A SPATIAL COMPARISON APPROACH FOR MULTIPLE INDICATOR SPECIES UNDER EVERGLADES RESTORATION

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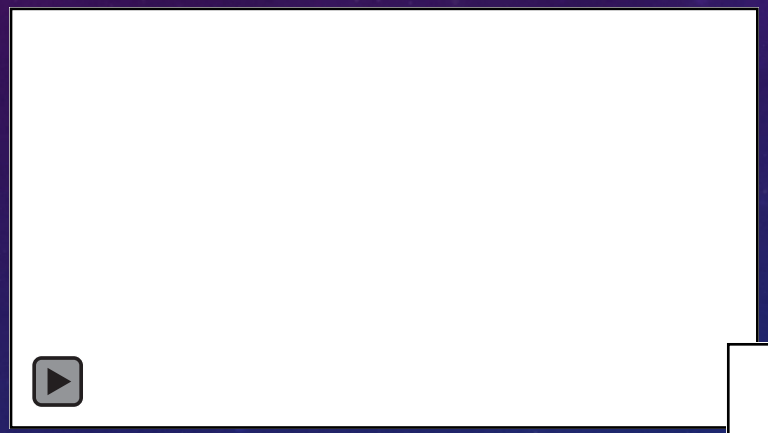
THE EVERGLADES FOUNDATION

EVERGLADES IMPACTED BY MULTIPLE THREATS

Changes in regional hydrology
Compartmentalization
– canals & levees
Reduction by 50%

Pollution, particularly, phosphorus



Soil loss
Invasive species
Climate change & sea level rise

Everglades restoration is complex!

Billions of dollars, Long time scales, Multiple Stakeholders

Everglades Indicator Species help gauge restoration responses

Abundance and diversity of native plants and animals

↓

Health and Integrity of ecosystems

↓

Restoration success

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Snail Kites
Apple snail

Marl Prairie

Open Marsh

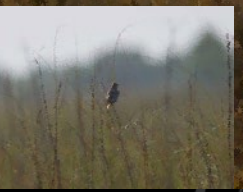
American
Alligator

Great egret

© Brian Call & Mac Stone

Snail Kites
Apple snail

Marl Prairie



Open Marsh

American Alligator

Top predators
Alligators create holes used by other species during dry season

Great egret

© Brian Call & Mac Stone

RESTORATION SCENARIOS

Natural Systems Model – NSM

Predrainage, predevelopment system

Comprehensive Everglades Restoration Plan – CERP0

Massive restoration plan of 68 projects

Moderate decomp & seepage wall – MDS_MS

2 million acre ft EAA storage

Moderate decomp & seepage wall – MDS

240,000 acre ft of storage in EAA

Existing Baseline Condition - ECB No management actions beyond 2010

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Less similar to Natural System

Natural Systems Model – NSM

Predrainage, predevelopment system

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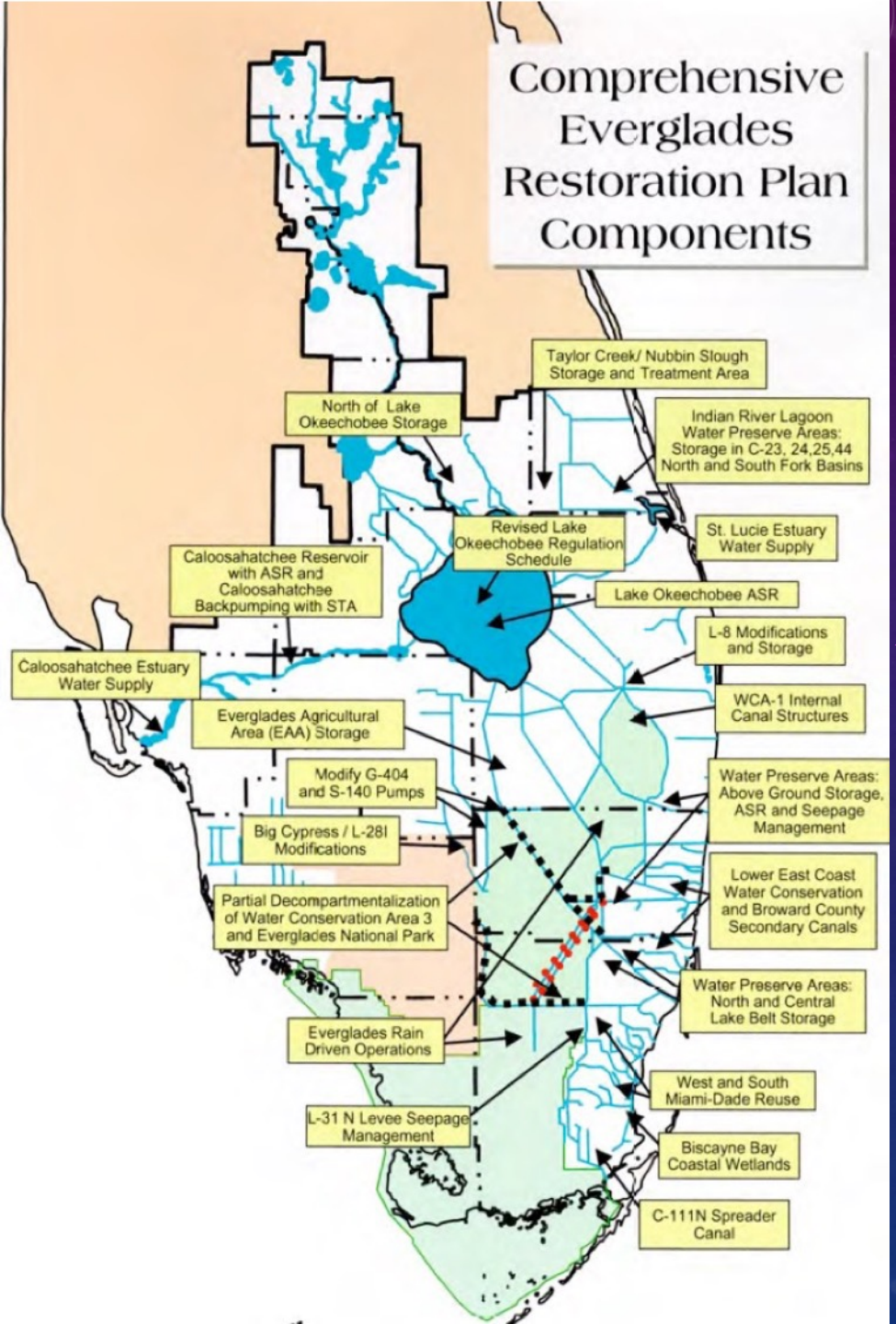
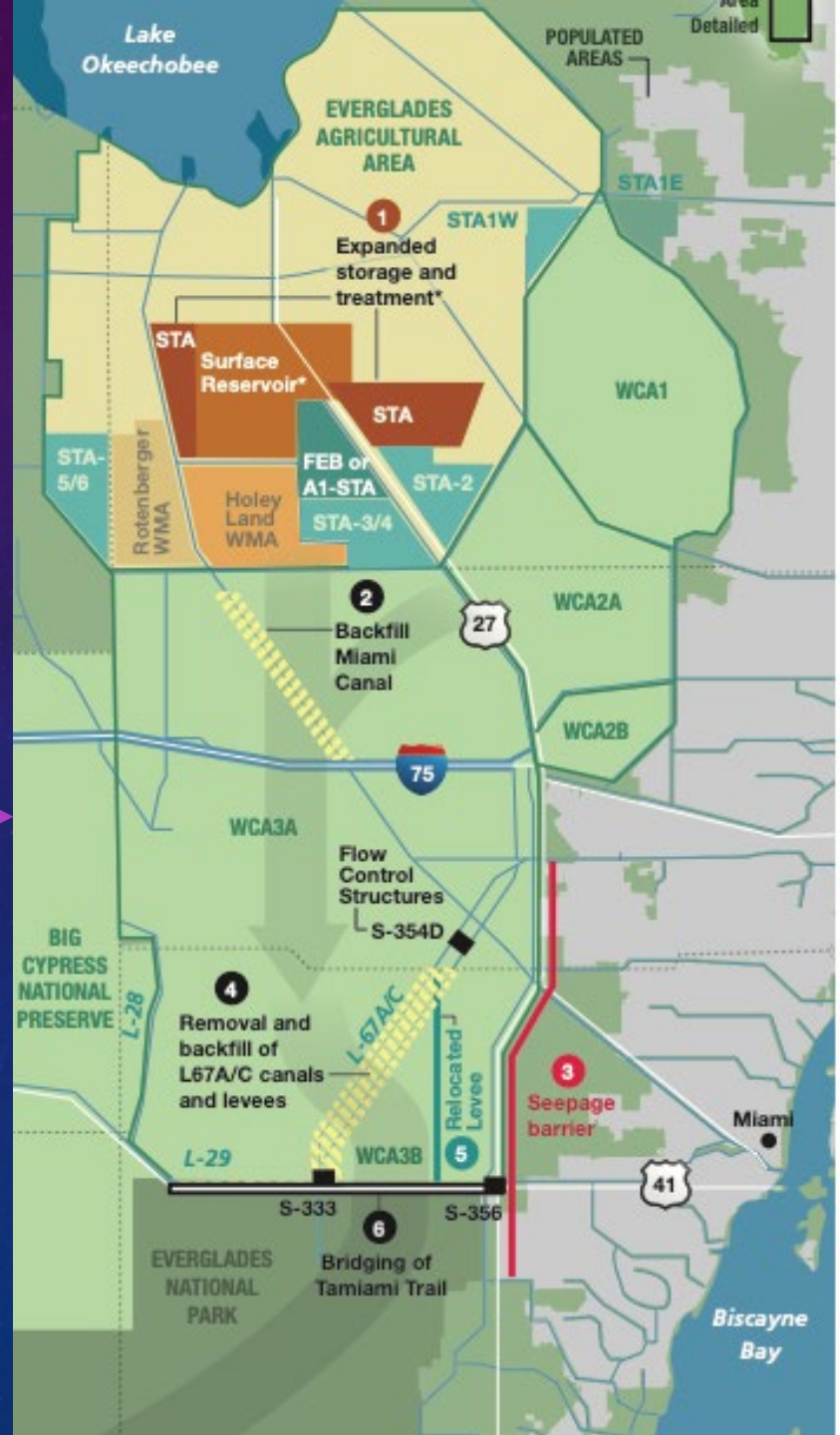

Comprehensive Everglades Restoration Plan Components
Taylor Creek/ Nubbin Slough Storage and Treatment Area
North of Lake Okeechobee Storage
Indian River Lagoon Water Preserve Areas: Storage in C-23, 24,25,44 North and South Fork Basins
Revised Lake Okeechobee Regulation Schedule
St. Lucie Estuary Water Supply
Caloosahatchee Reservoir with ASR and Caloosahatchee Backpumping with STA
Lake Okeechobee ASR
L-8 Modifications and Storage
Caloosahatchee Estuary Water Supply
WCA-1 Internal Canal Structures
Everglades Agricultural Area (EAA) Storage
Modify G-404 and S-140 Pumps
Water Preserve Areas: Above Ground Storage, ASR and Seepage Management
Big Cypress / L-28I Modifications
Lower East Coast Water Conservation and Broward County Secondary Canals
Partial Decompartmentalization of Water Conservation Area 3 and Everglades National Park
Water Preserve Areas: North and Central Lake Belt Storage
Everglades Rain Driven Operations
West and South Miami-Dade Reuse
L-31 N Levee Seepage Management
Biscayne Bay Coastal Wetlands
C-111N Spreader Canal

CERP0

MDS


Lake Okeechobee
POPULATED AREAS
Detailed
EVERGLADES AGRICULTURAL AREA
STA1E
STA1W
1
Expanded storage and treatment*
STA
Surface Reservoir*
STA
WCA1
STA-5/6
Rotenberger WMA
FEB or A1-STA
STA-2
Holey Land WMA
STA-3/4
2
Backfill Miami Canal
27
WCA2A
WCA2B
75
WCA3A
Flow Control Structures
S-354D
BIG CYPRESS NATIONAL PRESERVE
L-28
4
Removal and backfill of L67A/C canals and levees
L-67A/C
Relocated Levee
5
3
Seepage barrier
Miami
L-29
WCA3B
41
S-333
S-356
6
Bridging of Tamiami Trail
EVERGLADES NATIONAL PARK
Biscayne Bay

SCENARIO COMPARISONS HELP PREDICT RESTORATION SUCCESS

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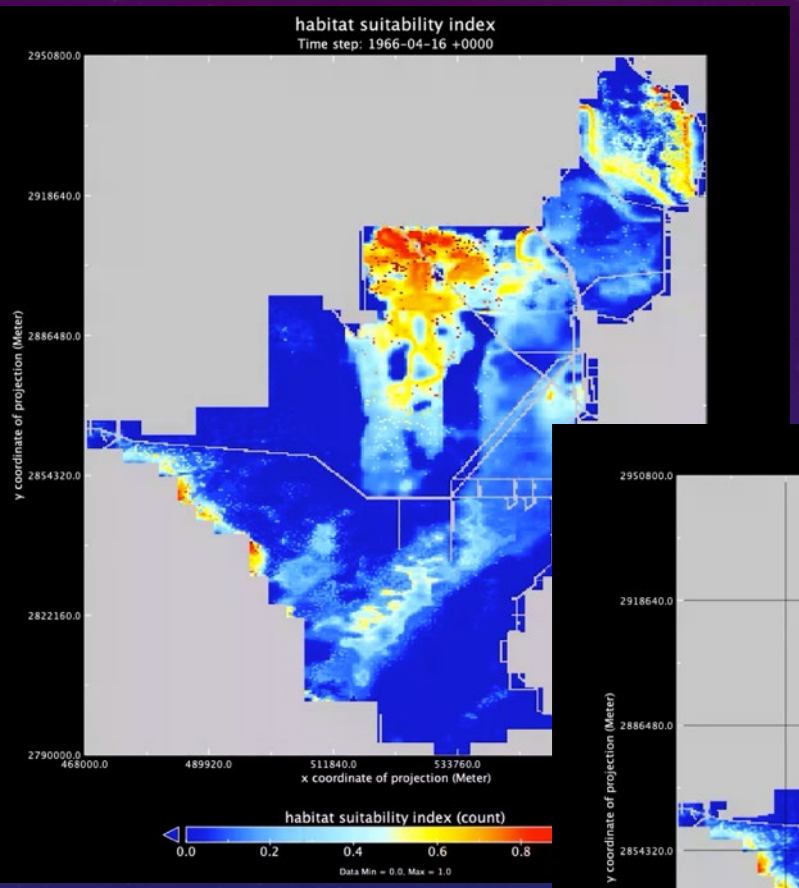
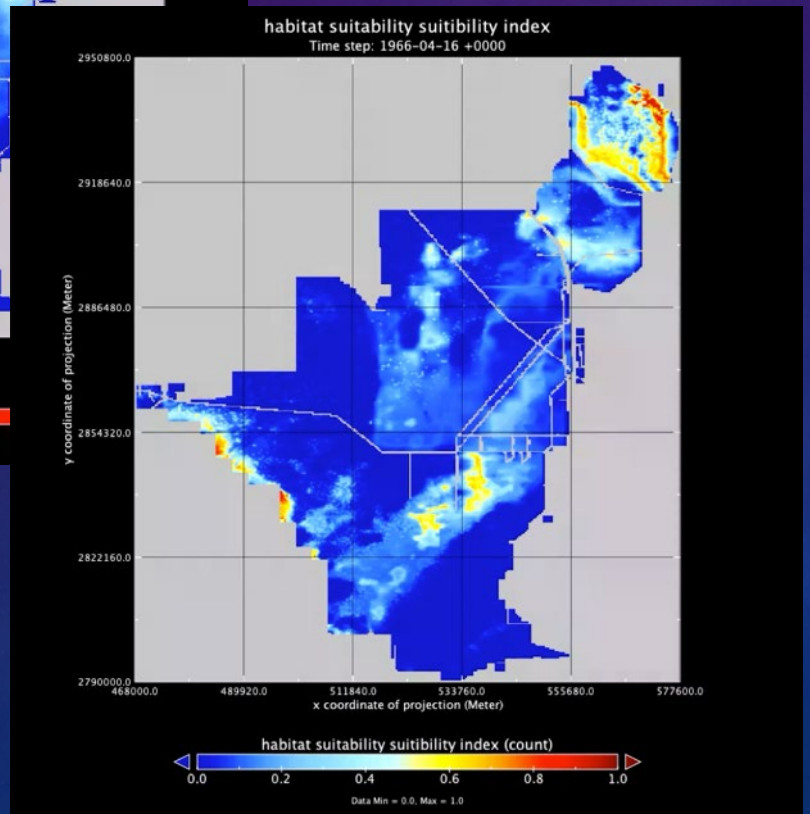




Often compare scenarios
"Relative change approach"
Mean values compared to a baseline

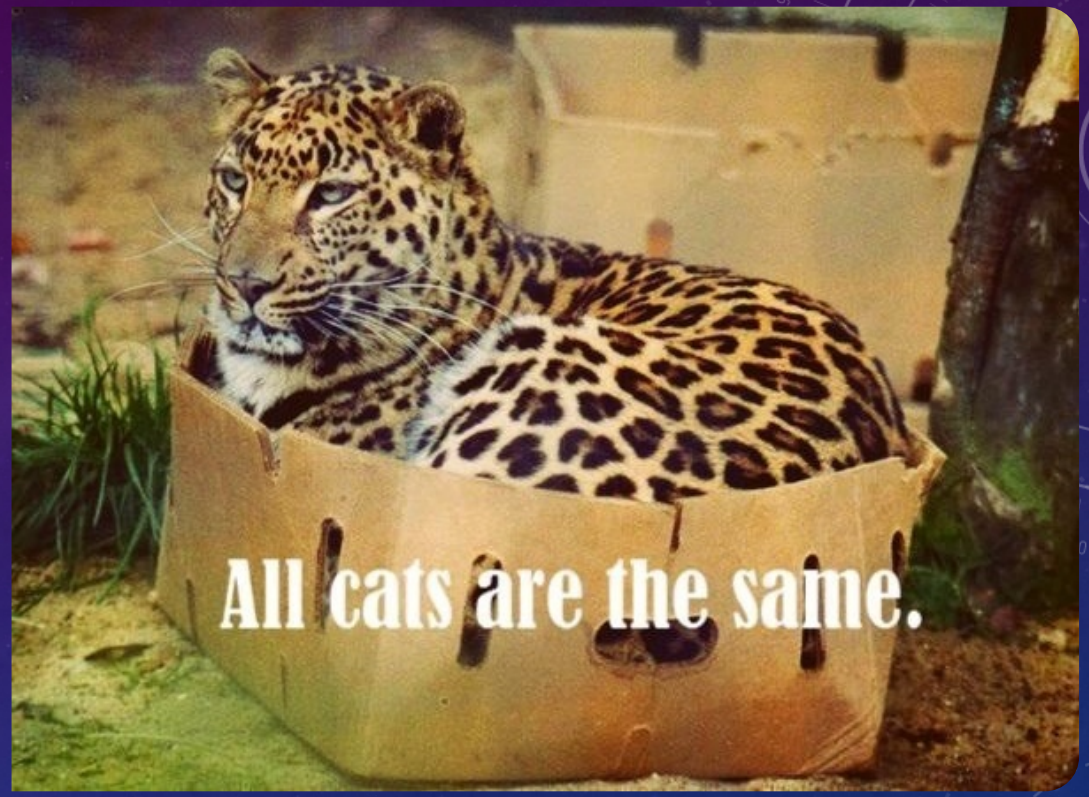
Grid cells in local regions - spatially dependent
Only using one statistic
Variance and Covariance between maps

DIGITAL IMAGE COMPARISON TO HELP PREDICT RESTORATION SUCCESS

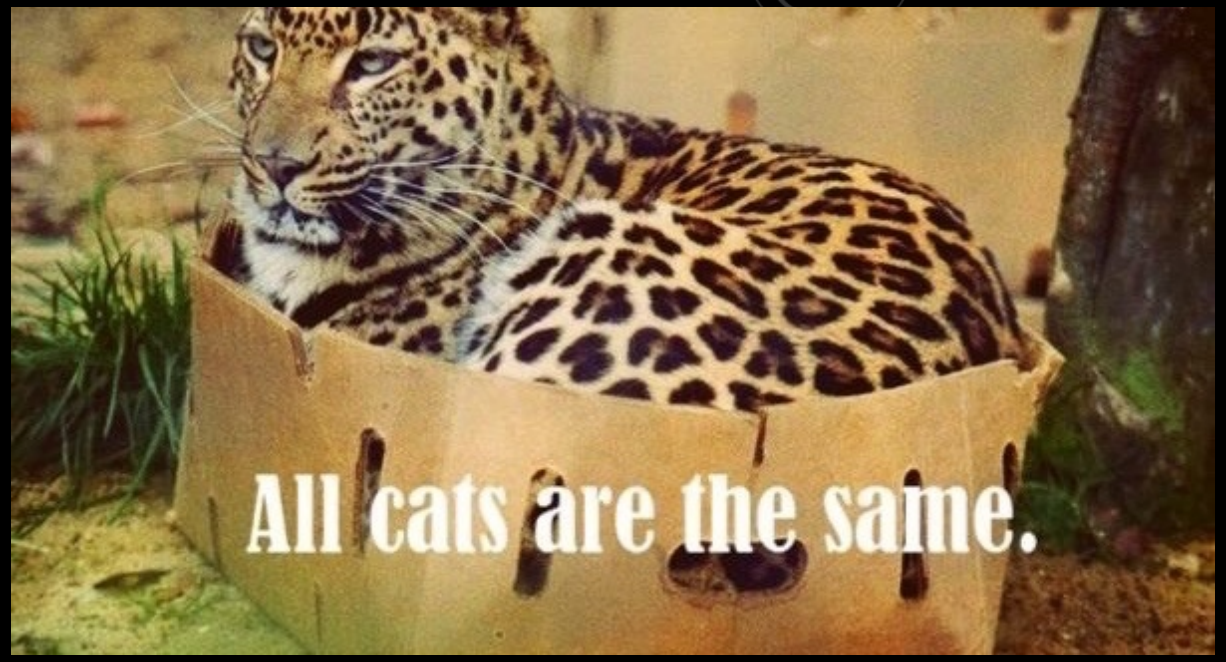
Widely used in Computer science
Recently applied to ecology

DIGITAL IMAGE COMPARISON

DIGITAL IMAGE COMPARISON



DIGITAL IMAGE COMPARISON


All cats are the same.


All cats are the same.

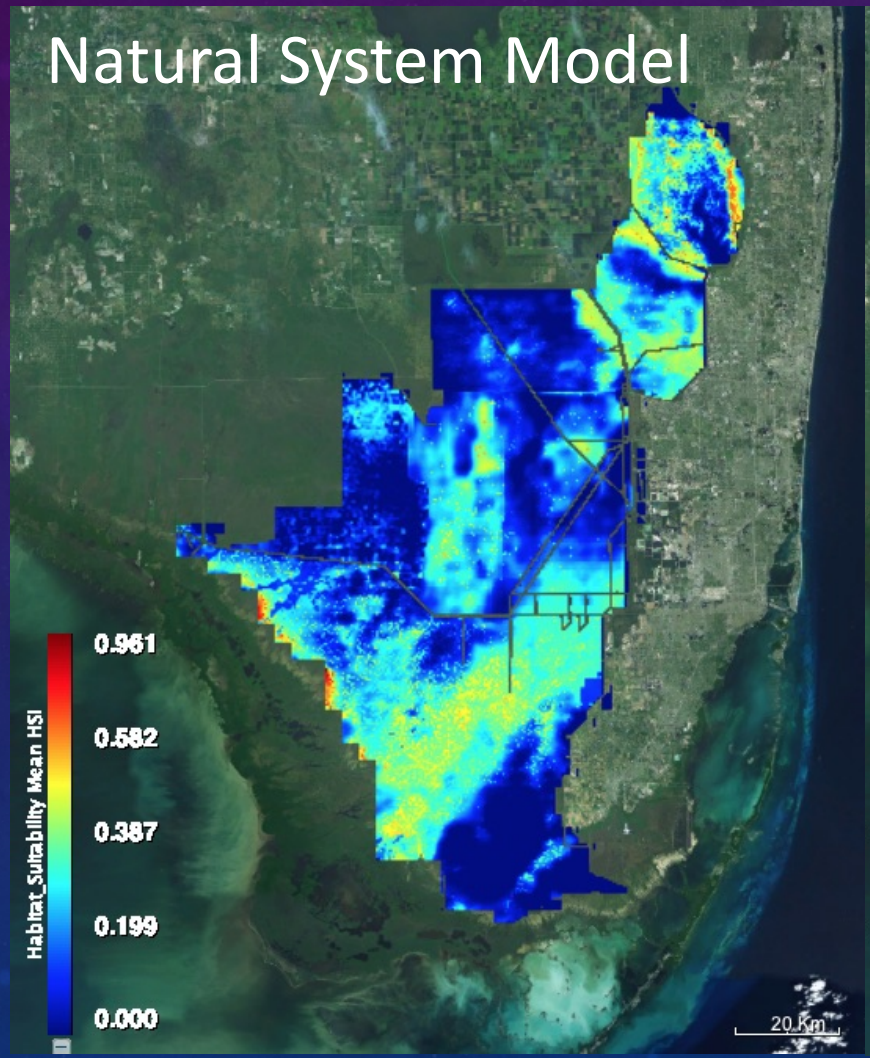
STRUCTURAL SIMILARITY INDEX

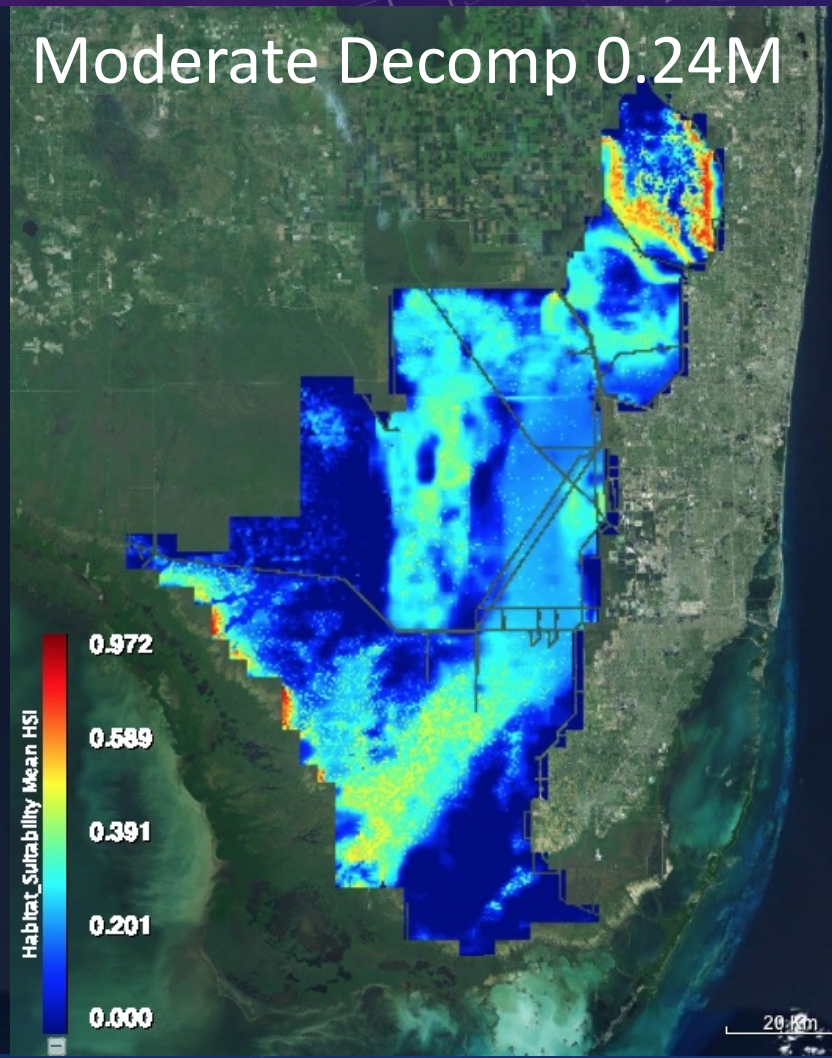
Overall measure of comparison between 2 maps (-1 to 1)

Locally moving window

Annual comparisons to NSM

Product of similarity in means, covariances & variances





Jones et al 2016, Wang et al 2004

Similarity in Means

$$SIM(A,B) = \frac{2\mu_a\mu_b + c_1}{\mu_a^2 + \mu_b^2 + c_1}$$

Similarity in Variances

$$SIV(A,B) = \frac{2\sigma_a\sigma_b + c_2}{\sigma_a^2 + \sigma_b^2 + c_2}$$

Similarity in Covariances

$$SIP(A,B) = \frac{\sigma_{ab} + c_3}{\sigma_a\sigma_b + c_3}$$

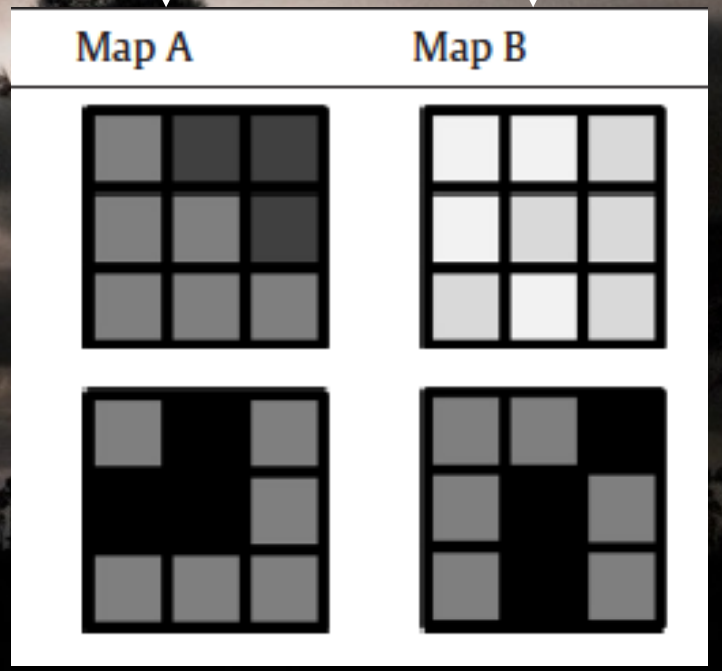
Overall Structural Similarity Index SSIM

$$SSIM(A,B) = [SIM(A,B)]^{\alpha} \cdot [SIV(A,B)]^{\beta} \cdot [SIP(A,B)]^{\gamma}$$

Similarity in Means (0, 1)

Similarity in abundances, habitat suitability, etc

Map A has high values Map B has low values = 0



Both Map A & B have high values = 1

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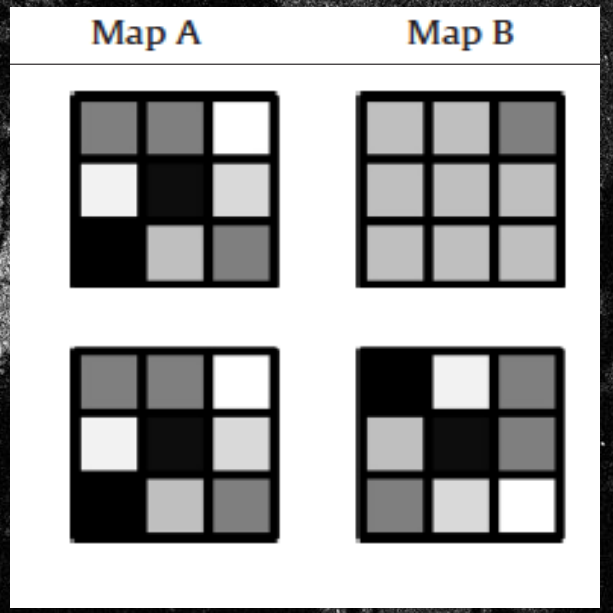
Similarity in Variances (0, 1)

Map A high variance
Spatial clustering

Map B has low variance
Homogenous distribution

= 0



Similarity in distributions
– either homogeneous
or spatially clustered

Both Map A & B have high variance
Both spatially clustered

= 1

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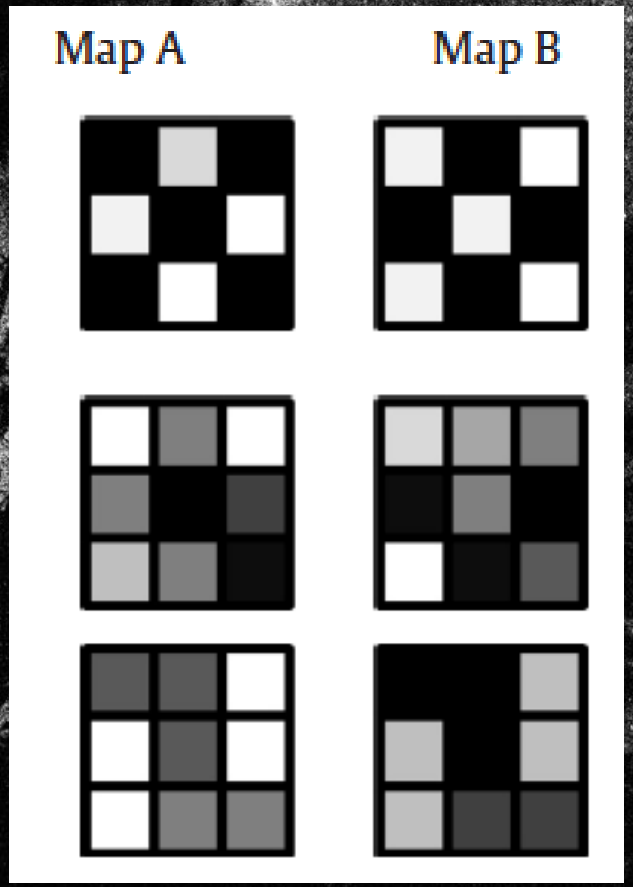
Similarity in Covariances

(-1, 1)

Similarity in spatial patterns & spatial correlation

Map A has high values in some cells

Map B has high values = -1 In other cells



Map A & B have no spatial correlation = 0

Both Map A & B have low & high values in same cells = 1

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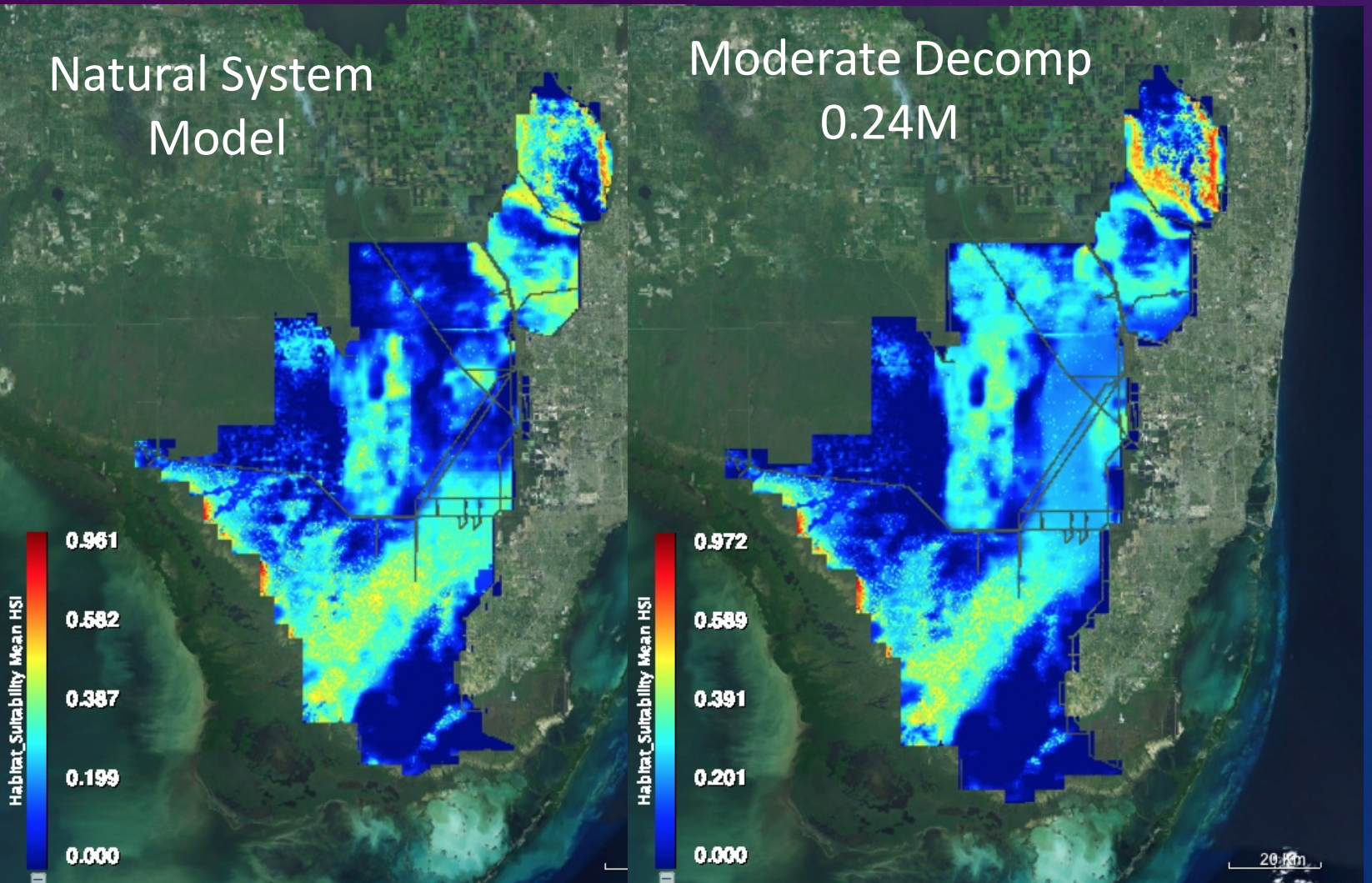
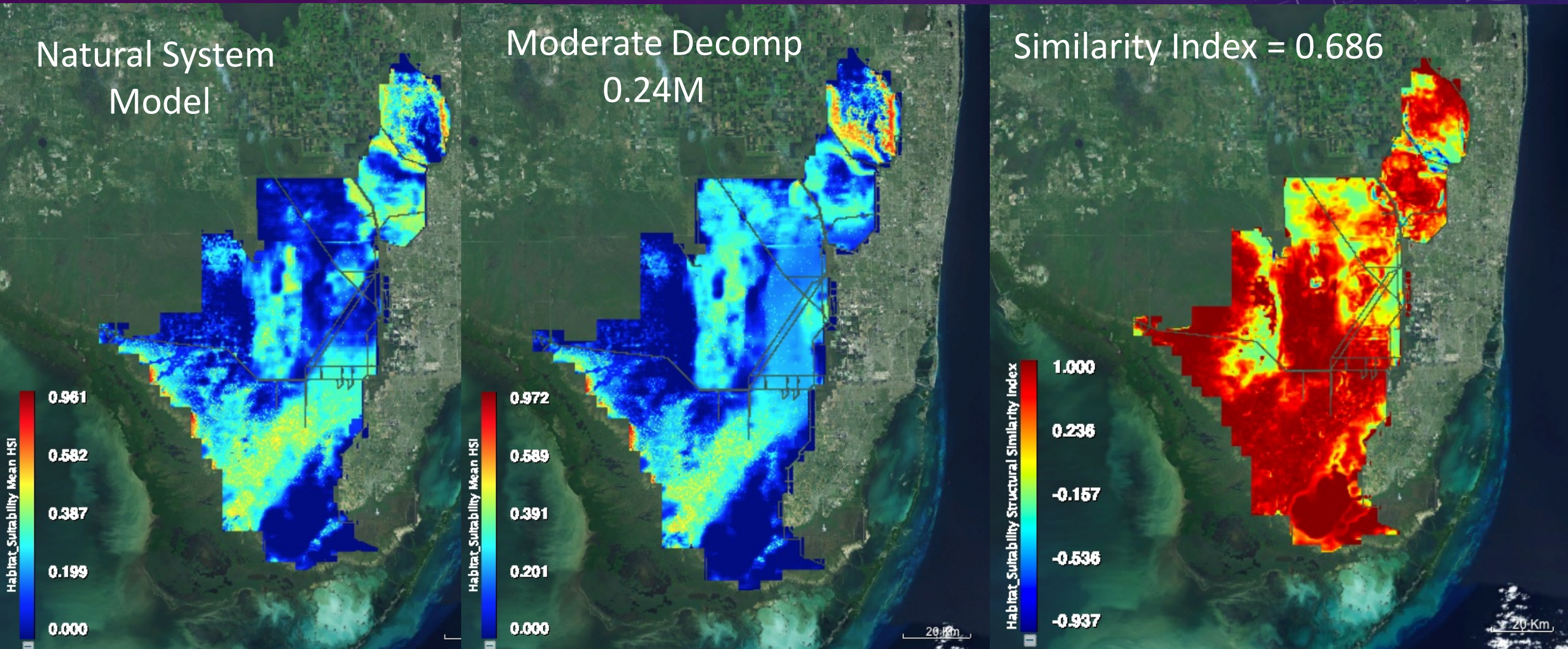
AMERICAN ALLIGATORS



AMERICAN ALLIGATORS



Overall Similarity Index

Habitat Suitability Means

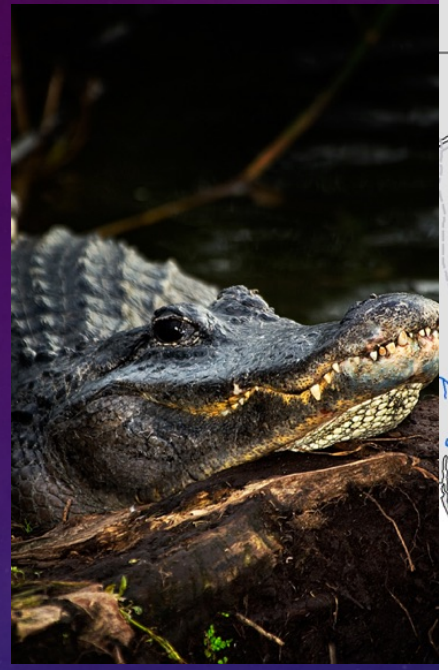
Variances - Distributions of Habitat Suitability

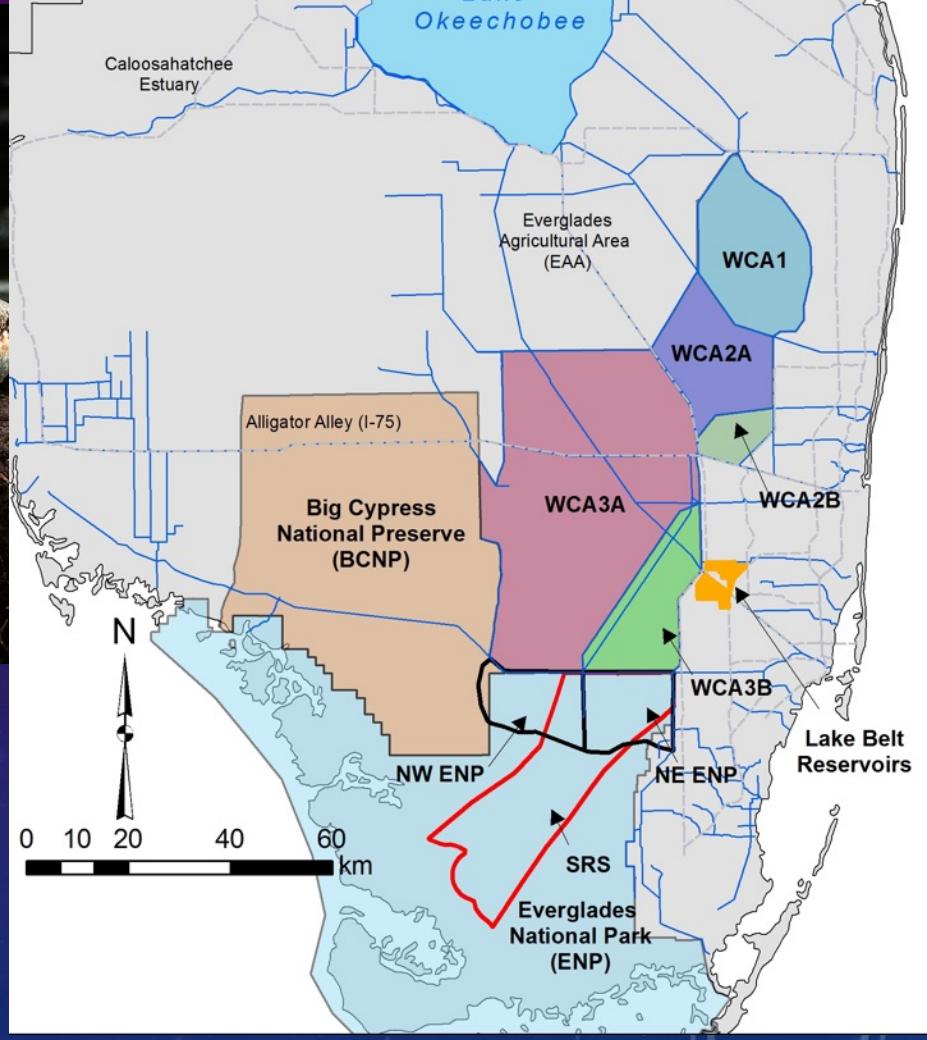
Covariances – Spatial Patterns of Habitat Suitability

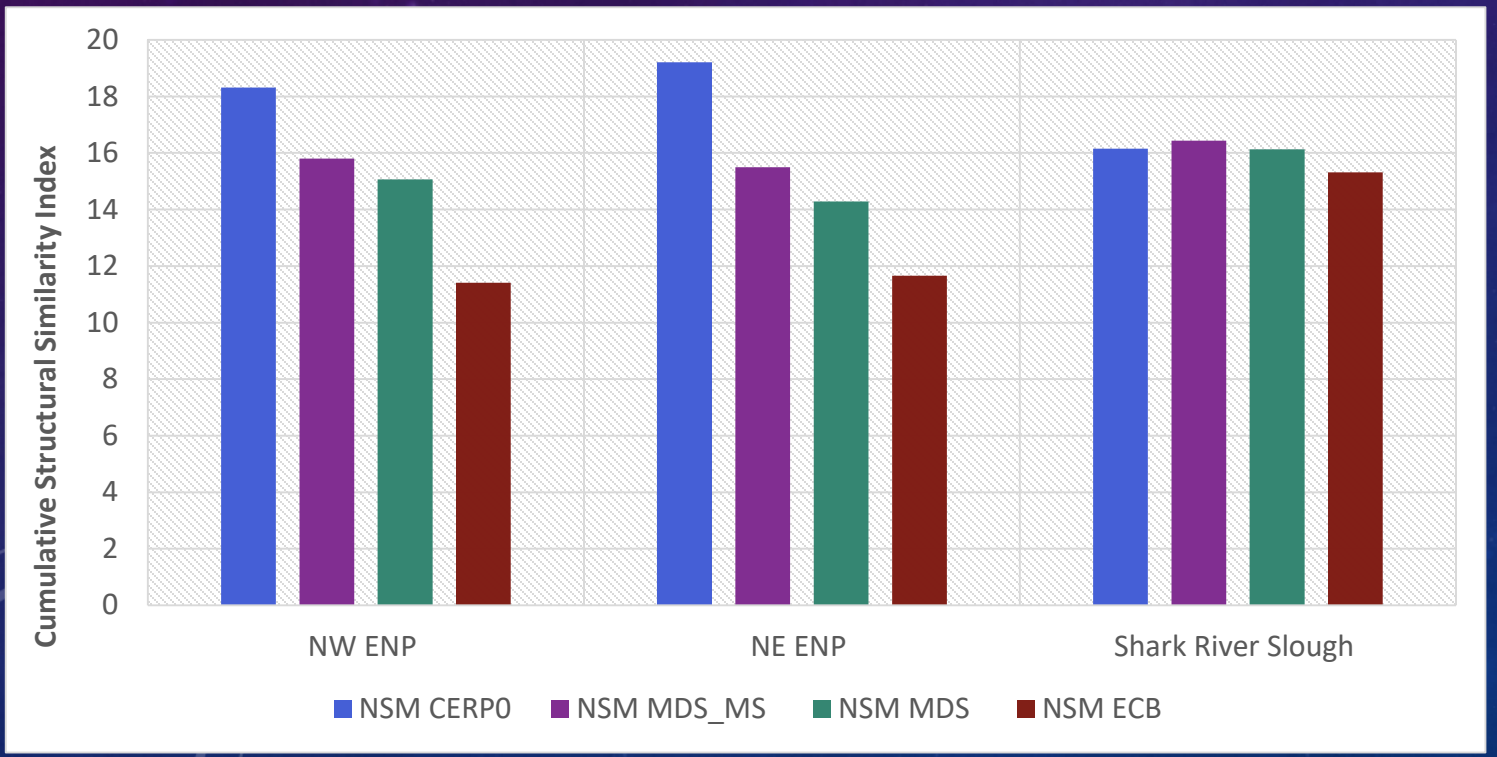
ALLIGATORS SIMILARITY INDICES

NSM MDS 0.24 M

ALLIGATOR STRUCTURAL SIMILARITY INDEX



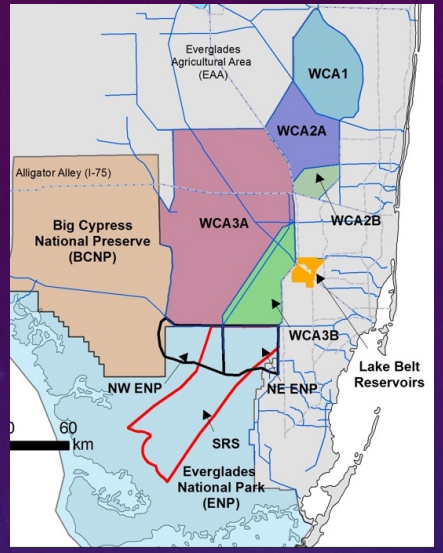


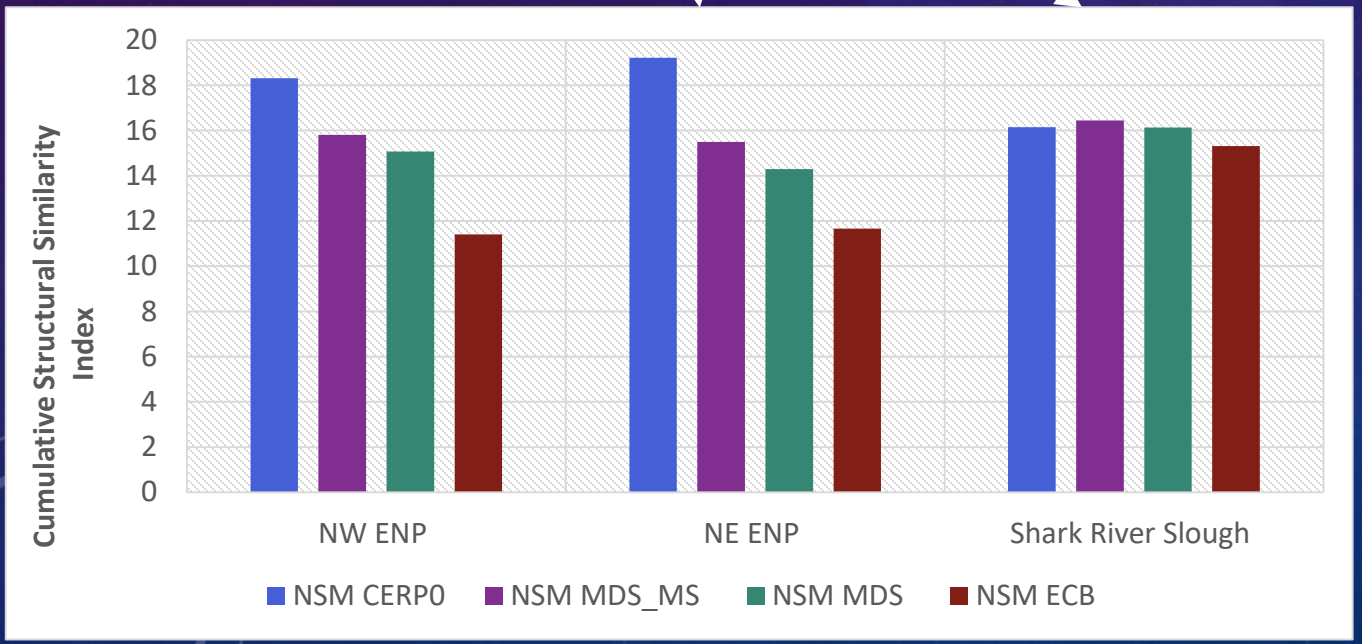


ALLIGATOR STRUCTURAL SIMILARITY INDEX

NSM & MDS_MS = Higher similarity in pattern indices

Same cells had similar levels (high versus low) of alligator habitat suitability





Natural Systems Model – NSM

Comprehensive Everglades Restoration Plan – CERP0

Moderate decomp & seepage wall – MDS_MS

2M acre-ft

Moderate decomp & seepage wall – MDS

0.24 K acre-ft

Existing Baseline Condition - ECB

Structural Similarity Index is a novel technique for restoration scenario comparison

Flexible metric for continuous, grid data

Multi-factor: Similarity in means, pattern, and distribution

Grid cells in local regions are spatially dependent

Code for netcdf files

QUESTIONS?

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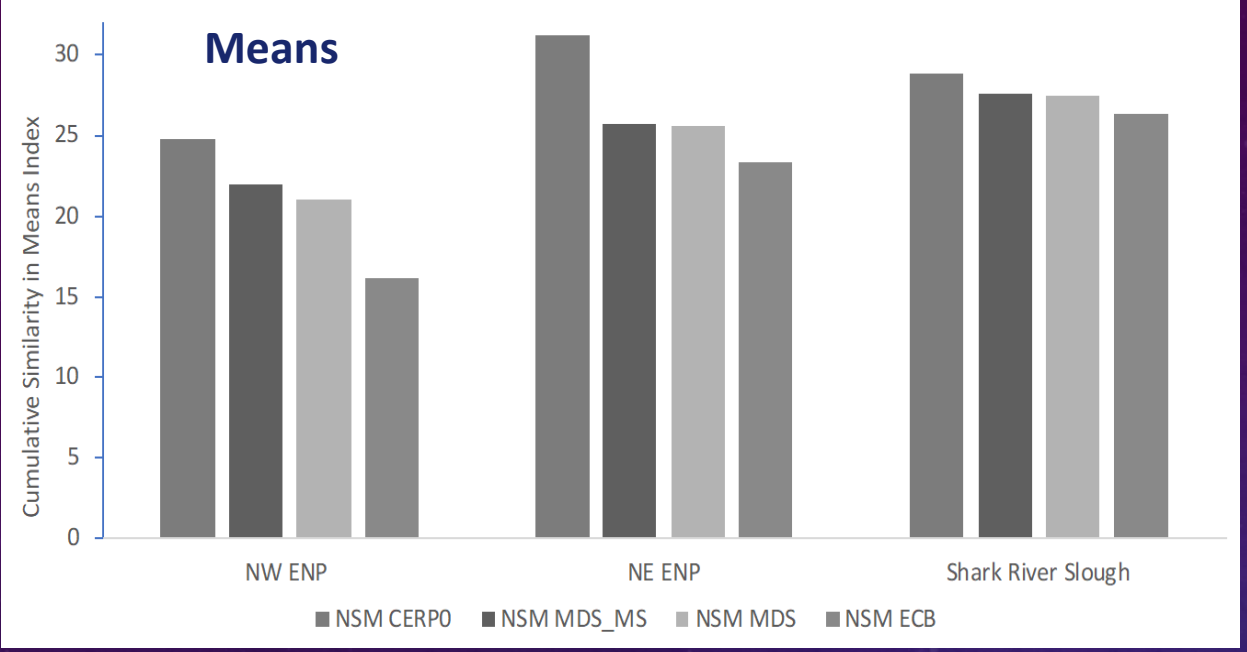
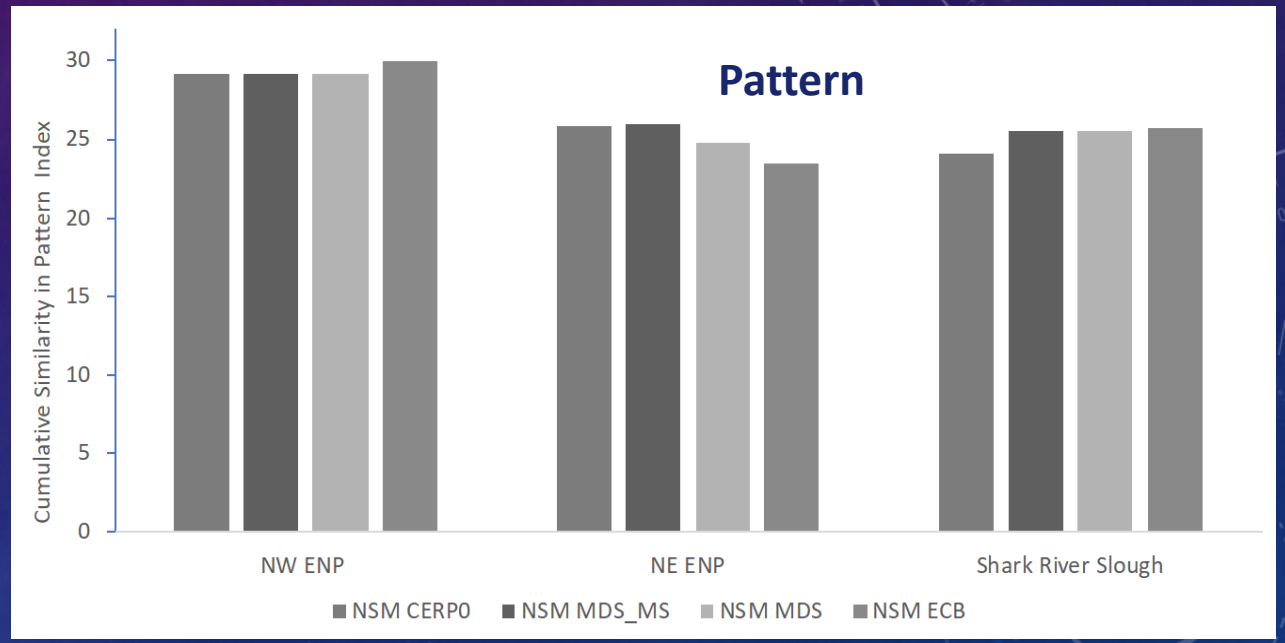
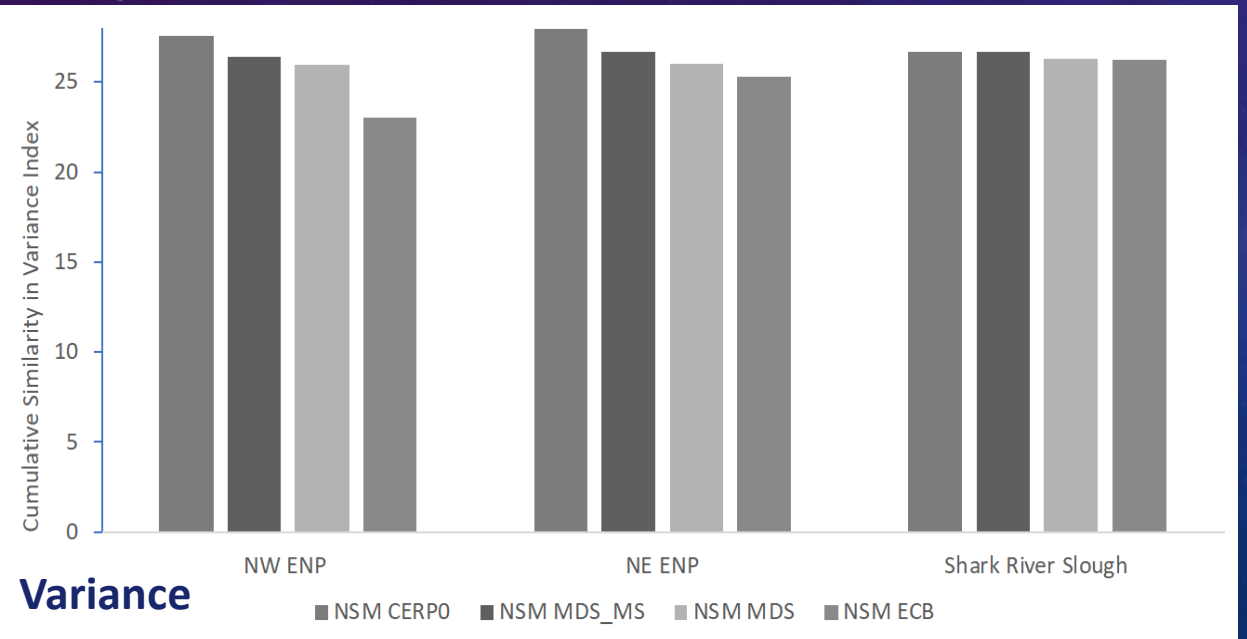


Habitat Suitability Means

Covariances – Spatial Patterns of Habitat Suitability



Similar Pattern to Overall Index



Variances - Distributions of Habitat Suitability