actions

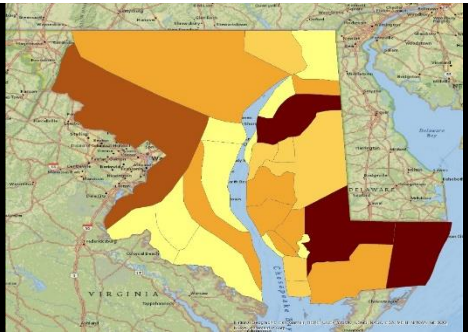
Waterfowl Hotspot Modeling



- 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

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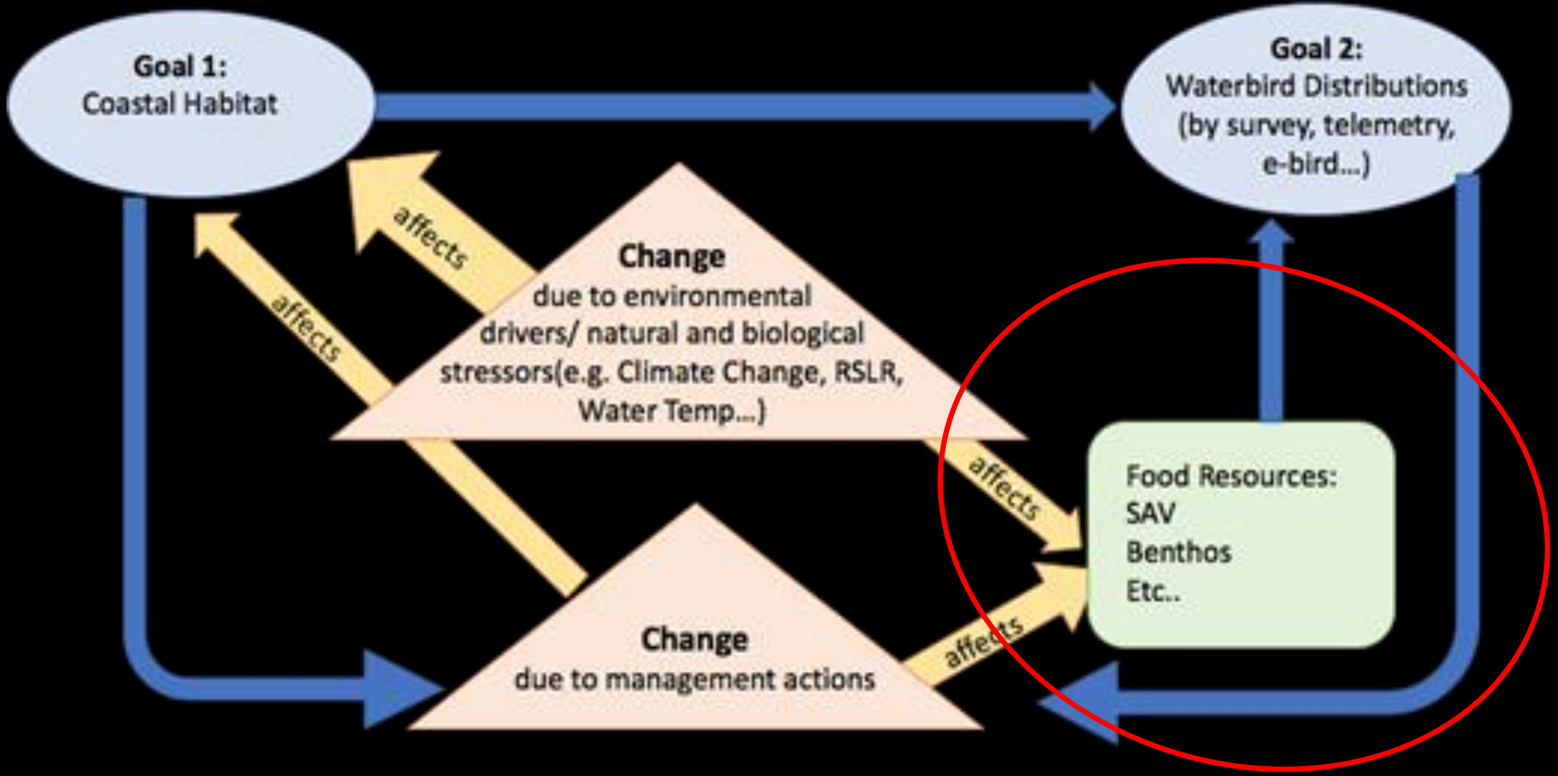
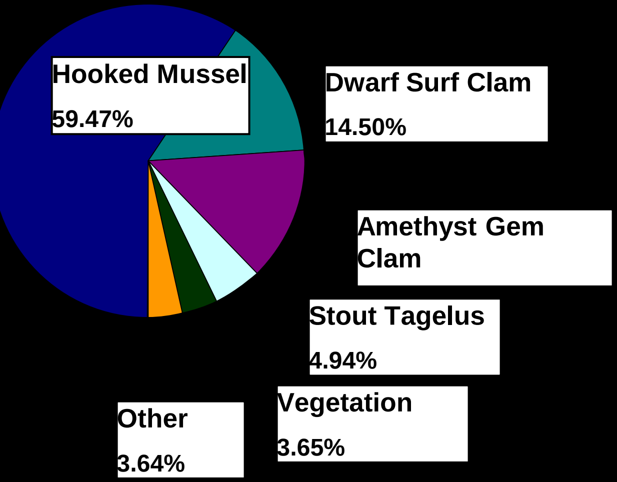
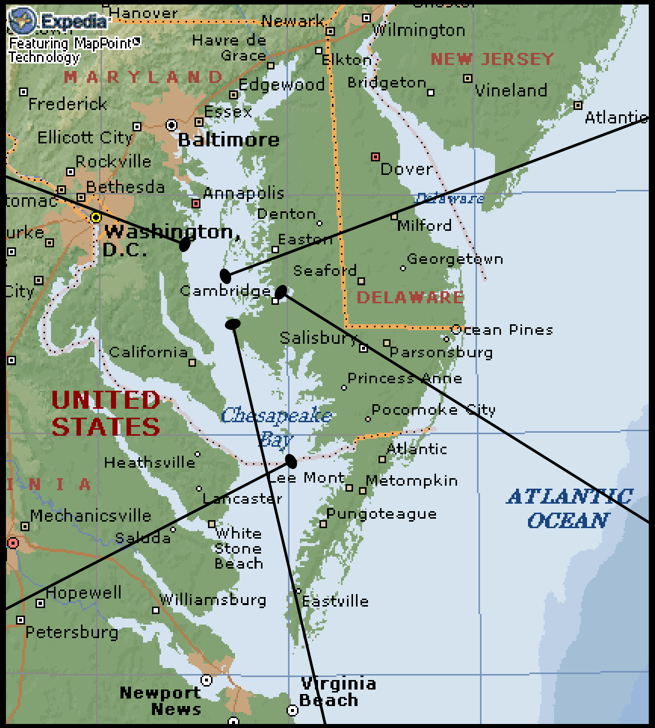


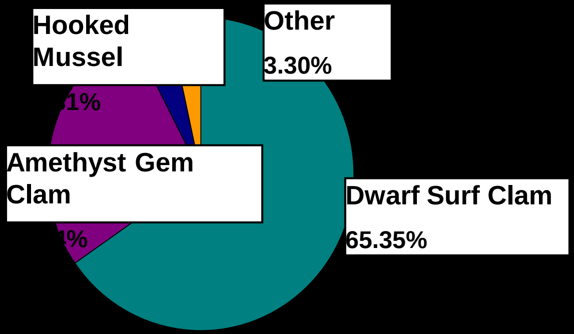
FOOD HABITS IN THE CHESAPEAKE BAY

Herring Bay n=93





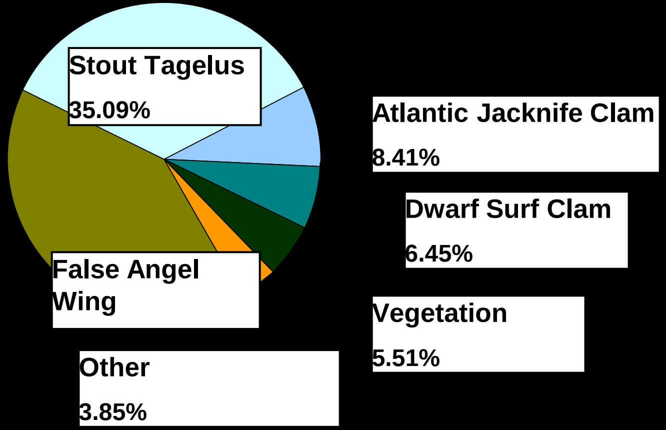
Tilghman Island n=27



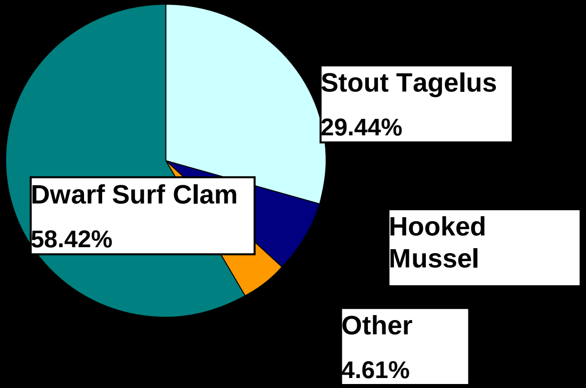
Food Habits Dataset:
32 different species, mainly waterfowl

1953 food habits samples

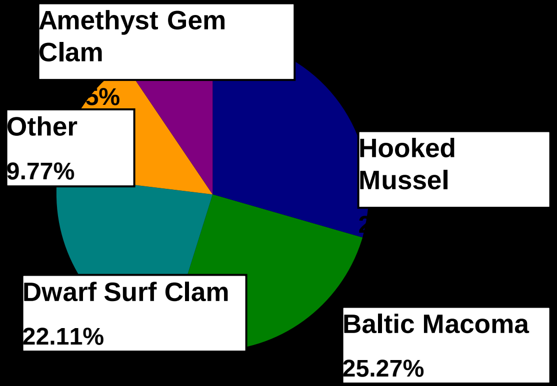
Smith Island n=13

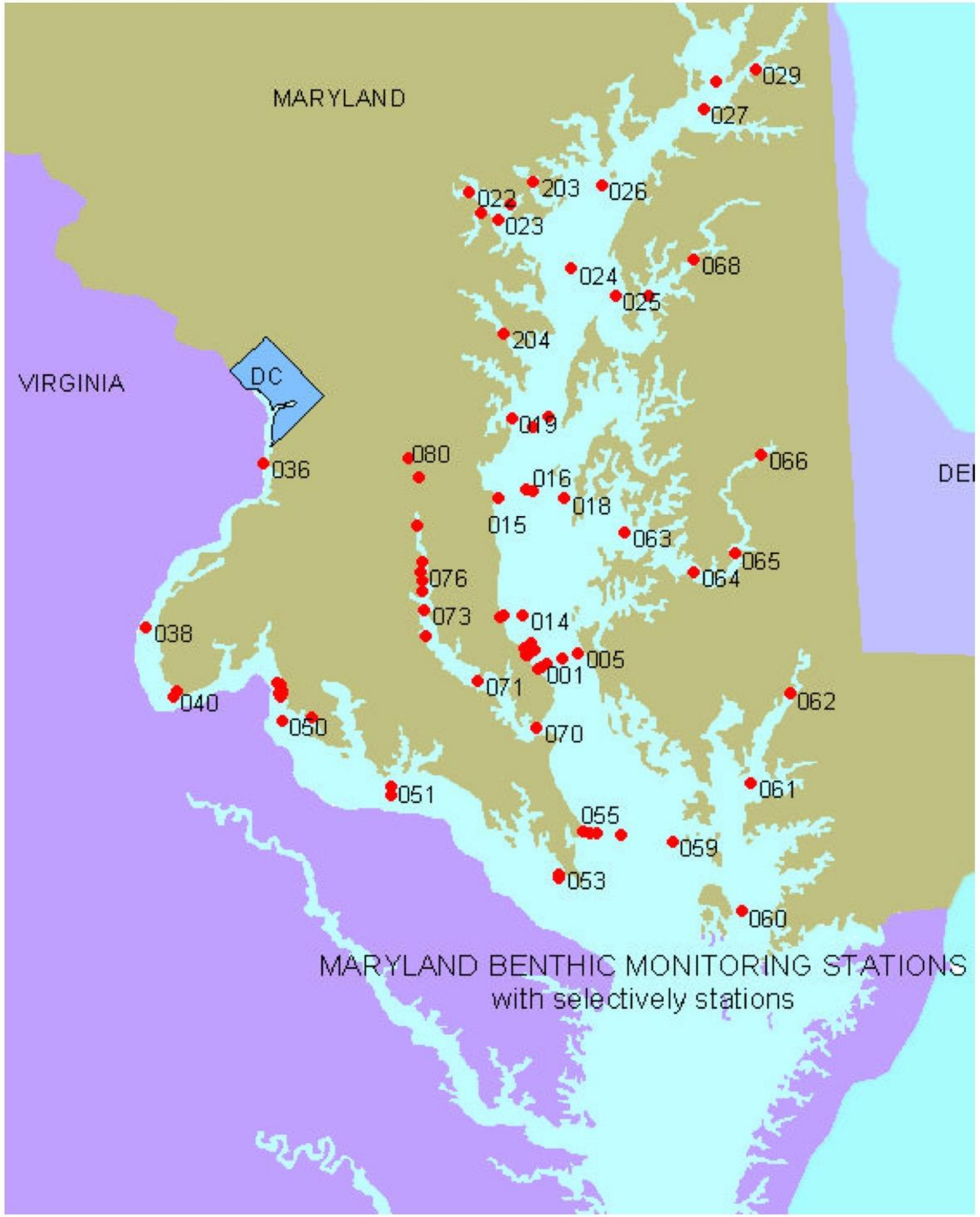


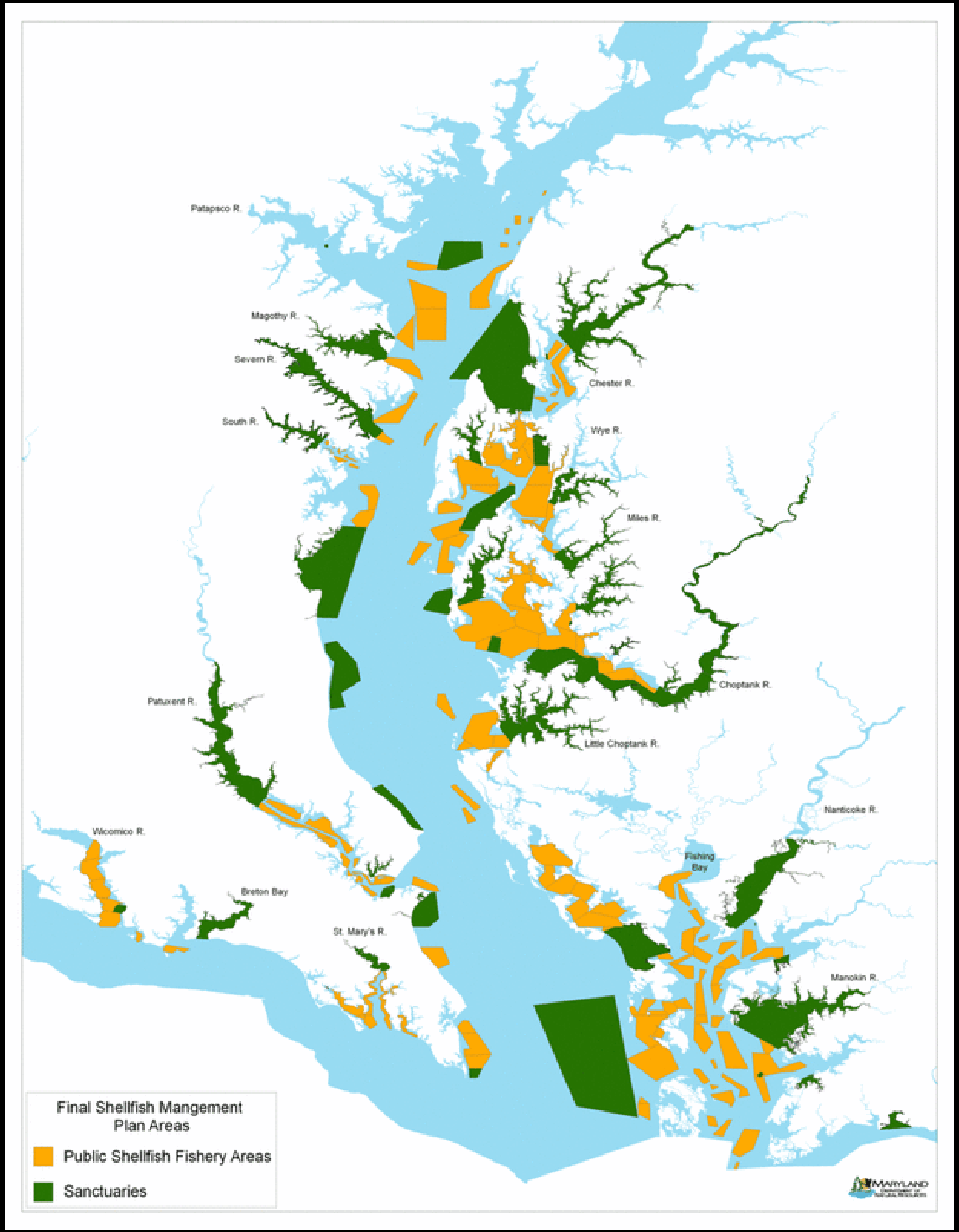
Taylors Island n=38



Choptank River n=65

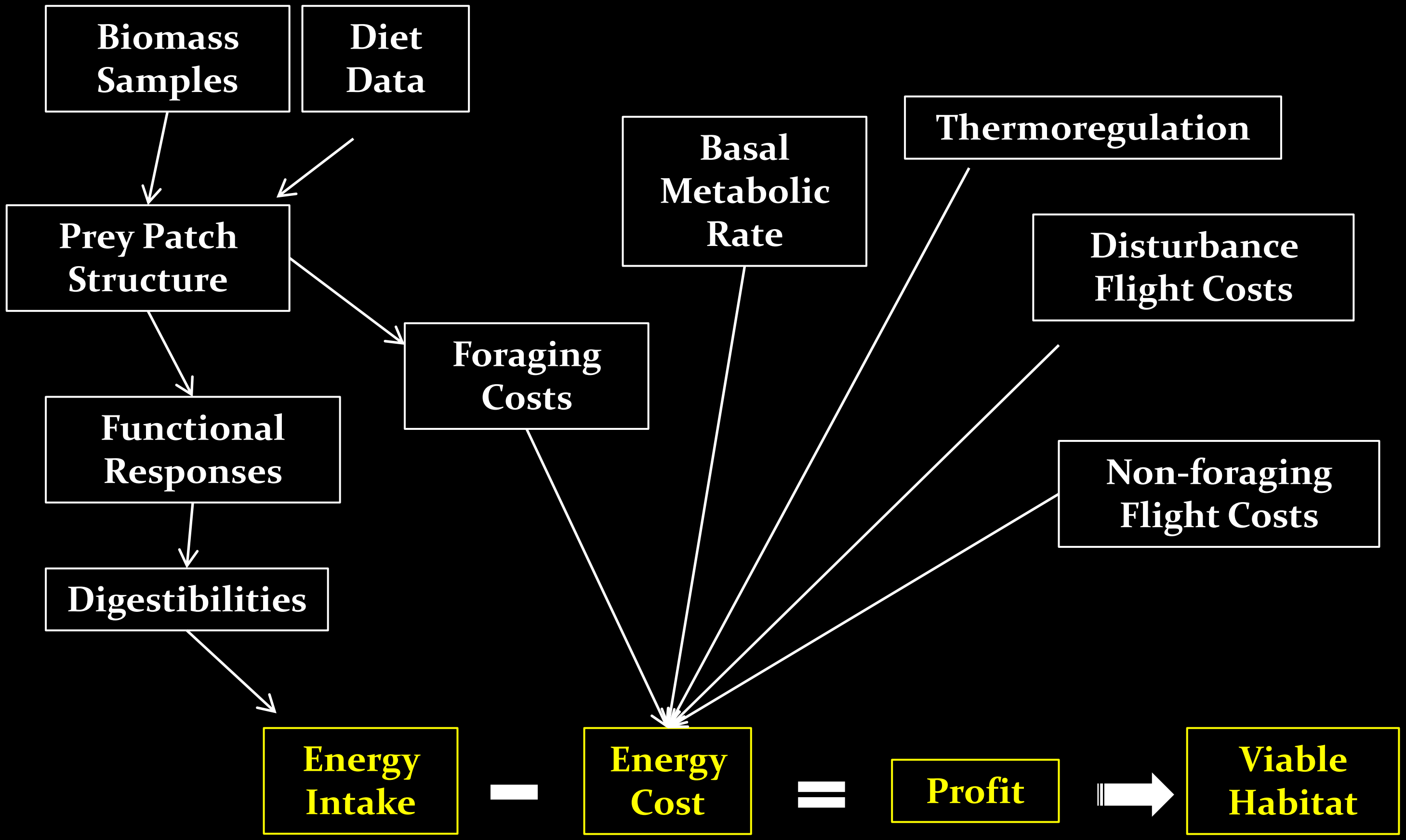






Add additional SAV and other benthic layers

One way to look at food resource utilization is Bioenergetic modeling



Biomass Samples

Diet Data

Prey Patch Structure

Functional Responses

Digestibilities

Foraging Costs

Basal Metabolic Rate

Thermoregulation

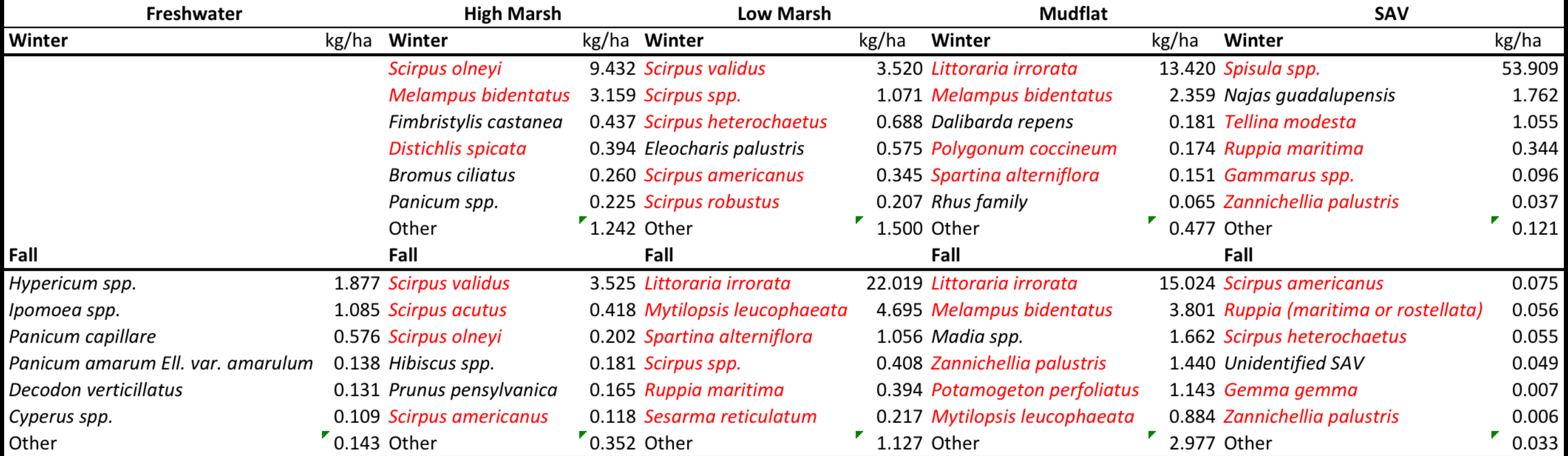
Disturbance Flight Costs

Non-foraging Flight Costs

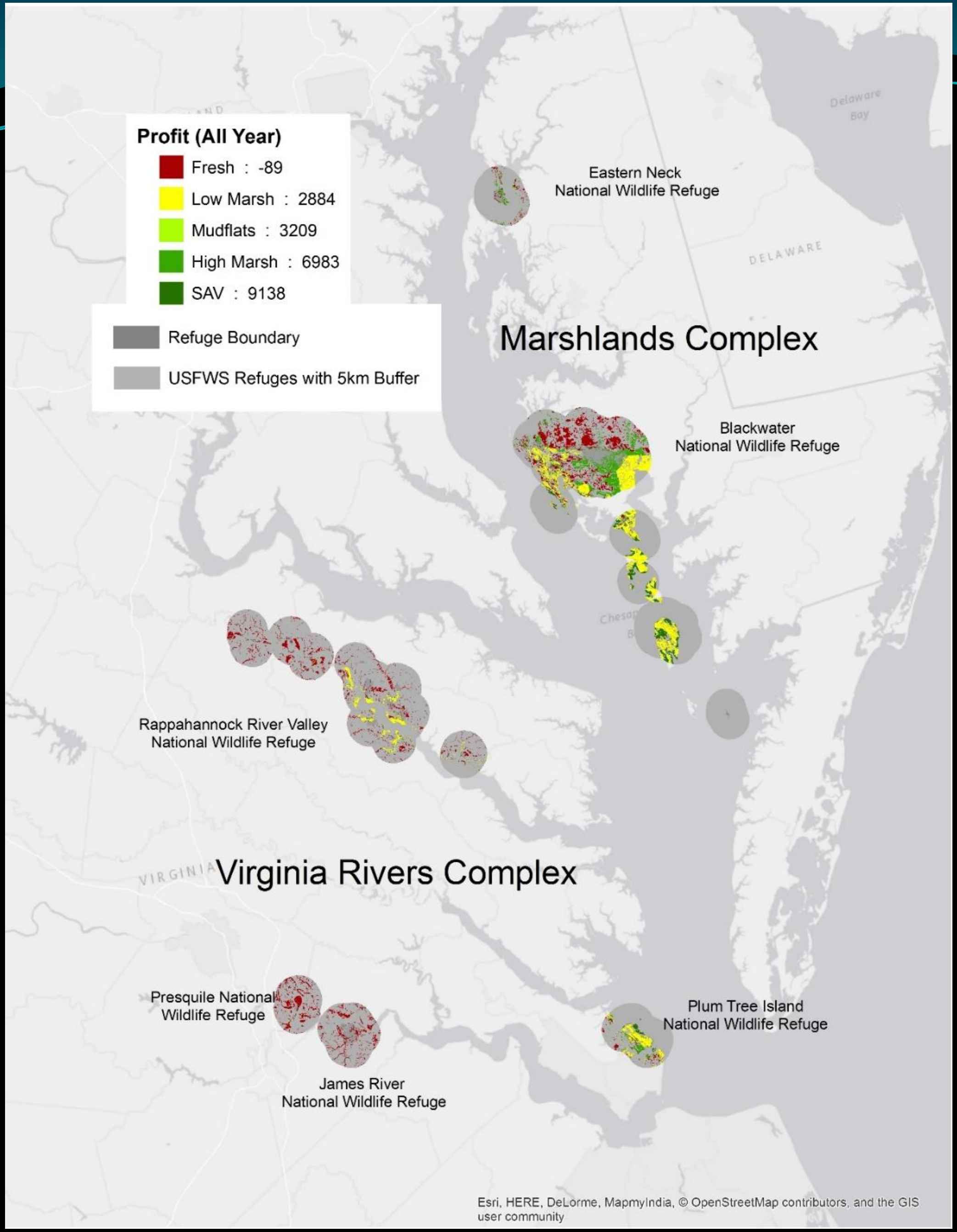
Energy Intake – Energy Cost = Profit ➡ Viable Habitat

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
		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



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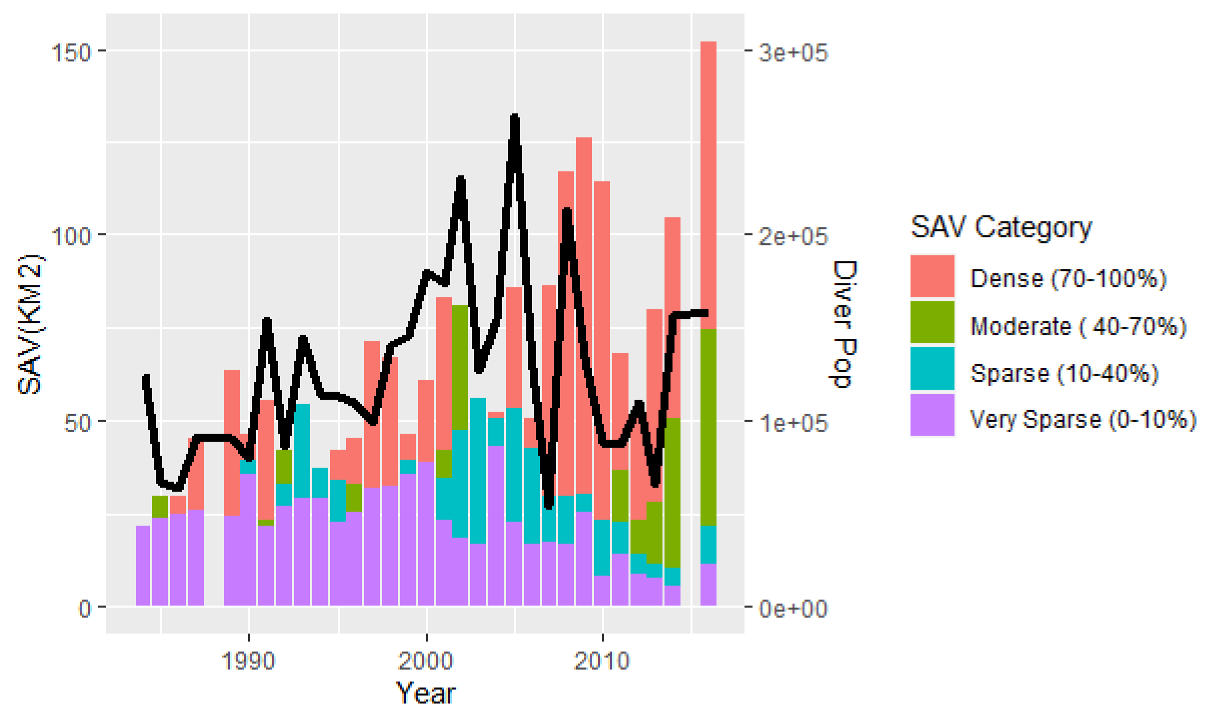
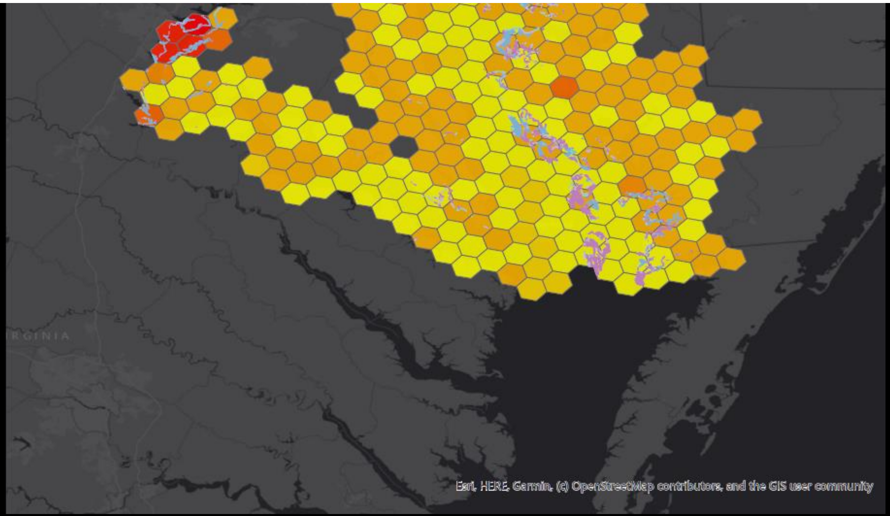
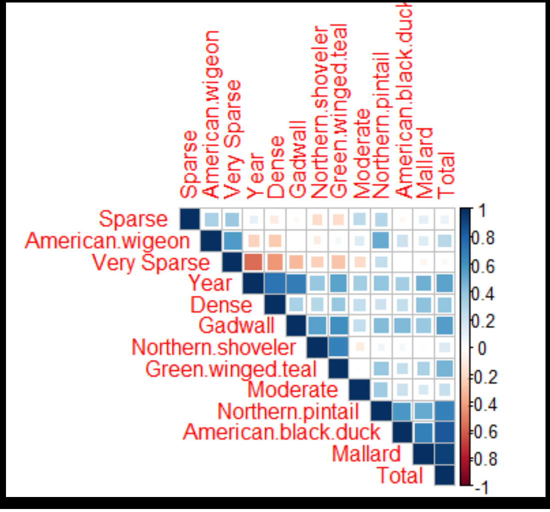
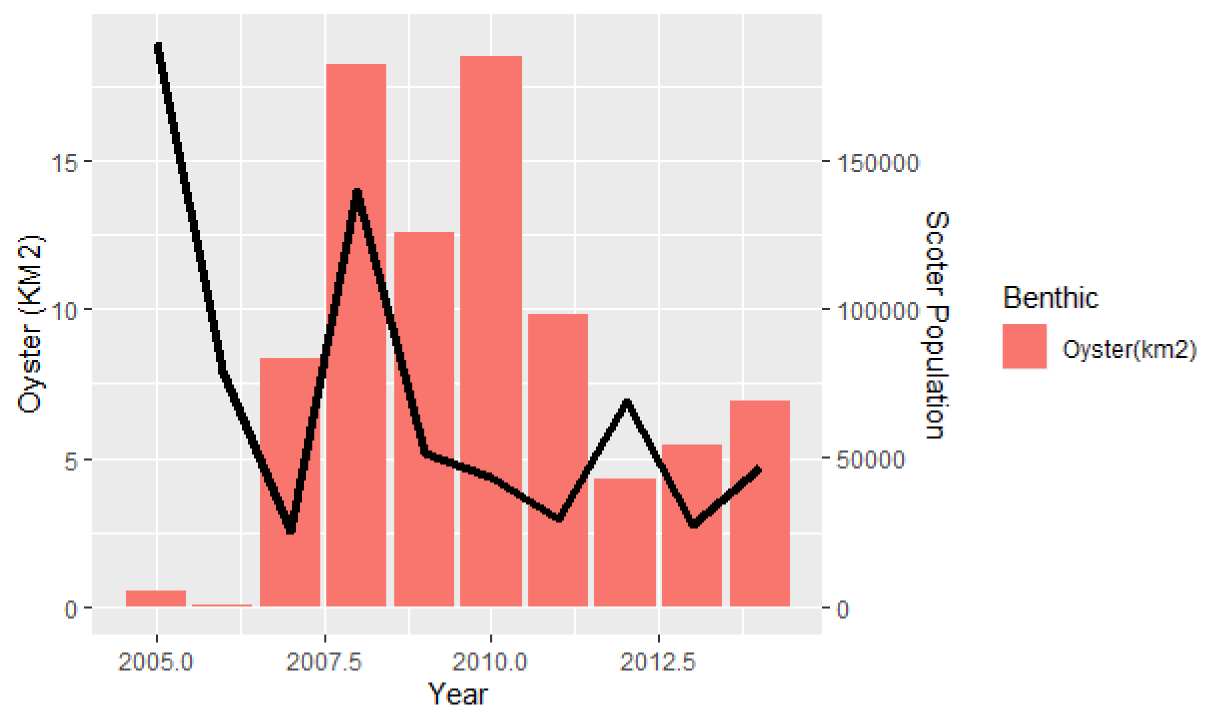
- This type of information allows for estimating per hectare profit based on habitat type and time of year

- Expanding analysis to explore relationships between different bird species/guilds population estimates and food resources









USGS

Towards Modeling Habitat Change

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

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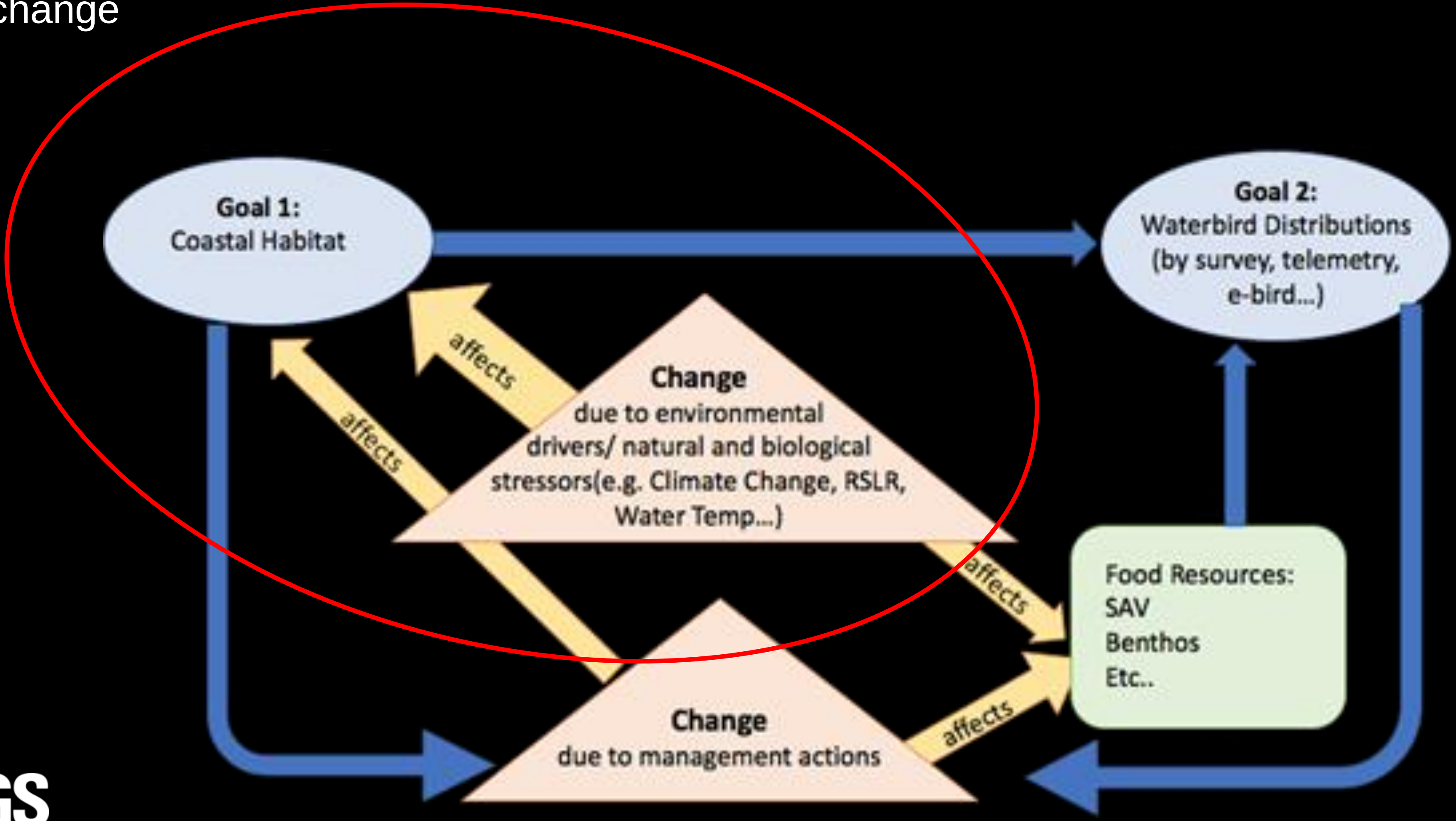

Goal 1:
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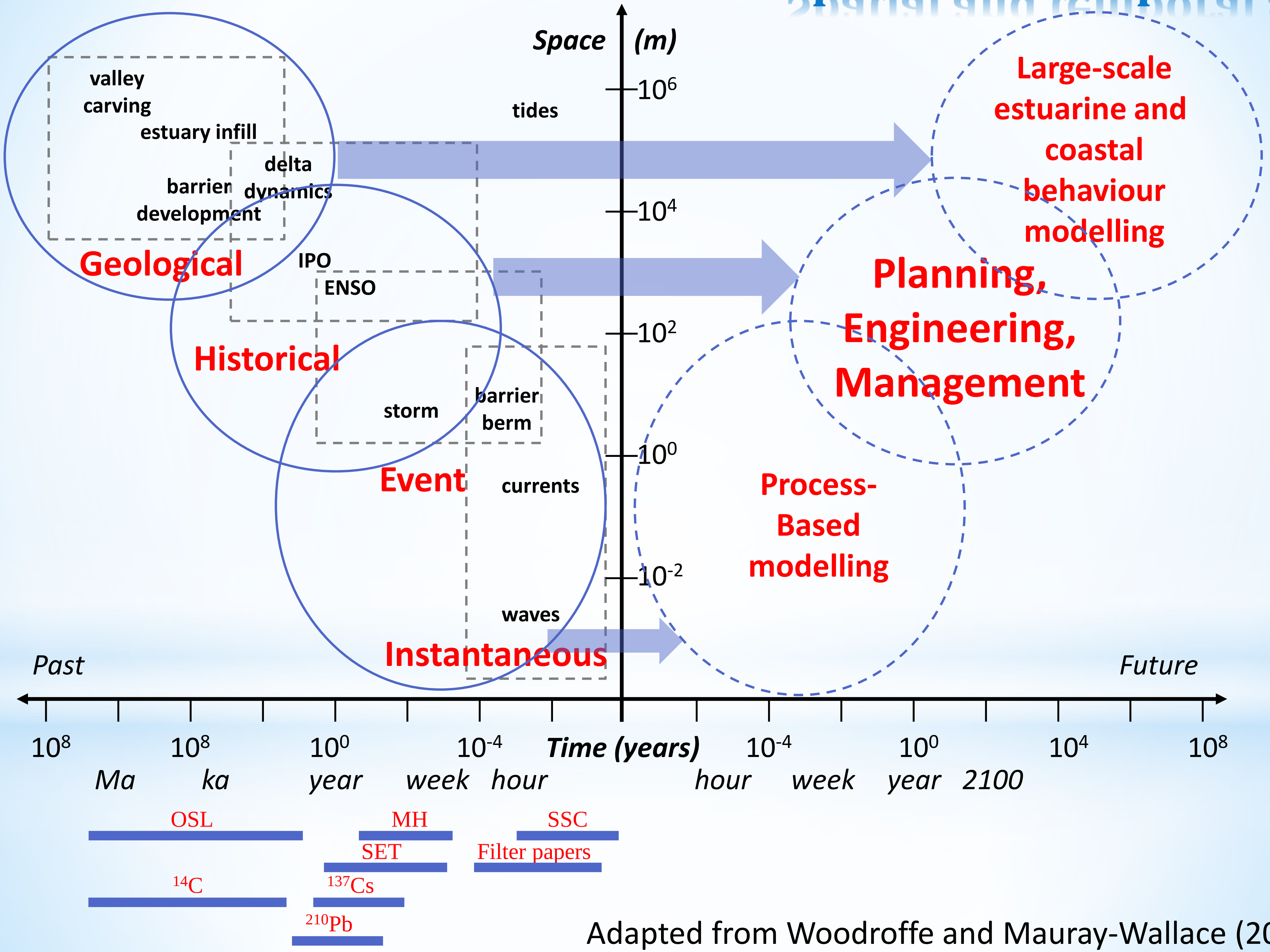
Waterbird Distributions
(by survey, telemetry, e-bird...)

Change
due to environmental drivers/ natural and biological stressors(e.g. Climate Change, RSLR, Water Temp...)

Food Resources:
SAV
Benthos
Etc..

Change
due to management actions

* Spatial and temporal scales



Space (m)

10^6

10^4

10^2

10^0

10^{-2}

valley carving

estuary infill

delta dynamics

barrier development

Geological

tides

IPO

ENSO

Historical

storm

barrier berm

Event

currents

waves

Instantaneous

Large-scale estuarine and coastal behaviour modelling

Planning, Engineering, Management

Process-Based modelling

Past

Future

10^8 10^8 10^0 10^{-4} *Time (years)* 10^{-4} 10^0 10^4 10^8

Ma *ka* *year* *week* *hour* *hour* *week* *year* *2100*

OSL

MH

SSC

SET

Filter papers

^{14}C

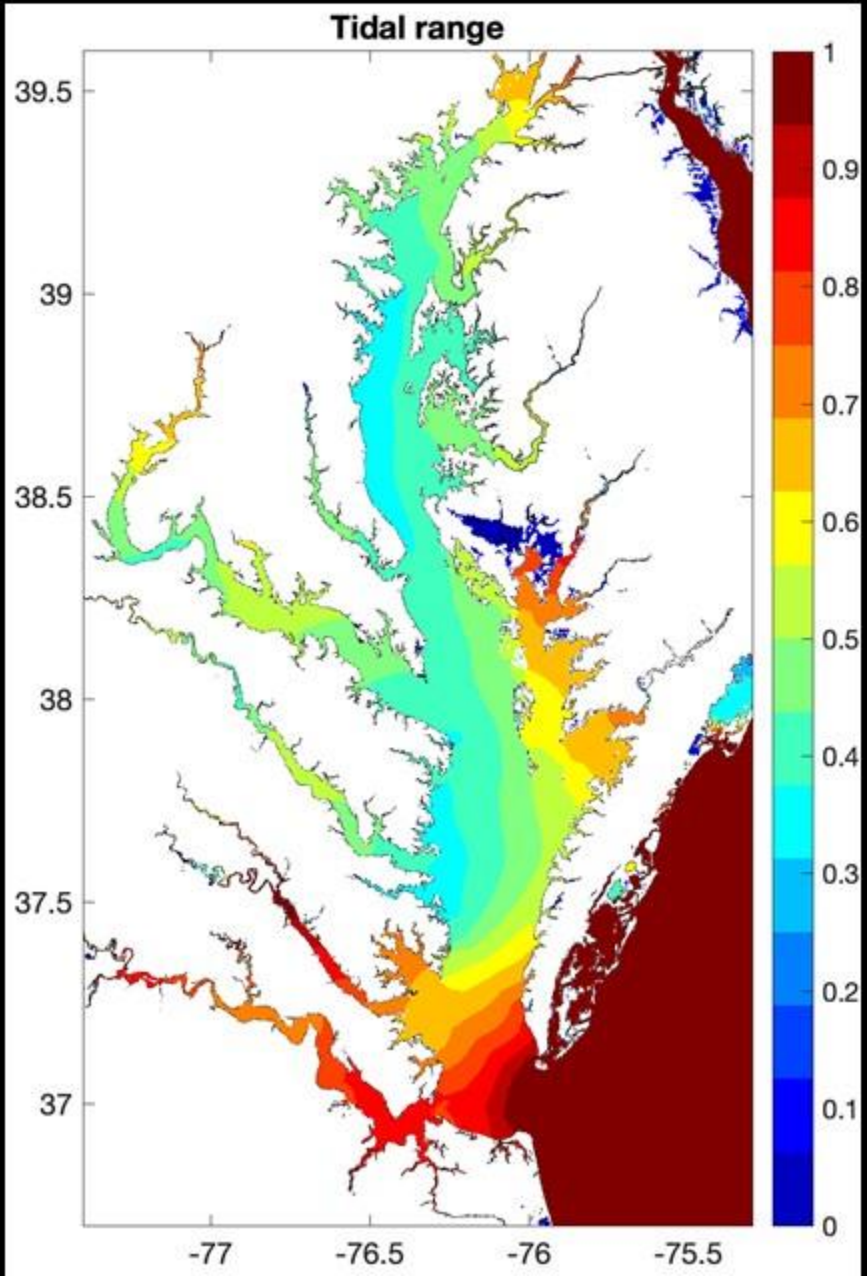
^{137}Cs

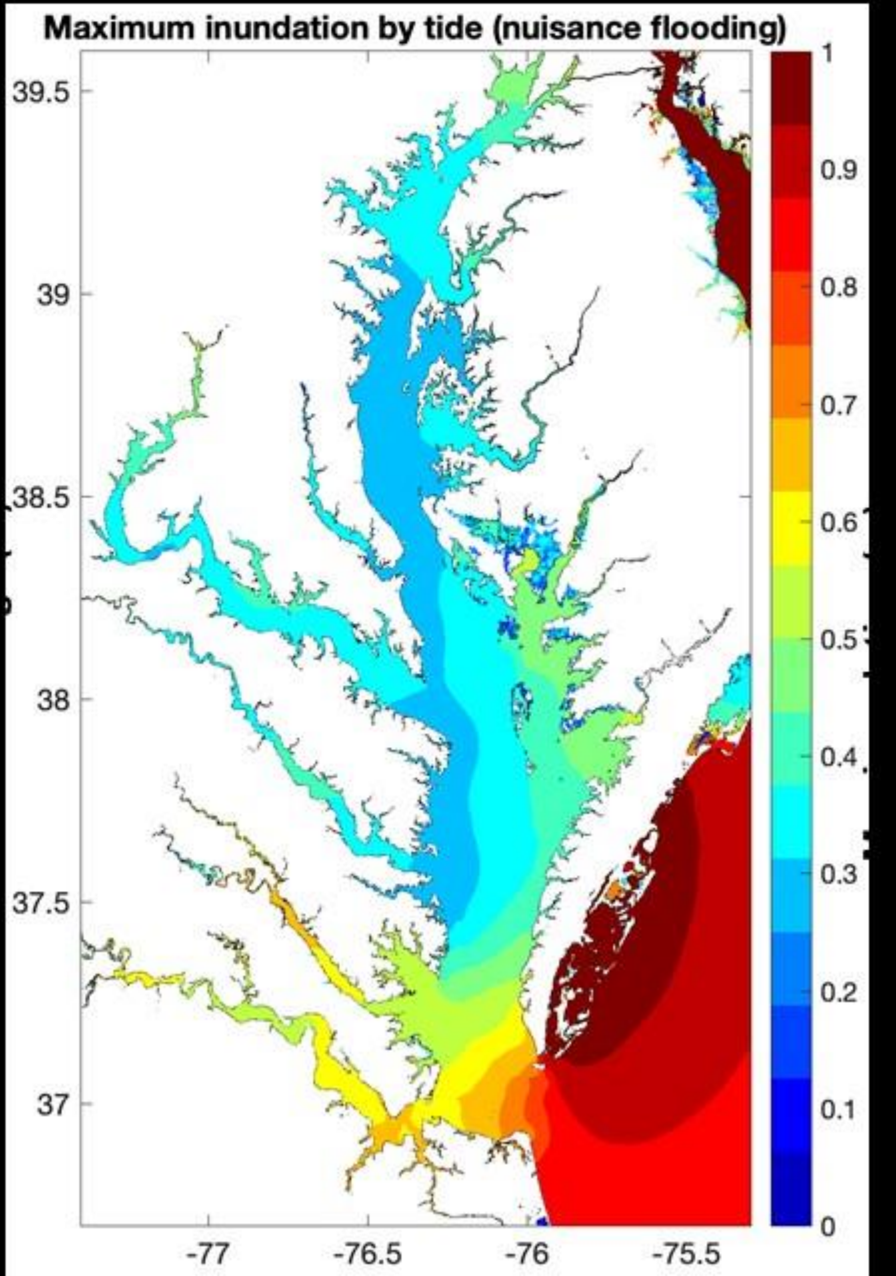
^{210}Pb

Adapted from Woodroffe and Mauray-Wallace (2012)

Waterfowl Hotspot: Eastern Neck National Wildlife Refuge

Using ADCIRC high-resolution model for tidal determination


Tidal range

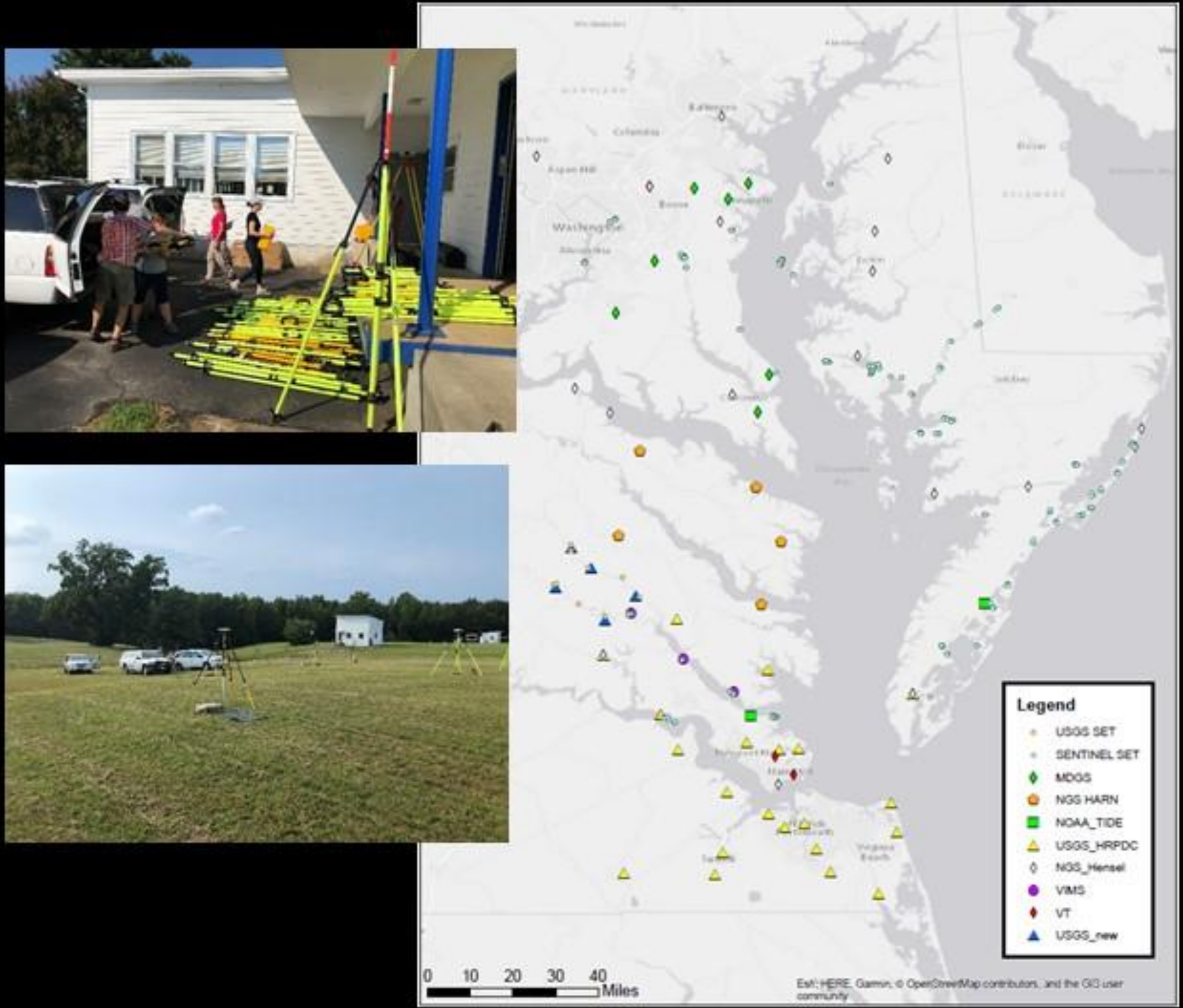

Maximum inundation by tide (nuisance flooding)

Next steps:

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

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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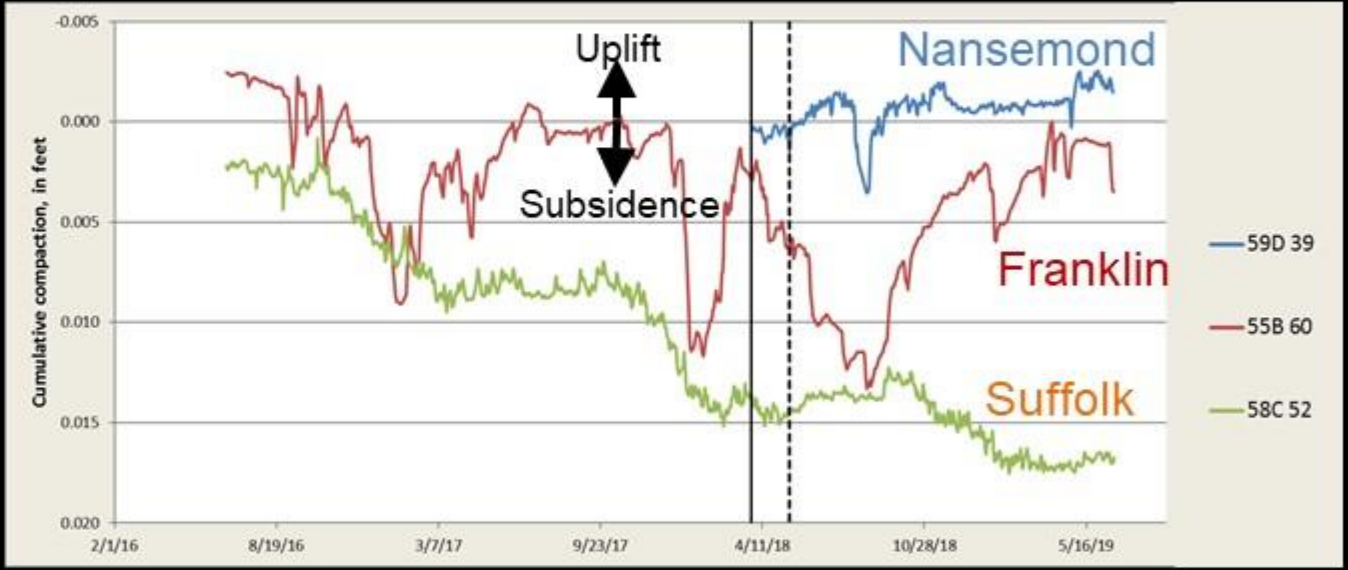
Extensometers

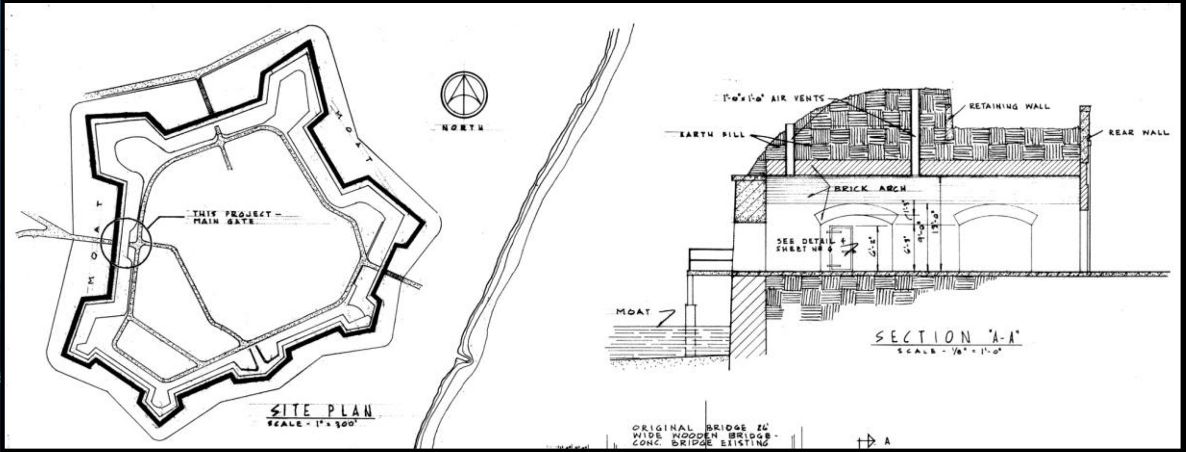
- Measure aquifer compaction
- Reactivated two sensors (2016):
    - Franklin
    - Suffolk
- Historic data recovered (late 1970s – mid 1990s)
- Installed new sensor (2018):
    - Nansemond
    - Co-located at HRSD SWIFT facility
    - CORS tied to bedrock
- Planning for 4th sensor (West Point)



Historic sea-level rise, GIA, 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).

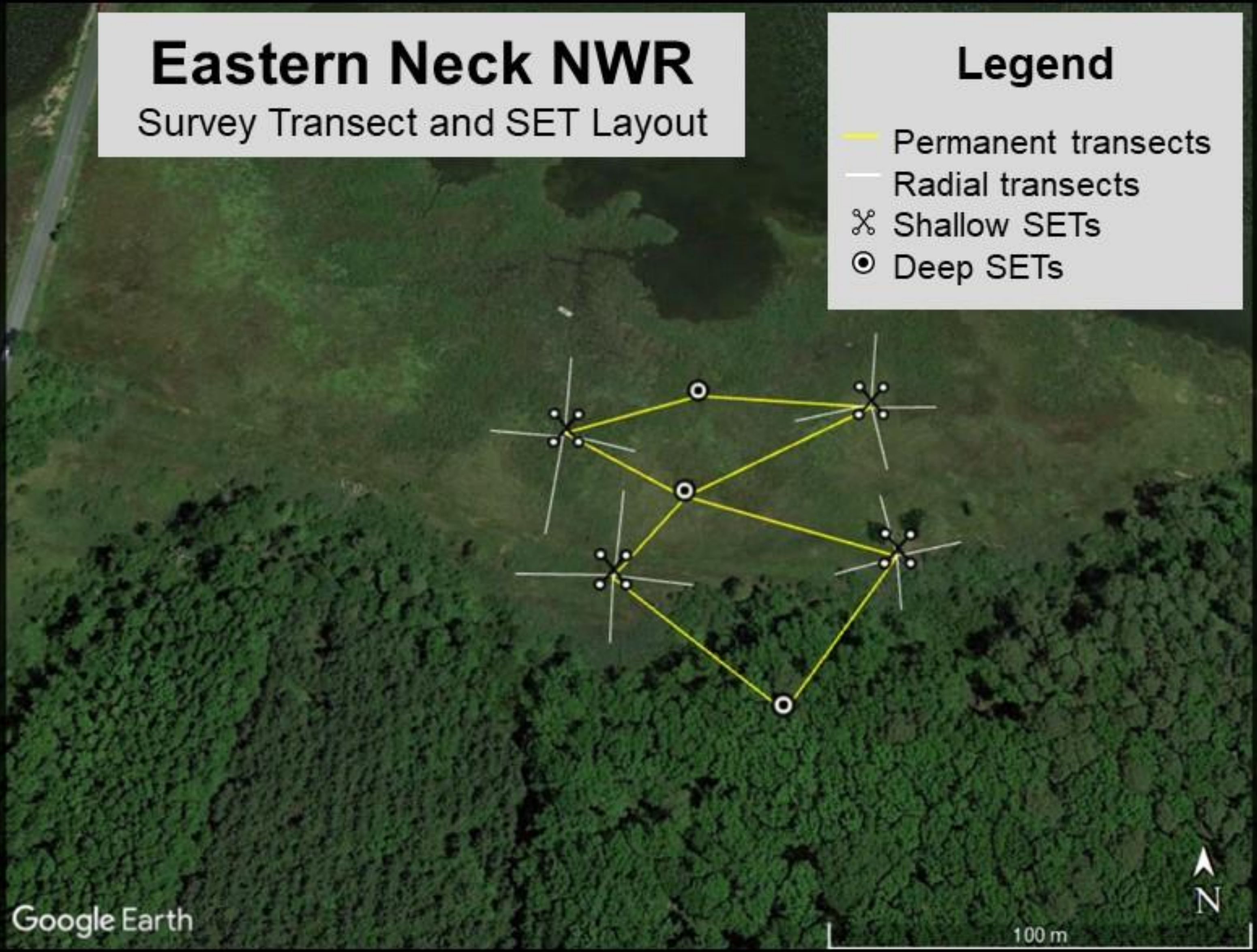


Approach: (1) Resurvey historic structures designed relative to sea level—for example, Fortress Monroe (built 1819-1834 CE), above.

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

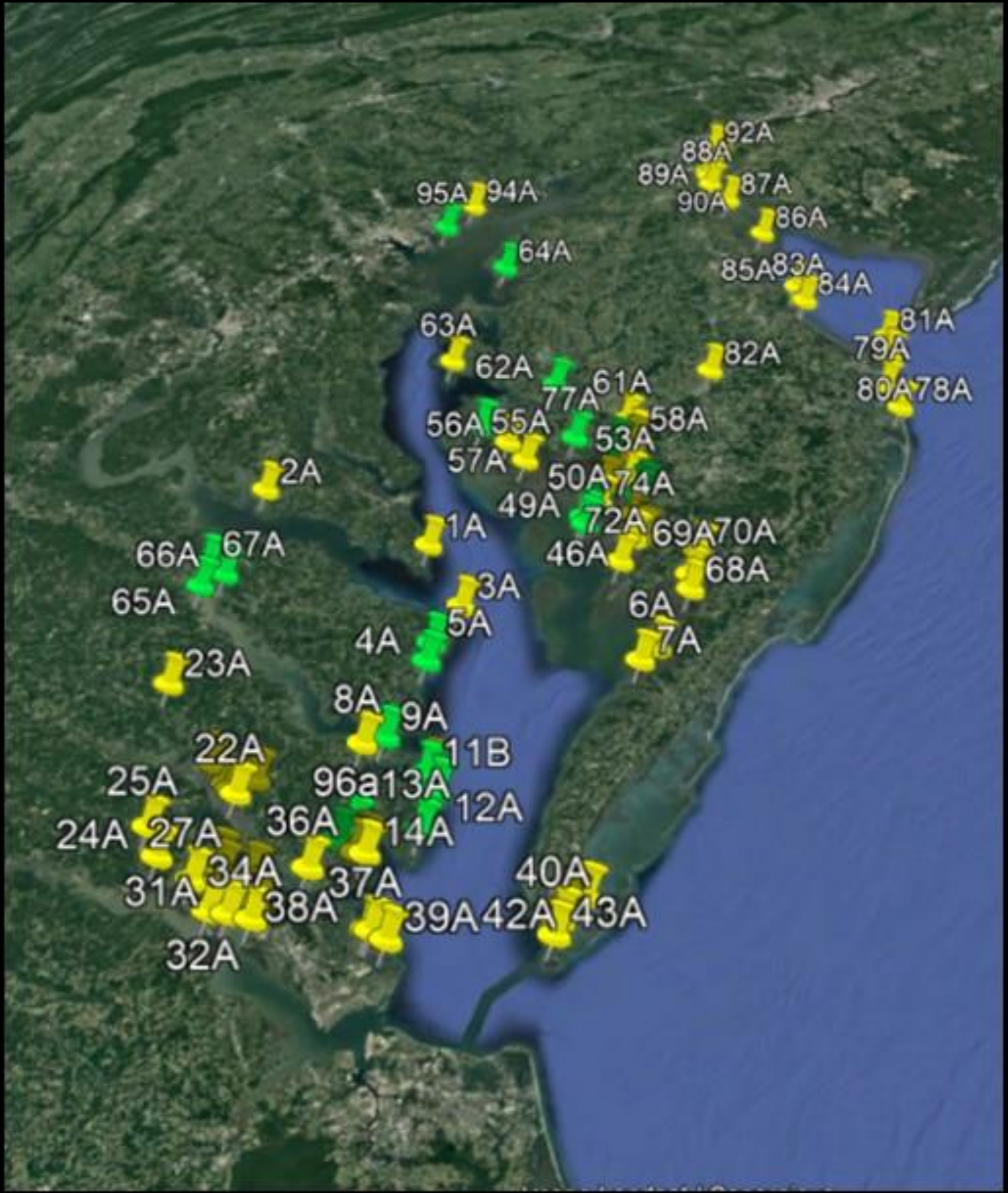
(3) Develop proxy records from sediment cores to reconstruct marsh loss and storm frequency over the last millennium.

Refs: NPS; Library of Congress



- 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

Chesapeake Bay Marsh-Upland Transect Surveys

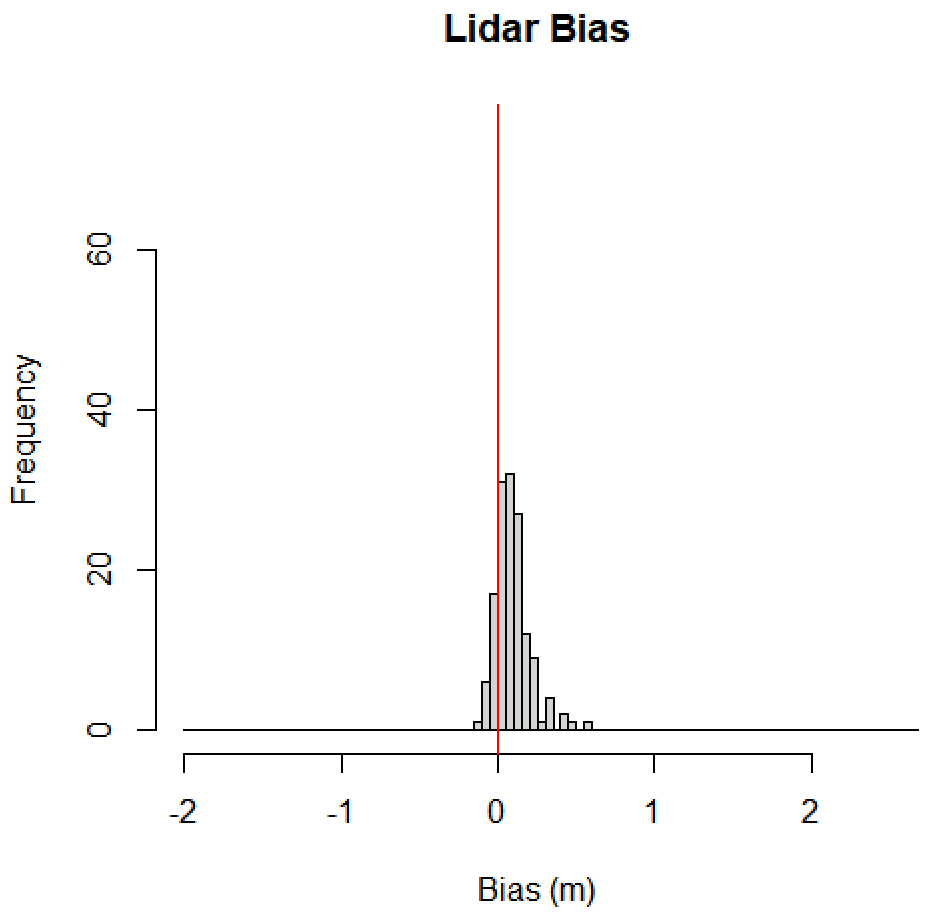


22 sites completed from 2019-2021

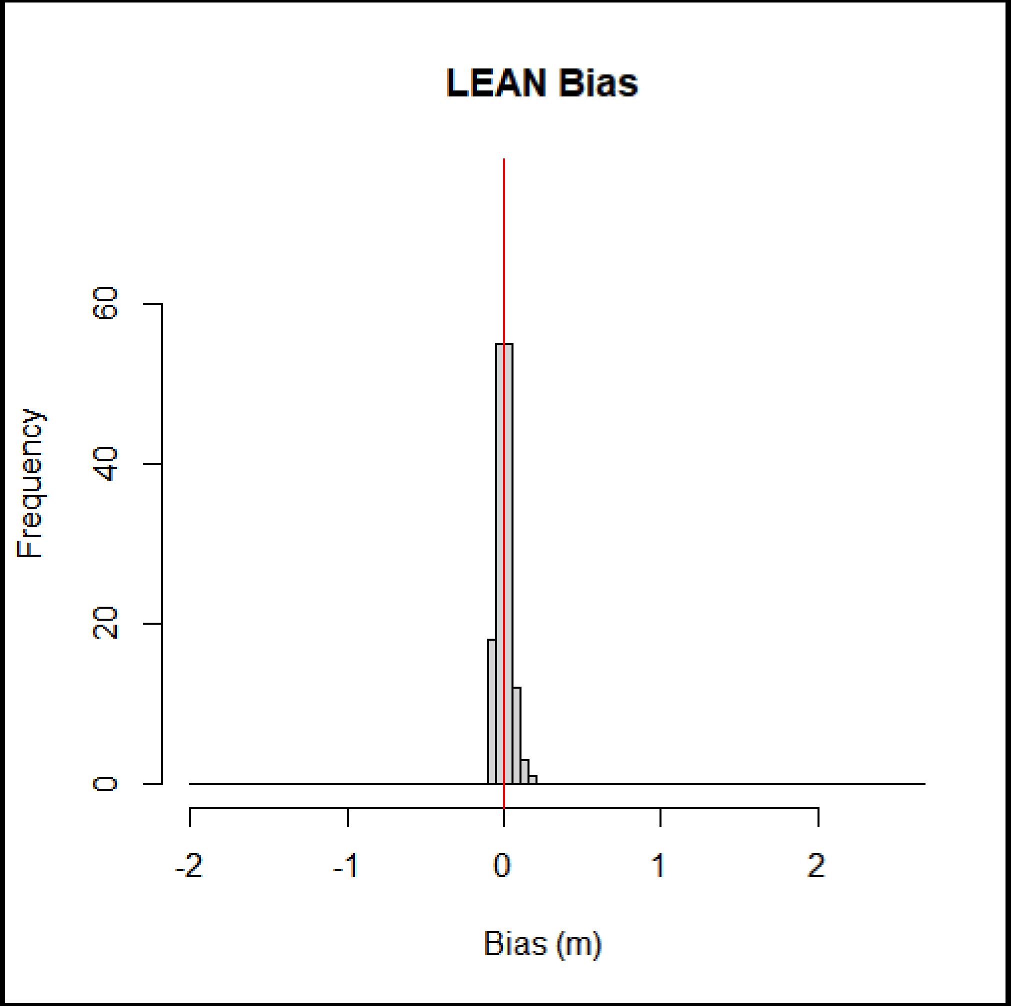
Sites Identified via ArcGIS based on criteria:

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

Lidar error and bias, and correction



Correction of Lidar DEM

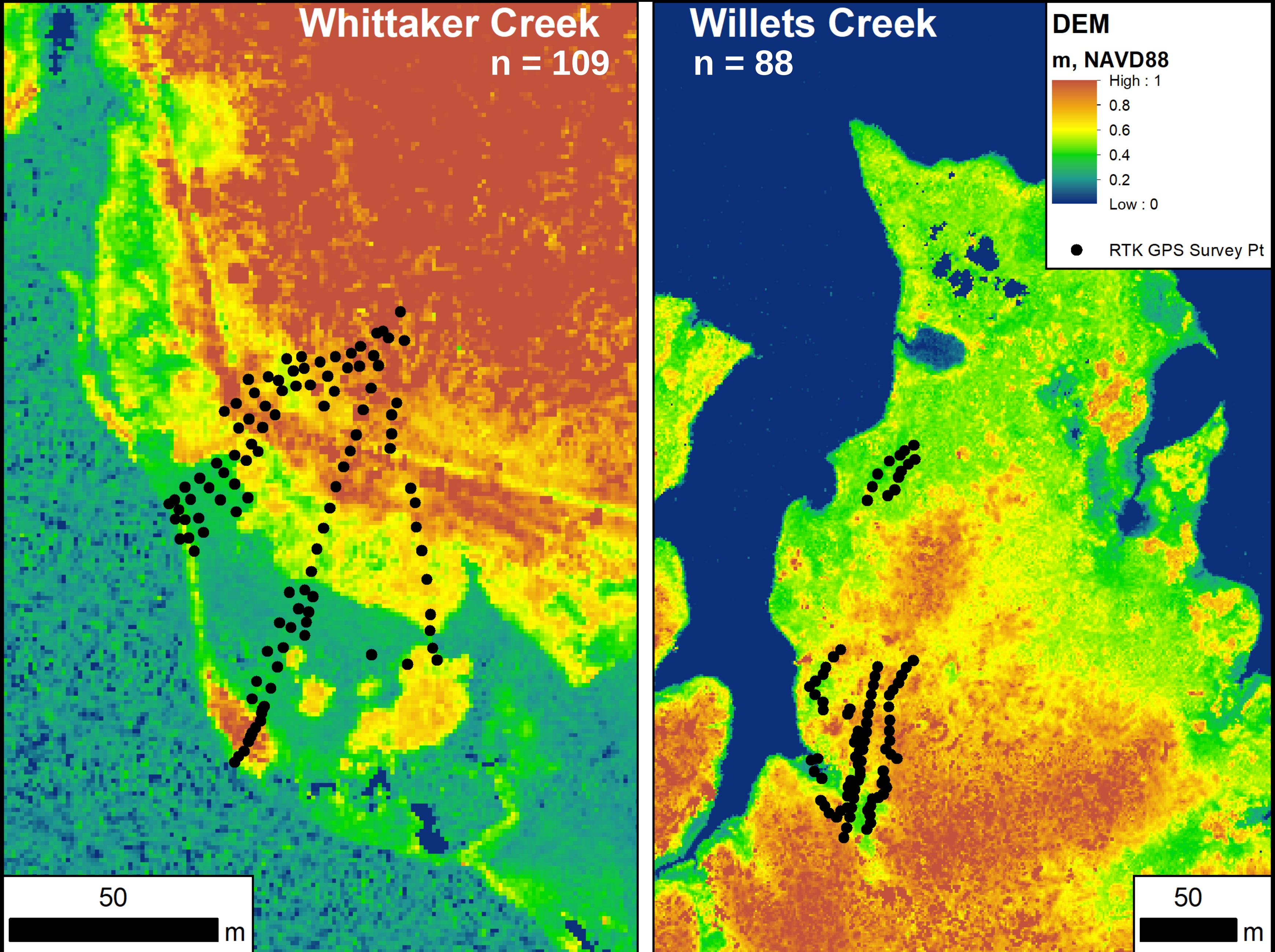


Holmquist JR, Schile-Beers L, Buffington K, Lu M and others (2021) Scalability and performance tradeoffs in quantifying relationships between elevation and tidal wetland plant communities. Mar Ecol Prog Ser 666:57-72. https://doi.org/10.3354/meps13683

Original

RMSE: 0.277 m
Mean Error: 0.099 m

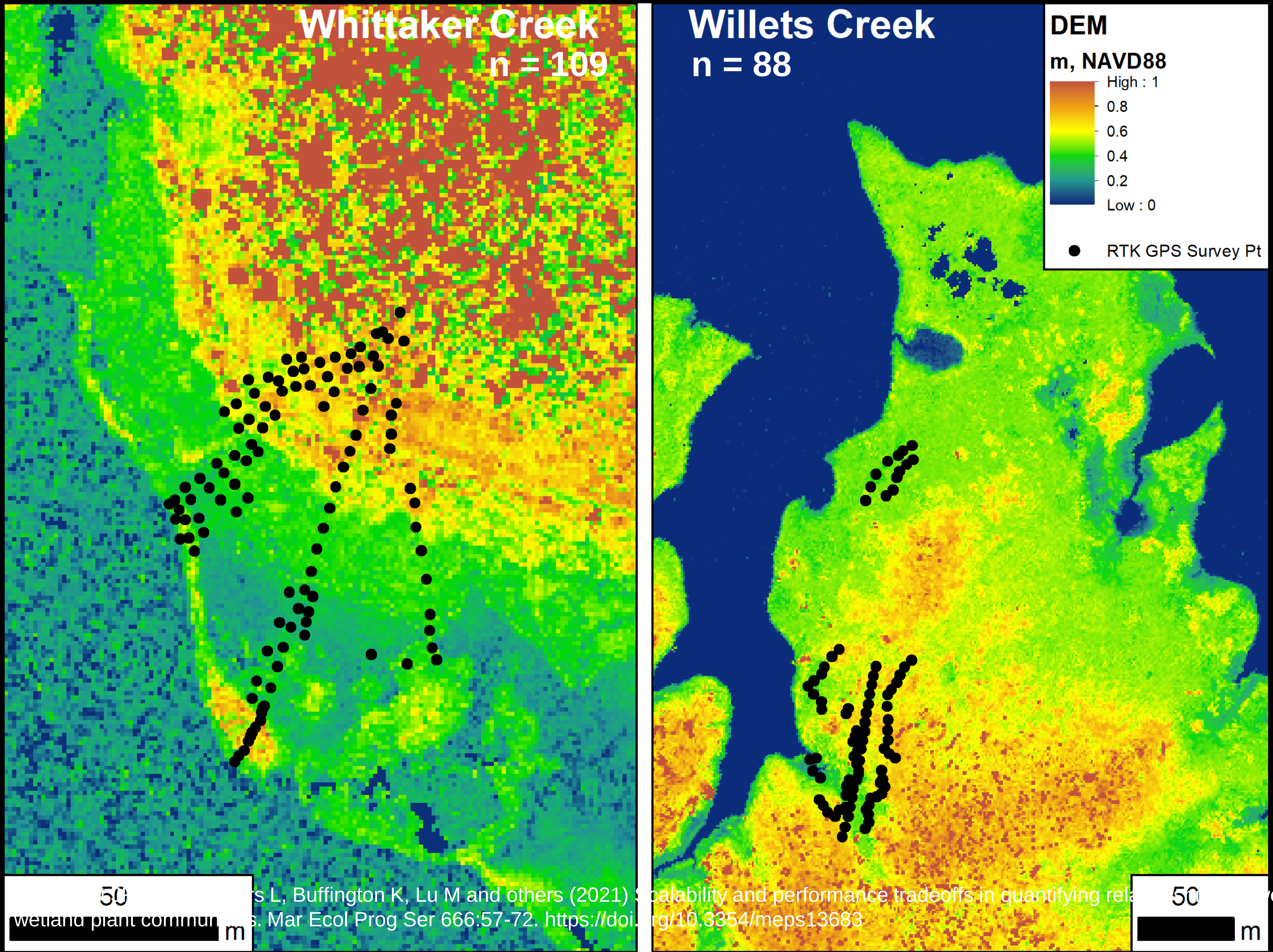
RMSE: 0.341 m
Mean Error: 0.11 m



LEAN

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

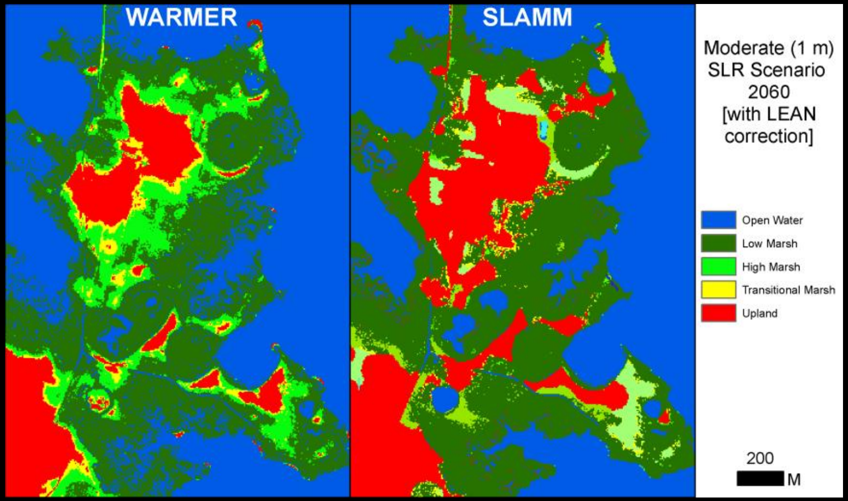
RMSE: 0.042 m, 86.9% improvement
Mean Error: -0.0063 m

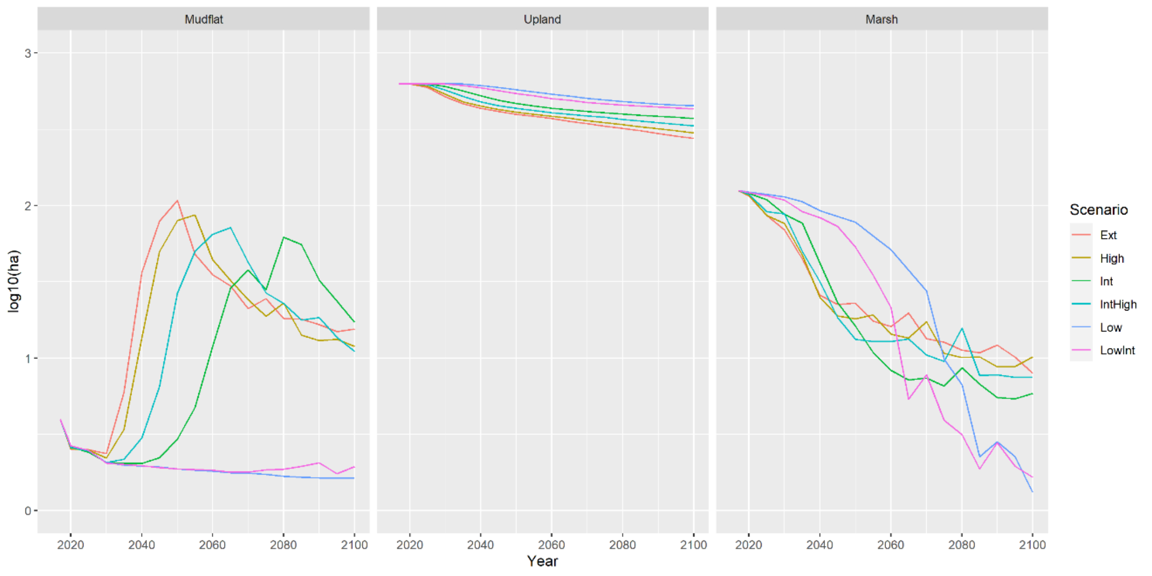


rs L, Buffington K, Lu M and others (2021) calability and performance tradeoffs in quantifying rela een elevation and tidal wetland plant commun s. Mar Ecol Prog Ser 666:57-72. https://doi. rg/10.3354/meps13683

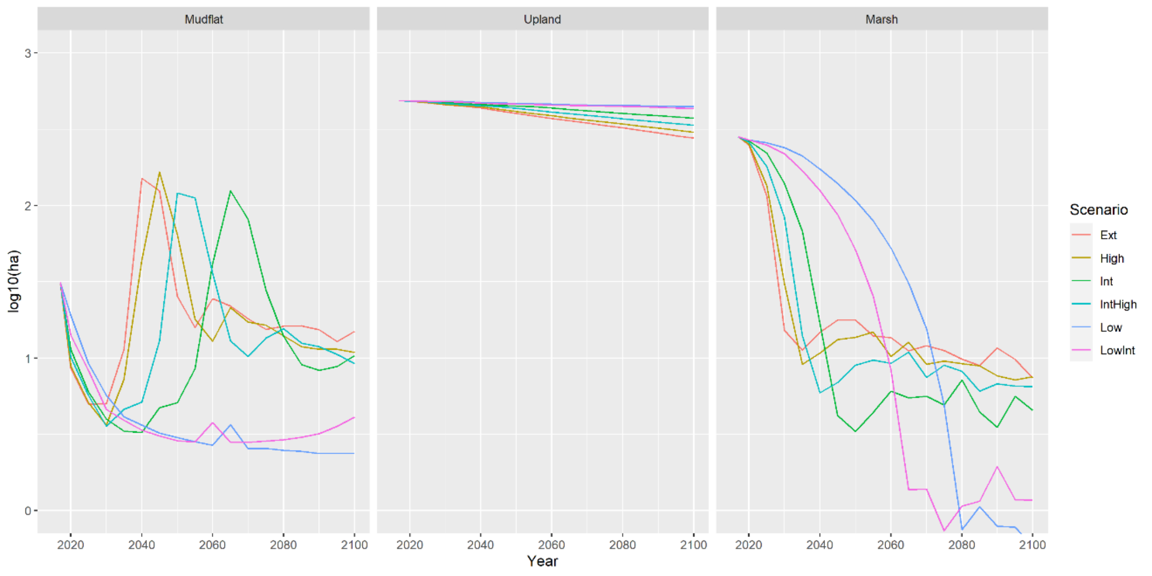
Vertical dynamic models (SLAMM, WARMER), Eastern Neck NWR

Importance of initial “state” of the system





SLAMM CONED



SLAMM LEAN

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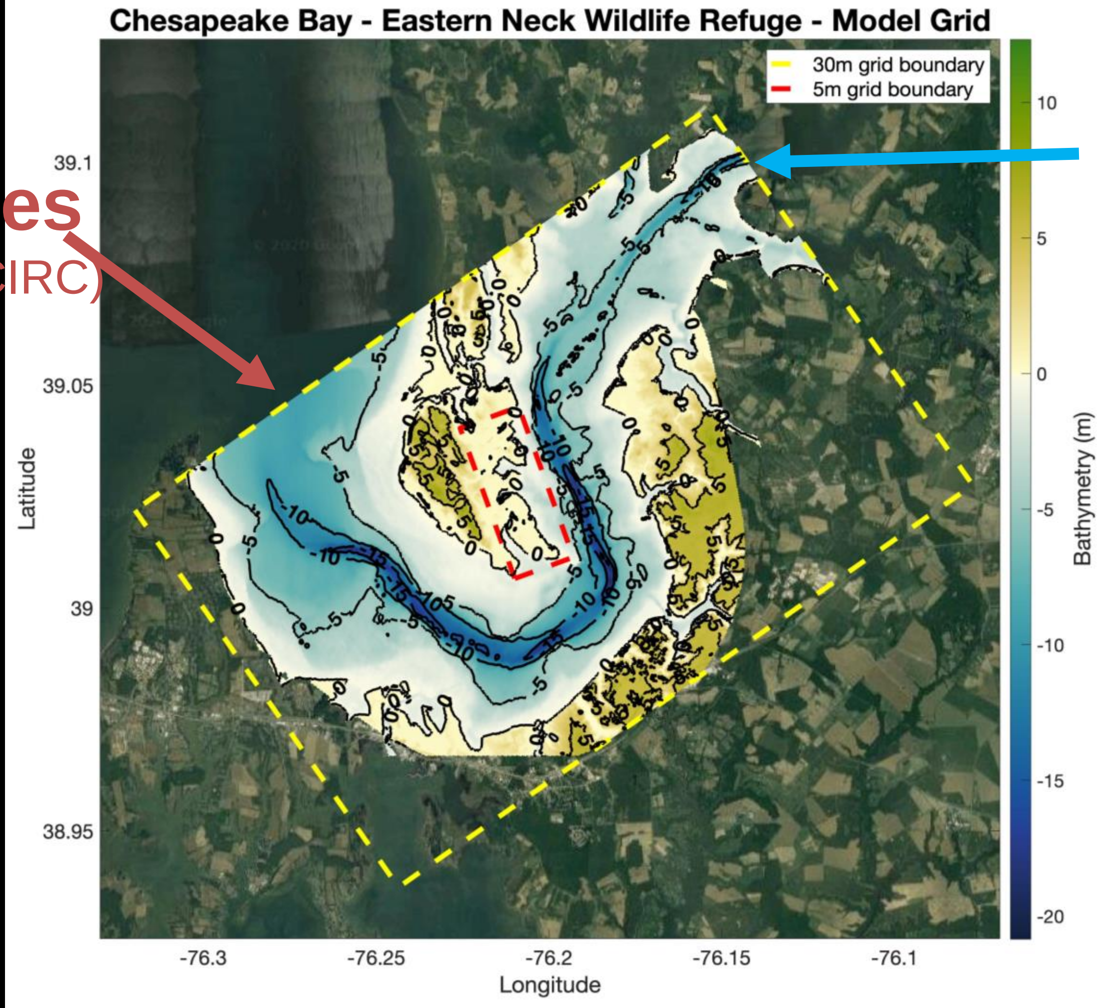
Hydrodynamic model forcing (COAWST)

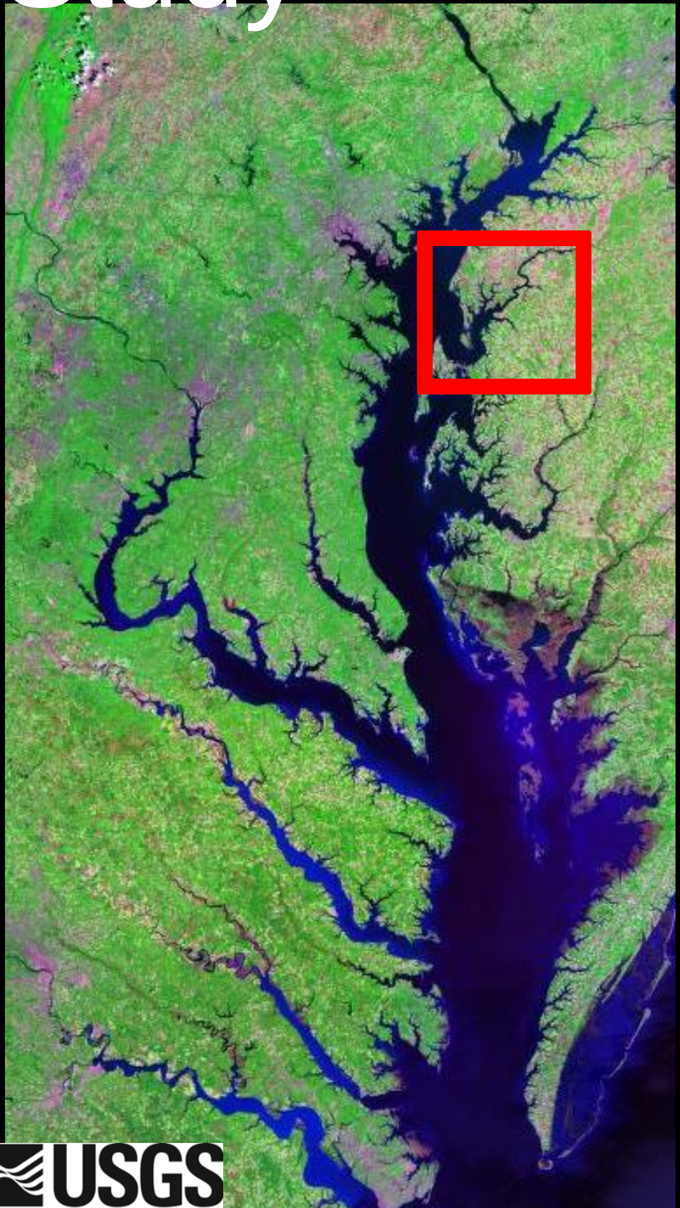


Tides
(ADCIRC)

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

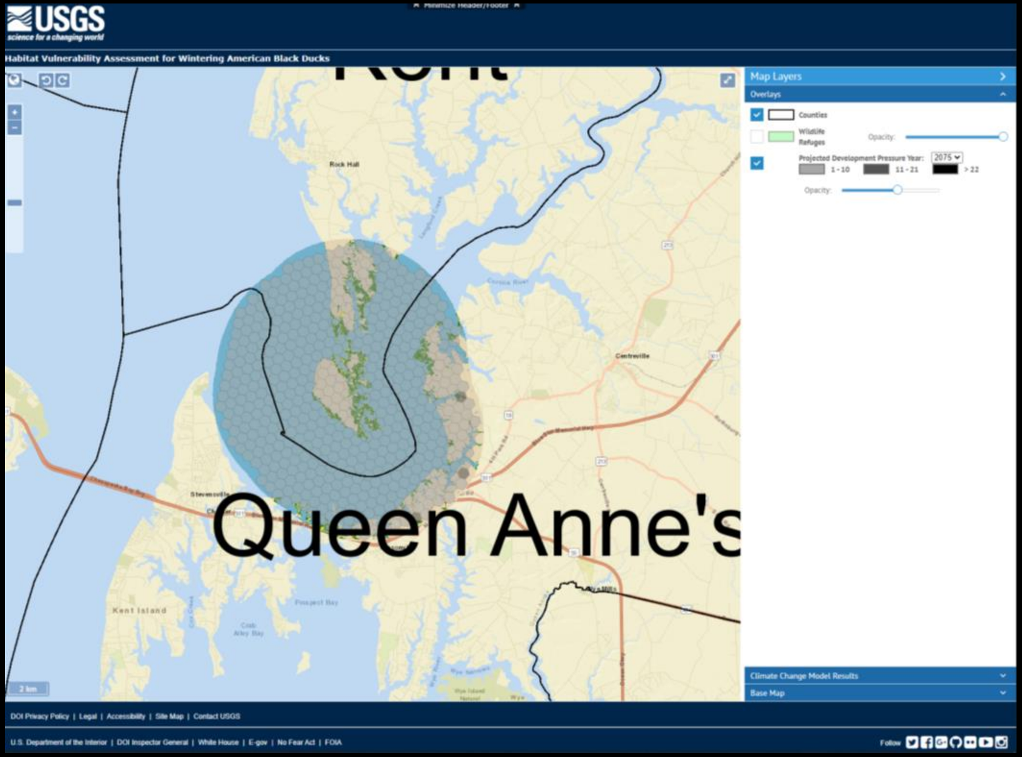
VIMS dataset: http://web.vims.edu/bio/sav/index.html

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



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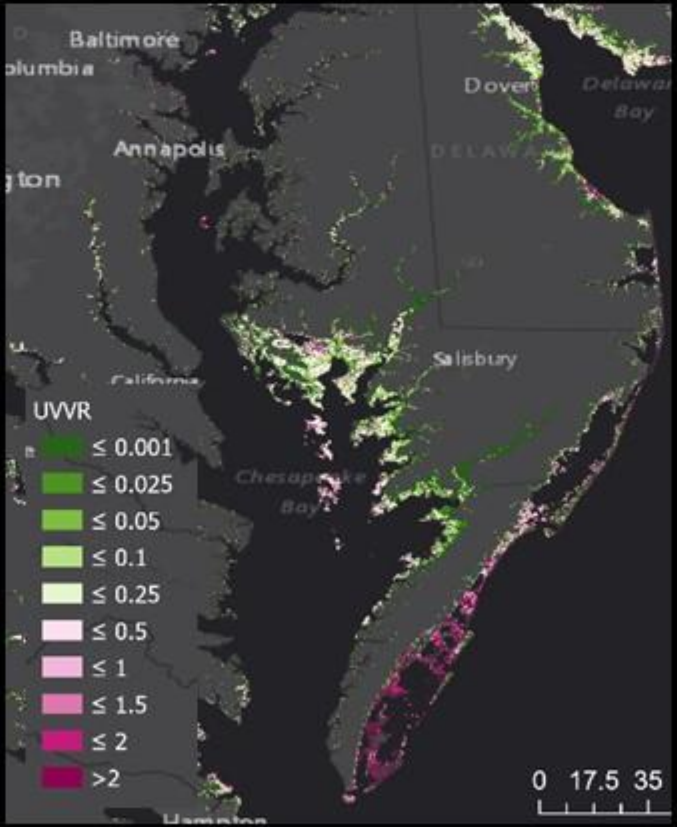
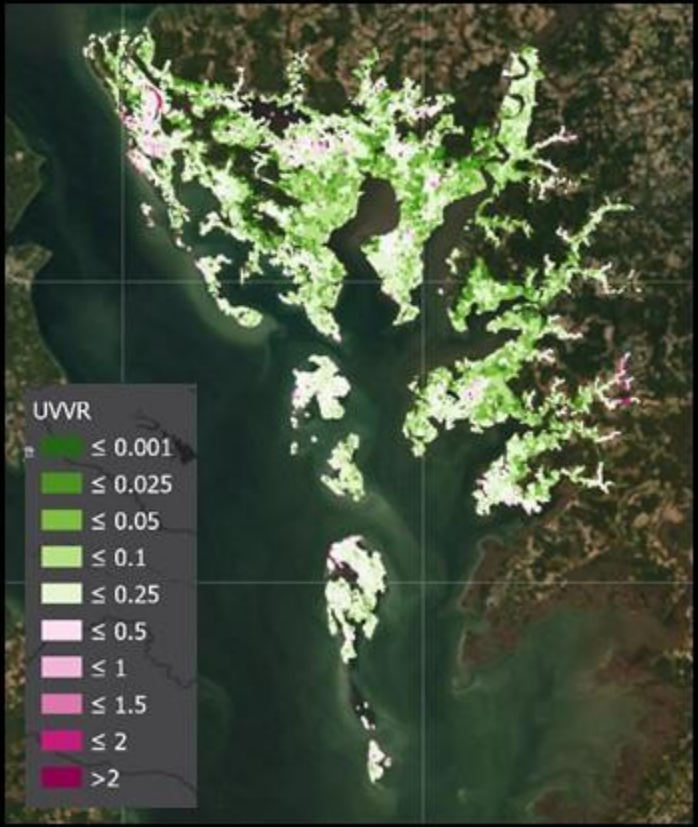
Geospatial studies and likelihood of habitat change

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

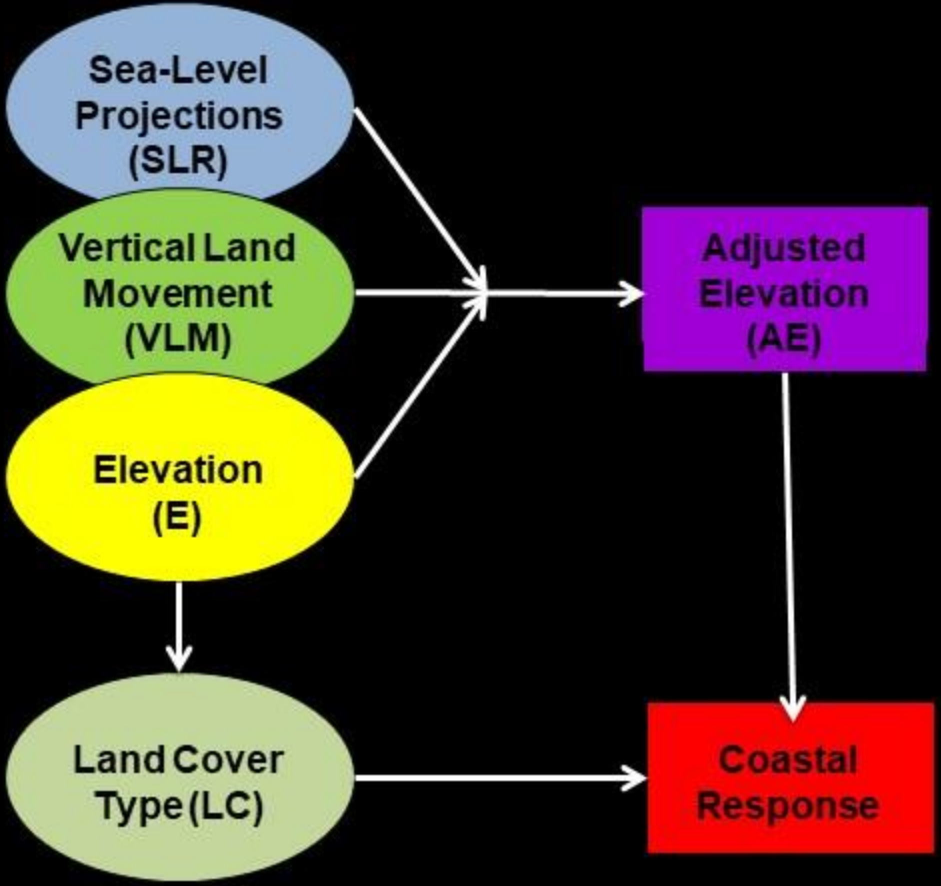
Includes mapping of elevation, tide range

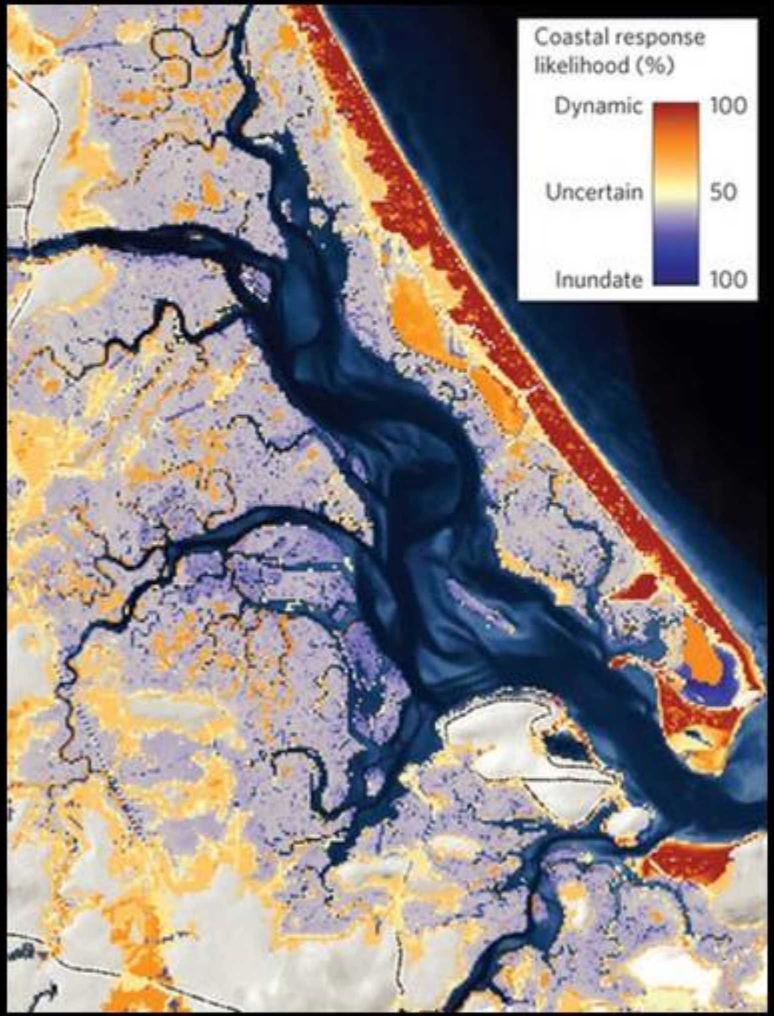
USGS
science for a changing world

https://www.usgs.gov/news/usgs-releases-nationwide-marsh-vulnerability-maps?qt-news_science_products=7#qt-news_science_products

Coastal Response model: likelihood of vertical response

Bayesian network of coastal response





Lentz et al. 2016 Nat. Clim. Change

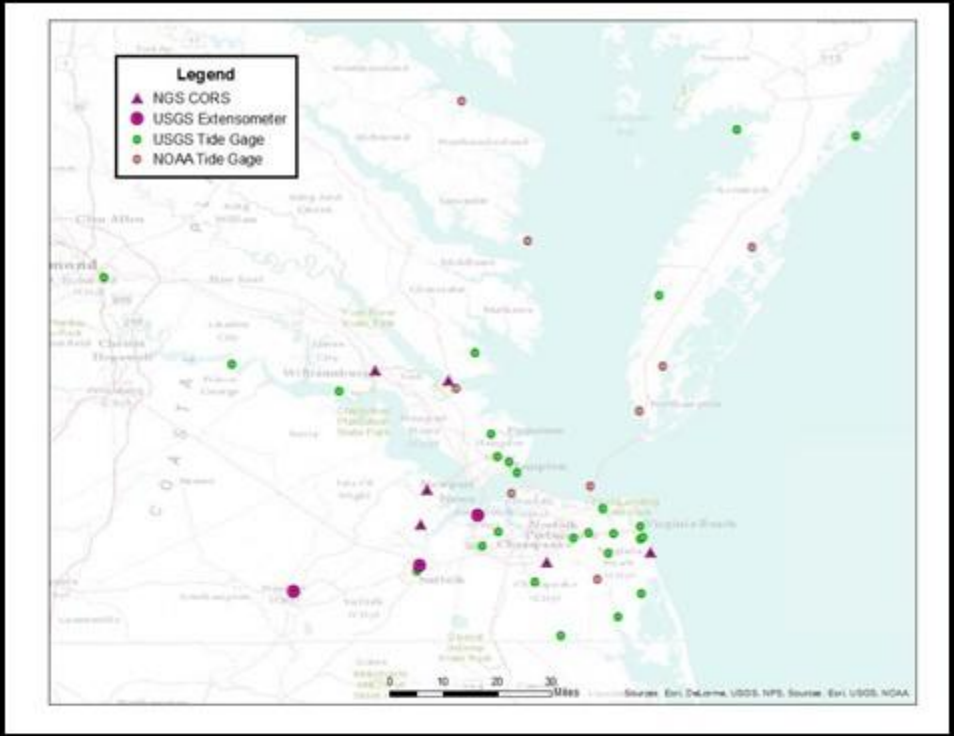
Enhancing the Coastal Response Model

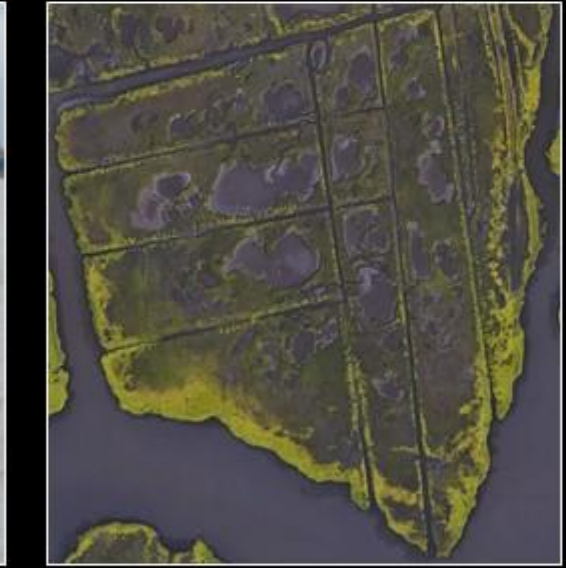
Vertical land movement: expand network of benchmark stations to get updated picture of subsidence

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

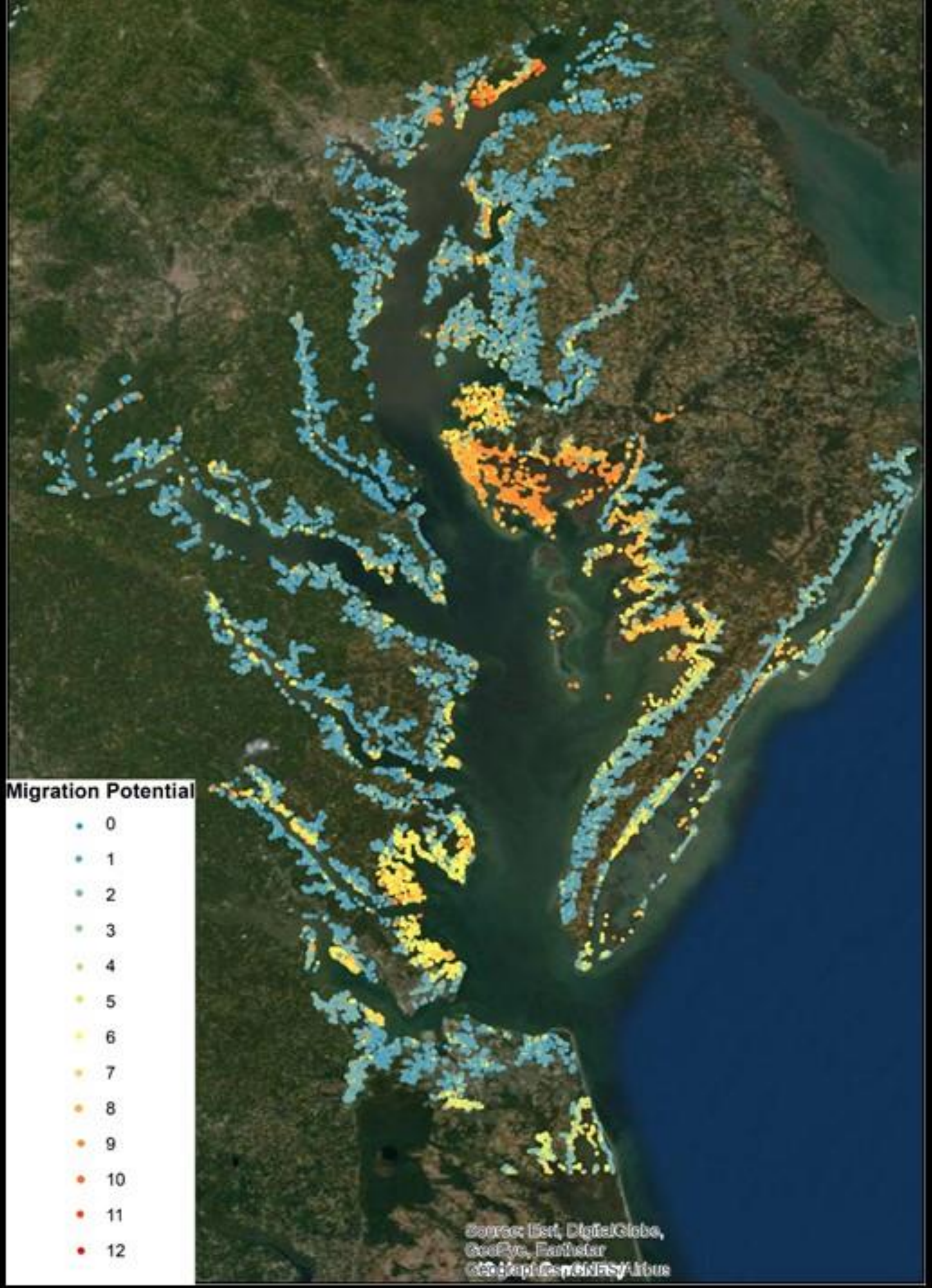
Internal response of marshes: use remote-sensing metrics to estimate likelihood of internal deterioration (UVVR)





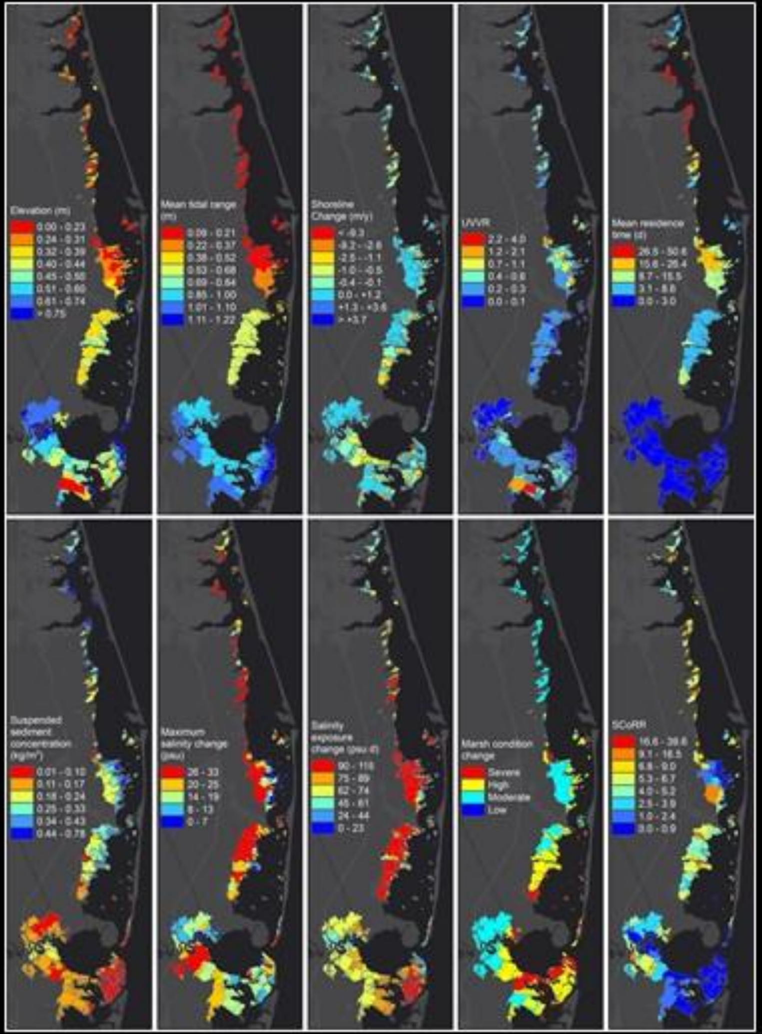
Combine slope and storm likelihood and inundation inundation to provide one estimate of migration potential

Molino GD, Defne Z, Aretxabaleta AL, Ganju NK and Carr JA. 2021, Quantifying Slopes as a Driver of Forest to Marsh Conversion Using Geospatial Techniques: Application to Chesapeake Bay Coastal-Plain, United States. Front. Environ. Sci. 9:616319. doi: 10.3389/fenvs.2021.616319



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus

Metrics to guide restoration investments:

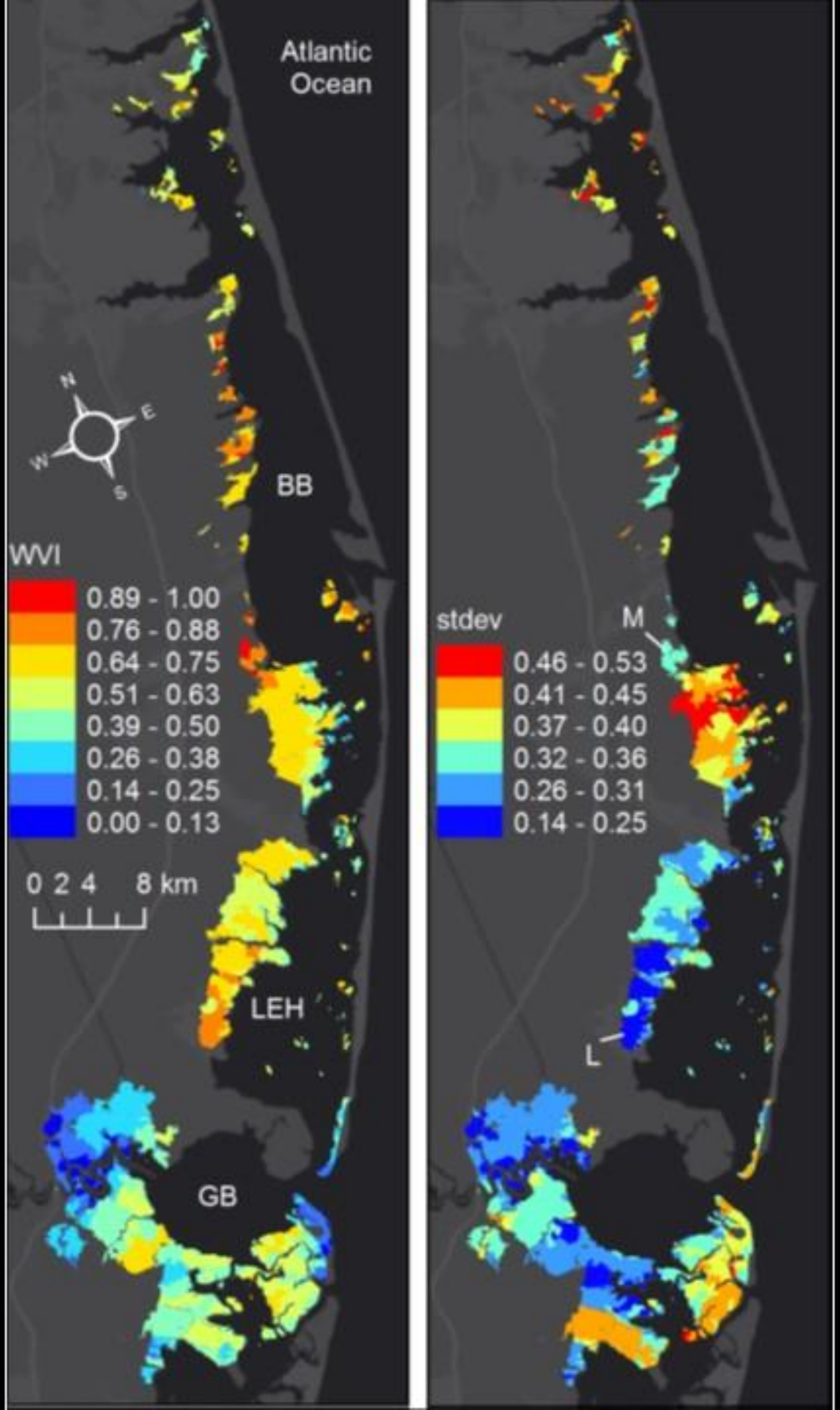


Combine multiple data layers into wetland vulnerability index

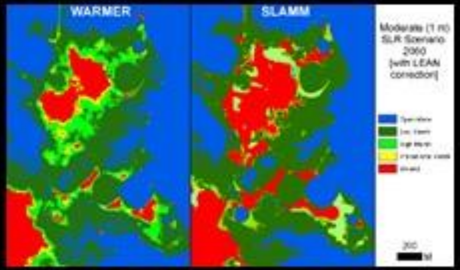
Deliver WVI through portals

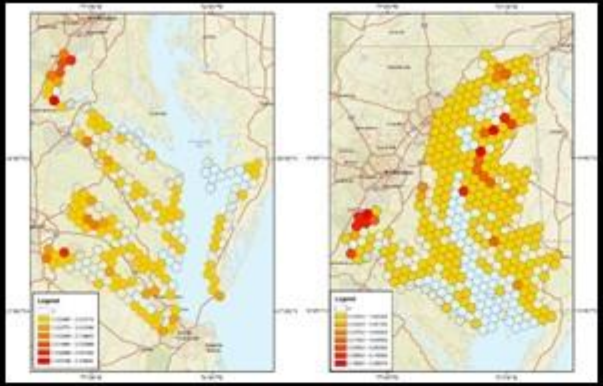
Map can be explored unit-by-unit to identify parameters causing most vulnerability

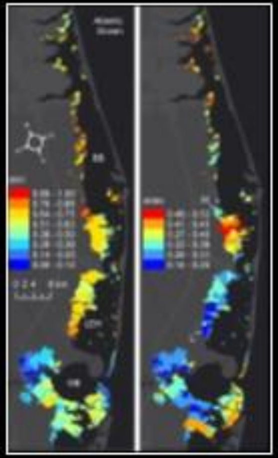
Products can be updated regularly to get time-series of vulnerability

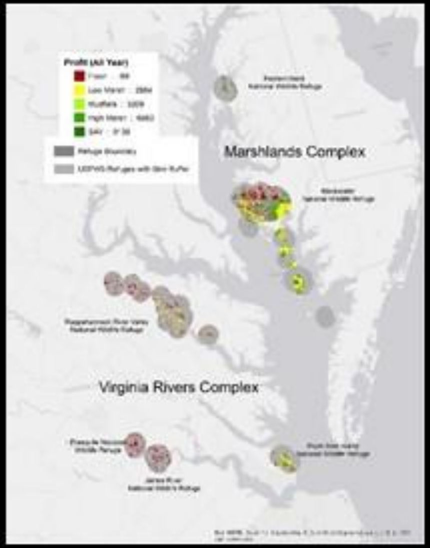


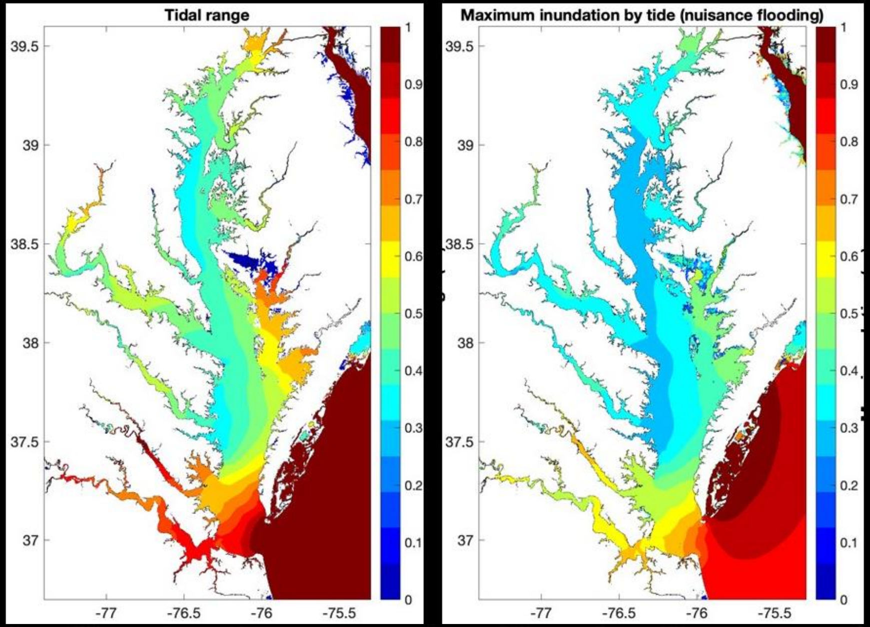
Metrics to guide restoration investments:

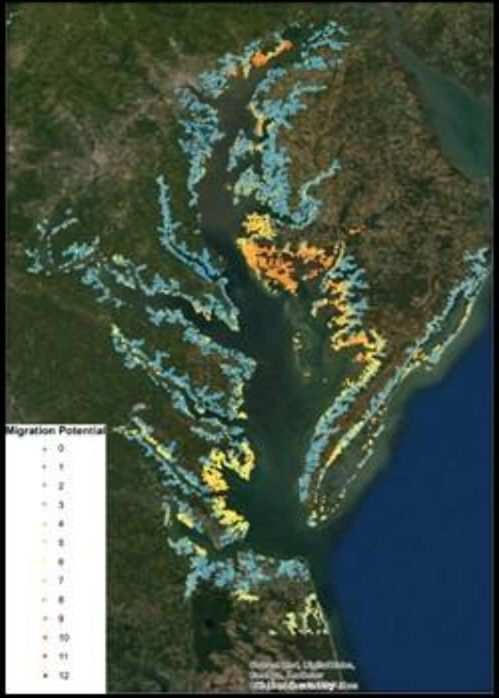


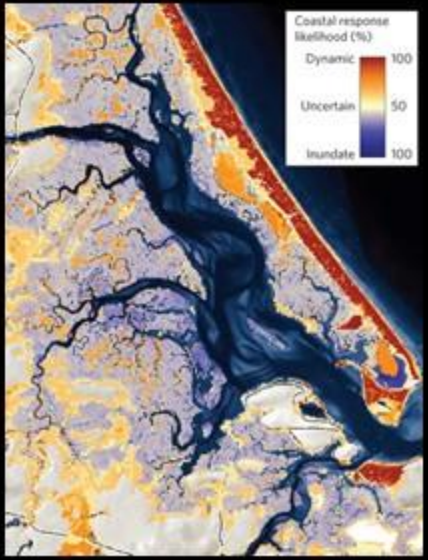


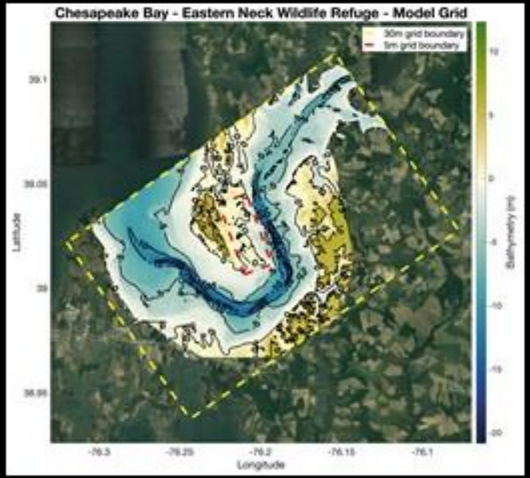












Similarly…

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

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science for a changing world

End-user applications

Can we:

- Identify critical system parameters that determine rates of change (for example : marsh migration, marsh loss?)

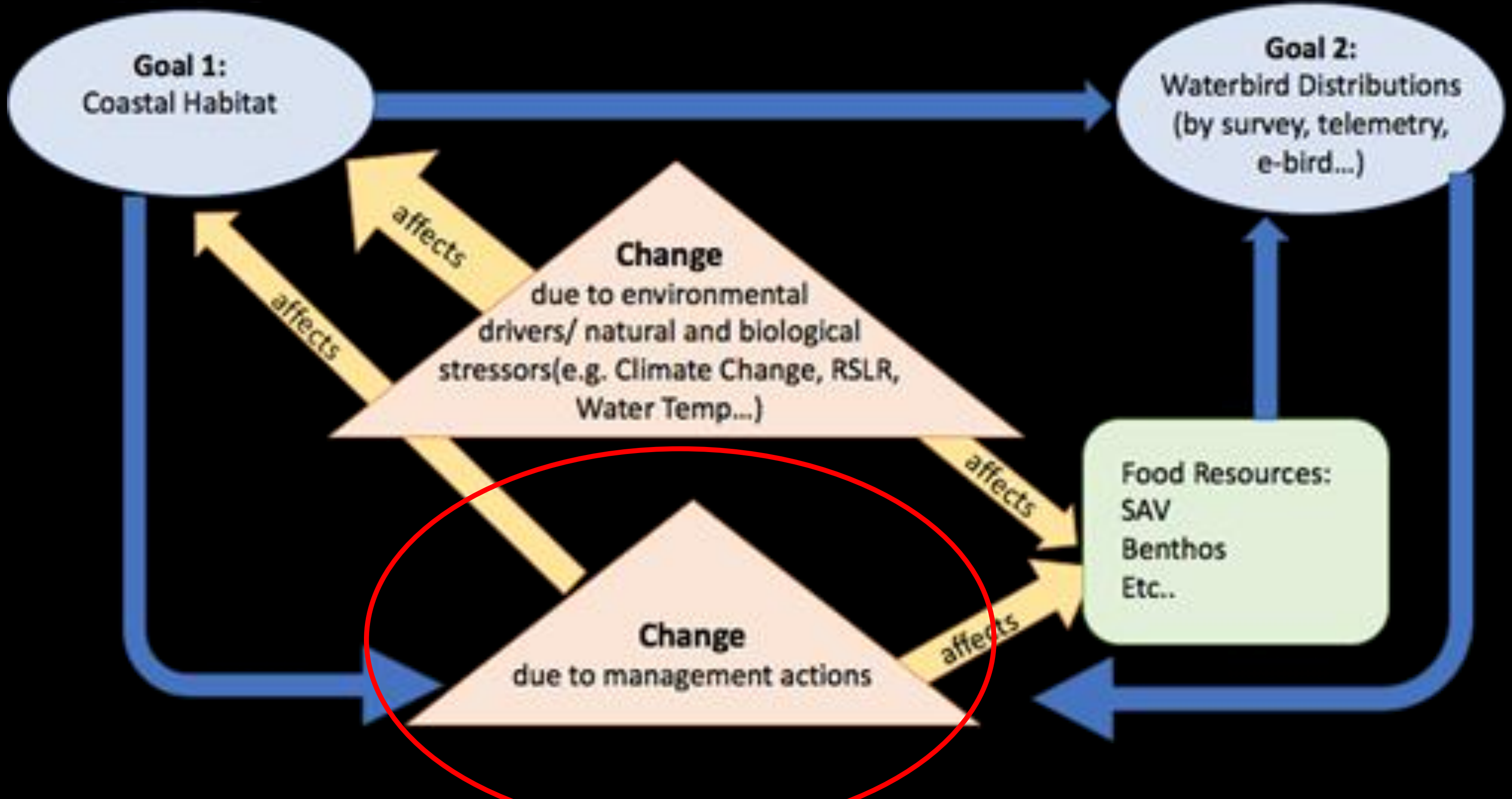
- Extract these parameters from remote sensing and or model output in Ches. Bay?

- Deliver maps of change likelihood (example: migration likelihood?)

- Use those maps to guide management, acquisition, and restoration?

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

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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).

Processes we need to better constrain and understand

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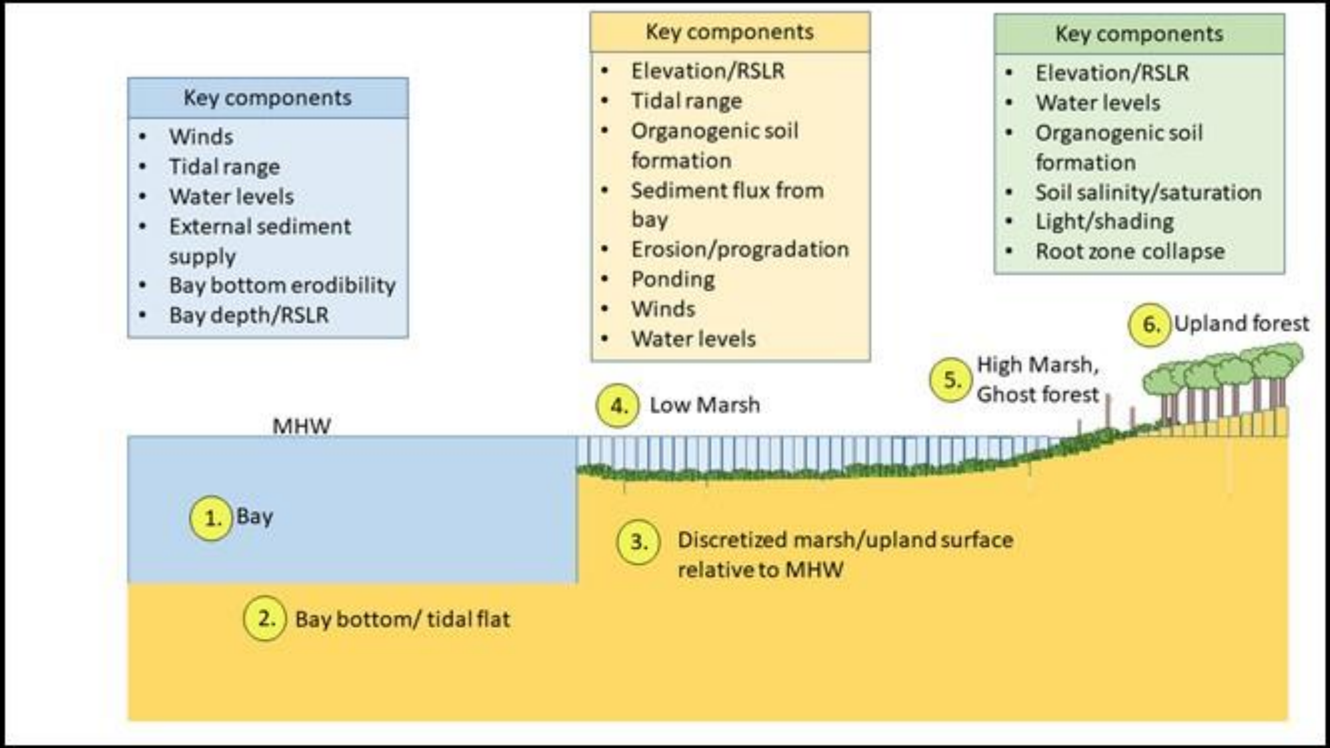
Models to generate hypotheses and understand complex interactions

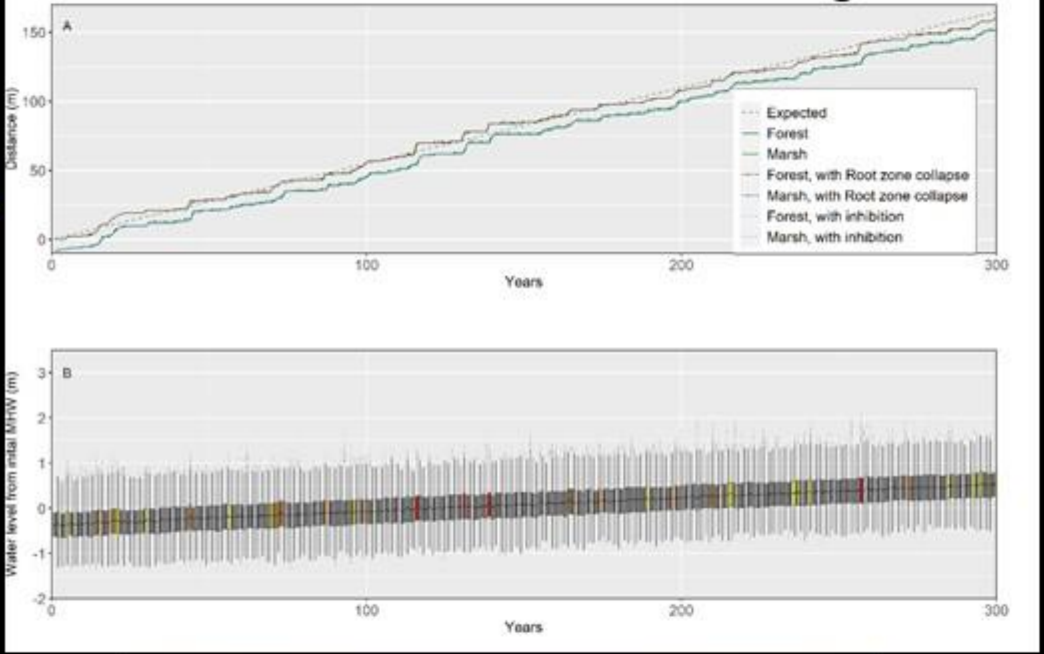


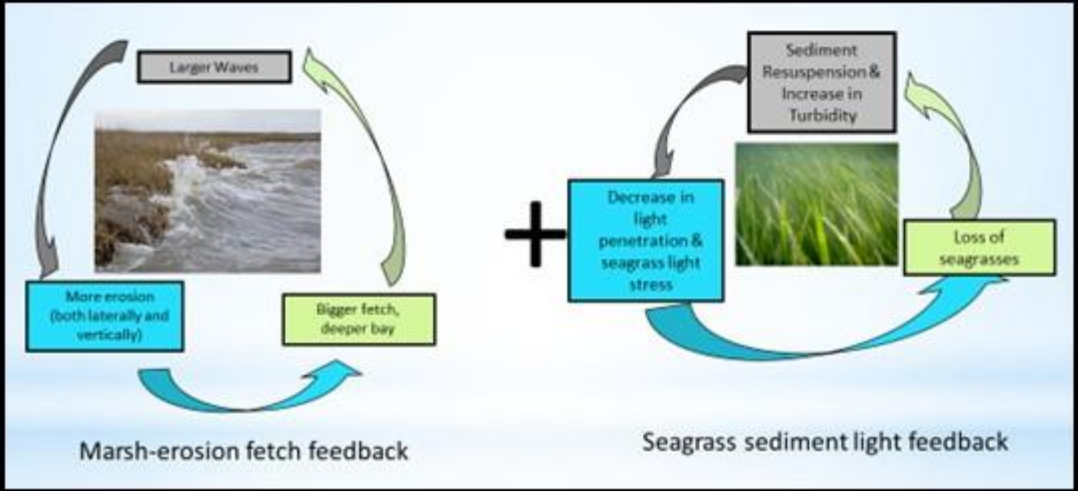
Key components
- Winds
- Tidal range
- Water levels
- External sediment supply
- Bay bottom erodibility
- Bay depth/RSLR

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

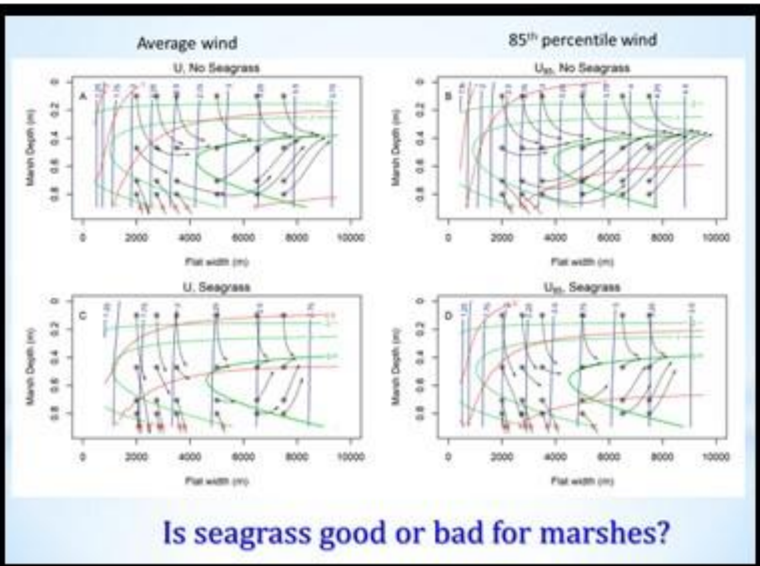
Controls on forest retreat and marsh migration?





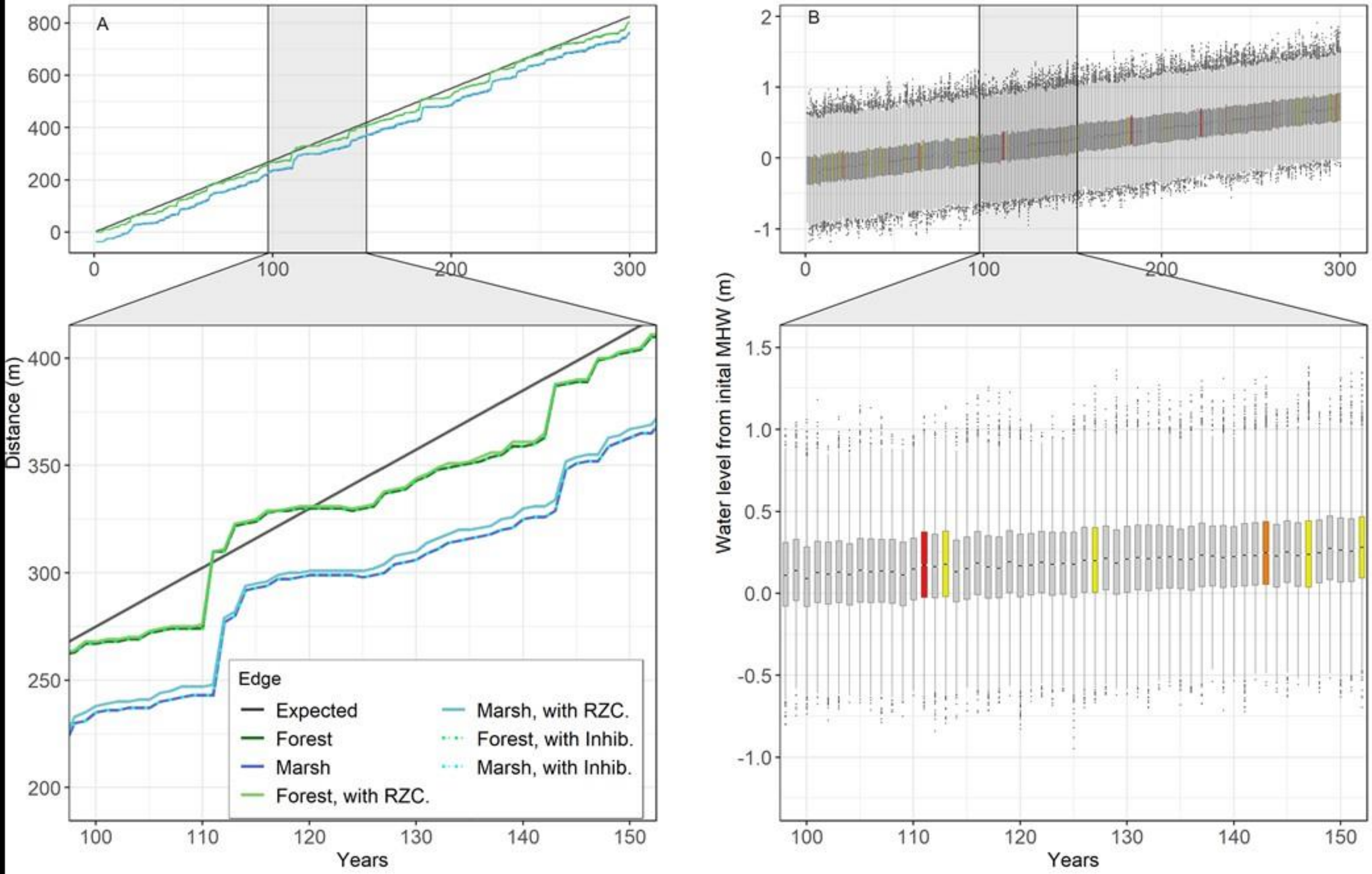
Marsh-erosion fetch feedback

Seagrass sediment light feedback



Is seagrass good or bad for marshes?

Seedling inhibition, root zone collapse? Limited memory?

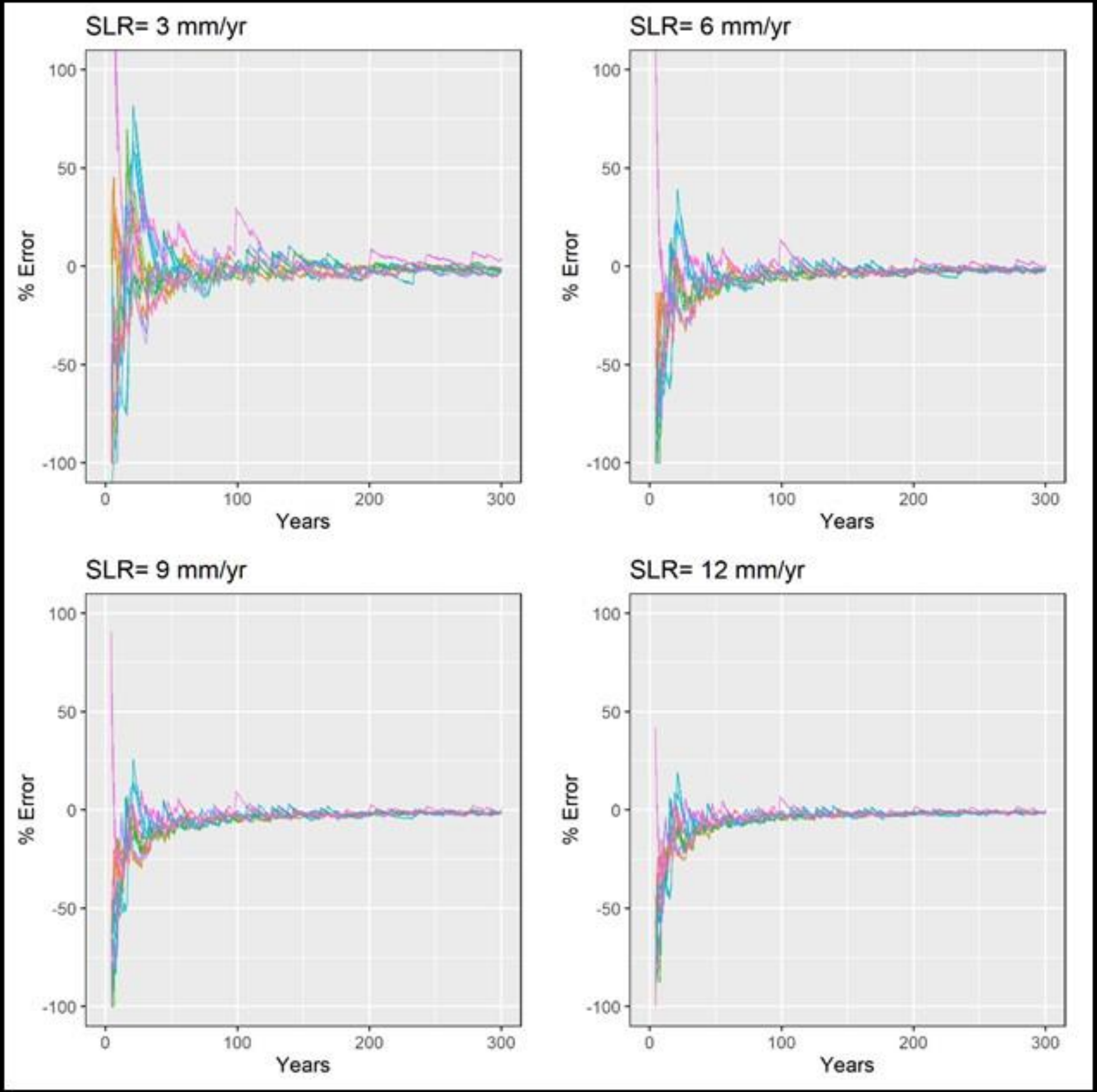


Large errors are likely to remain in estimation of forest retreat and marsh migration rates from remote sensing

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.



Carr, J., Guntenspergen, G., & Kirwan, M. (2020). Modeling marsh-forest boundary transgression in response to storms and sea-level rise. Geophysical Research Letters, 47, e2020GL088998. https://doi.org/10.1029/2020GL088998

Theme 2

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

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