Assessing and Managing Consequences Related to Sea Level Rise and Coastal Storms

Presenter: Gregory Kiker, Associate Professor

Dept of Agricultural & Biological Engineering, University of Florida

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Acknowledgements

- Integrated Climate Change and Threatened Bird Population Modeling to Mitigate Operations Risks on Florida Military Installations (SERDP funded)
  - USACE-ERDC: **Igor Linkov**, **Richard Fischer**
  - UF: **Greg Kiker**, **Rafael Munoz-Carpena**, **Chris Martinez**, Anna Linhoss, Matteo Convertino, Maria Chu-Agor
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  - UF: **Kathryn Frank, Paul Zwick, Greg Kiker**
  - **Michael Shirley**: Guana Tolomato Matanzas National Estuarine Research Reserve (GTM NERR)
  - OK State Univ: **Dawn Jourdan**
- Predicting and Mitigating the Effects of Sea-level Rise and Land Use Changes on Imperiled Species and Natural Communities in Florida (State of Florida & Kresge Foundation Funded)
  - UF: **Tom Hoctor, Michael Volk, Greg Kiker and Paul Zwick**, University of Florida Center for Landscape Conservation Planning
  - **Reed Noss** and Joshua Reese, University of Central Florida
  - **Jon Oetting**, Florida Natural Areas Inventory

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Agenda

1. Motivation: Florida - between the devil and the deep blue sea?
2. Canaries in a coal mine: Florida style
3. Sea Level Rise and Military Infrastructure
4. Getting local and personal: Sea Level Rise predictions meet stakeholders in NE Florida
5. The Way Forward: Where to go? How to grow?

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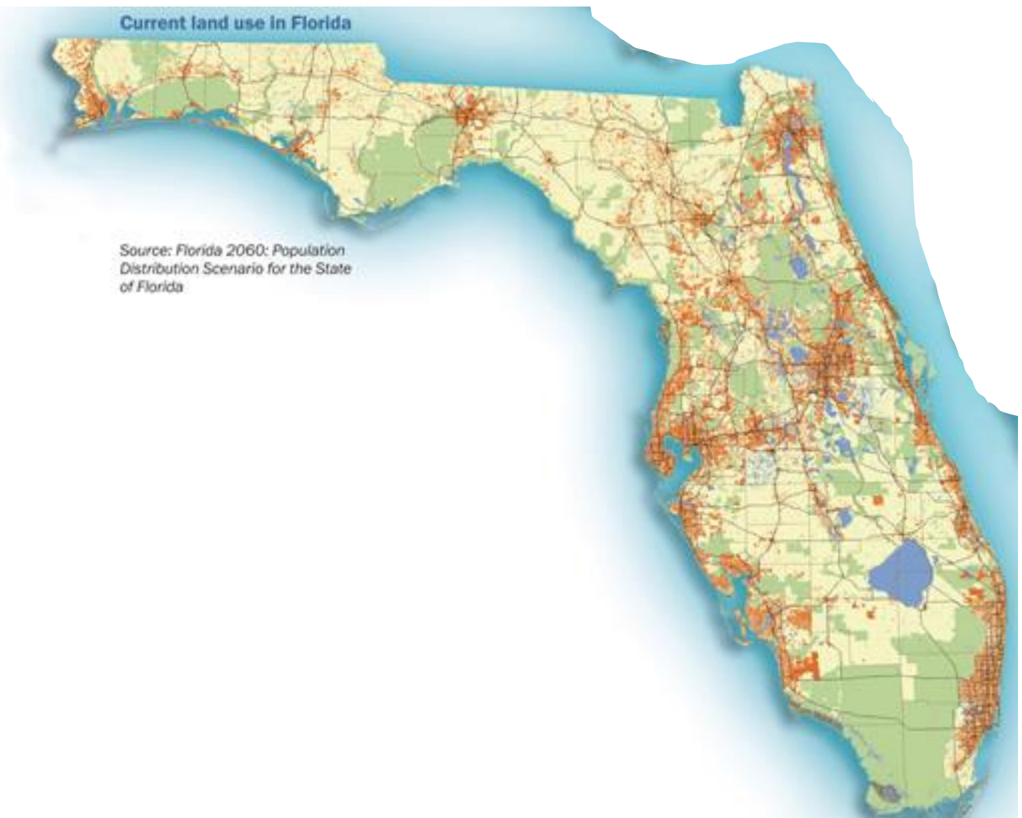
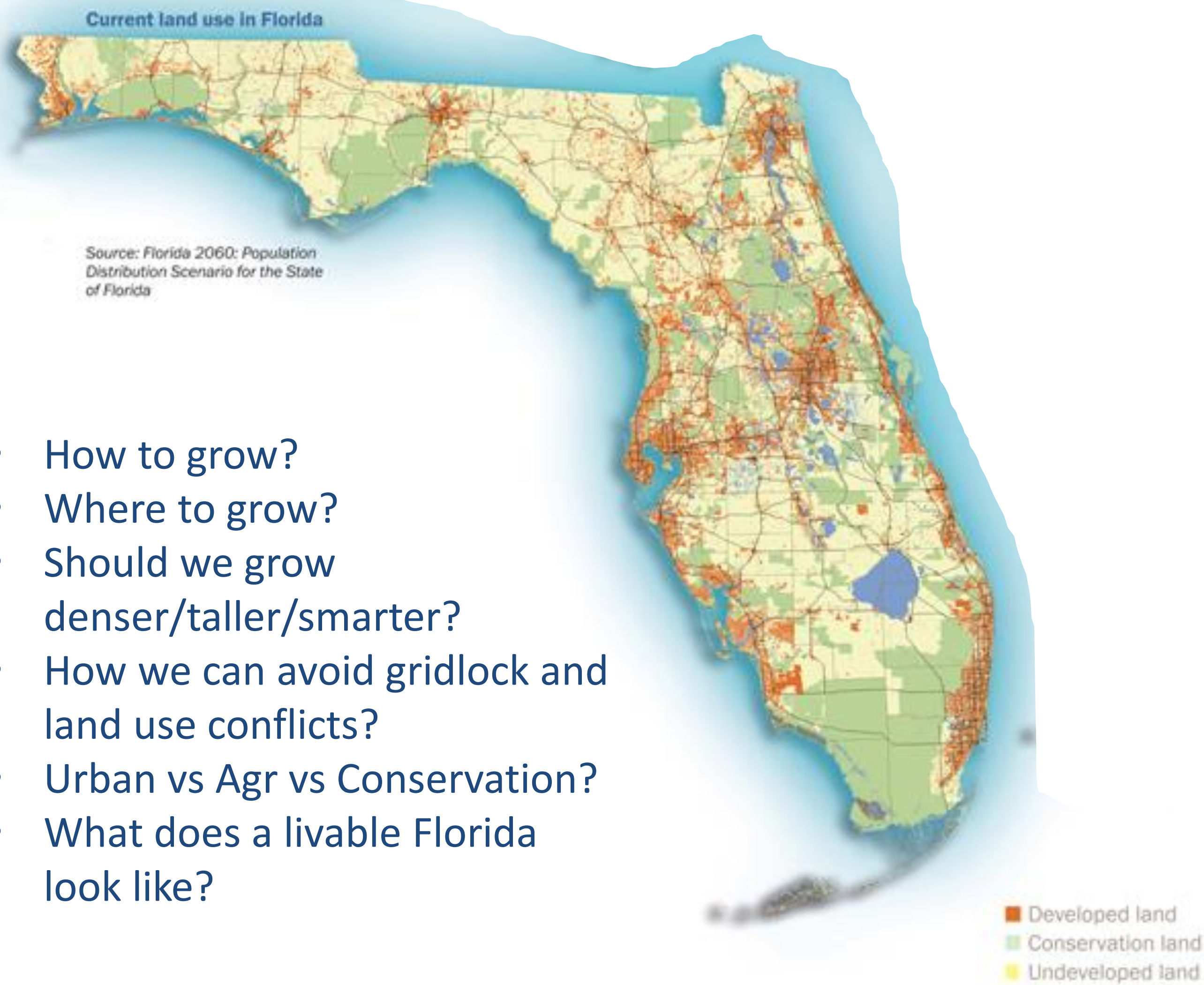
Florida: Between the devil (growth) and the deep blue sea (SLR)



Source: After (Florida 2060 Report http://www.1000friendsofflorida.org/connecting-people/florida-smart-growth-advocates-2/

- *Noss (2011) Climatic Change*
- *Harris and Cropper (1992)*
- *19.318 million* (July, 2012)
  - Within 200k of NY state (U.S. Census Bureau)
  - Within ≈ 3 years, Florida will be the third most populous state in the USA (CA, TX, FL)
- Florida has 3,660 km of tidal shoreline (Donoghue 2011),
- No point in the state is more than 120 km from the coast (CSO 2010)
- Fifteen of the state's major population centers and more than 75% of the population are in coastal counties, and 86% of the GDP is derived from the coastal economy (CSO 2010;Wilson and Fischetti 2010).

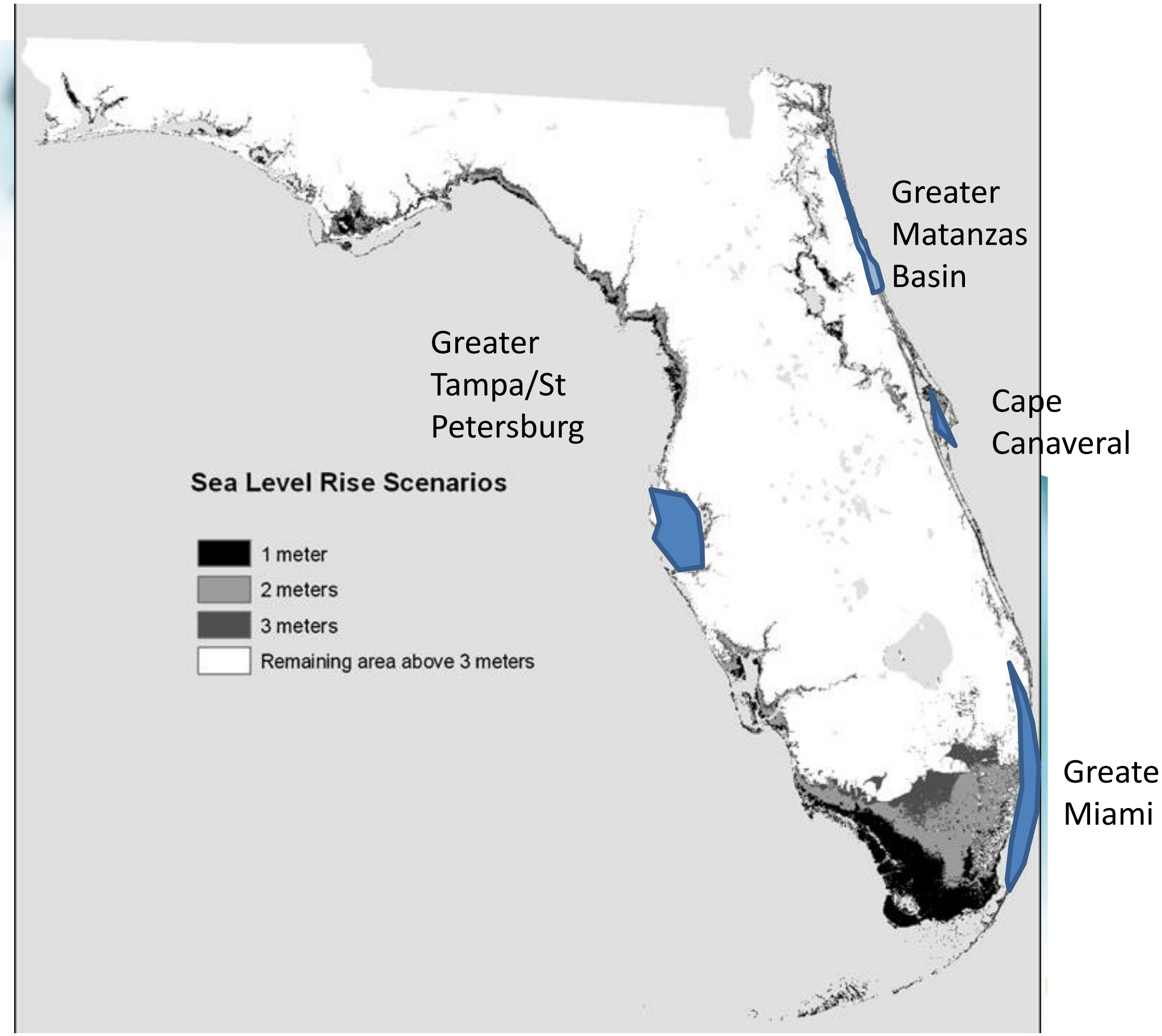
The devil we know: growth and development



- How to grow?
- Where to grow?
- Should we grow denser/taller/smarter?
- How we can avoid gridlock and land use conflicts?
- Urban vs Agr vs Conservation?
- What does a livable Florida look like?

Source: Florida 2060 Report http://www.1000friendsofflorida.org/connecting-people/florida-smart-growth-advocates-2/

…Devil… meet blue sea..



Source: Noss,R. Climatic Change (2011) 107:1–16

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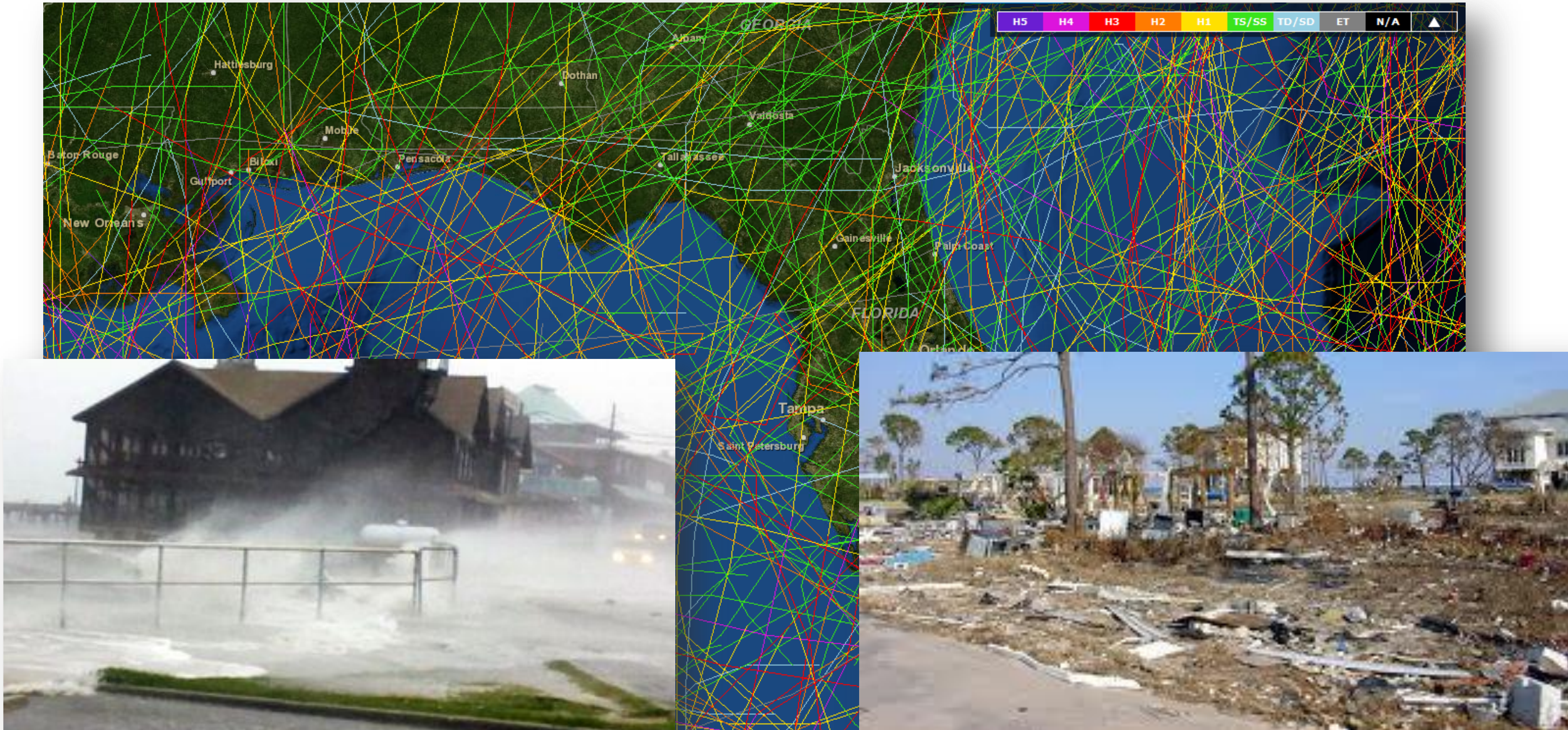
Because it’s not the heat or the humidity or the sea level rise that scares people… **It’s the storms…**



While hurricanes, tropical storms and tropical depressions are not exactly a surprise to most Gulf Coast Residents, the combination of storm surge and SLR is a rarely anticipated or addressed in planning

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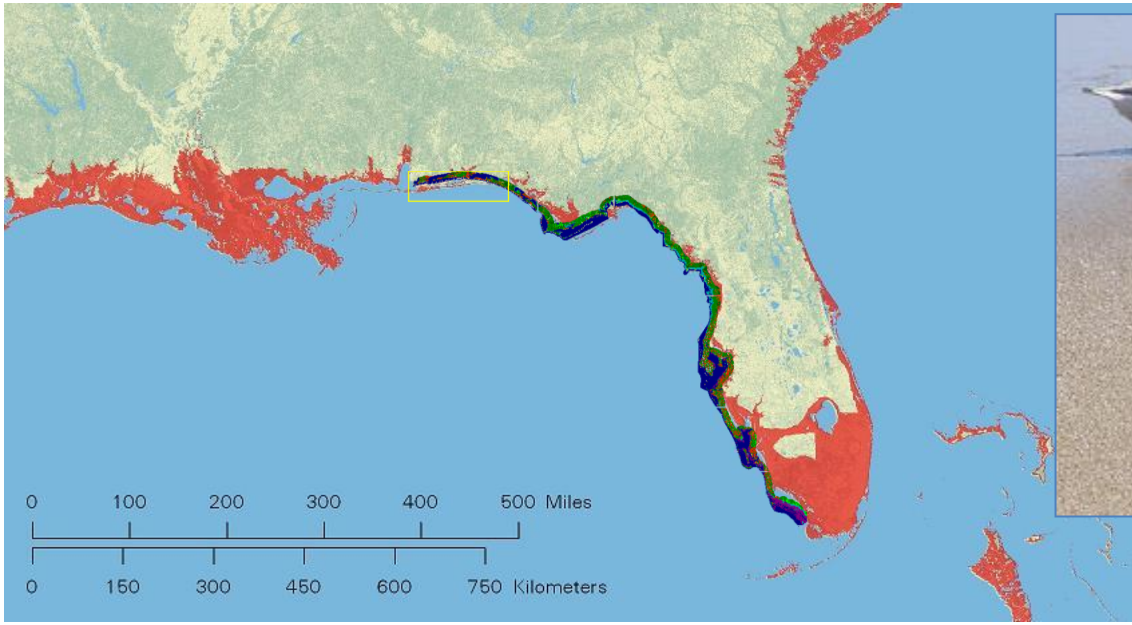
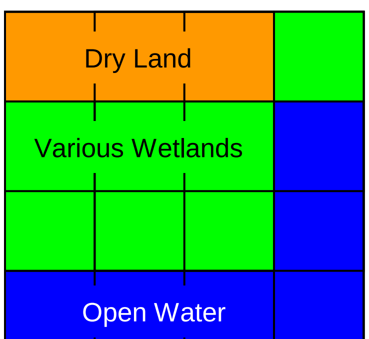
Strategic Environmental Research and Development Program (SERDP): Linking models to management outcomes - Florida Snowy Plover Populations and Sea Level Rise

(Partners: US Army Corps of Engineers, Univ of Florida, SUNY Stoney brook



Global Sensitivity/Uncertainty Analysis
Multi-Criteria Decision Analysis

Sea Level Affecting Marshes Model (SLAMM)



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MaxEnt – Species Distribution Model

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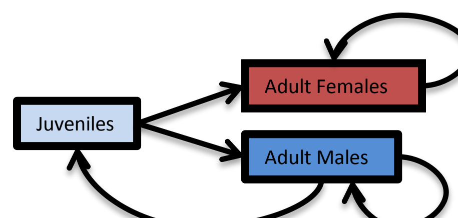
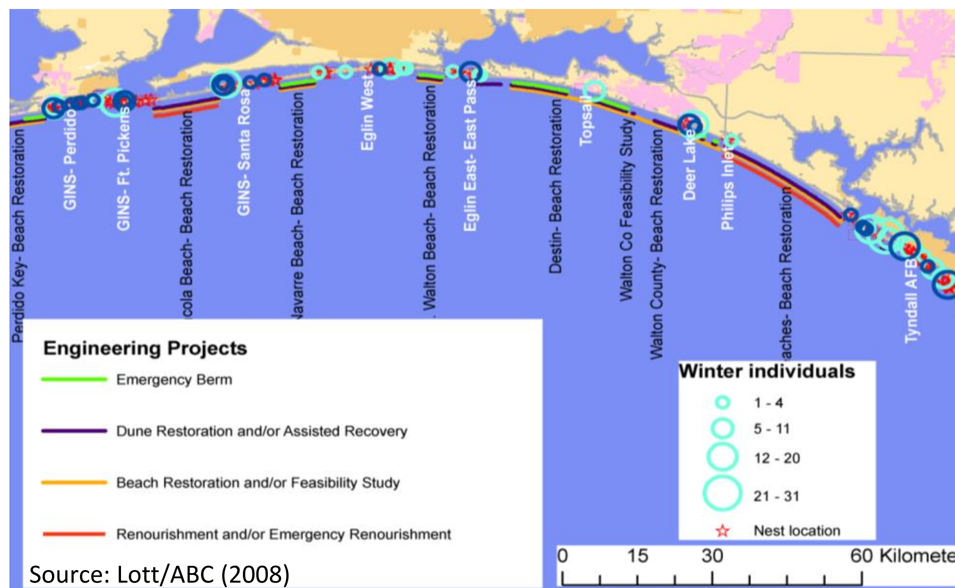
RAMAS MetaPopulation Model



Study Area: Eglin Air Force Base

Why are military areas important habitats?

- Important forage areas and nesting habitats for shoreline birds



Source: Lott/ABC (2008)

Focal Species - Snowy Plover (SNPL) *Charadrius alexandrinus* –

A beach-nesting and wintering species found year-round in FL

- **Status**

  State Threatened Species - FL Fish and Wildlife Conservation Commission

  "Extremely High Priority for Conservation" - US Shorebird Conservation Plan

  Potential Federal Candidate Species for Listing - USFWS

- **Importance of DoD Lands**

  Eglin AFB and Tyndall AFB, along with State Park and NPS shorelines accounted for 80% of all estimated nesting Snowy Plover pairs in the Florida Panhandle during recent statewide surveys.

- **Justification for Selection**
  - Species is easily surveyed; population data and estimates of population parameters are available.
  - SNPL is a good sentinel for detecting climate change effects on coastal habitats. Habitat changes are relatively easily detected and birds respond rapidly to these alterations.

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Additional Species of Interest

Piping Plover (PIPL) (*Charadrius melodus)*

- The Piping Plover (SNPL), is federally listed as 3 separate sub-populations
- Birds from all populations winter in high numbers on Florida's barrier islands during the non-breeding season
- DoD has high stewardship responsibility for this species

Red Knot (REKN) (*Calidris canutus)*

- Red Knots have declined dramatically during the past decade
- Species may be Federally listed in the near future
- This species "stops over" in Florida during spring and fall migration at various locations along the Atlantic and Gulf Coasts

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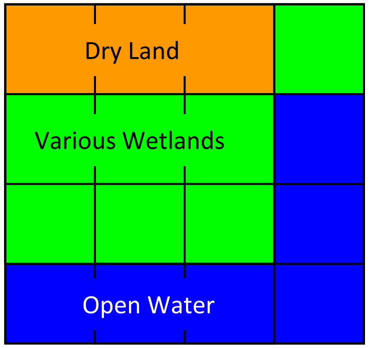
Linking ecological models to management outcomes - Florida Snowy Plover Populations and Sea Level Rise

Models, Global Sensitivity/Uncertainty Analysis & Multi-Criteria Decision Analysis

Sea Level Affecting Marshes Model (SLAMM)



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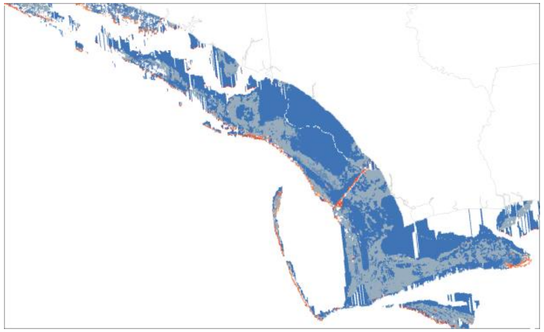
MaxEnt – Species Distribution Model



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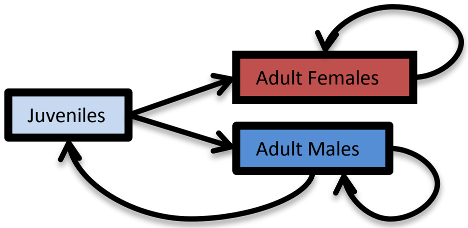
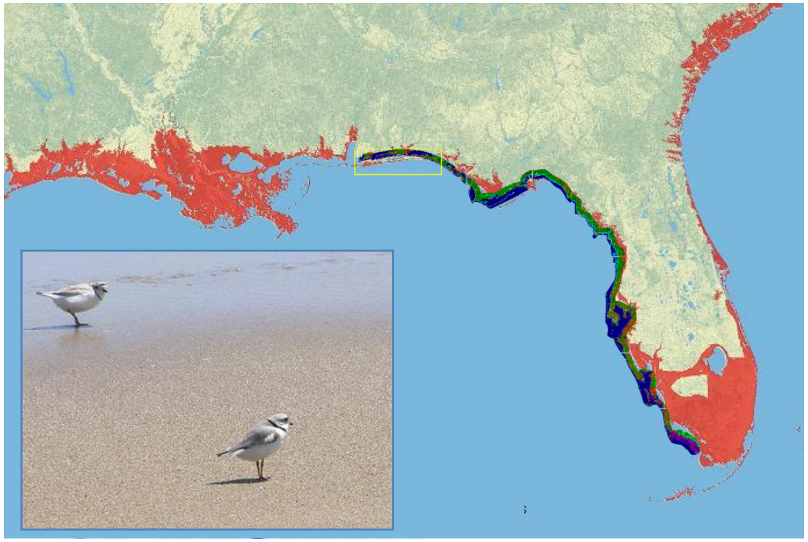
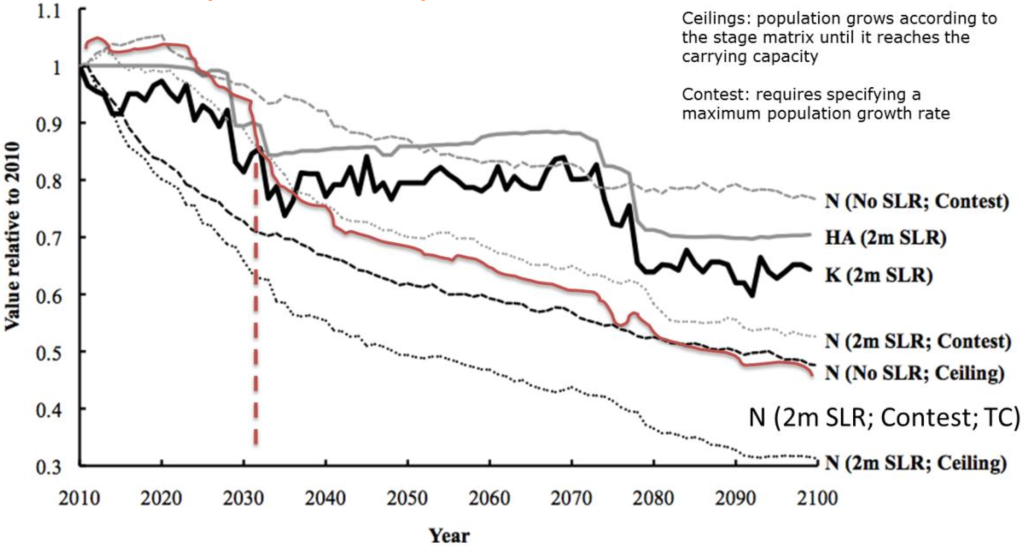
RAMAS MetaPopulation Model



Pensacola to Naples - 120m grid resolution

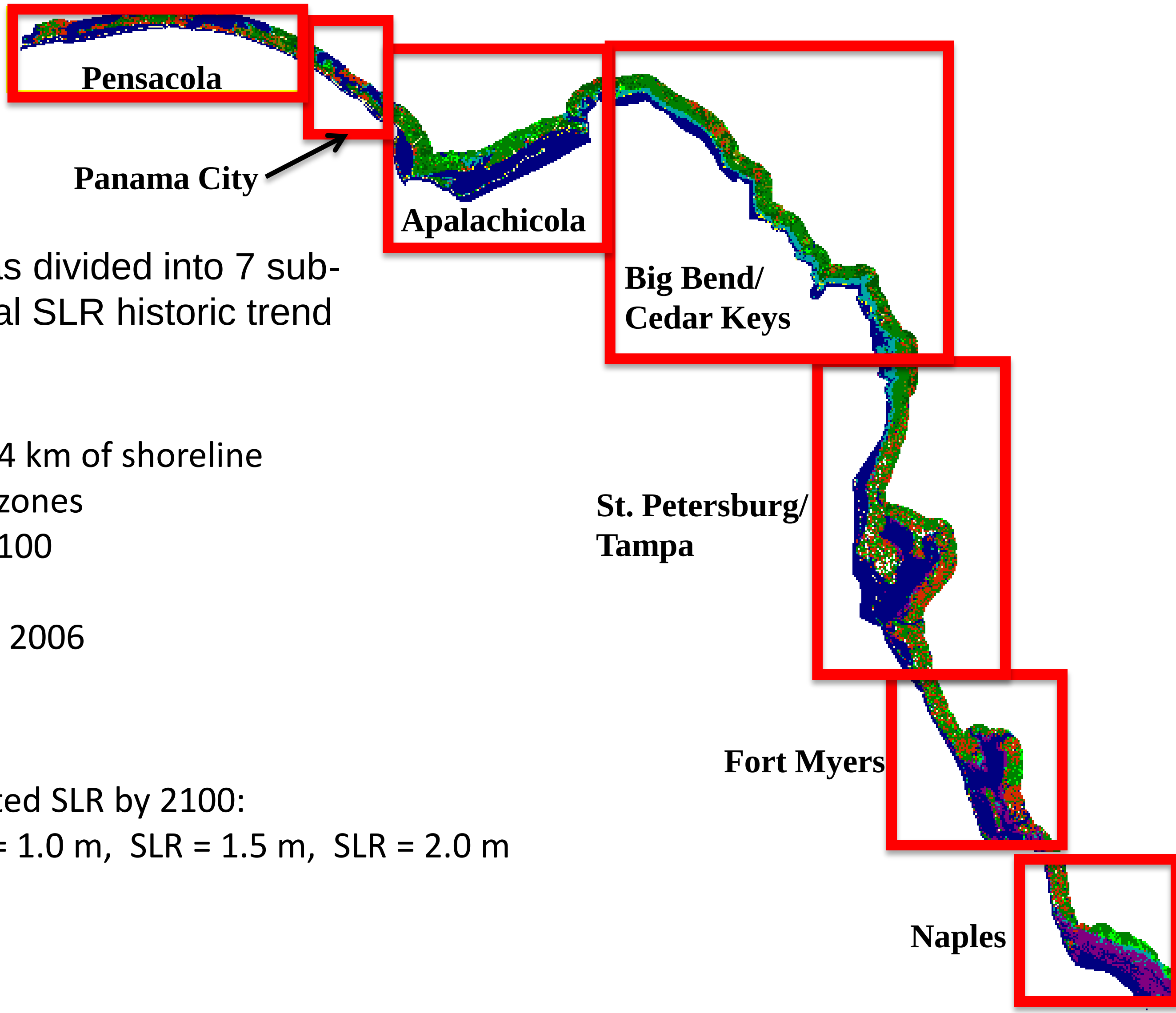


Snowy Plover Population Scenarios



[Aiello-Lammens et al., 2011, Global Change Biology]

Florida-Scale SLAMM v6 Simulations

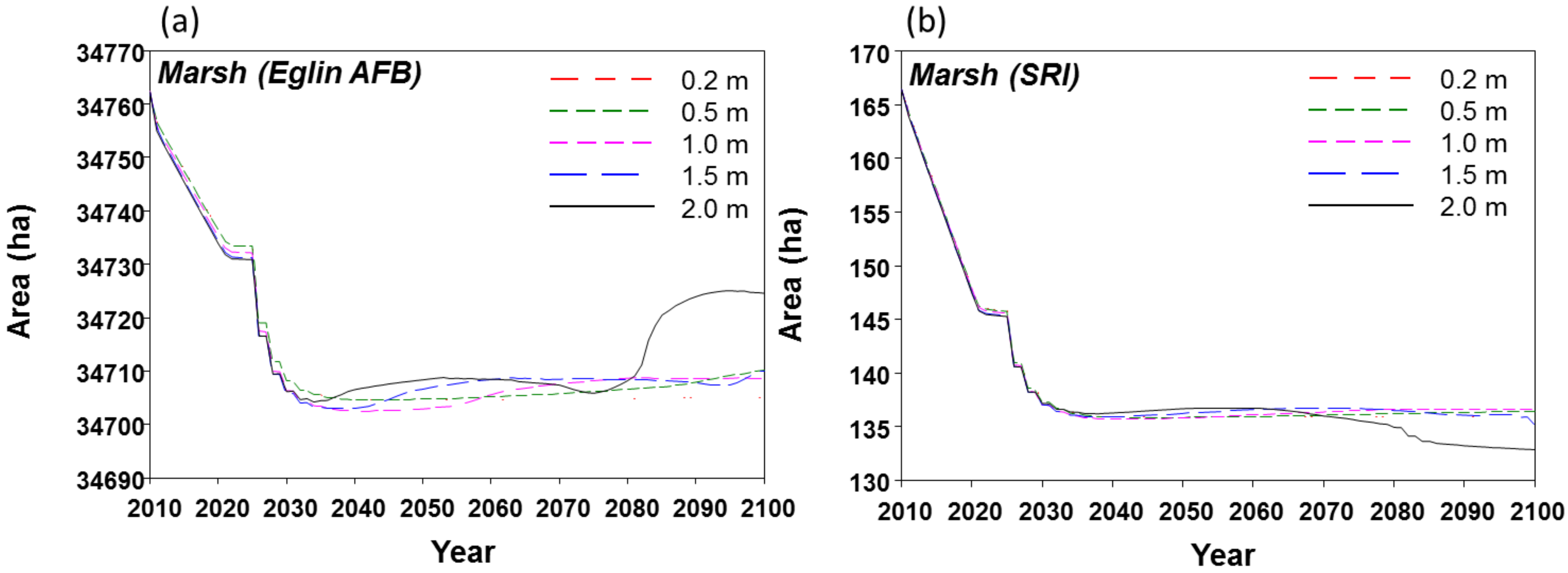


The Gulf coast of Florida was divided into 7 sub-sites based on available local SLR historic trend measurements

- Eglin AFB was simulated as 74 km of shoreline
- 10-km distance inland on all zones
- Simulation period: 2010 to 2100
- Time step: 10 years
- Land Cover map used: NOAA 2006
- DEM map used: USGS 2003
- Resolution: 120x120 m

Change in land cover at projected SLR by 2100:
SLR = 0.2 m, SLR = 0.5 m, SLR = 1.0 m, SLR = 1.5 m, SLR = 2.0 m

Habitat Change: Eglin Base vs its Barrier Island (SRI)



Chu_Agor, M.L., Muñoz-Carpena, R., Kiker, G.A., Aiello-Lammens, M., Akçakaya,R.,Convertino, M. and Linkov, I. 2012. Simulating the fate of Florida Snowy Plovers with sea-level rise: exploring potential population management outcomes with a global uncertainty and sensitivity analysis perspective. Ecological Modelling v224(1): 33–47.

Chu-Agor, M.L. , R. Muñoz-Carpena, G. Kiker, A. Emanuelsson and I. Linkov. 2011. Exploring sea level rise vulnerability of coastal habitats through global sensitivity and uncertainty analysis. *Env. Model. & Software* 26:593-604.

SERDP Fact Sheet and Final Report - http://www.serdp.org/Program-Areas/Resource-Conservation-and-Climate-Change/Natural-Resources/Coastal-and-Estuarine-Ecology-and-Management/RC-1699

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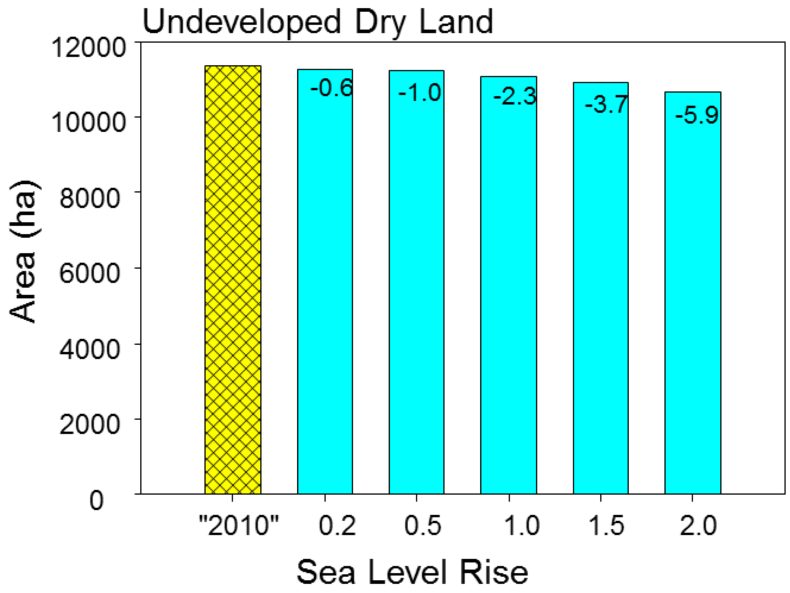
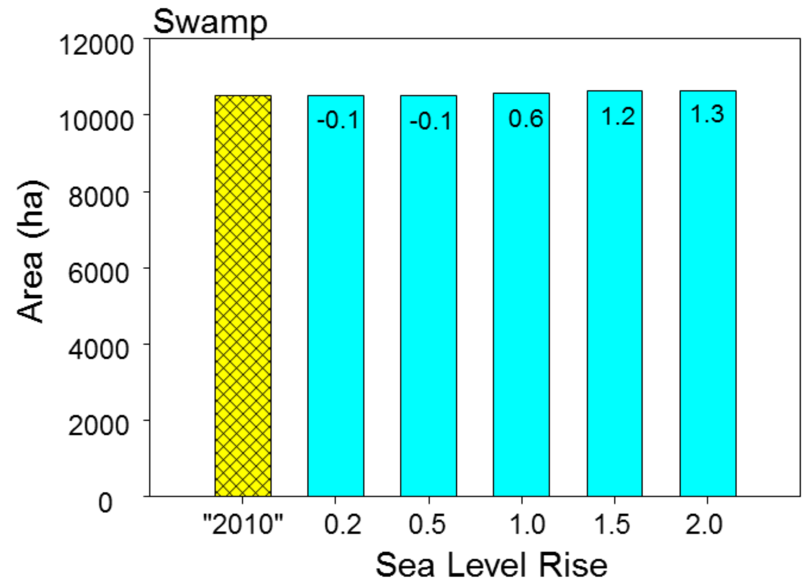
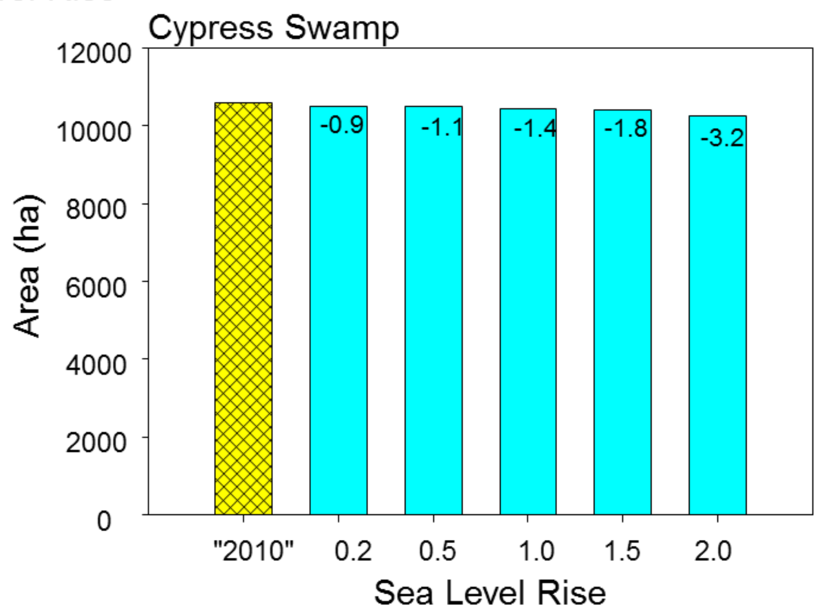
Local Scale: Eglin AFB Habitat Changes

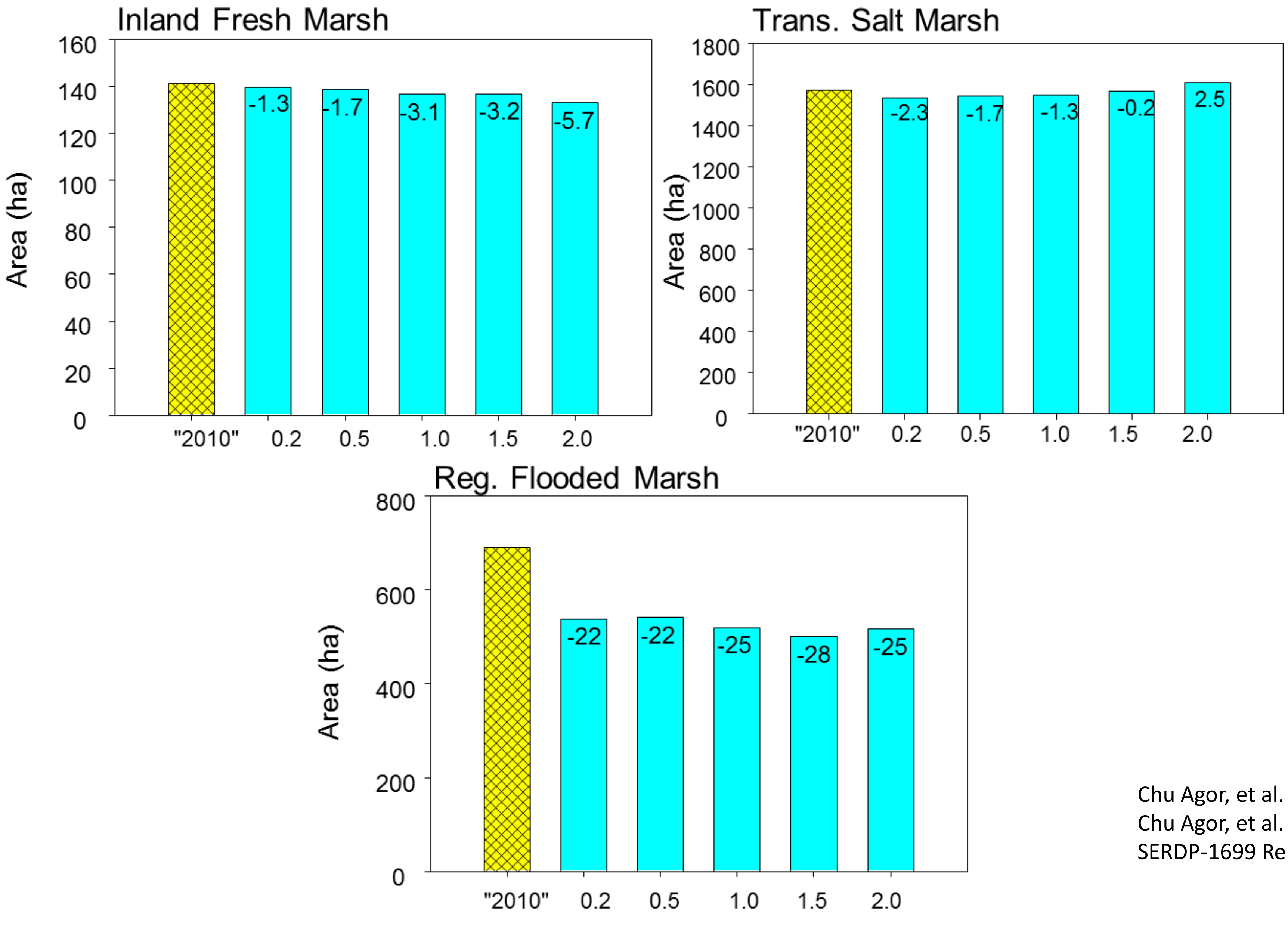






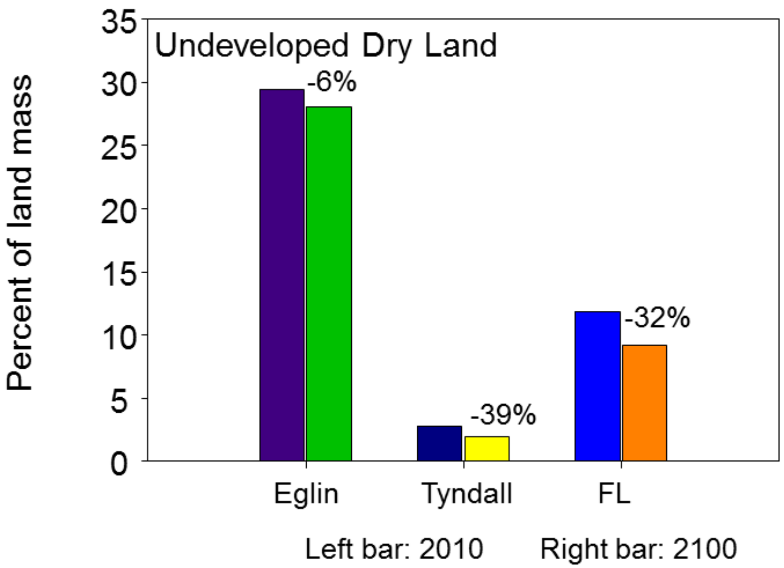
Chu Agor, et al. (2011)
Chu Agor, et al. (2012)
SERDP-1699 Report

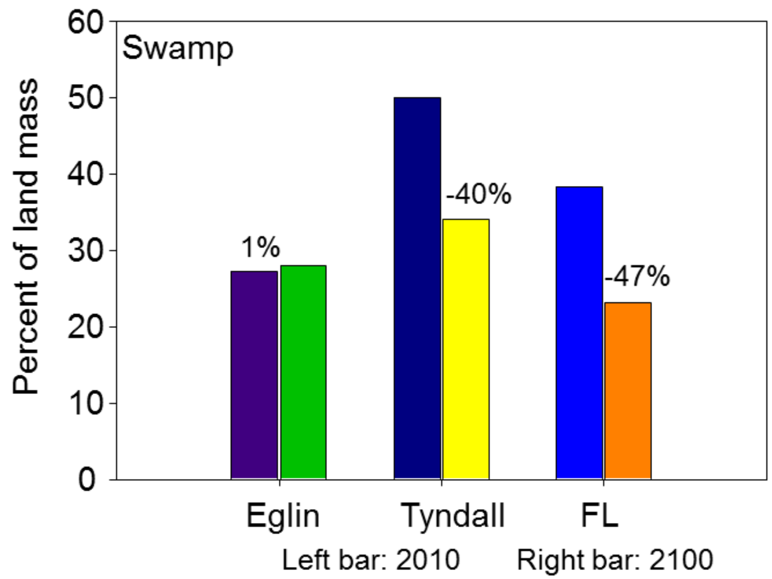
Local Scale: Eglin AFB Habitat Changes

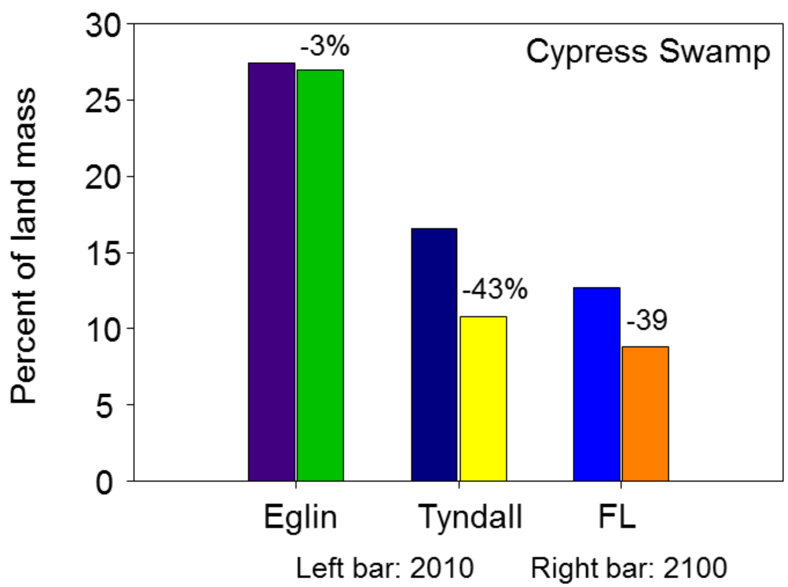


Chu Agor, et al. (2011)
Chu Agor, et al. (2012)
SERDP-1699 Report

Florida Gulf Coast Scale:
Land Cover Change: Eglin vs Tyndall vs Gulf Coast Florida







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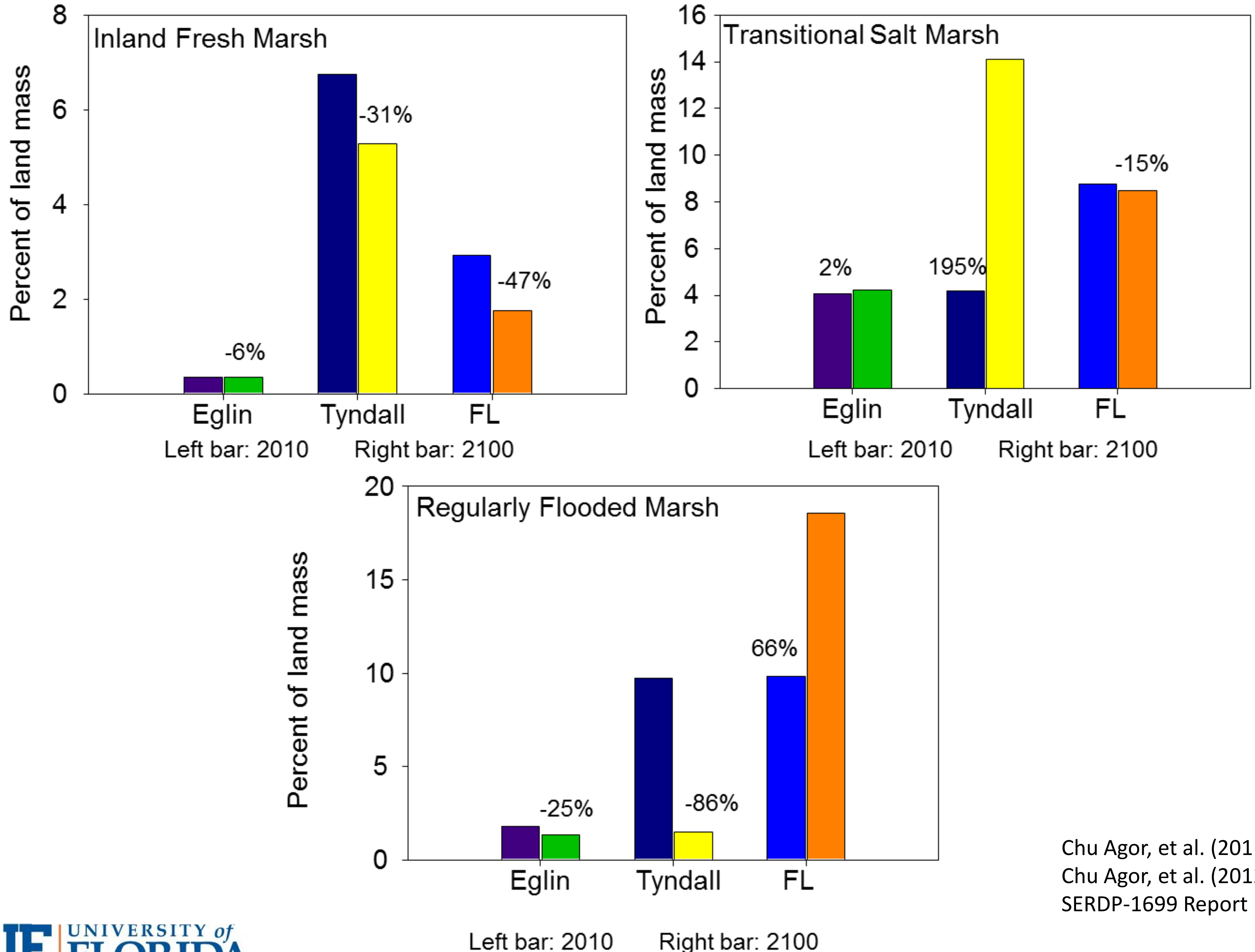

Chu Agor, et al. (2011)
Chu Agor, et al. (2012)
SERDP-1699 Report

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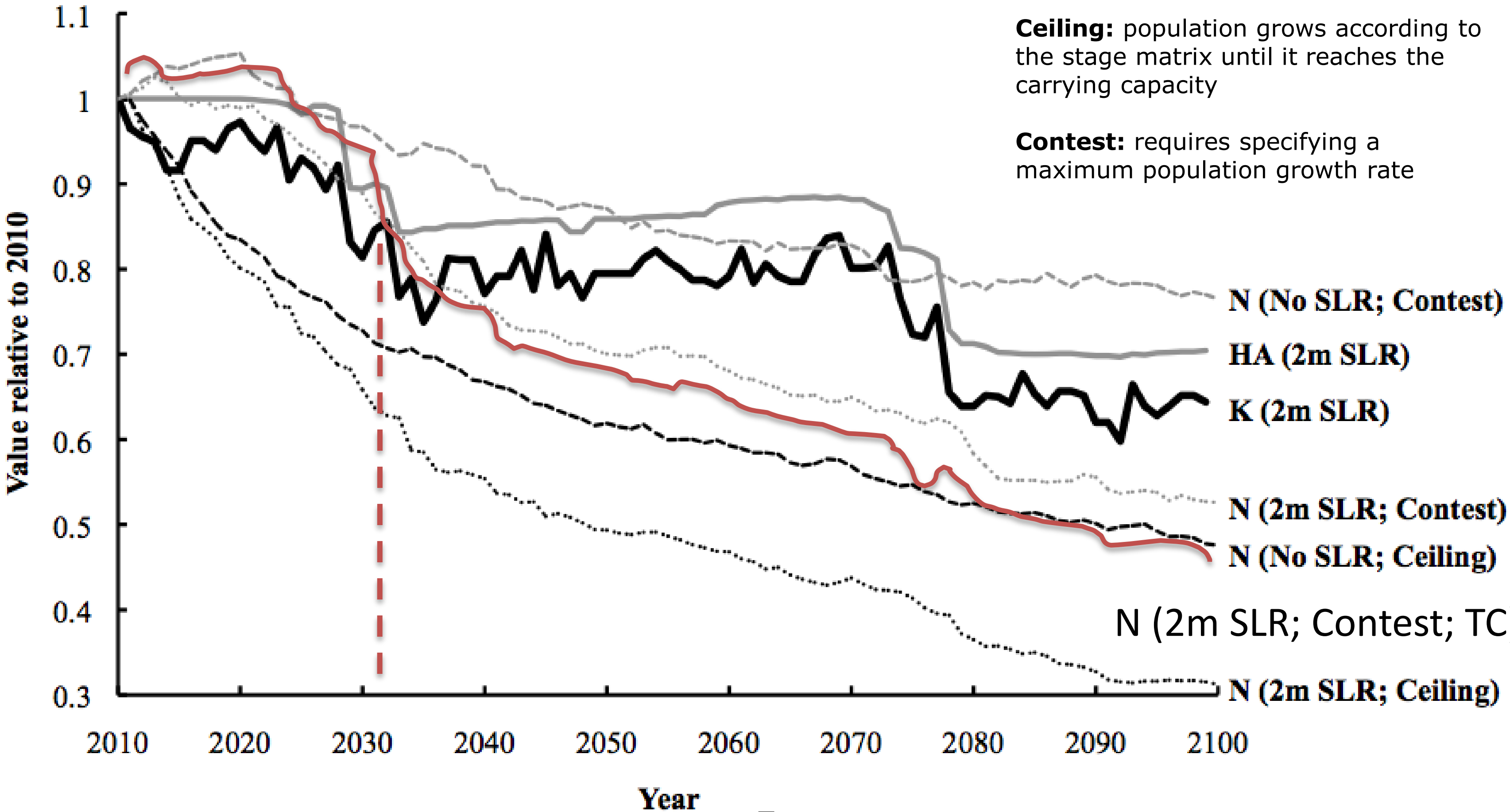
Snowy Plover Populations in many futures…



Ceiling: population grows according to the stage matrix until it reaches the carrying capacity

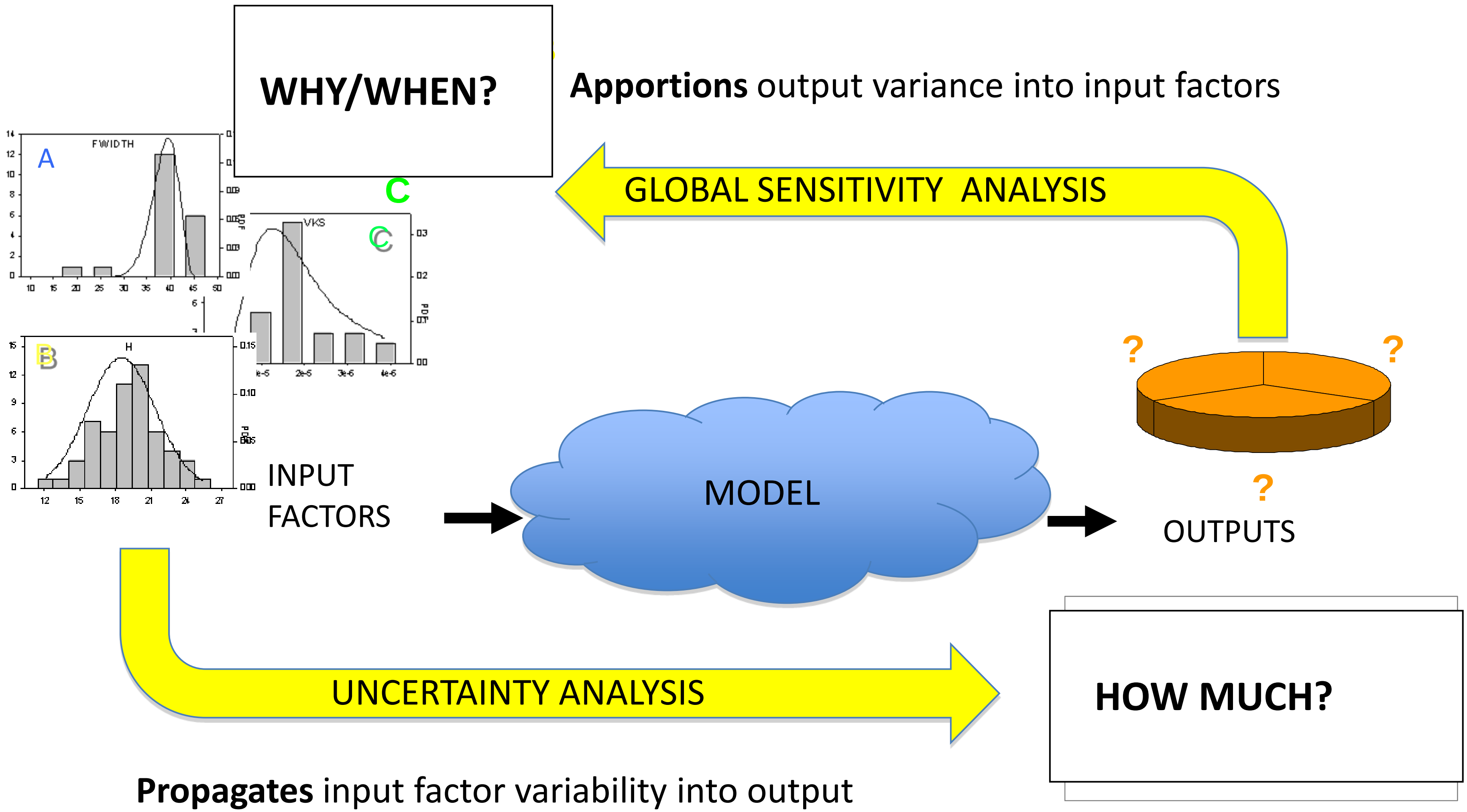
Contest: requires specifying a maximum population growth rate

Mean over 10^5 trajectories

Aiello-Lammens et al., 2011, Global Change Biology

Convertino et al., 2011, in ``Global Change and Local Adaptation'', Springer

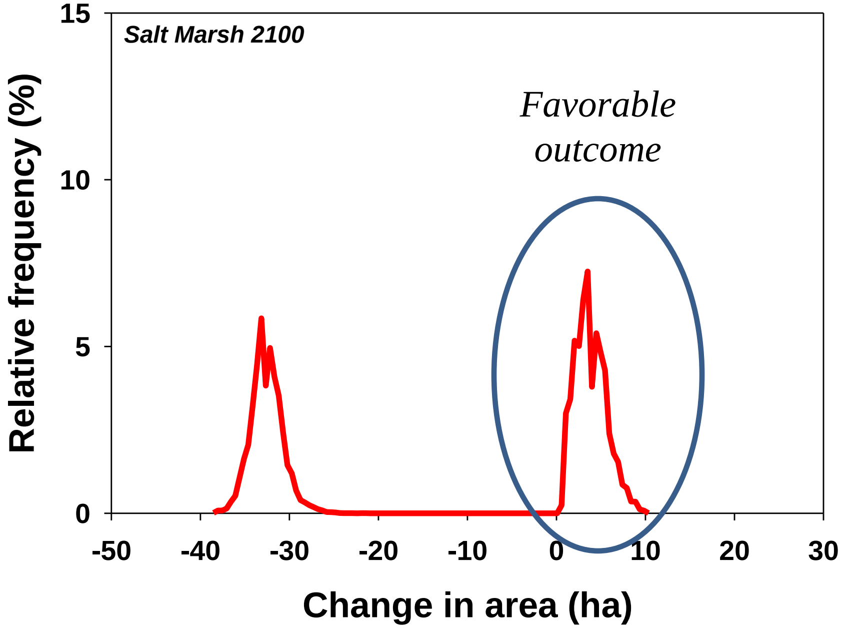
Global Sensitivity/Uncertainty Analysis



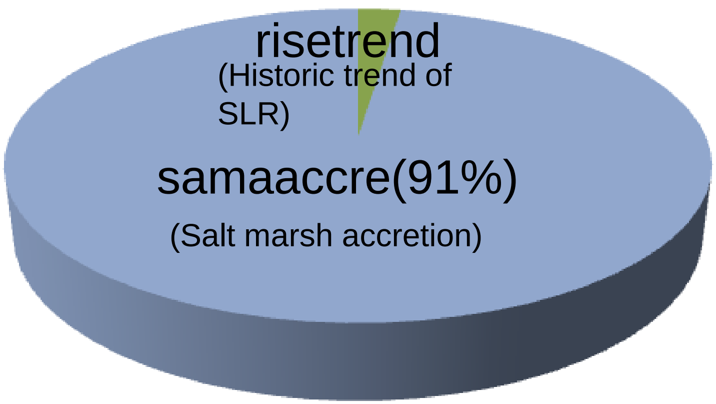
Linking GSA/UA to management outcomes in RAMAS: Snowy Plover Habitat

Change in Area of Salt Marsh

Results of Uncertainty analysis (1 m SLR)



Sensitivity analysis shows results are being driven by two inputs

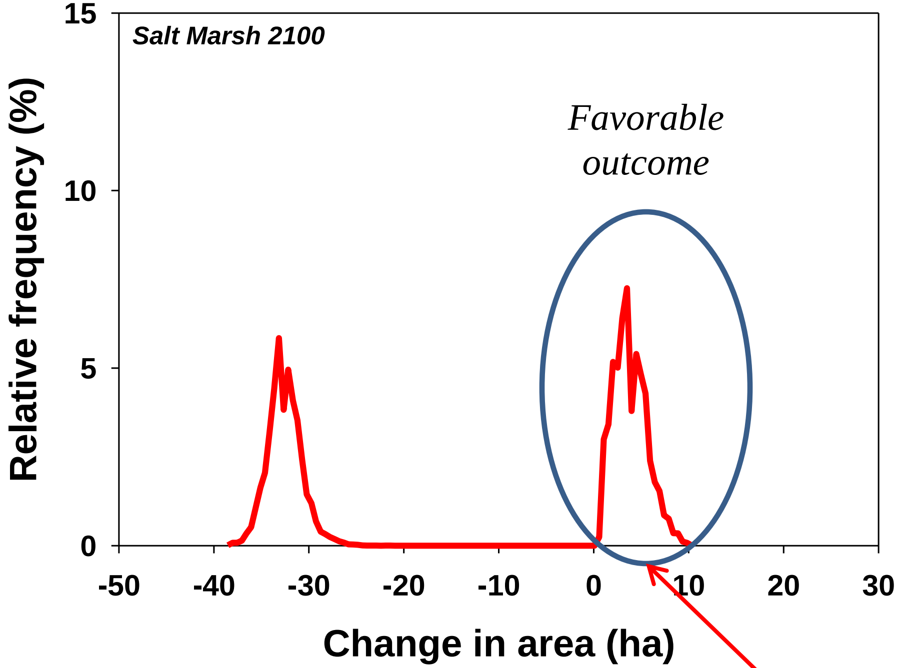


What model input values created the favorable outcome?

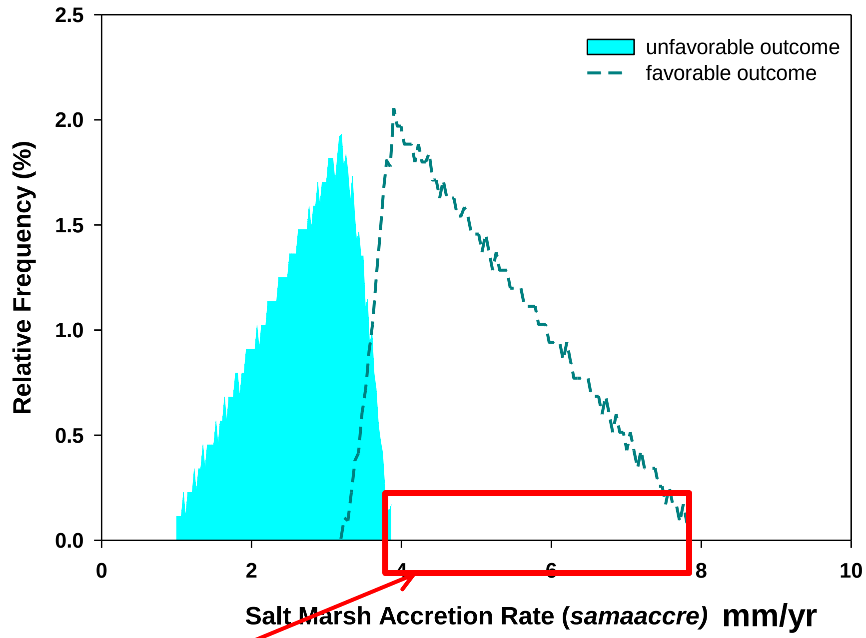
Chu-Agor, M.L. , R. Muñoz-Carpena, G. Kiker, A. Emanuelsson and I. Linkov. 2011. Exploring sea level rise vulnerability of coastal habitats through global sensitivity and uncertainty analysis. *Env. Model. & Software* 26:593-604.

Linking GSA/UA to management outcomes: Snowy Plover Habitat

Output: Area of Salt Marsh



Range of Input: samaaccre (91%)



These model input values (accretion rates in the red box) created the favorable management outcome

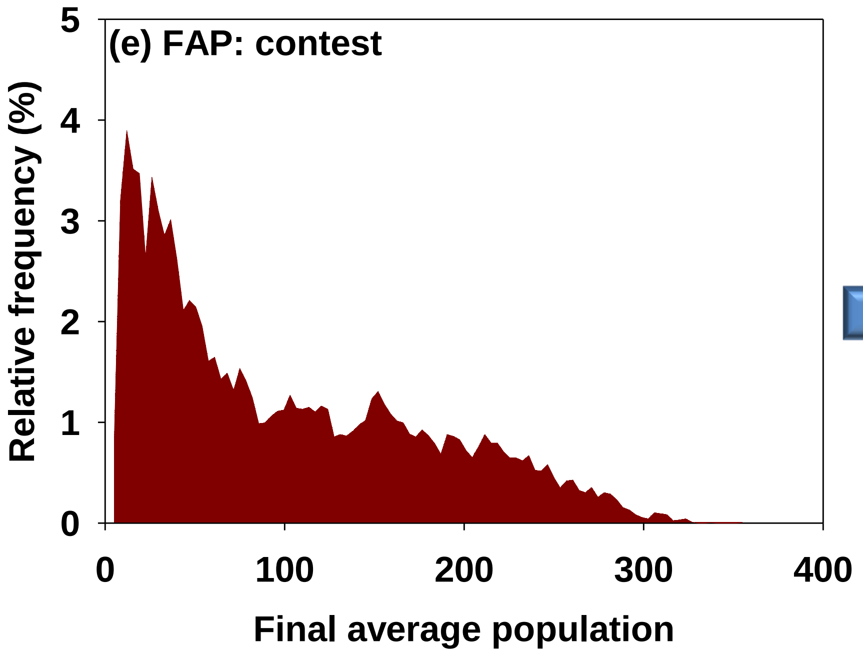
Chu_Agor, M.L., Muñoz-Carpena, R., Kiker, G.A., Aiello-Lammens, M., Akçakaya,R.,Convertino, M. and Linkov, I. 2012. Simulating the fate of Florida Snowy Plovers with sea-level rise: exploring potential population management outcomes with a global uncertainty and sensitivity analysis perspective. Ecological Modelling v224(1): 33–47.

Linking GSA/UA to management outcomes: Snowy Plover Population

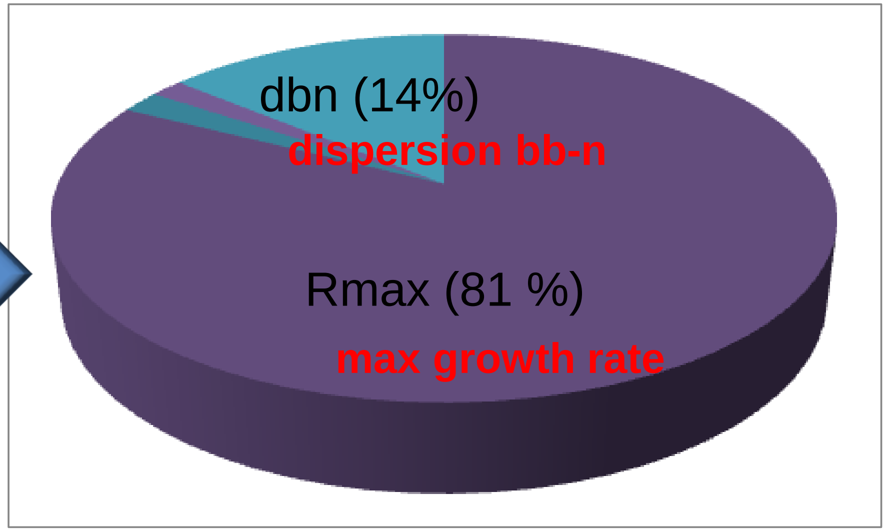
Final Average Population

Contest-type DD

Uncertainty analysis



Sensitivity analysis



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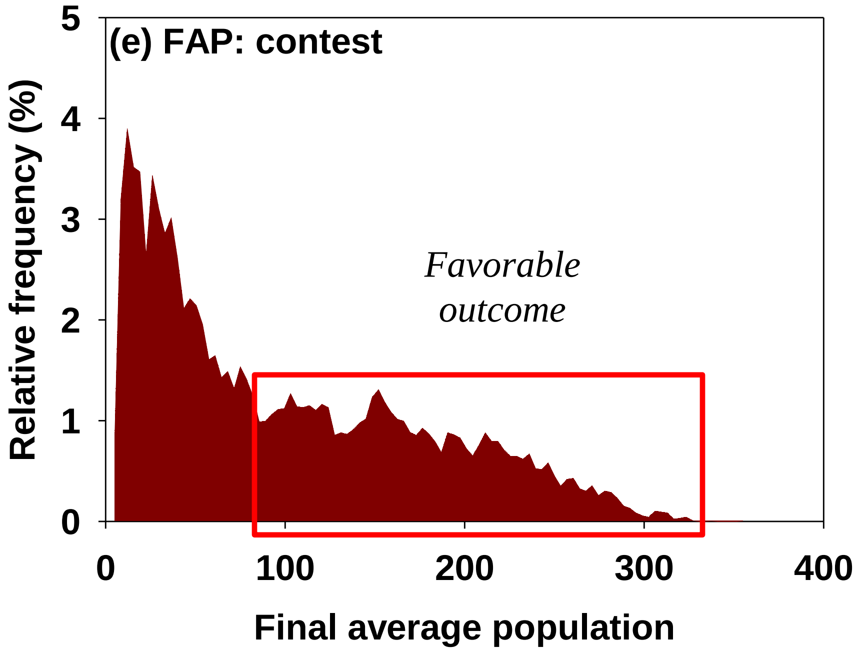
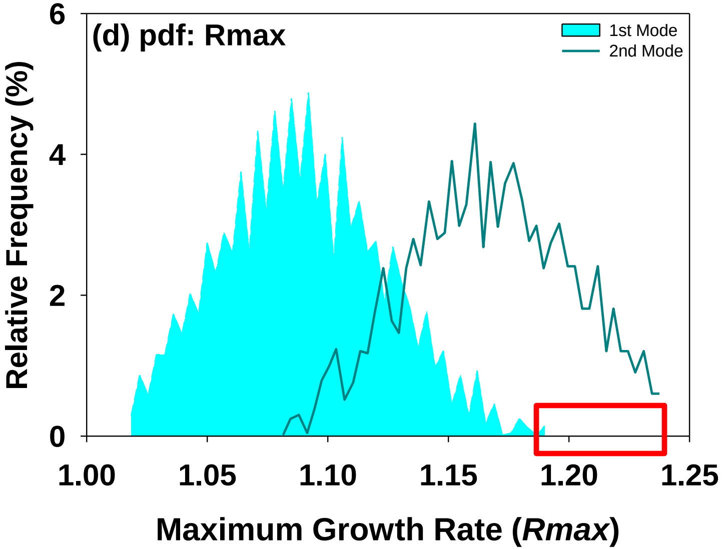
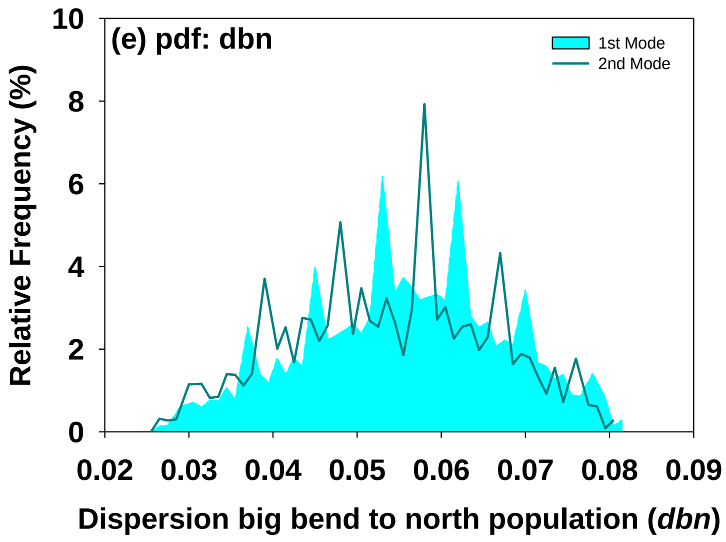
Linking GSA/UA to management outcomes: Snowy Plover Population

Output: Final Average Population



Ranges of Inputs





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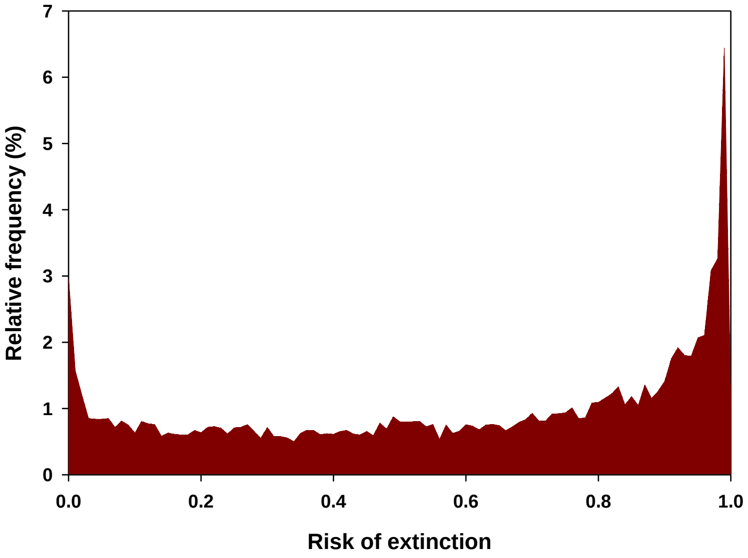
Linking GSA/UA to management outcomes: Snowy Plover Risk of Extinction

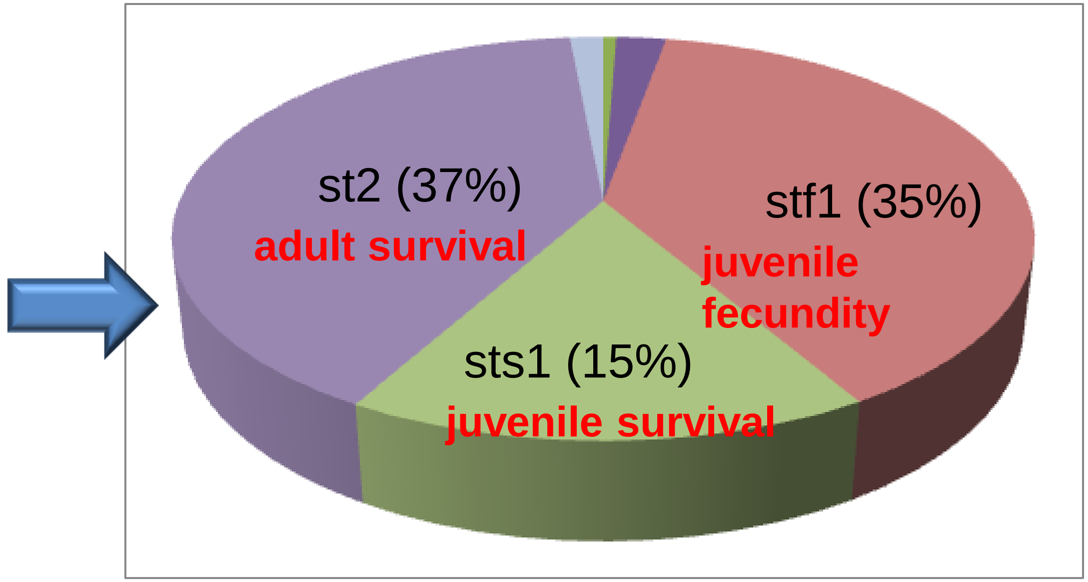
Risk of Extinction

Ceiling-type DD

Uncertainty analysis



Sensitivity analysis



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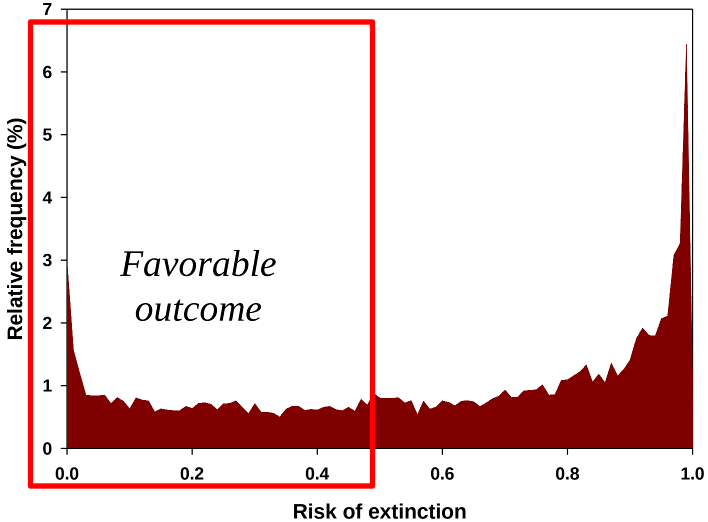
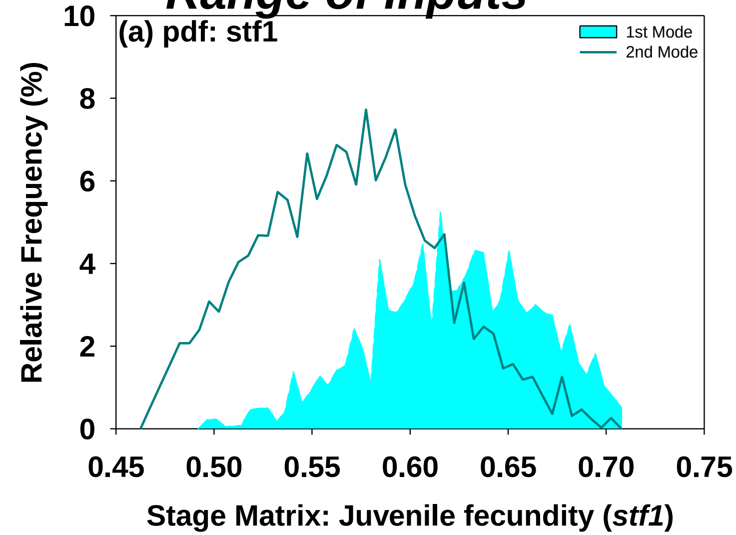
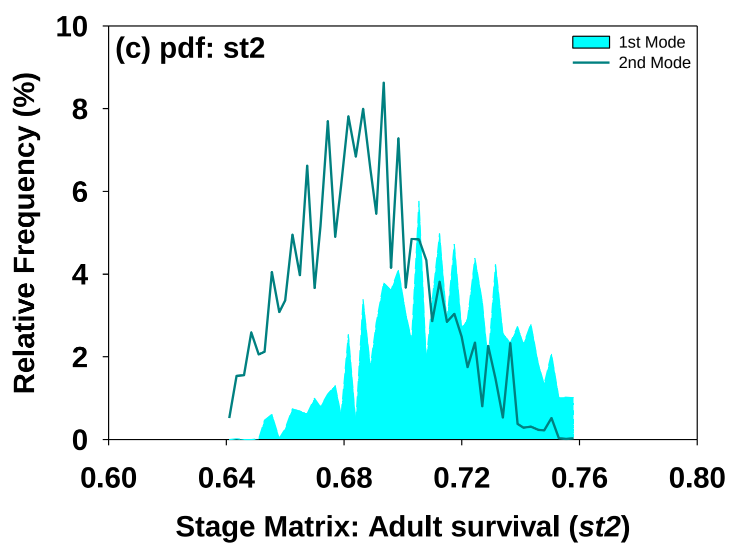
Linking GSA/UA to management outcomes: Snowy Plover Risk of Extinction

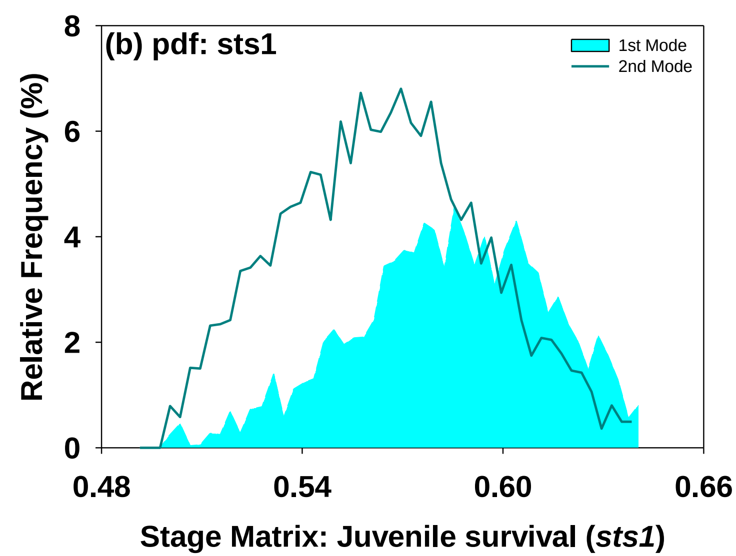
Output: Risk of Extinction



Range of Inputs







SLAMM Simulations for Coastal Management

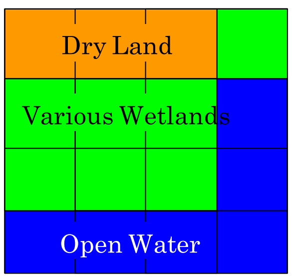
- SLAMM model alterations to allow coastal management inputs from users
- Extreme erosion events from storms
- Beach nourishment

Chu, M.L., Guzman, J.A., Muñoz-Carpena, R., Kiker, G.A. and Linkov, I. 2014. A simplified approach for simulating changes in beach habitat due to the combined effects of long-term sea level rise, storm erosion, and nourishment. *Env. Model. & Software* 52: 111-120.

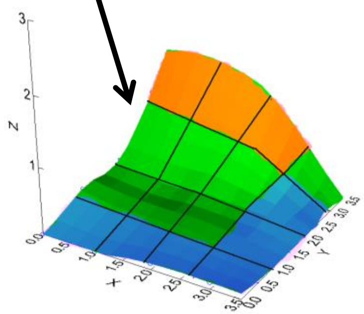
Vulnerability of beach habitat due to long-term sea level rise, storm erosion, and nourishment

[Chu-Agor, Guzman, Muñoz-Carpena, Kiker, Linkov. 2013. *Env. Mod and Soft.]*

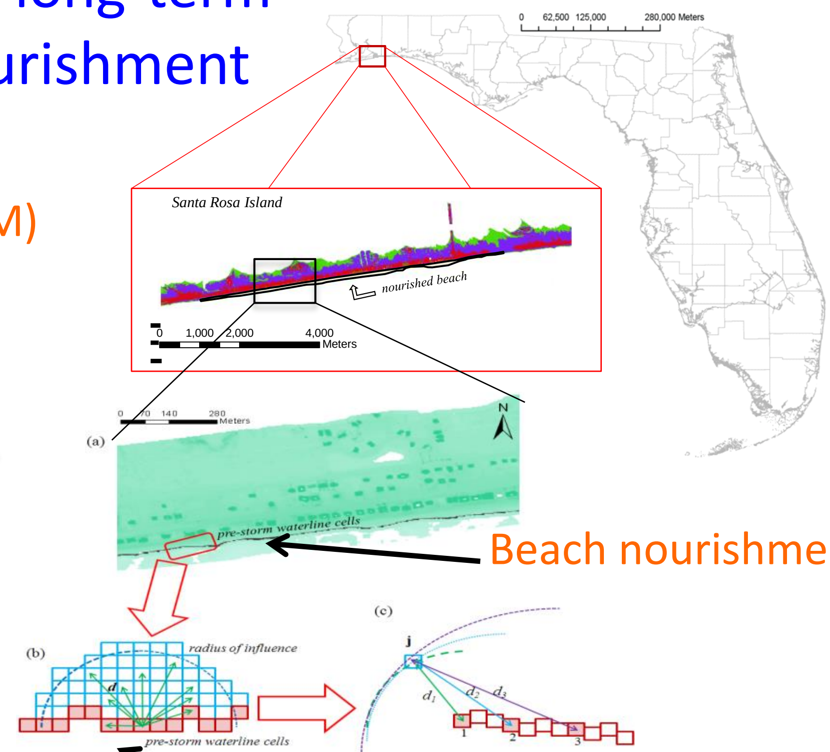
Habitat succession with Sea Level Rise (SLAMM)



2D representation



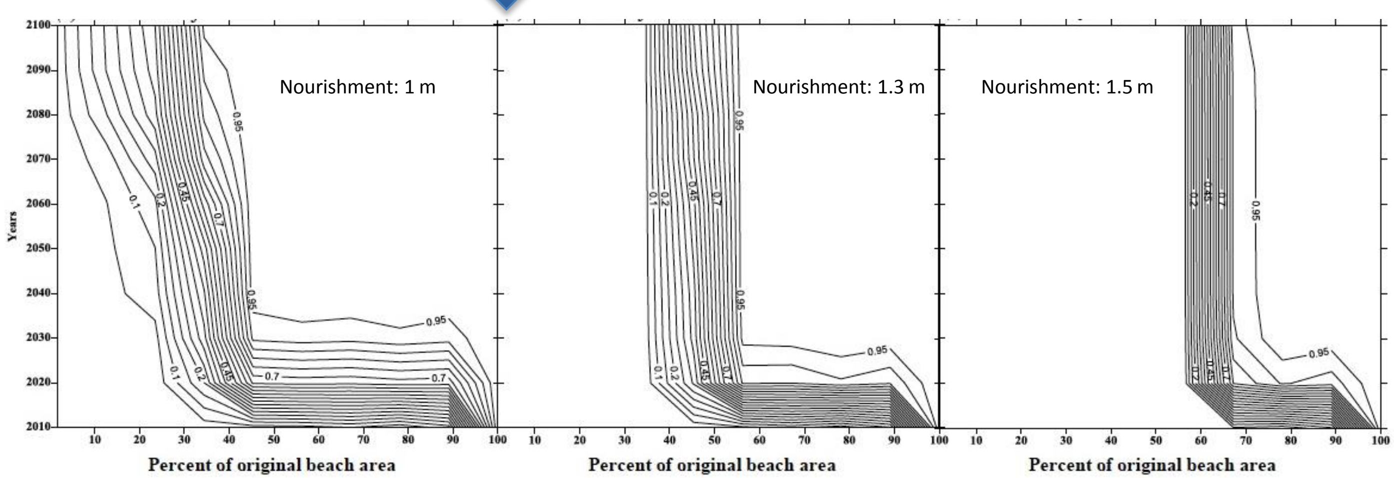
3D representation



Beach nourishment

Major storm effects of beach

Time contours of beach loss based on risk tolerance (SLR, storms & nourishment)



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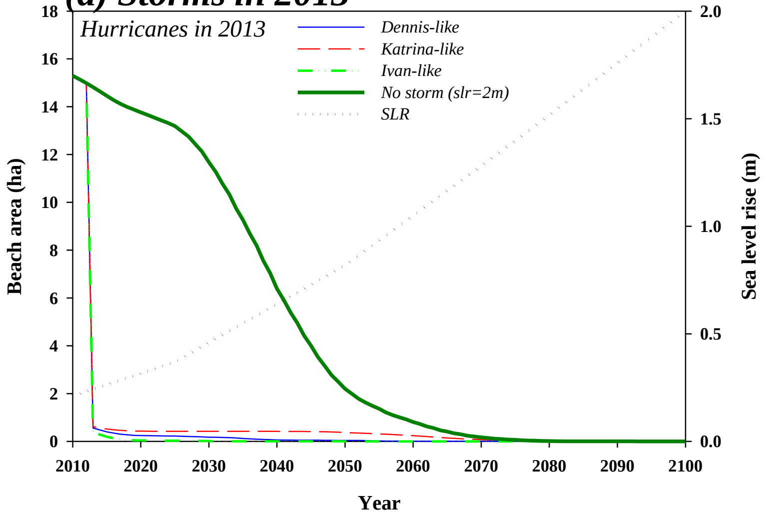
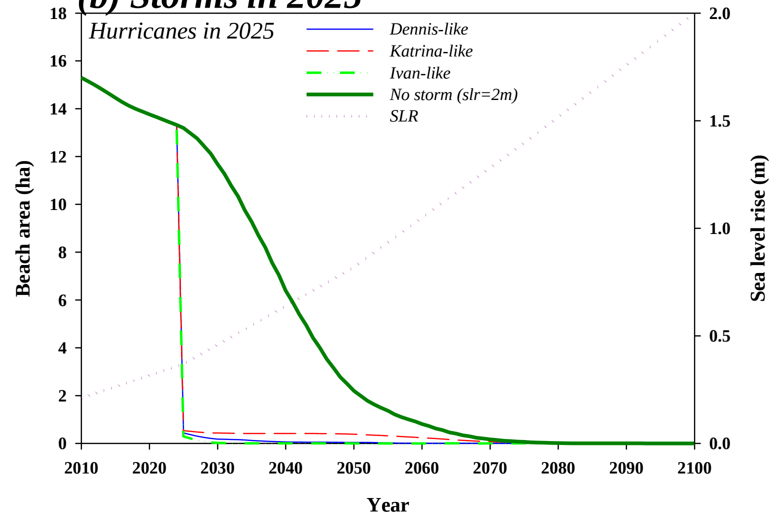
Individual Storms: immediate effects

(*without* re-nourishment)

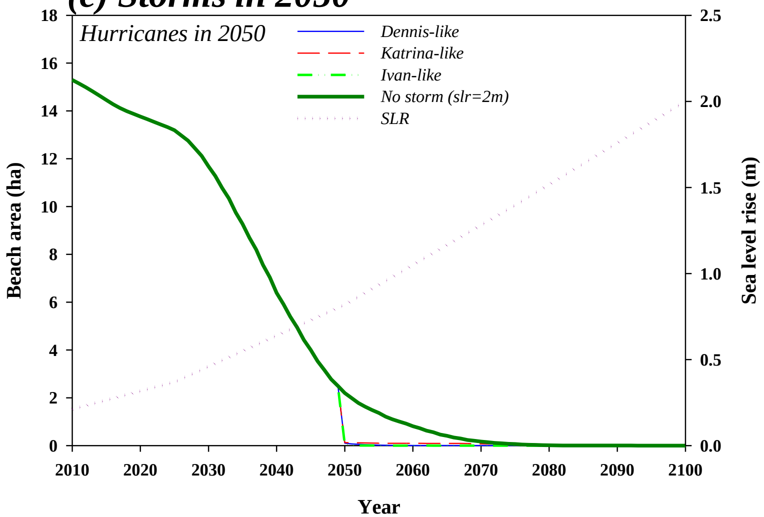
(a) Storms in 2013



(b) Storms in 2025



(c) Storms in 2050



Loss in area after the storm = 97-100%

Over time effects of the same storm are worse due to SLR

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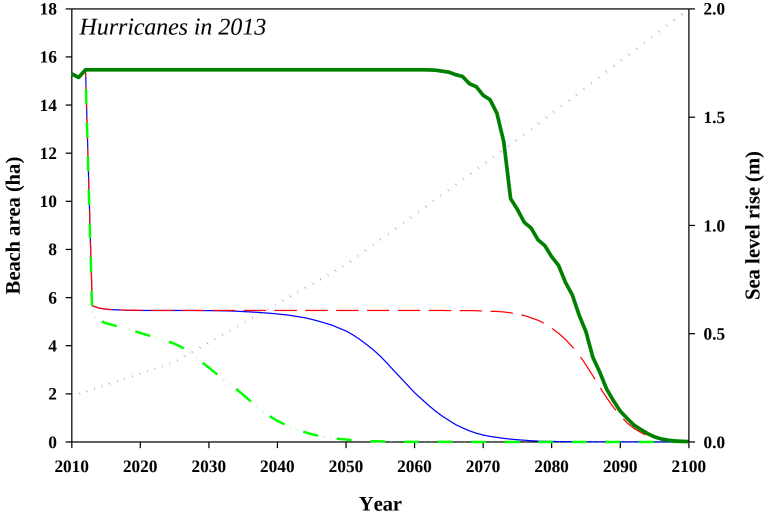
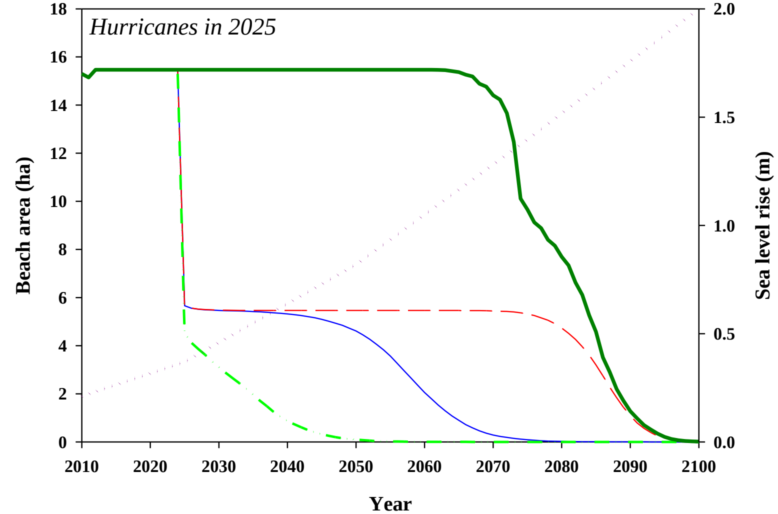
Individual Storms: immediate effects

(with re-nourishment in 2012)

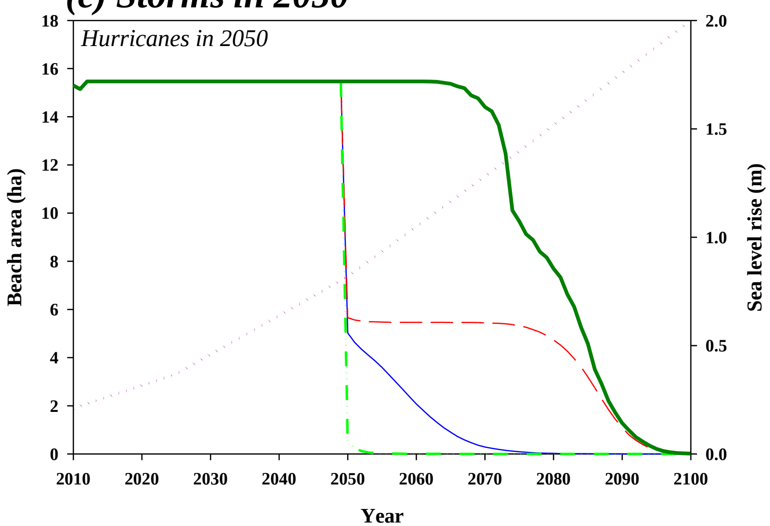
(a) Storms in 2013

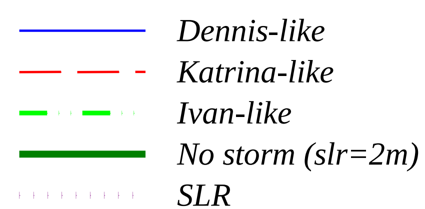


(b) Storms in 2025



(c) Storms in 2050



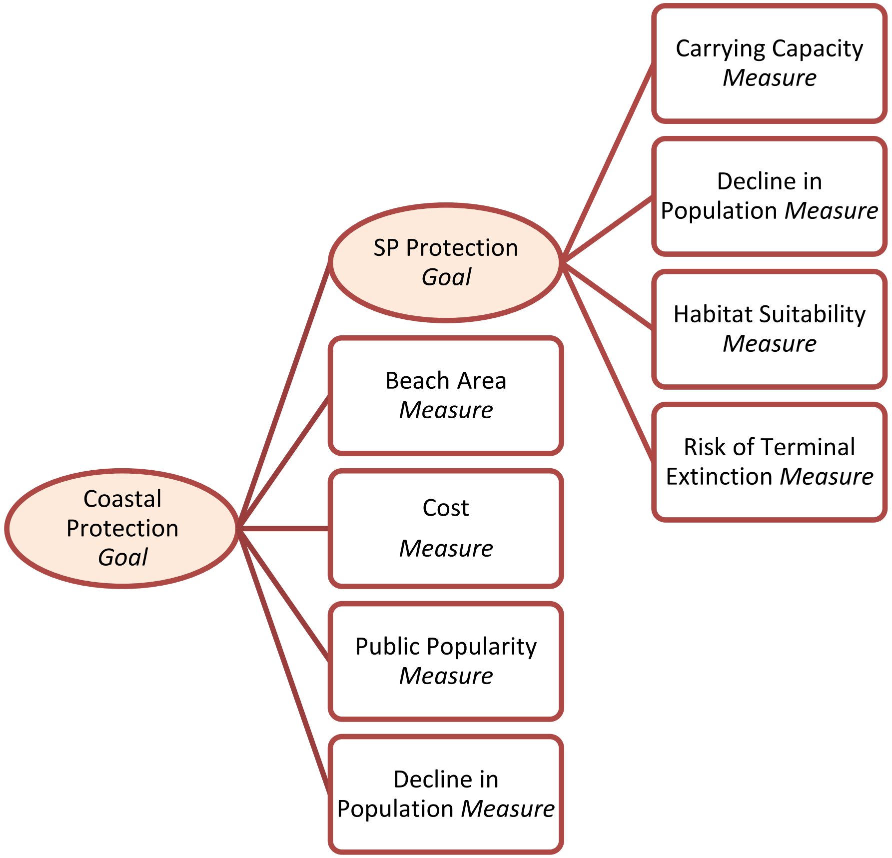


- *Loss in area after storm = 60%*
- *Length of time the remaining 40% stays depends on storm category*

Translating Integrated modeling results into Decision Information

Incorporates:

- Scenarios
  - 1m and 2m SLR by 2100
  - Ceiling and contest density dependence
- Management alternatives
  - No action
  - Species focused beach nourishment ($38m/yr)
  - Predator management ($1.8m/yr)
  - Predator exclosures ($1.8m/yr)
- Measures
- Levels of risk
- Uncertainty

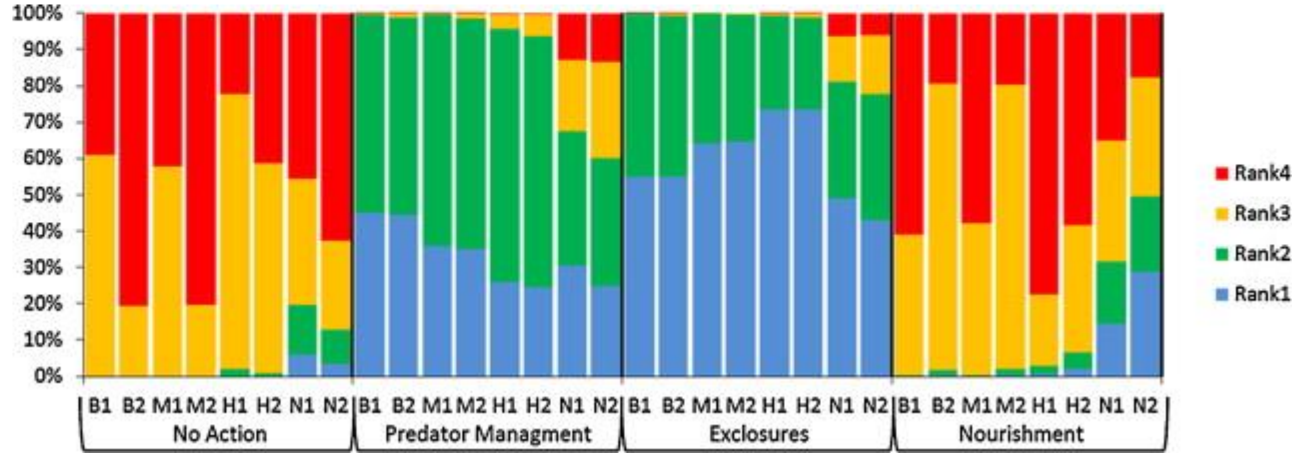


Decision Structure

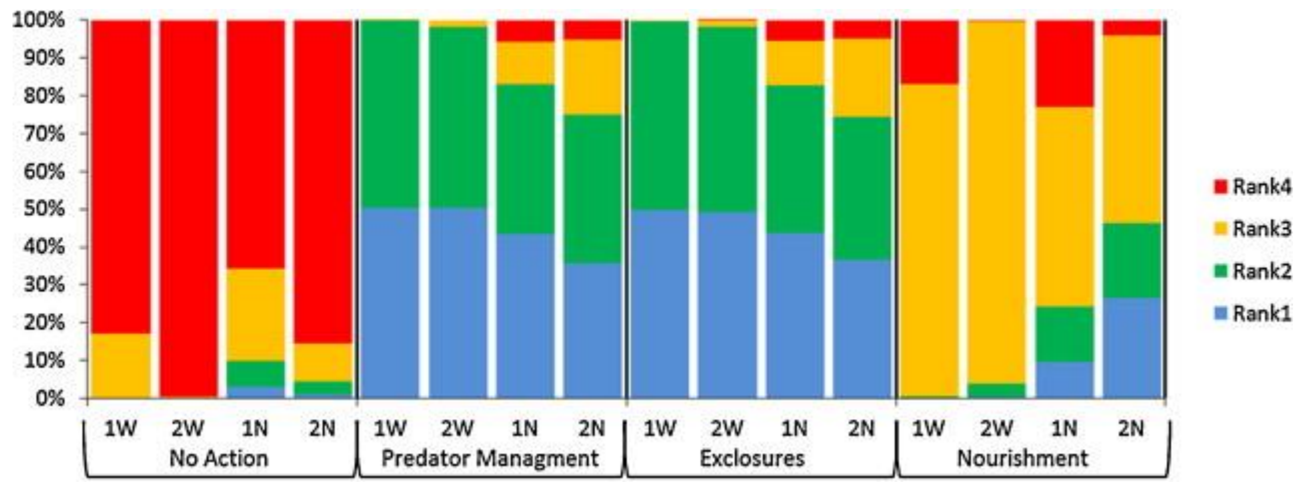
Linhoss, A., Kiker, G.A. Aiello-Lammens, M., Chu-Agor, M.L., Convertino, M. Muñoz-Carpena, R, Fischer, R. and Linkov, I. 2013. Decision analysis for species preservation under sea-level rise. *Ecological Modelling* 263: 264–272.

Decision Analysis allows the combination of model output uncertainty with different stakeholder valuations

Goal: Coastal Protection



Goal: Plover Protection



Linhoss, A.,Kiker, G.A. Aiello-Lammens, M., Chu-Agor, M.L., Convertino, M. Muñoz-Carpena, R, Fischer, R. and Linkov, I. 2013. Decision analysis for species preservation under sea-level rise. *Ecological Modelling* 263: 264–272.

Decision Analysis Results

- **The ranking of the alternatives is the same between 1 and 2 m SLR**
- **Information about the Snowy Plovers makes a significant difference**. The ranking of the alternatives is different between contest and ceiling type density dependence
- In all of the model scenarios Exclosures ranks higher than Predator Management
- **The level of uncertainty is higher in the 2 m SLR scenarios than in the 1 m SLR scenarios**
- **The uncertainty in each of the scenarios and in each of the management alternatives makes a definitive selection of an optimal alternative unclear.**

Linhoss, A.,Kiker, G.A. Aiello-Lammens, M., Chu-Agor, M.L., Convertino, M. Muñoz-Carpena, R, Fischer, R. and Linkov, I. 2013. Decision analysis for species preservation under sea-level rise. *Ecological Modelling* 263: 264–272.

Agenda

1. Motivation: Florida - between the devil and the deep blue sea?
2. Canaries in a coal mine: Florida style
3. **Sea Level Rise and Military Infrastructure**
4. Getting local and personal: Sea Level Rise predictions meet stakeholders in NE Florida
5. The Way Forward: Where to go? How to grow?

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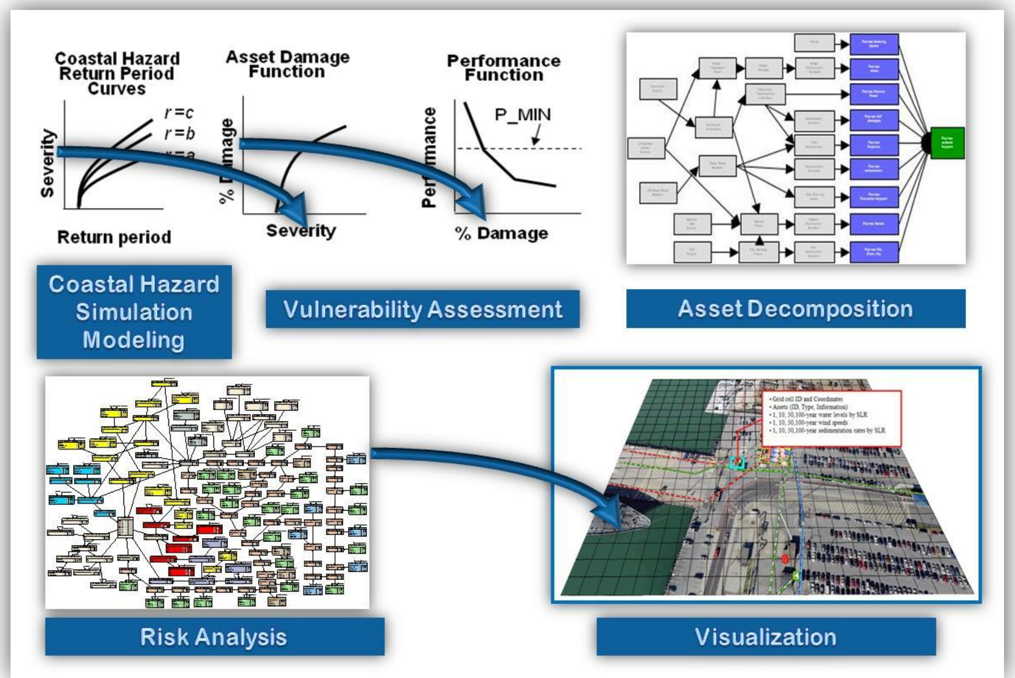
Quantifying Climate Change and Sea Level Rise Risks to Naval Station Norfolk

POC: Dr. Kelly A. Burks-Copes, US Army Engineer R&D Center (Vicksburg, MS)

- **Purpose/Objective**
  - Devise and demonstrate a **rigorous yet flexible** approach to quantitatively evaluating risks to critical military assets (i.e., infrastructure) and mission capabilities threatened by a range of SLR, tidal fluctuation, and storm stage-frequency hazards.

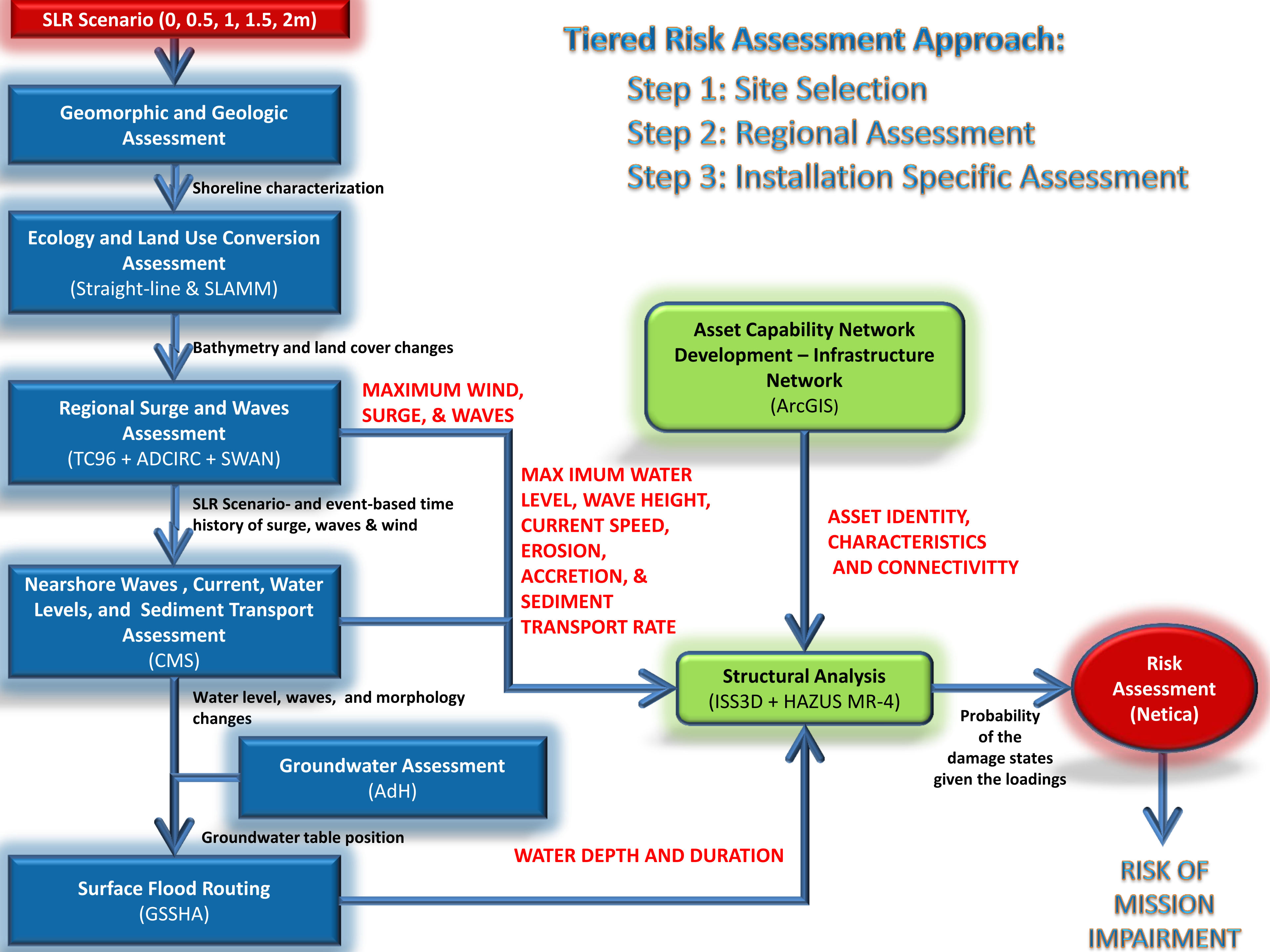


Solution/Approach/Tools

- **Characterize** the impacts
- **Decompose** mission & infrastructure systems
- **Pinpoint** vulnerabilities
- **Identify** thresholds or tipping points
- **Quantify** risks
- **Communicate** these to the field

Outcomes/Results/Products

- 3 yr effort, $3M
- Selected Hampton Roads region and Norfolk Naval Station for demo
- Developed an Approach and Capabilities to Assess Impacts



SLR Scenario (0, 0.5, 1, 1.5, 2m)
Tiered Risk Assessment Approach:
Step 1: Site Selection
Step 2: Regional Assessment
Step 3: Installation Specific Assessment
Geomorphic and Geologic Assessment
Shoreline characterization
Ecology and Land Use Conversion Assessment (Straight-line & SLAMM)
Bathymetry and land cover changes
Regional Surge and Waves Assessment (TC96 + ADCIRC + SWAN)
MAXIMUM WIND, SURGE, & WAVES
SLR Scenario- and event-based time history of surge, waves & wind
Nearshore Waves , Current, Water Levels, and Sediment Transport Assessment (CMS)
MAX IMUM WATER LEVEL, WAVE HEIGHT, CURRENT SPEED, EROSION, ACCRETION, & SEDIMENT TRANSPORT RATE
Asset Capability Network Development – Infrastructure Network (ArcGIS)
ASSET IDENTITY, CHARACTERISTICS AND CONNECTIVITTY
Structural Analysis (ISS3D + HAZUS MR-4)
Risk Assessment (Netica)
Probability of the damage states given the loadings
Water level, waves, and morphology changes
Groundwater Assessment (AdH)
Groundwater table position
WATER DEPTH AND DURATION
Surface Flood Routing (GSSHA)
RISK OF MISSION IMPAIRMENT

Storm & Flood Modeling Results

100-yr Storm

0.0 m SLR

0.5 m SLR

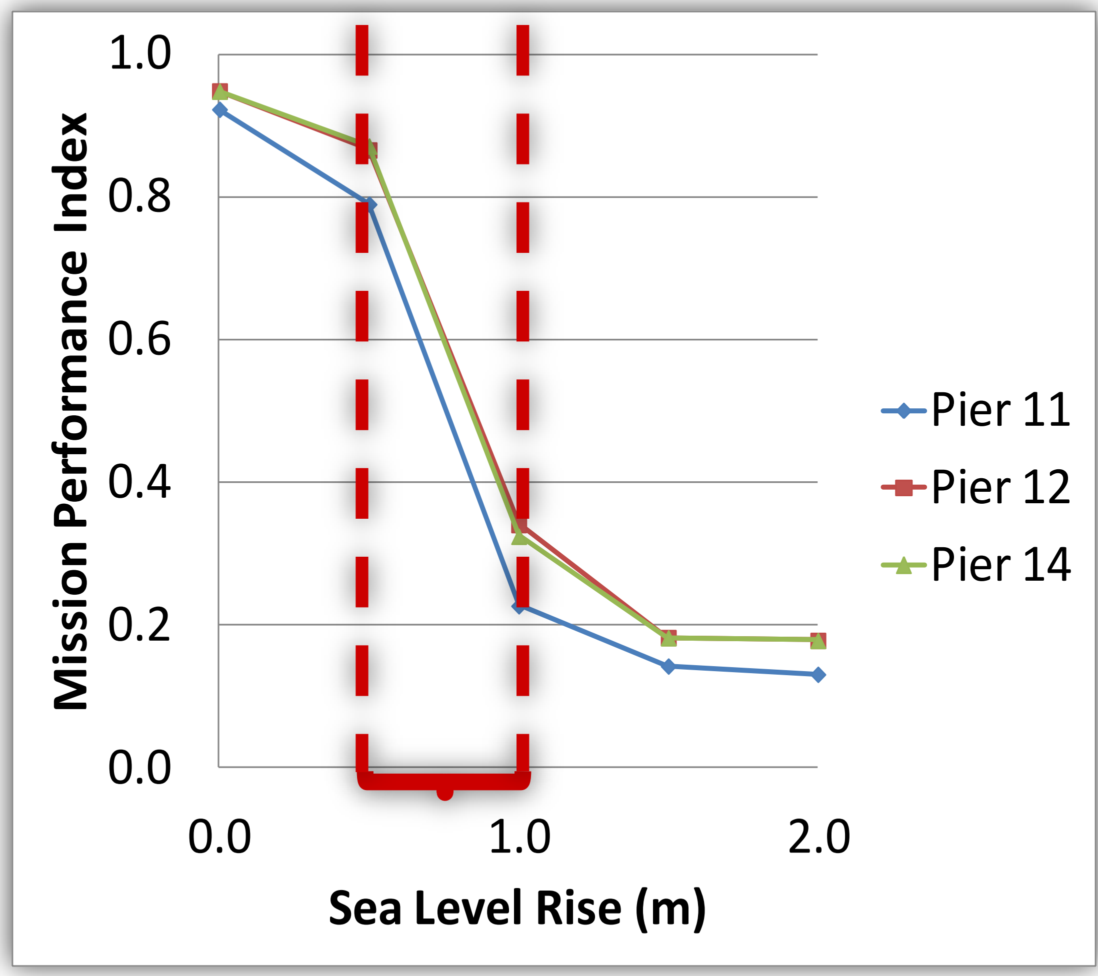
1.0 m SLR

1.5 m SLR

2.0 m SLR

The Risk-Based Tiered Approach Can Quantify:

1. The probability of asset **damage states** and functionality.
2. The probability of a loss in capability (**service interruption**).
3. The probability **potential losses in mission** performance.
4. The mission performance in light of **alternative system design** or retrofits.
5. Data gaps – identifying where **better information** on structural reliability is needed.



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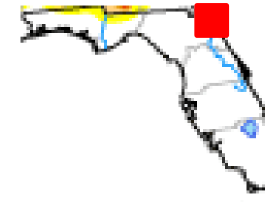
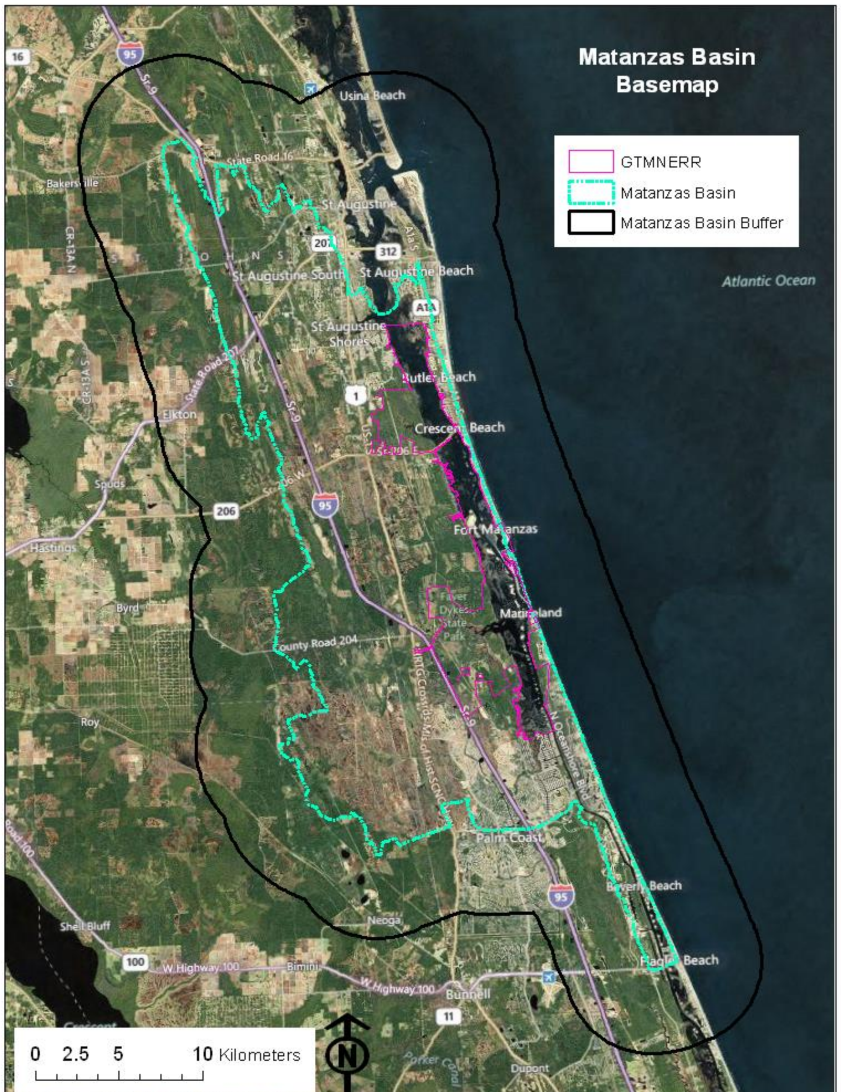
National Estuarine Research Reserve System Science Collaborative:

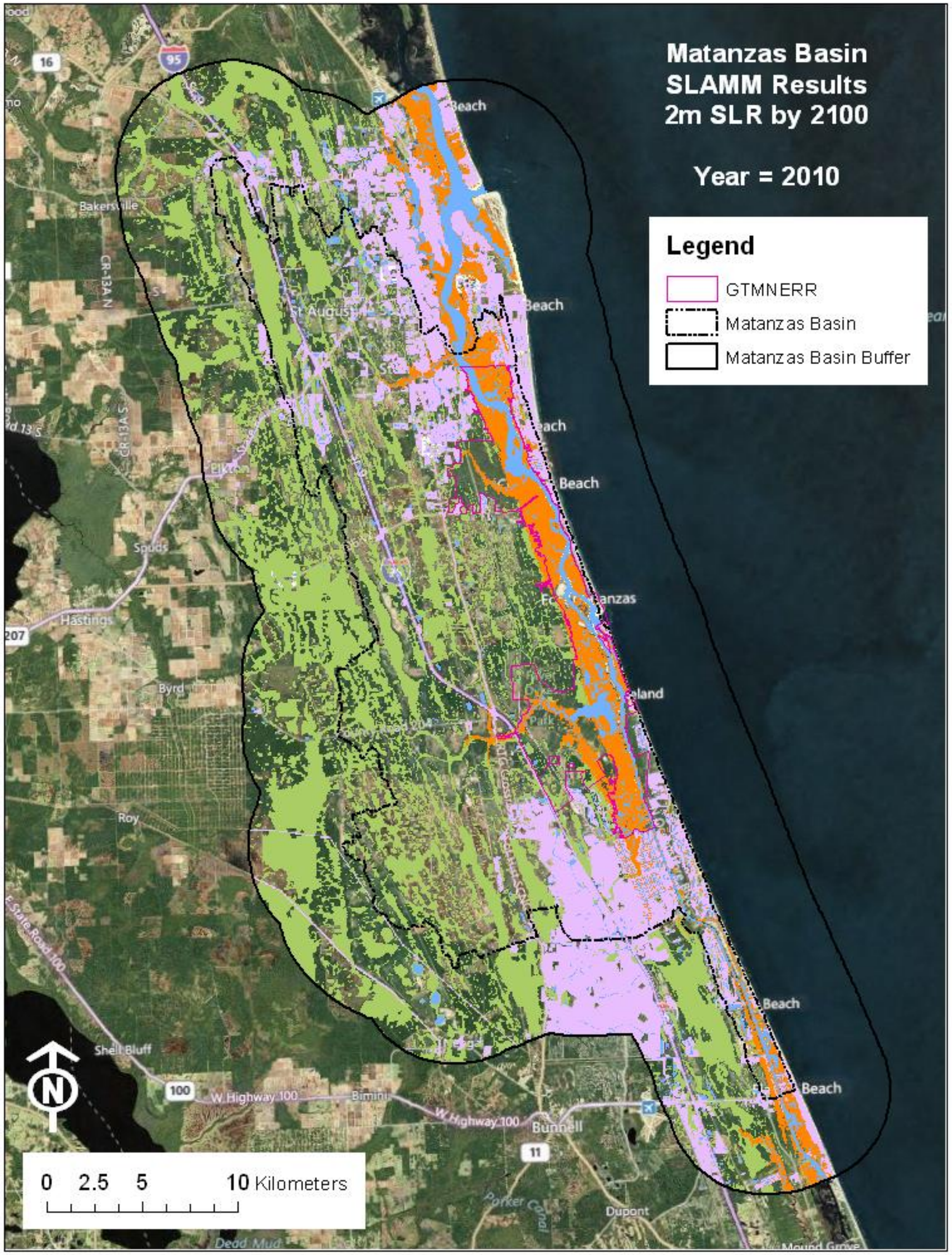




- Guana Tolomato Matanzas National Estuary Research Reserve (GTMNERR)
- Low elevation estuary between St Augustine, FL (America's oldest city) and the Palm Coast (rapidly growing retirement community)

SLAMM results 2m SLR by 2100

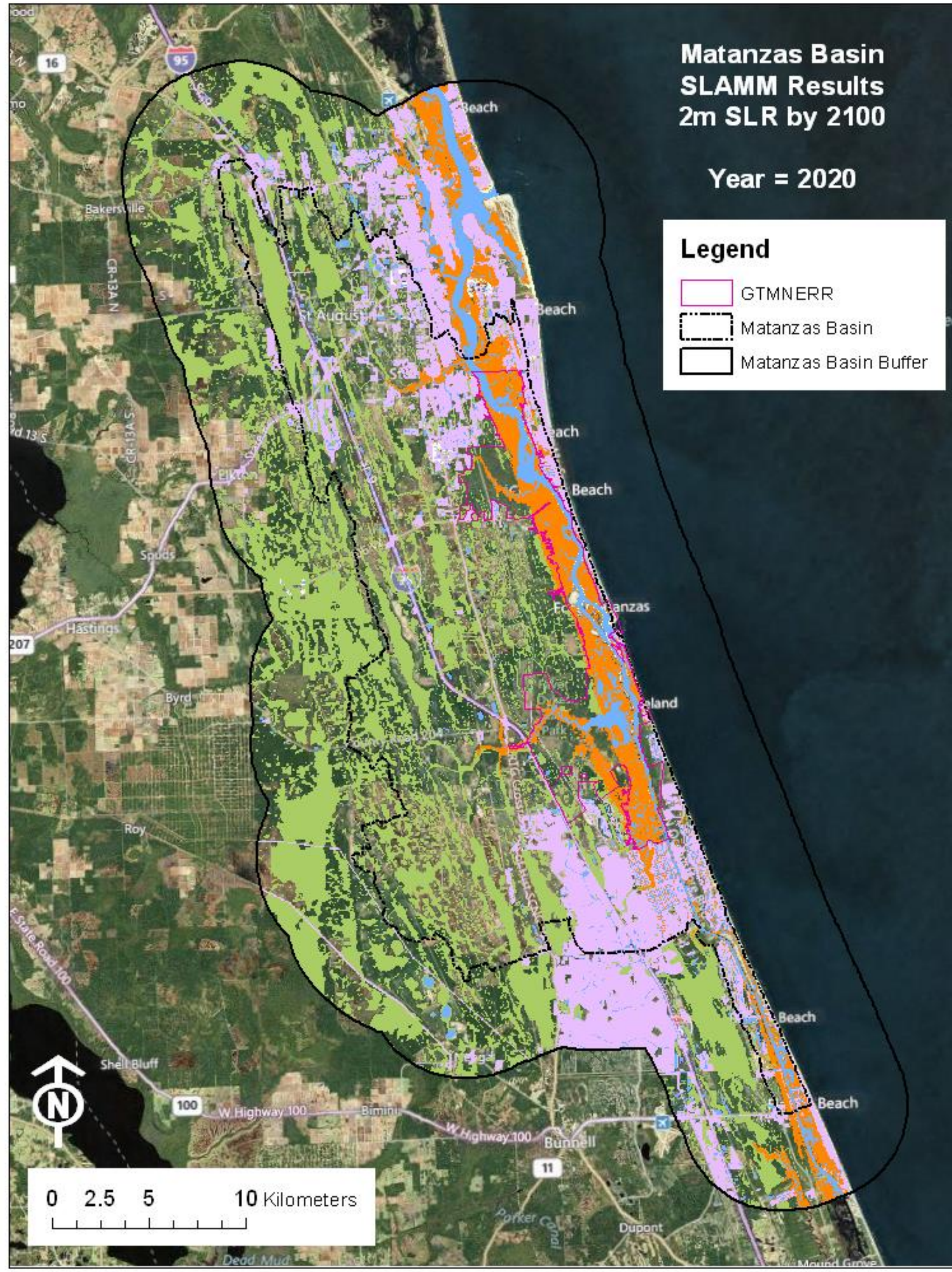
2010



- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water

SLAMM results 2m SLR by 2100

2020



- Developed Land
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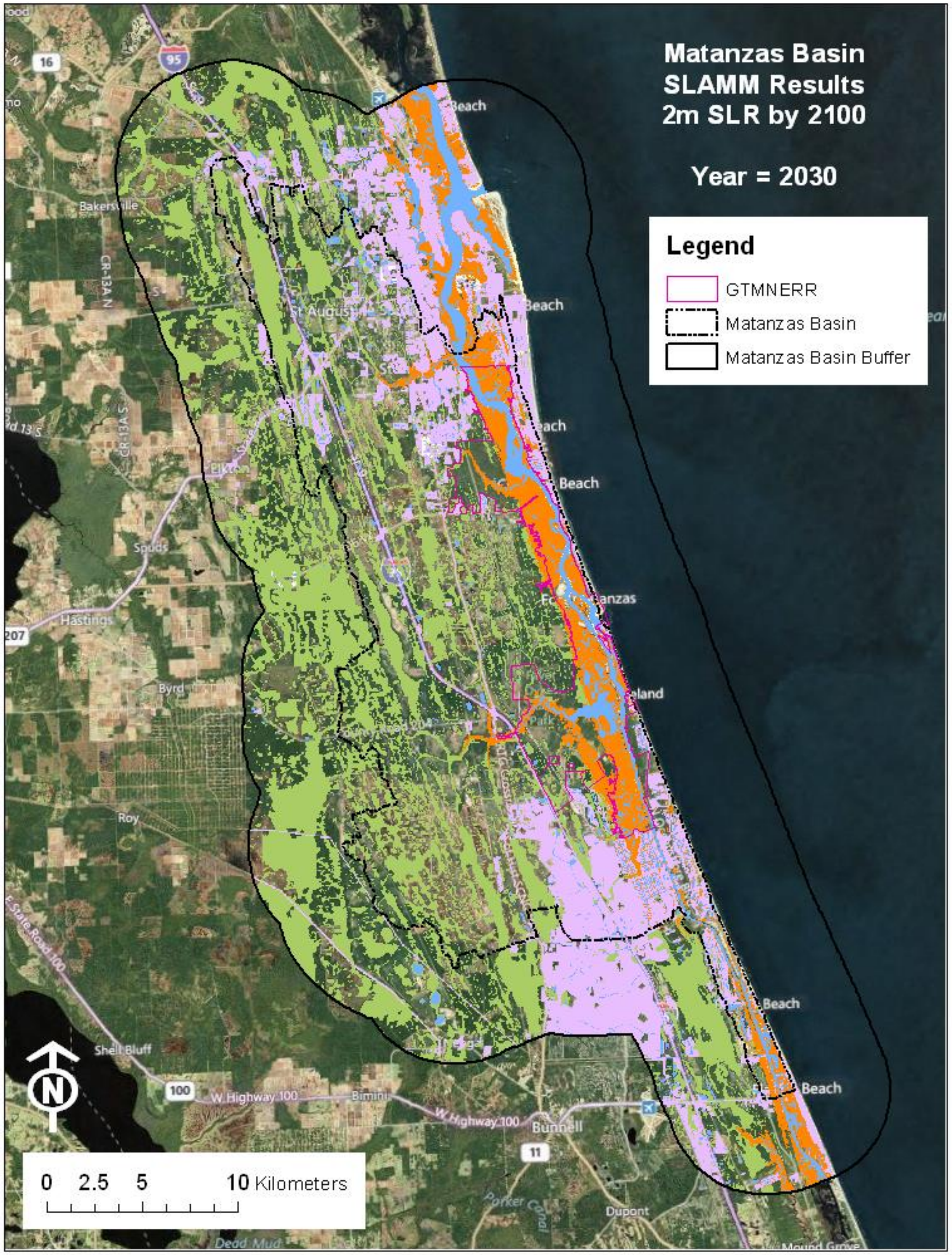
SLAMM results 2m SLR by 2100

2030



- Developed Land
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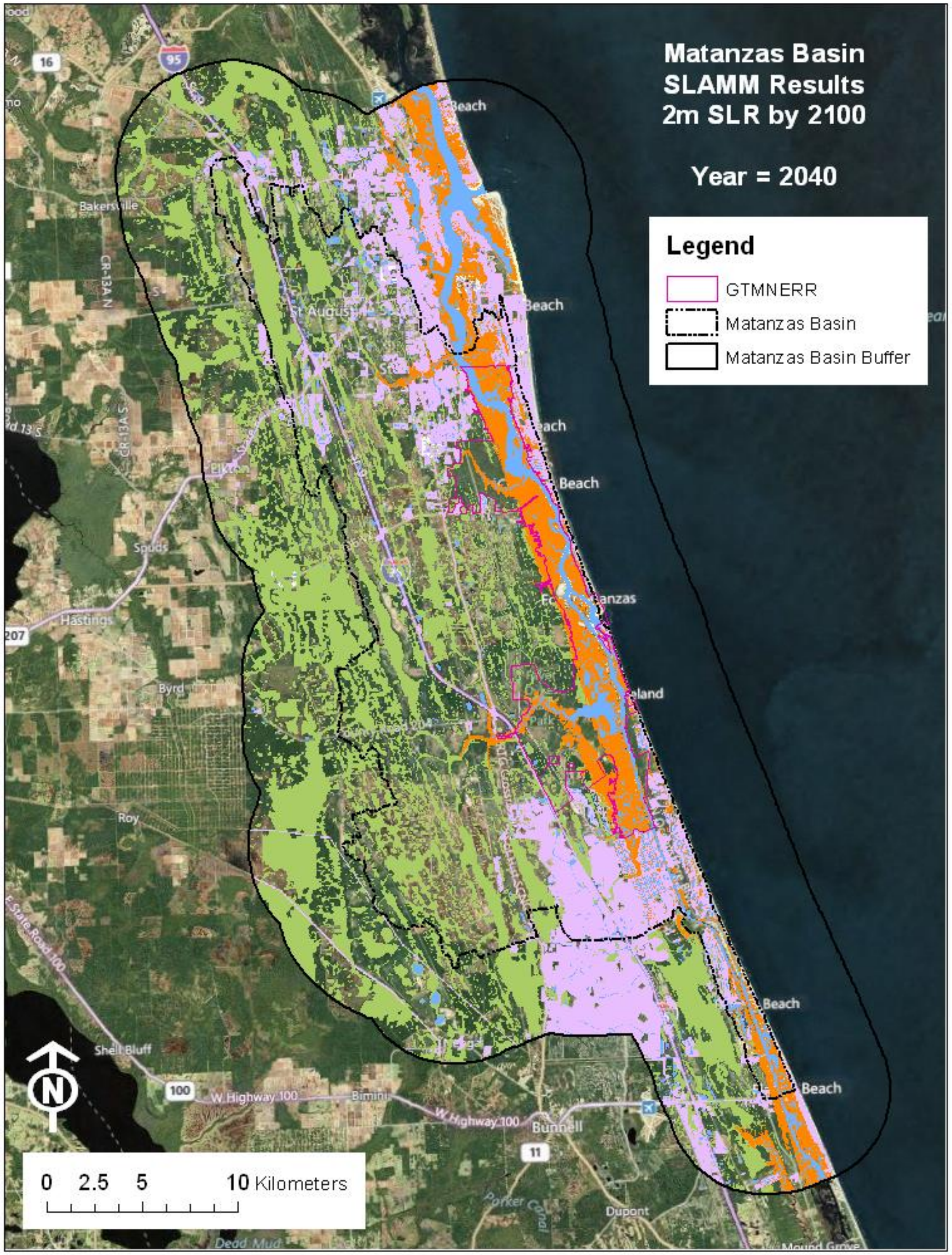
SLAMM results 2m SLR by 2100

2040



- Developed Land
- Freshwater Marsh
- Saltwater Marsh
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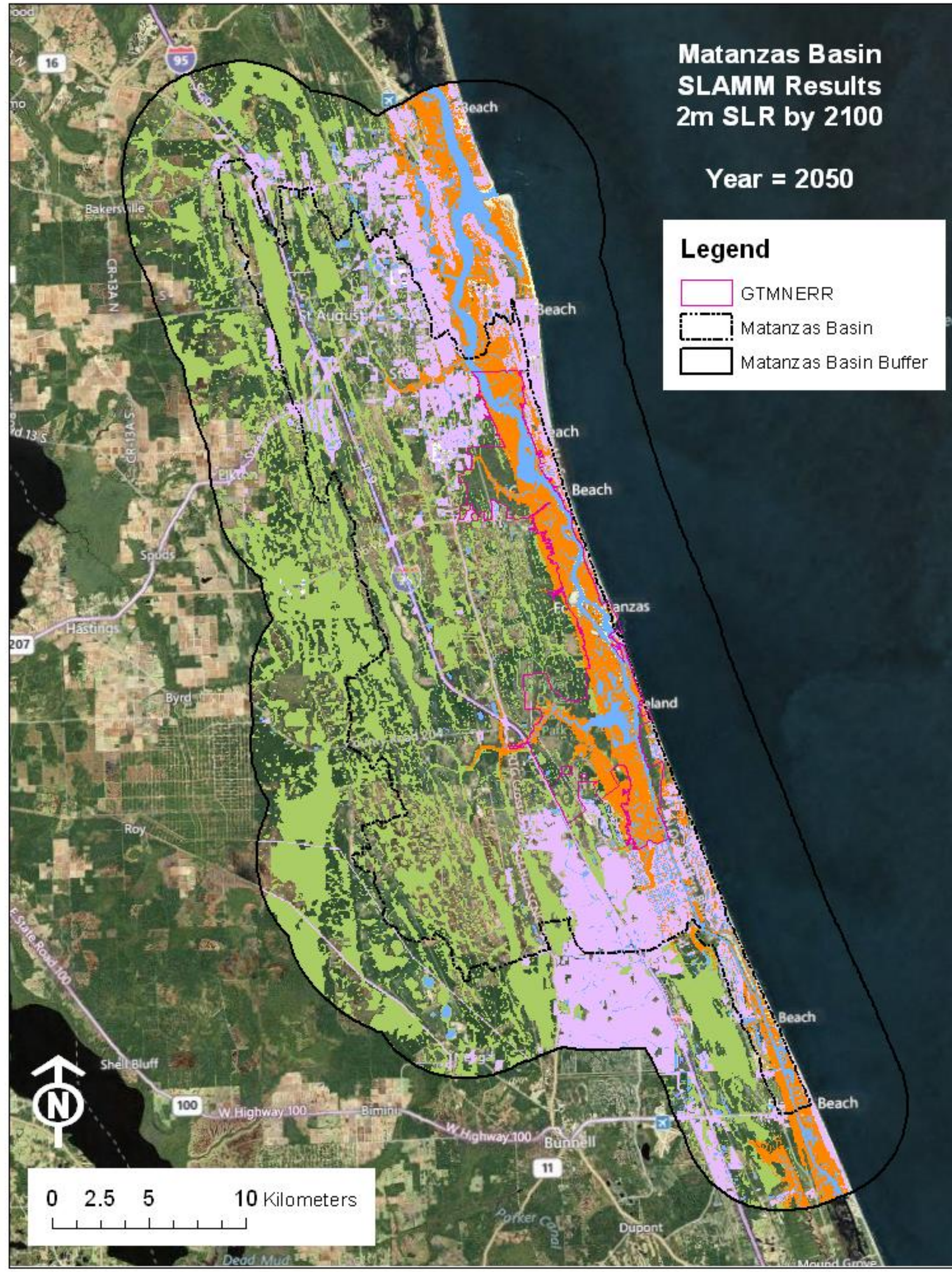
SLAMM results 2m SLR by 2100

2050



- Developed Land
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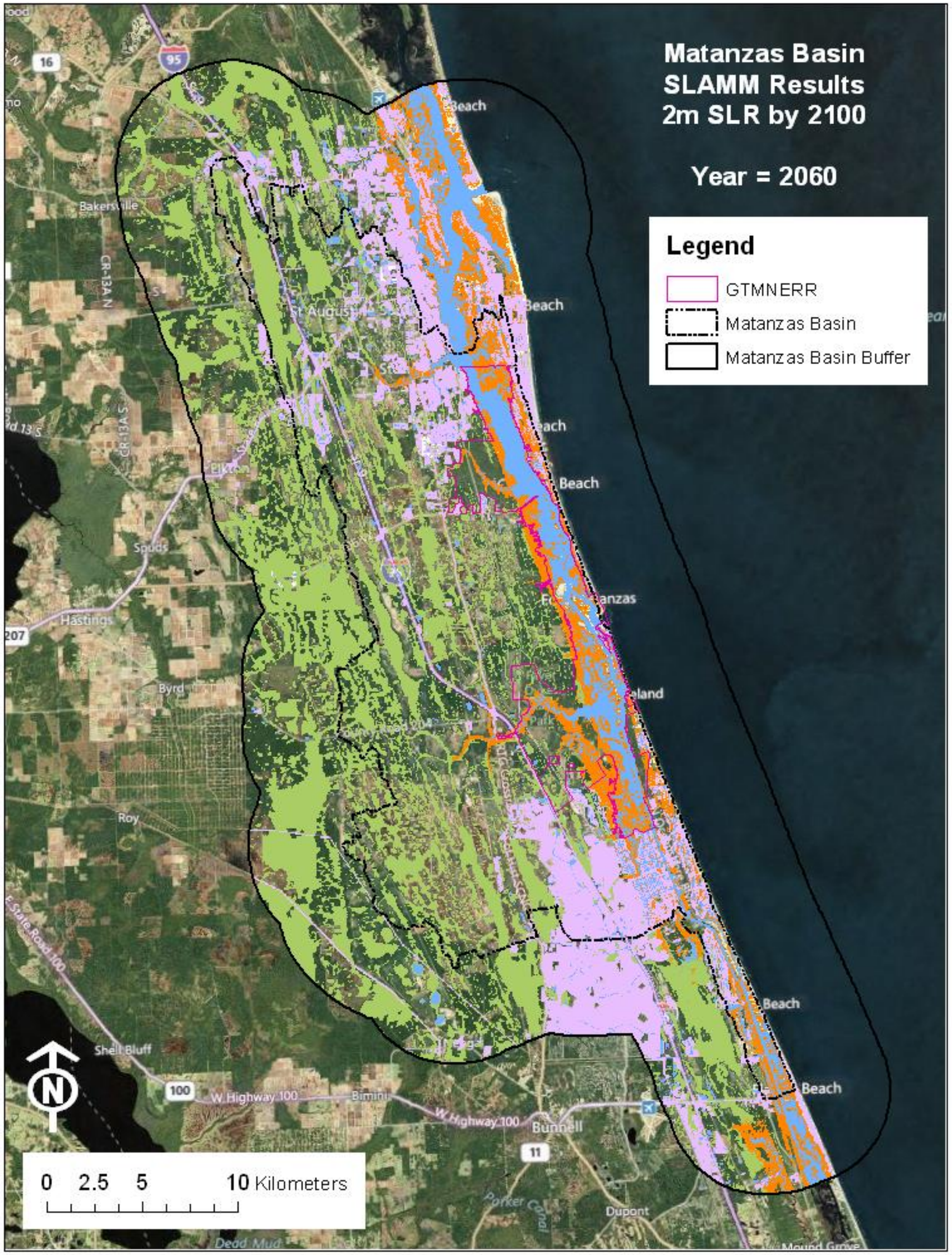
SLAMM results 2m SLR by 2100

2060



- Developed Land
- Freshwater Marsh
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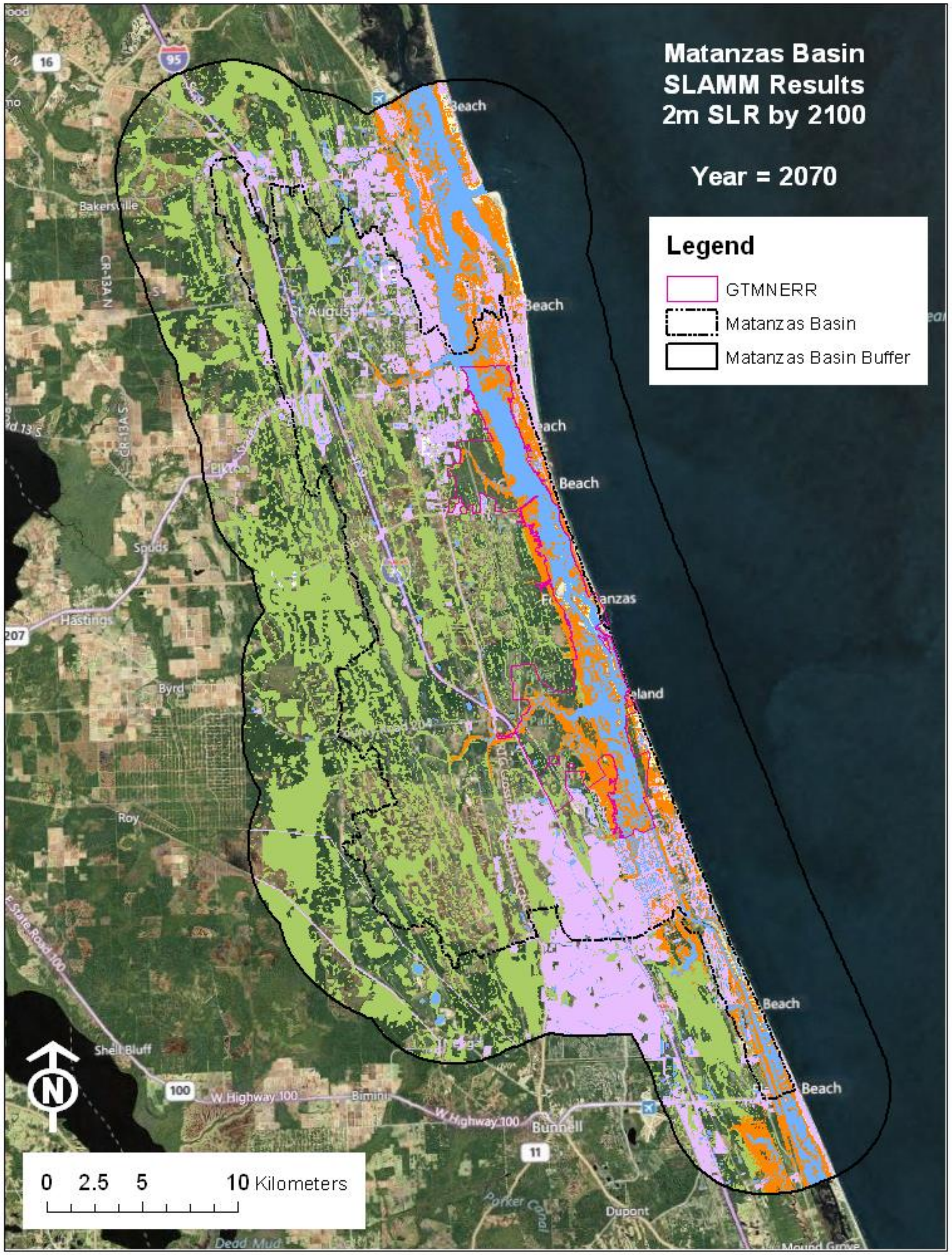
- Water

SLAMM results 2m SLR by 2100

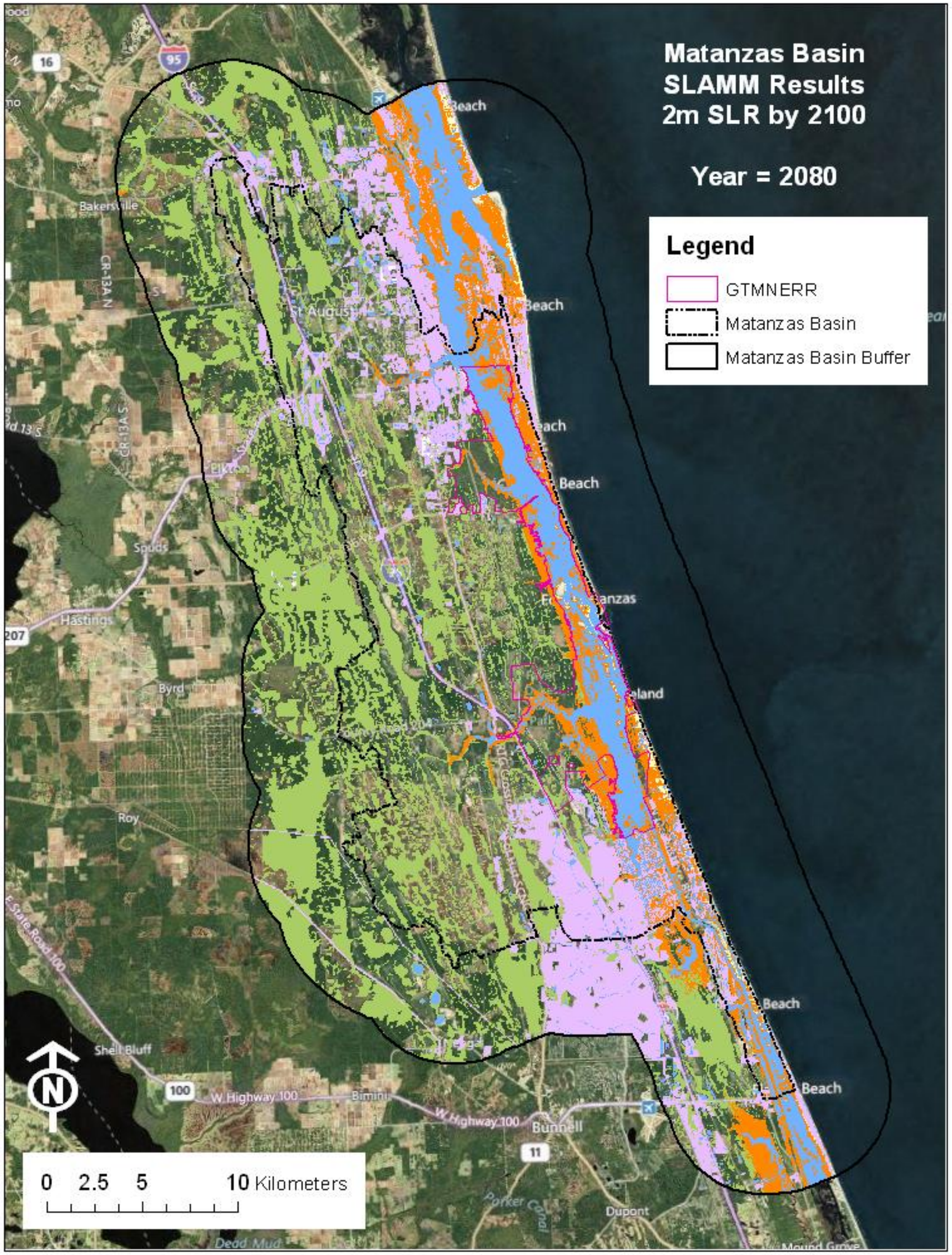
2070



Developed Land
Freshwater Marsh
Saltwater Marsh
Beach
Water

SLAMM results 2m SLR by 2100

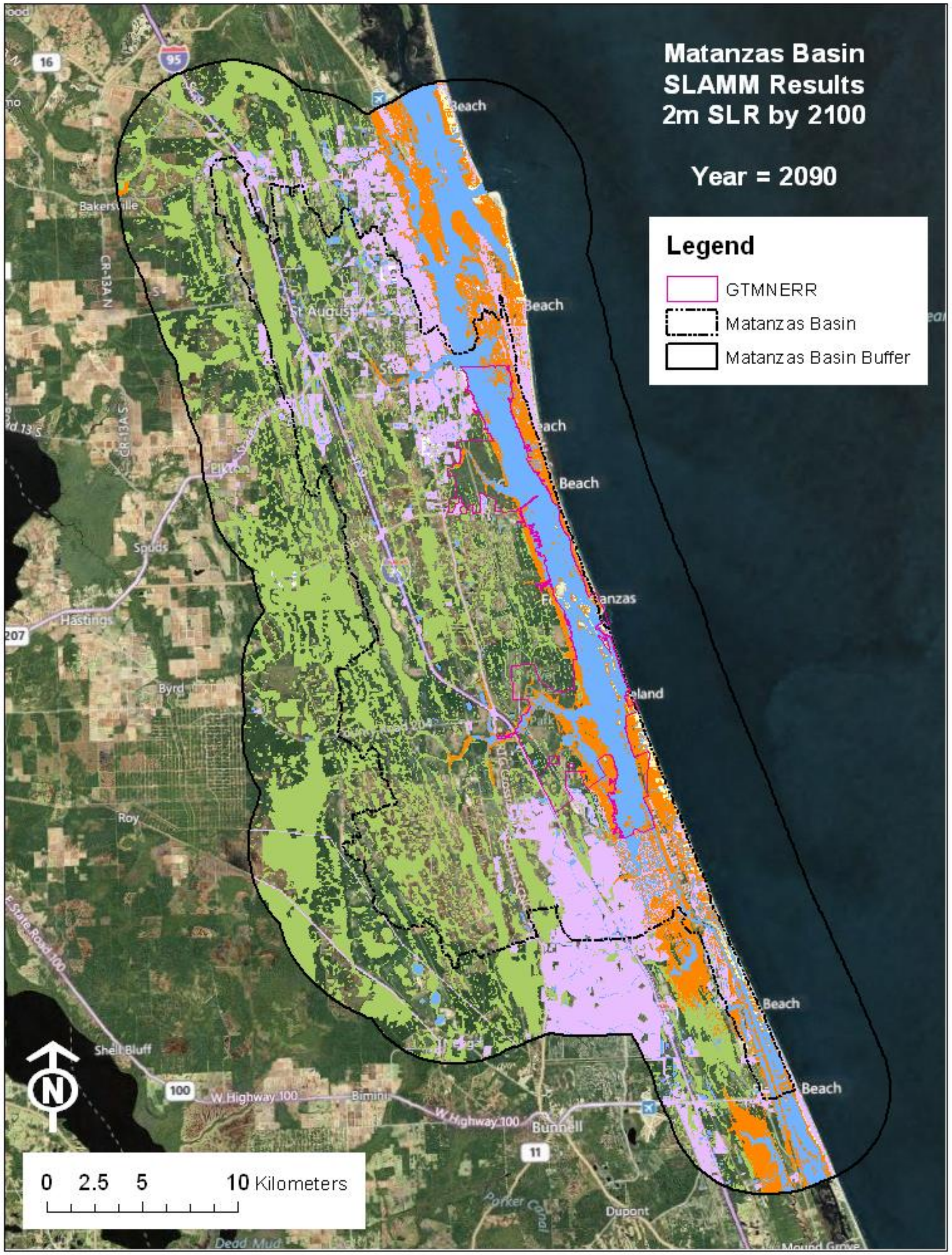
2080



- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water

SLAMM results 2m SLR by 2100

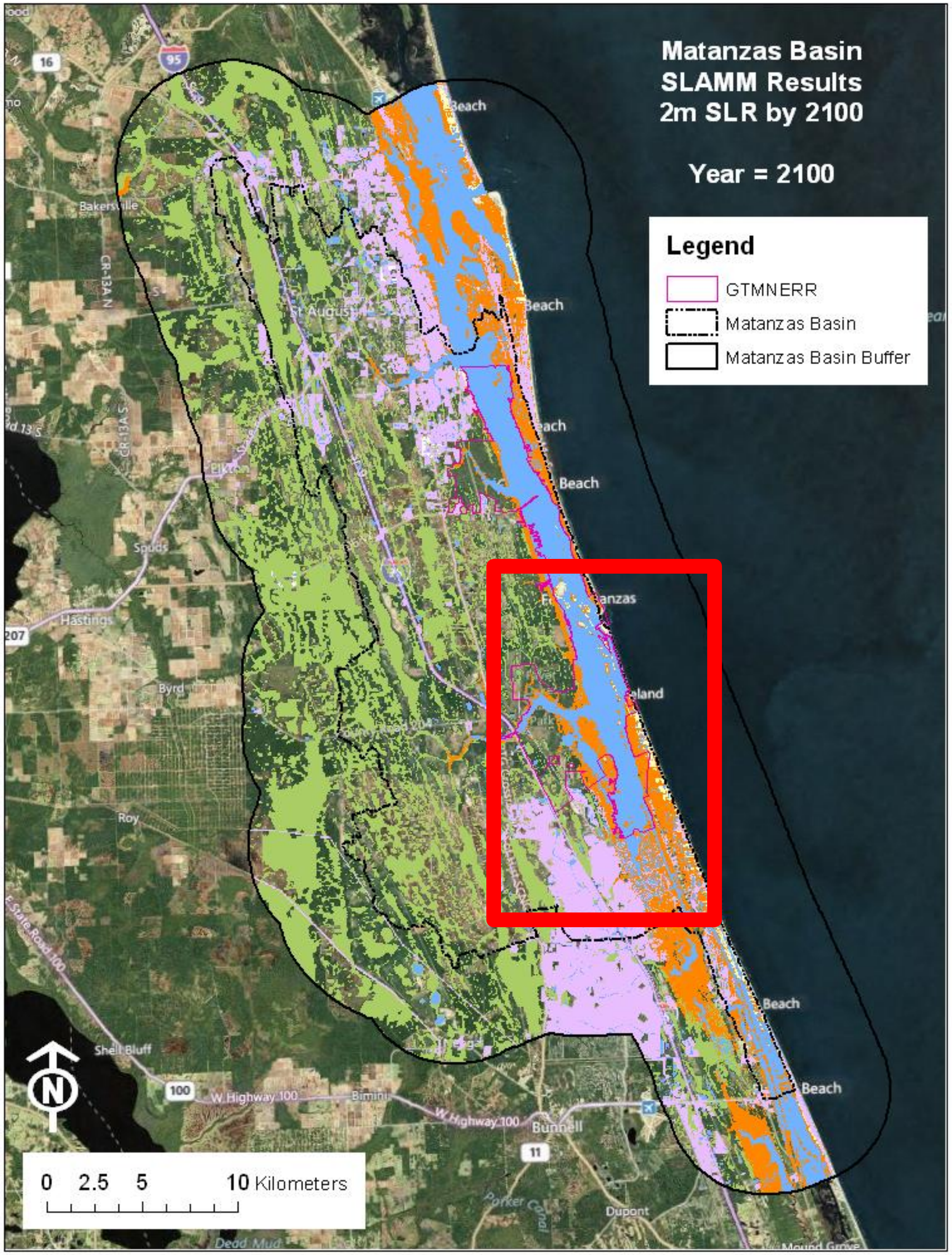
2090



Developed Land
Freshwater Marsh
Saltwater Marsh
Beach
Water

SLAMM results 2m SLR by 2100

2100



- Developed Land
- Freshwater Marsh
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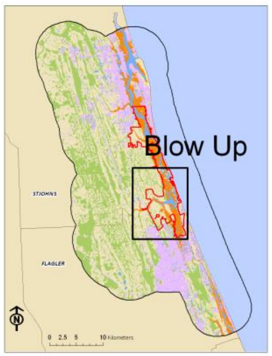
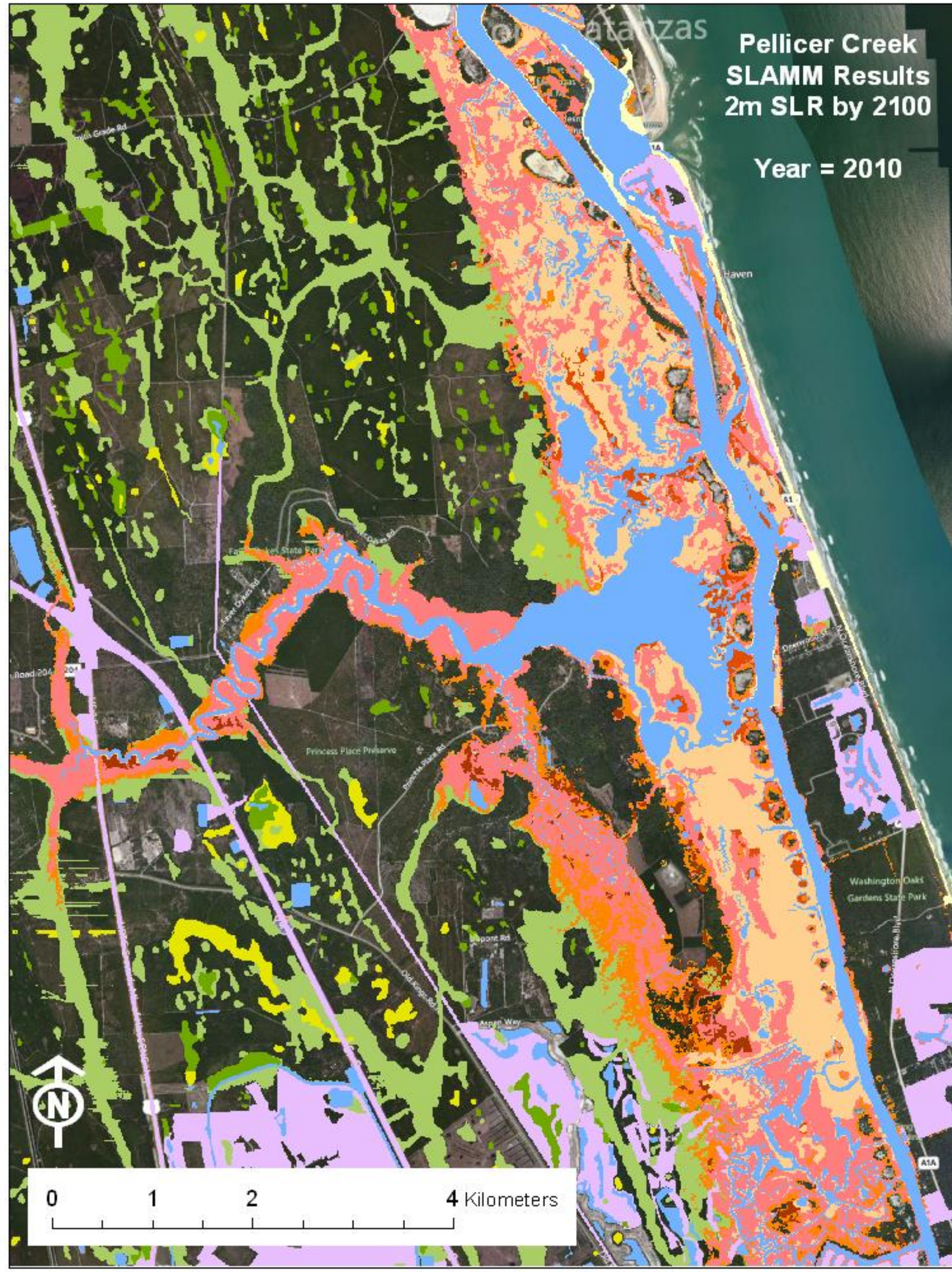
- Water

SLAMM results Pellicer Creek 2m SLR by 2100

2010

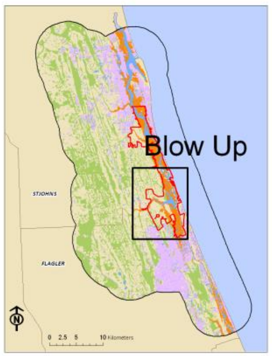


- Developed Dry Land
- Swamp
- Cypress Swamp
- Inland Fresh Marsh
- Transitional Salt Marsh
- Regularly Flooded marsh
- Mangrove
- Beach
- Water
- Irregularly Flooded Marsh
- Tidal Flat



SLAMM results
Pellicer Creek
2m SLR by 2100

2020



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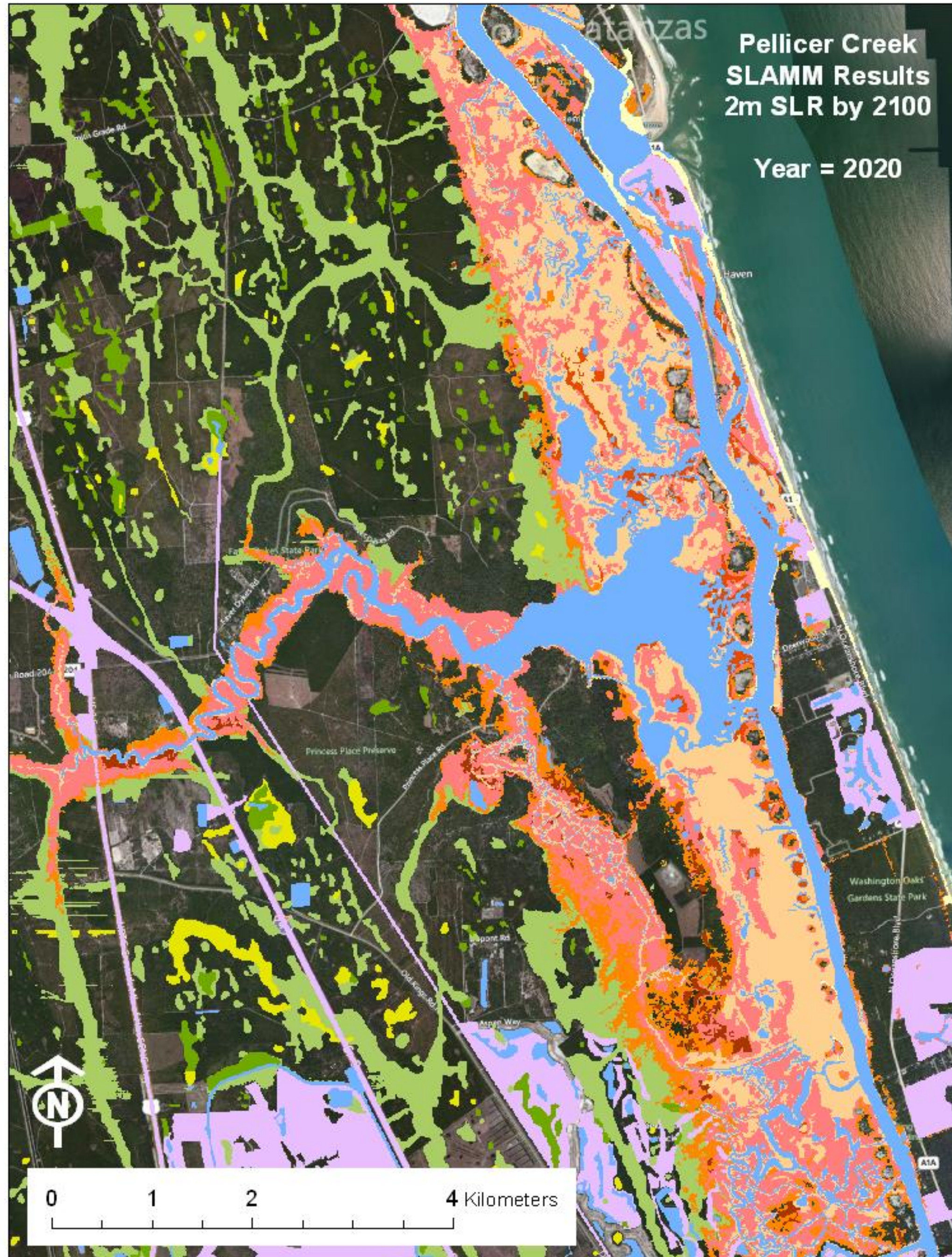
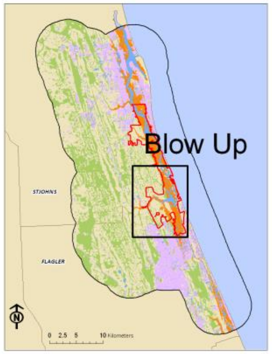


SLAMM results Pellicer Creek 2m SLR by 2100

2030



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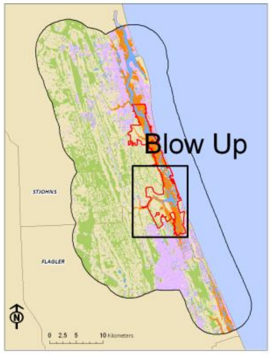
SLAMM results
Pellicer Creek
2m SLR by 2100

2040



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SLAMM results
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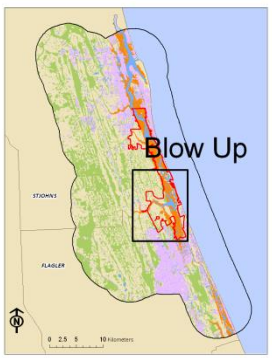
2m SLR by 2100

2050



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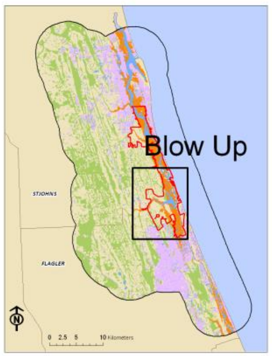
2060



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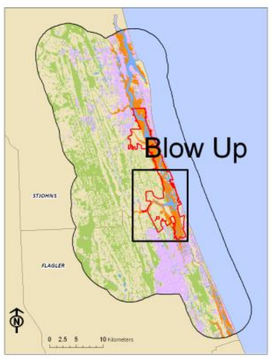
SLAMM results
Pellicer Creek
2m SLR by 2100

2070



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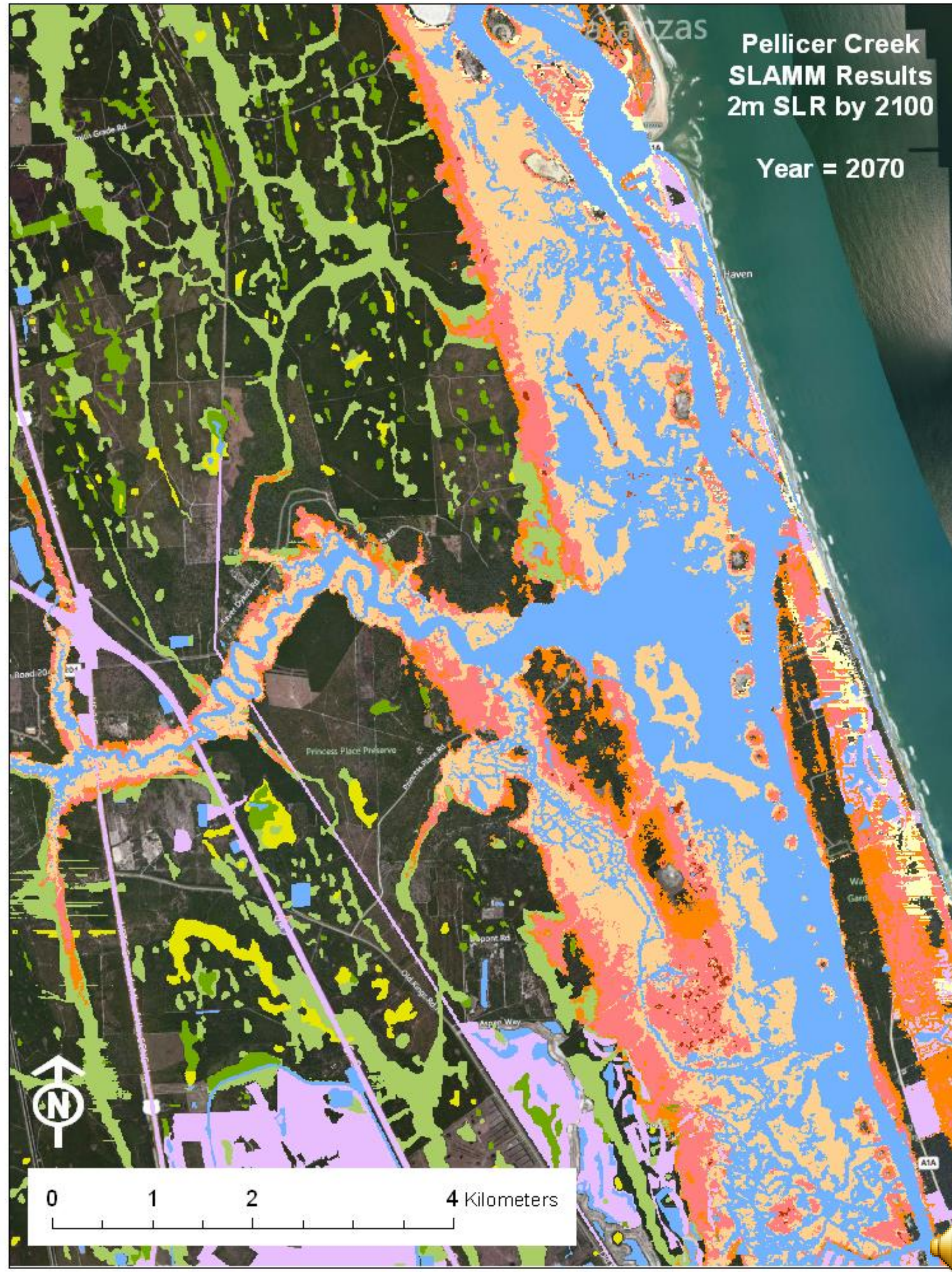
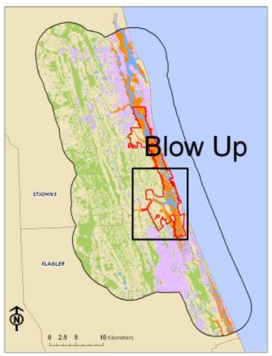


SLAMM results Pellicer Creek 2m SLR by 2100

2080



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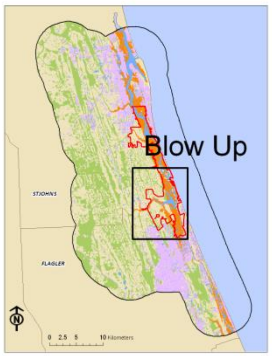
SLAMM results Pellicer Creek 2m SLR by 2100

2090



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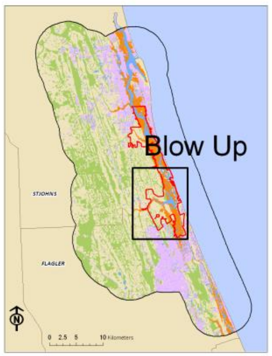
SLAMM results Pellicer Creek 2m SLR by 2100

2100



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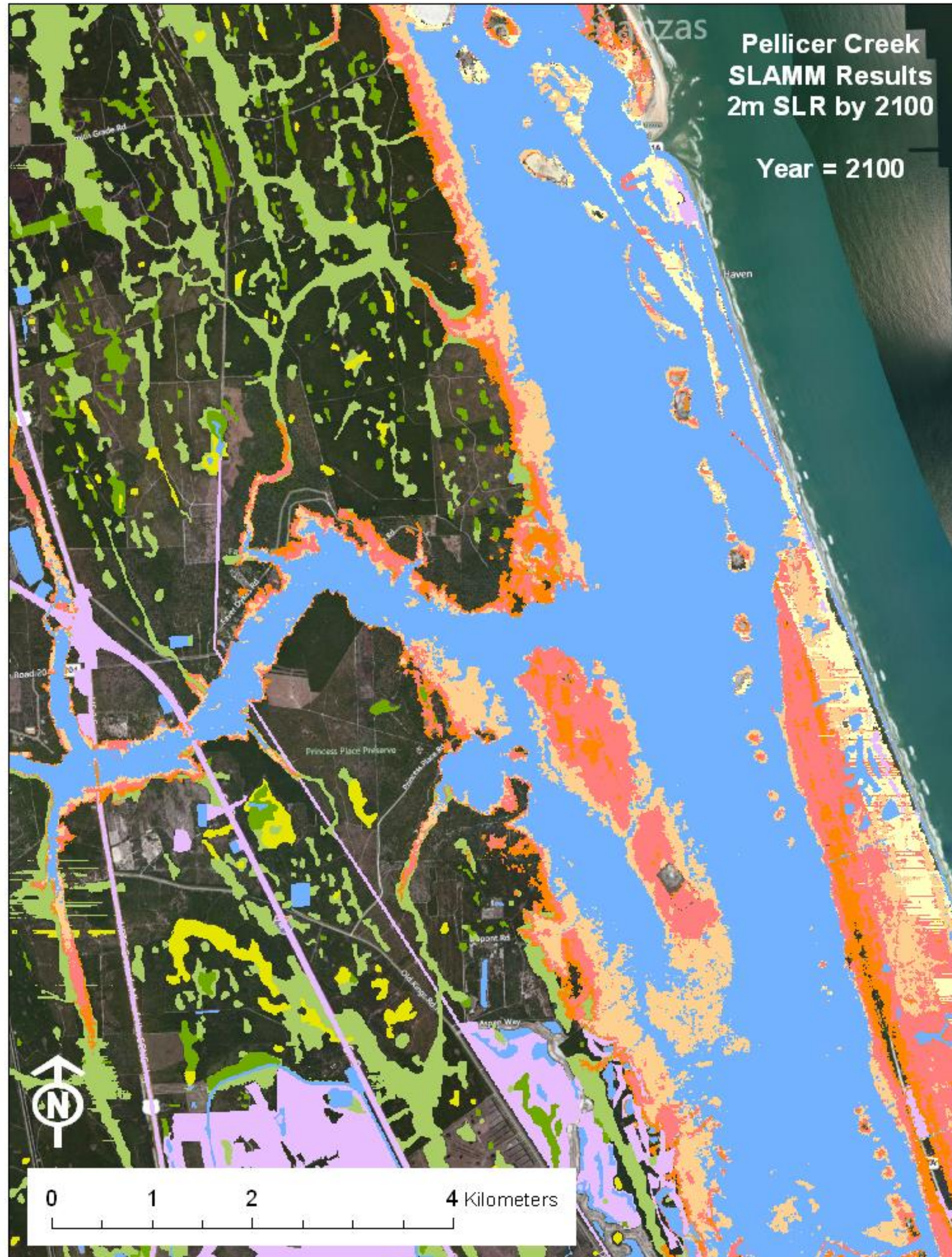
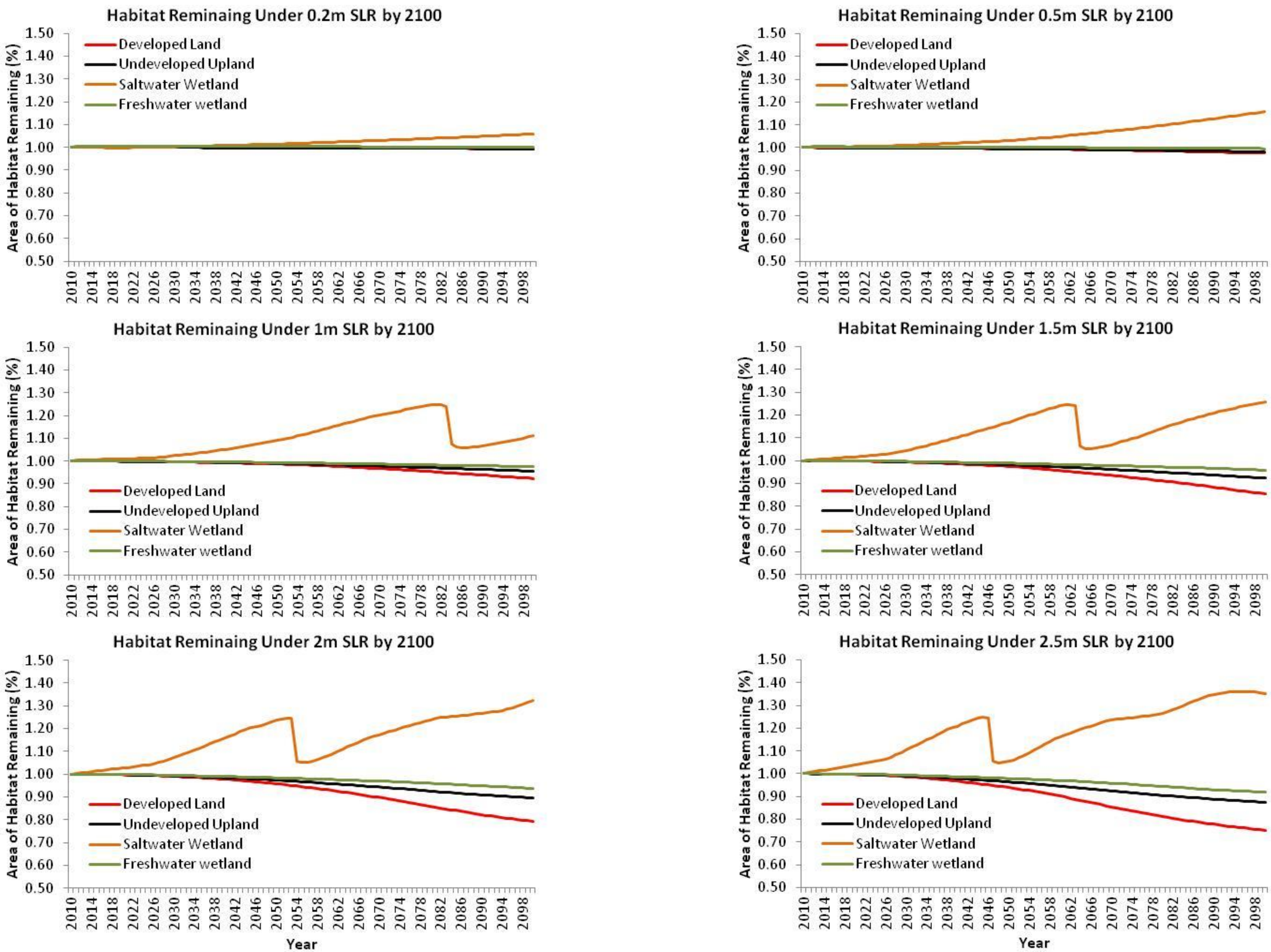
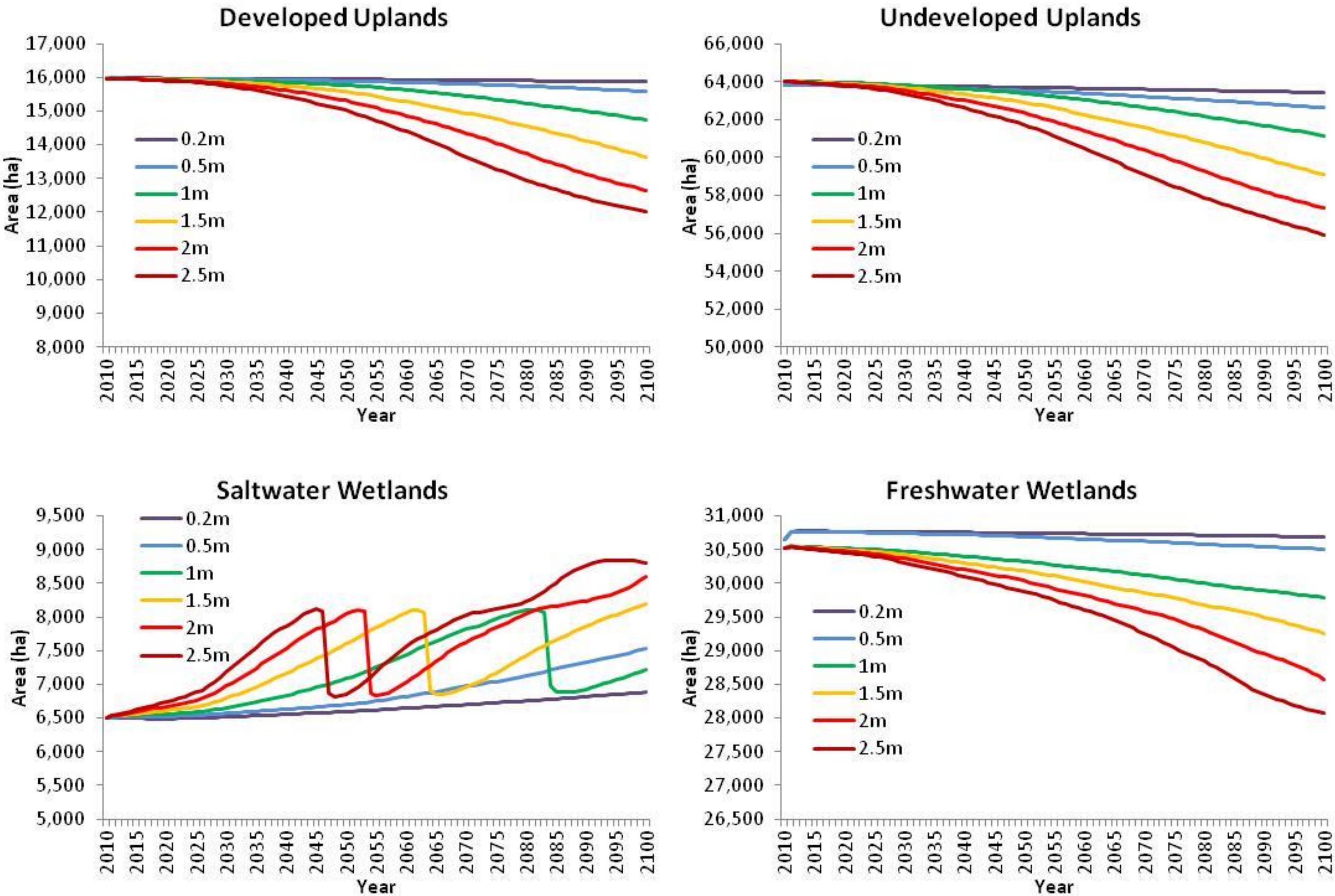
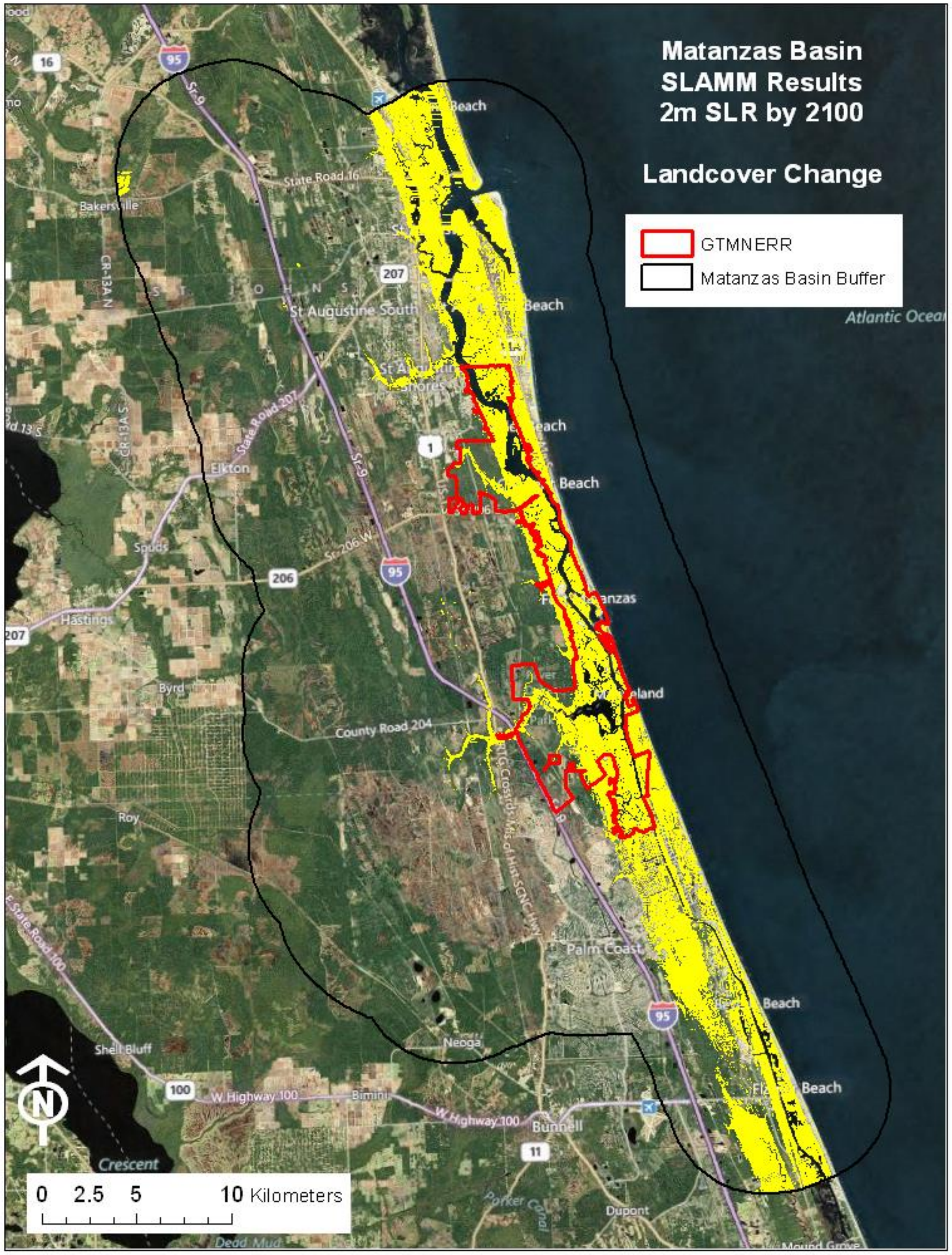


How much difference is there between the sea level rise scenarios?

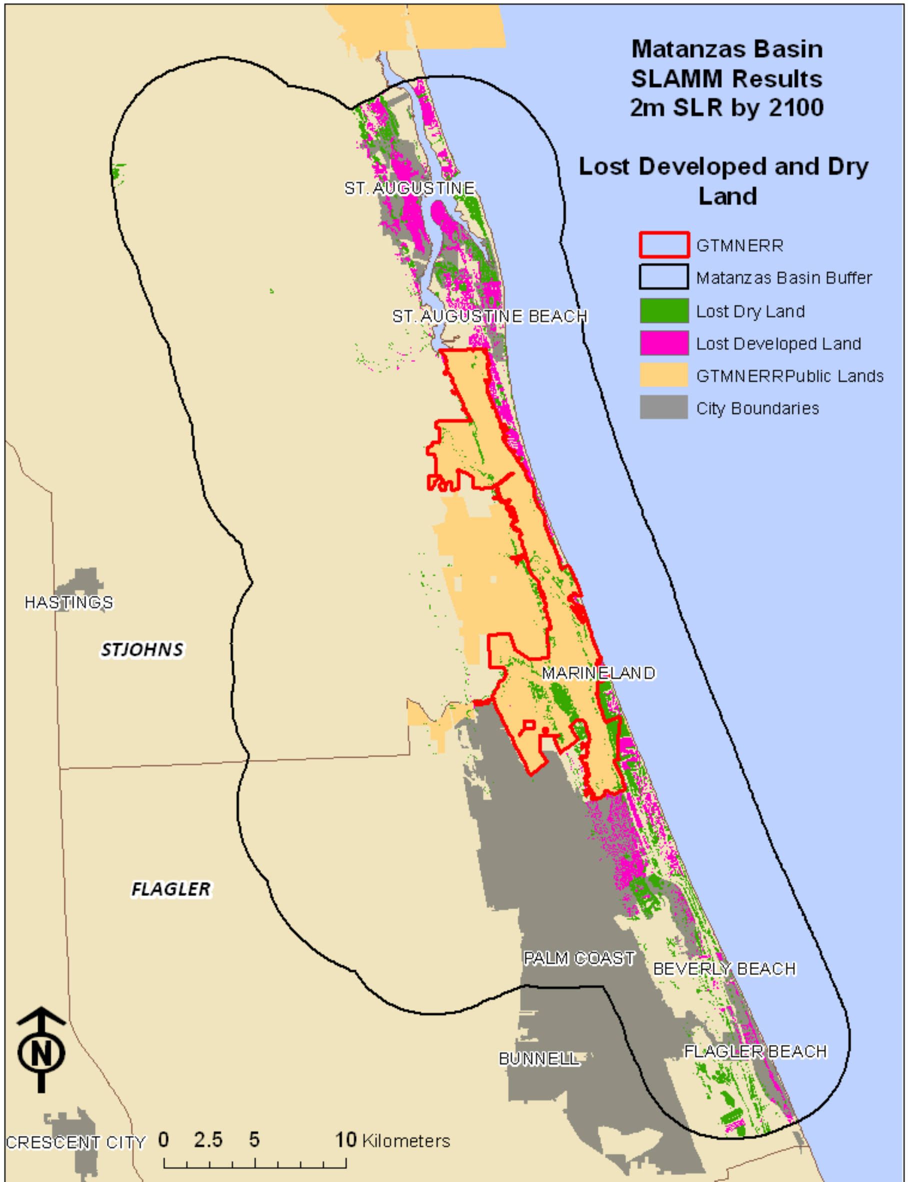


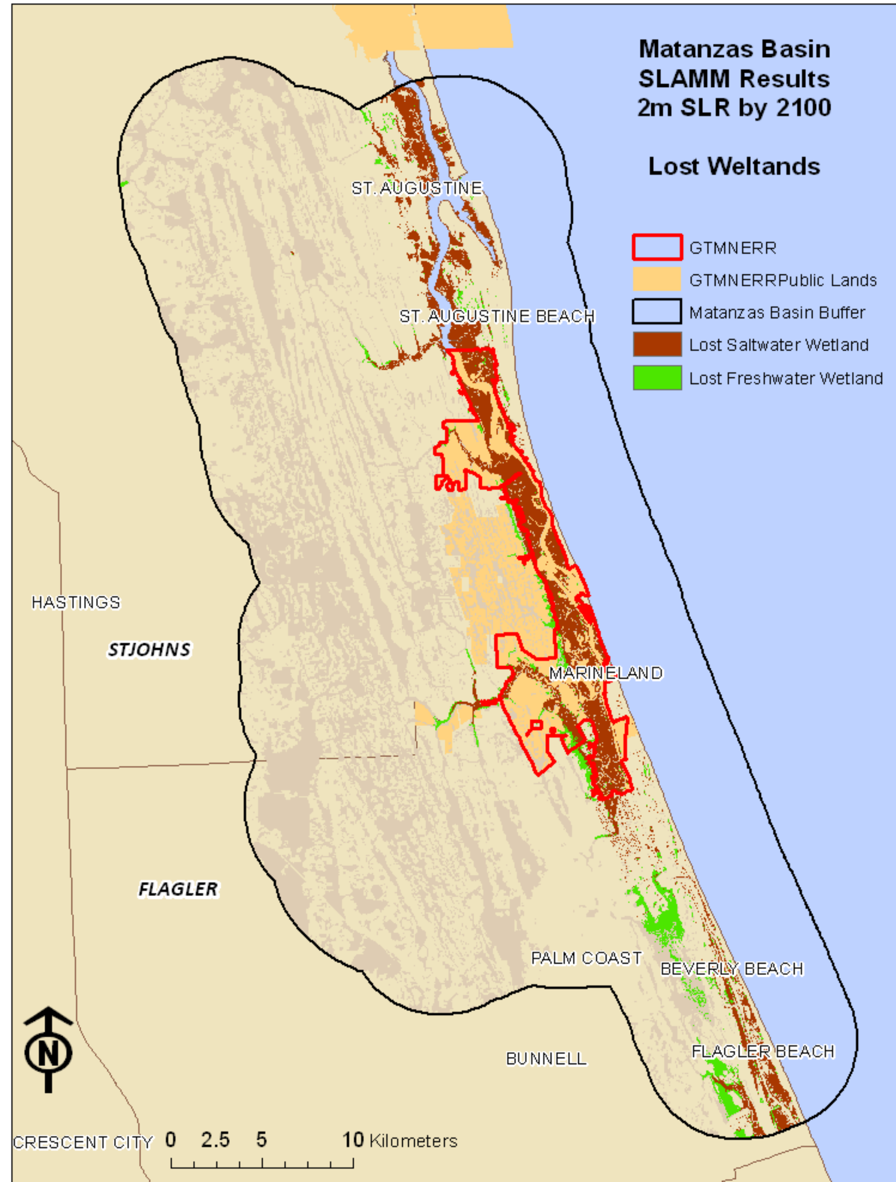

Developed Uplands
Area (ha)
Year
Undeveloped Uplands
Saltwater Wetlands
Freshwater Wetlands
0.2m
0.5m
1m
1.5m
2m
2.5m

What ***general*** areas are vulnerable to change and habitat migration?

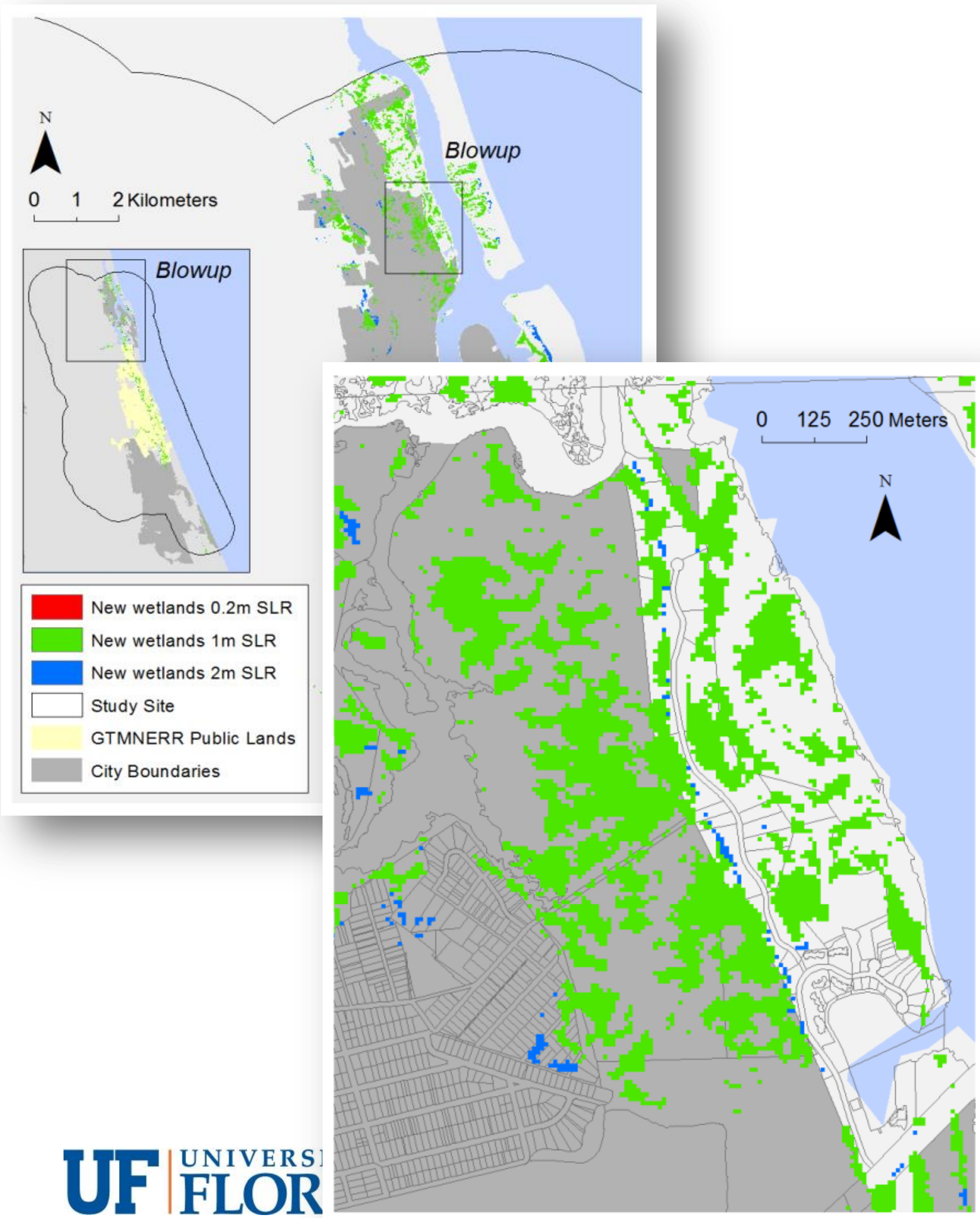


What areas are vulnerable to the loss of dry land and wetland?





So How Much Will This Cost Us?



- Simple flood/value rules – 10% flood means 10% taxable value lost… (very conservative…)
- Under a scenario of 1 m sea level rise by 2100, we project that 2,639 ha and $1 billion in land value will be lost to inundation
- If you want to replace wetlands as they are lost then we will need 2,758 ha of new wetland area costing about $3.8 billion in land value

Linhoss, A., G. Kiker, R. Watkins, M. Shirley, and K. Frank. 2014. Sea-level rise, inundation, and marsh migration: Simulating impacts on developed lands and environmental systems. *Journal of Coastal Research* (In press).

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Linking decision analysis and Stakeholders

- Role plays have been developed by Dr. D. Jourdan (Univ of Oklahoma) and Briana Ozor (Univ of Florida)
- 5 stakeholder roles with context/budgets for negotiation
- 8 alternatives for combination/negotiation
- More details at **Planningmatanzas.org**

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Example Roles

Local Resident — *$100 million*

- You have been selected to represent your community on this issue.
- Your community is a beach community.
- Members of your community enjoy living where they do because they enjoy seeing wildlife in their backyards, watching dolphins swim into the sunset, and going to the beach.
- Your houses are near the water and your neighborhood floods during heavy storms.

Government Official — *$350 million*

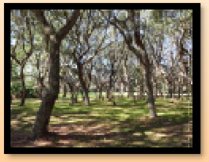
- As an elected official, you work in a position of power within your local government.
- You have lived in the area for many years and plan to continue living here because you are an amateur fisherman and you love the area.
- You have heard recent reports about the potential impact of sea level rise in your community but you find it difficult to dedicate the necessary resources towards this issue because more immediate issues weigh you down.

Ecotourism Business Owner — *$100 million*

- You are a born and raised resident of the area that owns a kayaking tour company.
- Recent storms have caused some damage to your business and you are beginning to worry about the intensification of coastal dynamics in the near future.
- You also notice increasing development pressures threatening marsh areas that you like to take some of your tours through.

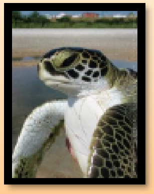
Inland Developer — *$150 million*

- You are not a full time local resident but you own large areas of land inland from the present communities.
- You anticipate that as people begin to worry about sea level rise they will be looking to move further inland and you would like to build a community to accommodate this anticipated demand.



Environmental Scientist — *$100 million*

- You are not a Florida native but you came to this area and continue living here because you recognize the uniqueness of the ecosystem and biodiversity of the area.
- You worry about the wellbeing of the local ecosystem, especially threatened species, with the pressures of development and now the threat of sea level rise.
- You are particularly interested in sea turtles and manatees.



Example Alternatives

Beach Nourishment — *$100 million*

- Replacing sand lost through erosion to re-widen a beach
- Lifespan: 5 years
- $3-15/cubic meter, depending on dredge site; $100 million for a large beach

Key benefits: Protect existing infrastructure, protect recreation and tourism

Seawalls — *$4.24 million/mile*

- Installing physical barriers between the sea and land to prevent flooding of developed areas.

Key benefits: Protect existing infrastructure

Habitat Migration Corridors — *$50,000/acre*

- Acquiring tracts of land connecting different wildlife habitats to allow for the safe migration of species, via purchases and conservation easements.

Key benefits: Allow migration of wetlands and threatened species

Elevating Structures — *$150,000**

- Elevating existing and future structures on stilts to protect them from storm surge and flooding.
- *$150,000 for 2300 sq. ft. building

Key benefits: Protect existing infrastructure

Ecosystem Conservation — *$50,000/acre*

- Government purchases relatively undeveloped land from coastal property owners to put into conservation. This conservation land will act as a buffer for retreating shorelines, protect habitats, and increase resiliency along the shoreline by preventing development in high-risk areas.

Key benefits: Protect private property rights, allow migration of wetlands and threatened species

Water Storage Easement: (Conceptual Strategy) — *$50,000/acre*

- Conservation easements of at least 10 acres on private lands to provide ecosystem services, mainly water storage. As sea levels rise, freshwater is susceptible to saltwater contamination. Water storage easements will help protect the community's freshwater supply, while supporting ecosystem health and allowing for habitat migration.

Key benefits: Support ecosystem services, protect freshwater supply

Planned Relocation — *$700 million*

- Gradually moving infrastructure away from high-risk areas, primarily through the use of rolling conservation easements. Land will be acquired inland to allow for infrastructure to be rebuilt outside of highly vulnerable areas.
- $700 million over the next 20 years

Key benefits: Protect future infrastructure, allow migration of wetlands and threatened species

Living Shoreline — *$25,000/acre*

- Maintaining natural vegetation along the shoreline.
  1. Reintroducing wetlands to areas that have lost them. Wetlands help absorb the impact of coastal dynamics by providing a place for the water to go, acting as a buffer between the sea and development.
  2. Using organic and structural materials like wetland plants, sand, aquatic vegetation, oyster reefs and stone to create a protective shoreline and maintain valuable habitat.

Key benefits: Allow migration of habitats and threatened species, protect recreation and tourism, protect fisheries and rookeries; improve water quality via filtration of upland runoff

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Coastal Protection: The Board Game!

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The way forward… SLR in the GTMNERR

- Areas within 2.5 to 5km of the ocean are generally affected
- Changes in landcover area (0.2 to 2.5m SLR)
  - Developed Areas: loss of 10 to 400 ha
  - Undeveloped Area: loss of 40 to 800 ha
  - Because it is largely located within 5km of the ocean, St. Augustine is particularly vulnerable to the loss of developed and dry land
  - **Estimated losses are in the tens of millions to billions**
- Ecological Losses: Vulnerable habitats throughout study area
  - Regularly Flooded Marshes loose 45% (1,100 ha) under the 2m SLR scenario.
  - Tidal Flats loose 25% (650 ha) under the 2m SLR scenario.
  - Swamps loose 7% (1,800 ha) under the 2m SLR scenario.
- More than 30 stakeholder meetings underway for role play and extended decision analysis – combinations?/portfolios?
- More info and videos-   www.planningmatanzas.org

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Agenda

1. Motivation: Florida - between the devil and the deep blue sea?
2. Canaries in a coal mine: Florida style
3. Sea Level Rise and Military Infrastructure
4. Getting local and personal: Sea Level Rise predictions meet stakeholders in NE Florida
5. **The Way Forward: Where to go? How to grow?**

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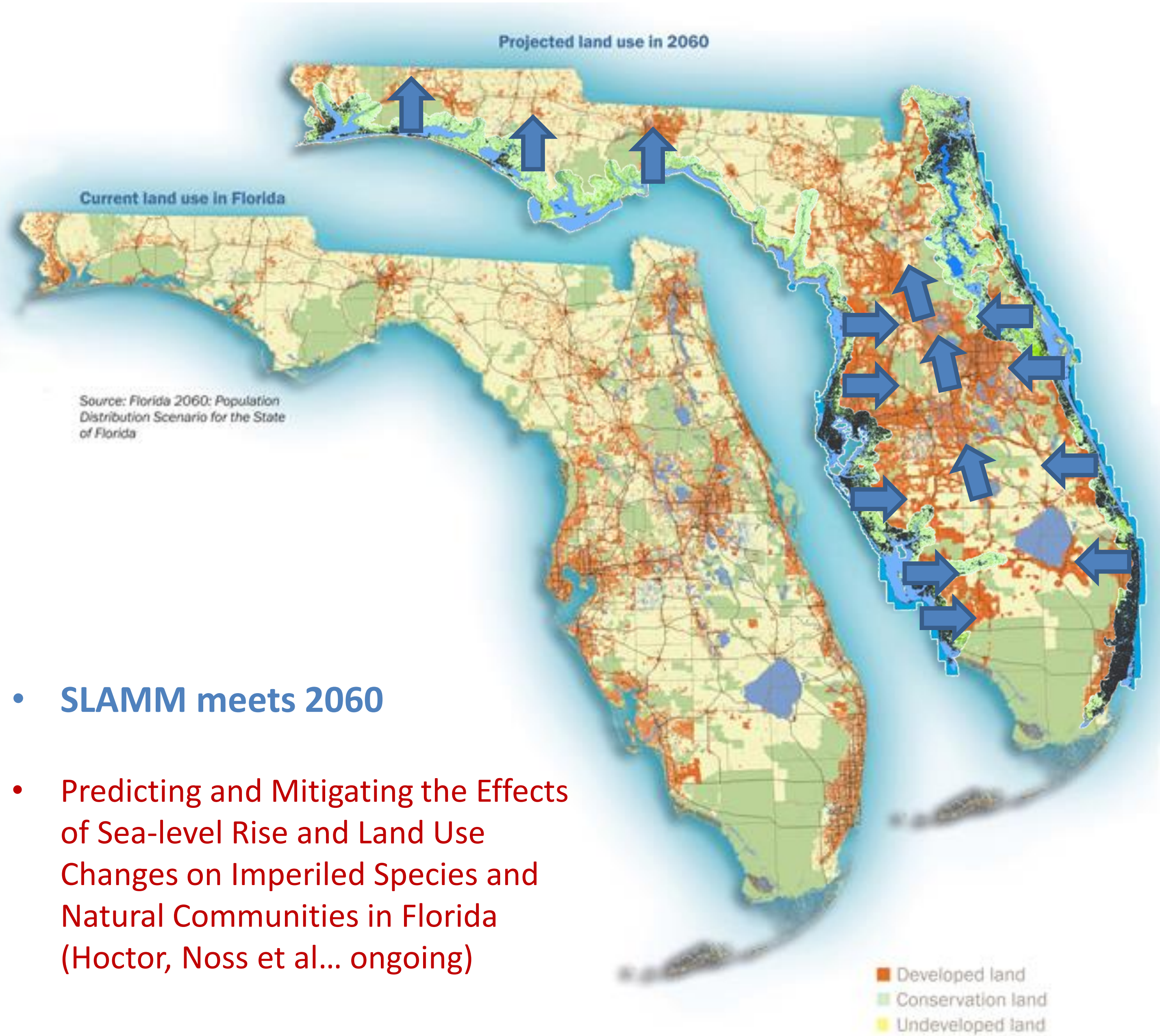
The devil is in the details… and… location, location, location

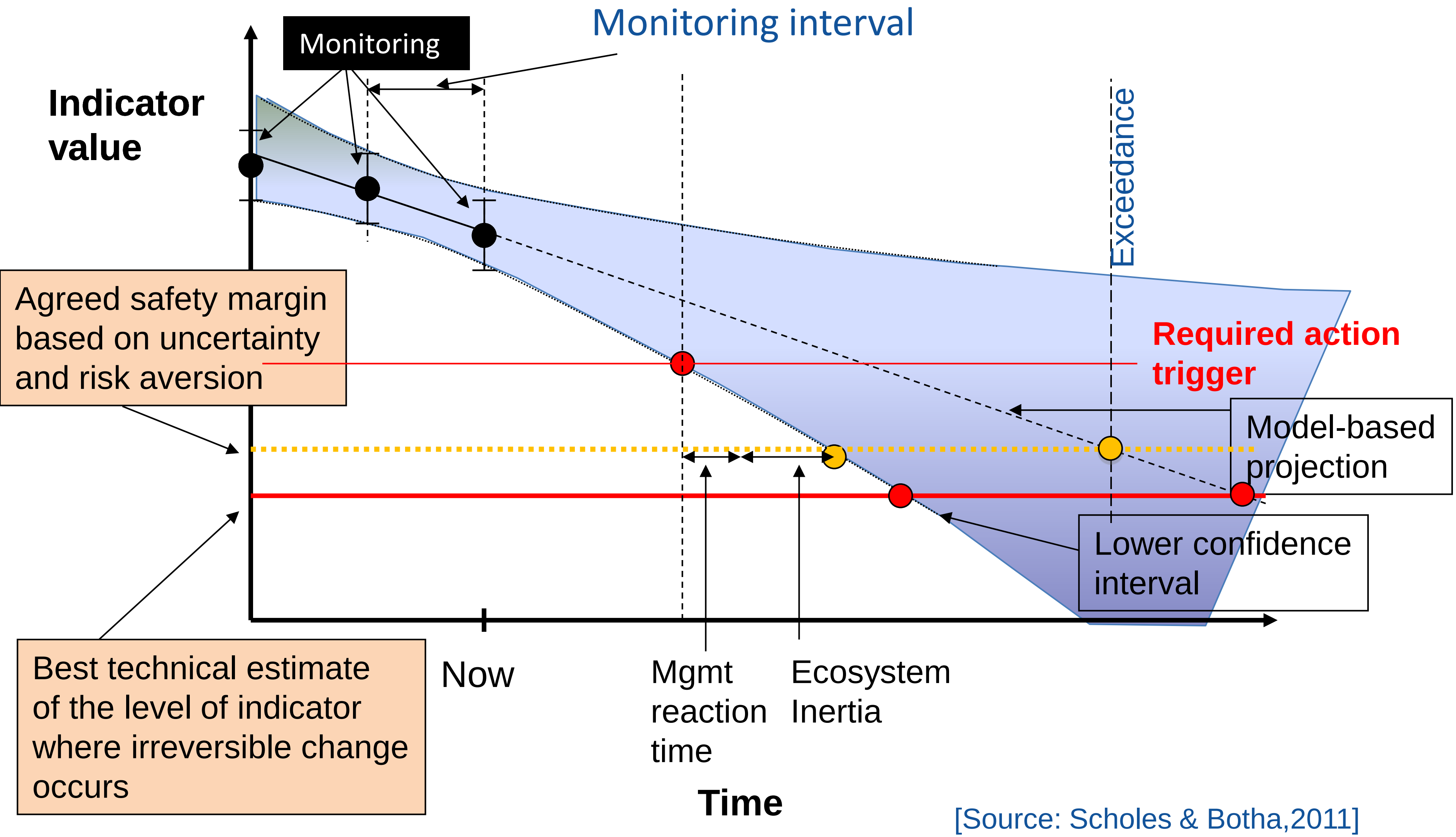


- Where will people move?
- Where will wildlife move?
- How can both thrive?

- **SLAMM meets 2060**

- Predicting and Mitigating the Effects of Sea-level Rise and Land Use Changes on Imperiled Species and Natural Communities in Florida (Hoctor, Noss et al… ongoing)

The Way Forward:
To integrate many types of information to help inform decisions



[Source: Scholes & Botha,2011]

Discussion:

Assessing and Managing Consequences Related to Sea Level Rise and Coastal Storms

1. There has been plenty of assessing, but precious little managing going on…
2. Historical beliefs about floods and storm surge still dominate planning discussions
3. Uncertainty paralyzes decision makers, even when the numbers are clear and compelling.
4. The Way Forward remains the same: Where to go? How to grow?

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Thank you for your attention

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