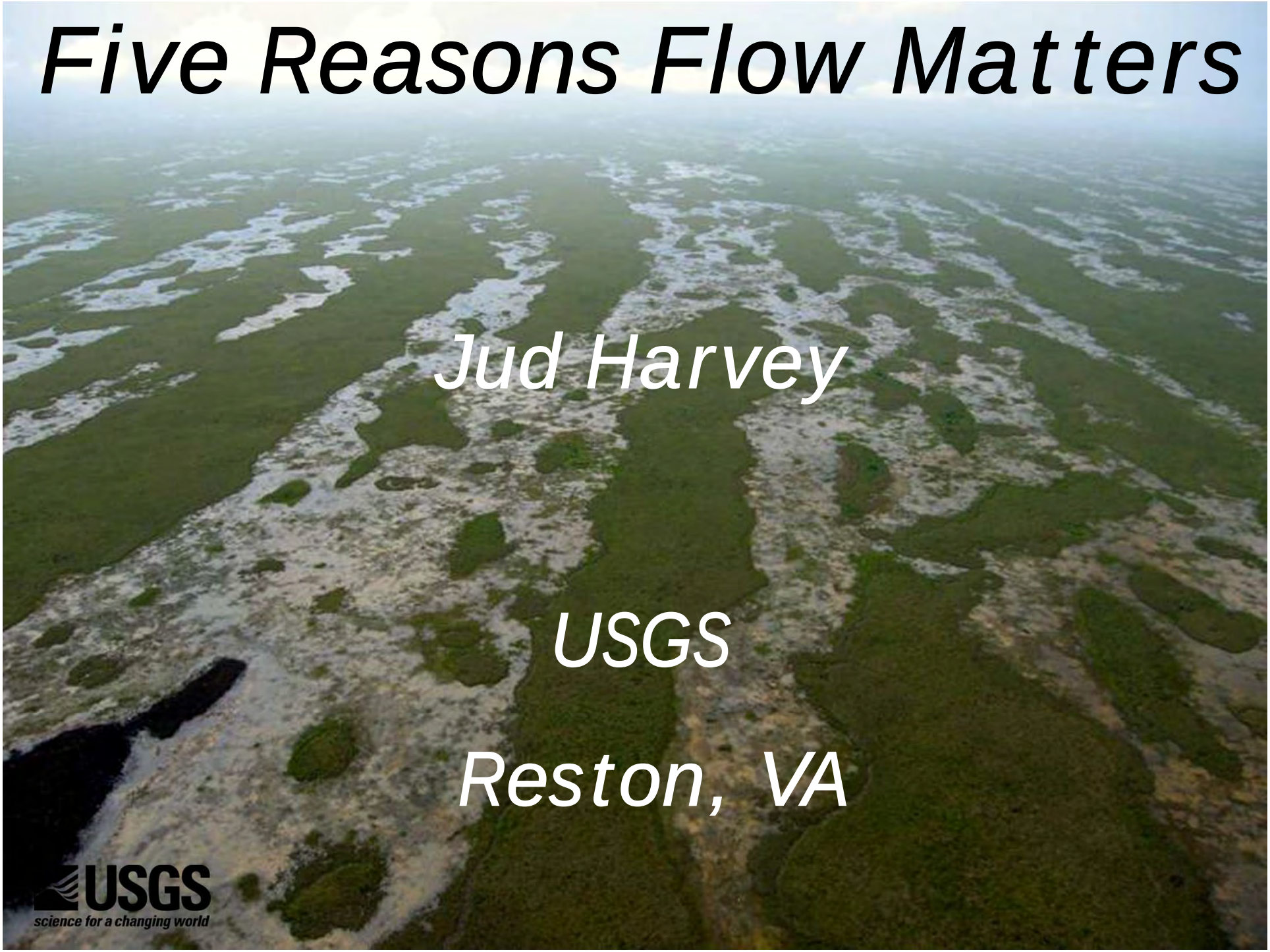
Five Reasons Flow Matters



Jud Harvey

USGS

Reston, VA

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Hydroecology of Flowing Waters

USGS, Reston, VA

Jud Harvey Laurel Larsen Katie Skalak Jay Choi

http://water/usgs.gov/nrp/jharvey

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Morgan Maglio, Jai Singh, and Geoff Sinclair, USGS, Reston

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Martha Nungesser and others, SFWMD, West Palm Beach

Synthesis of Everglades Restoration and Ecosystem Services (SERES)

Decompartmentalization Physical Model (DPM) team: SFWMD, USGS, FIU, ENP, and U. HI

funding from USGS, National Park Service, National Science Foundation, and Army Corps of Engineers

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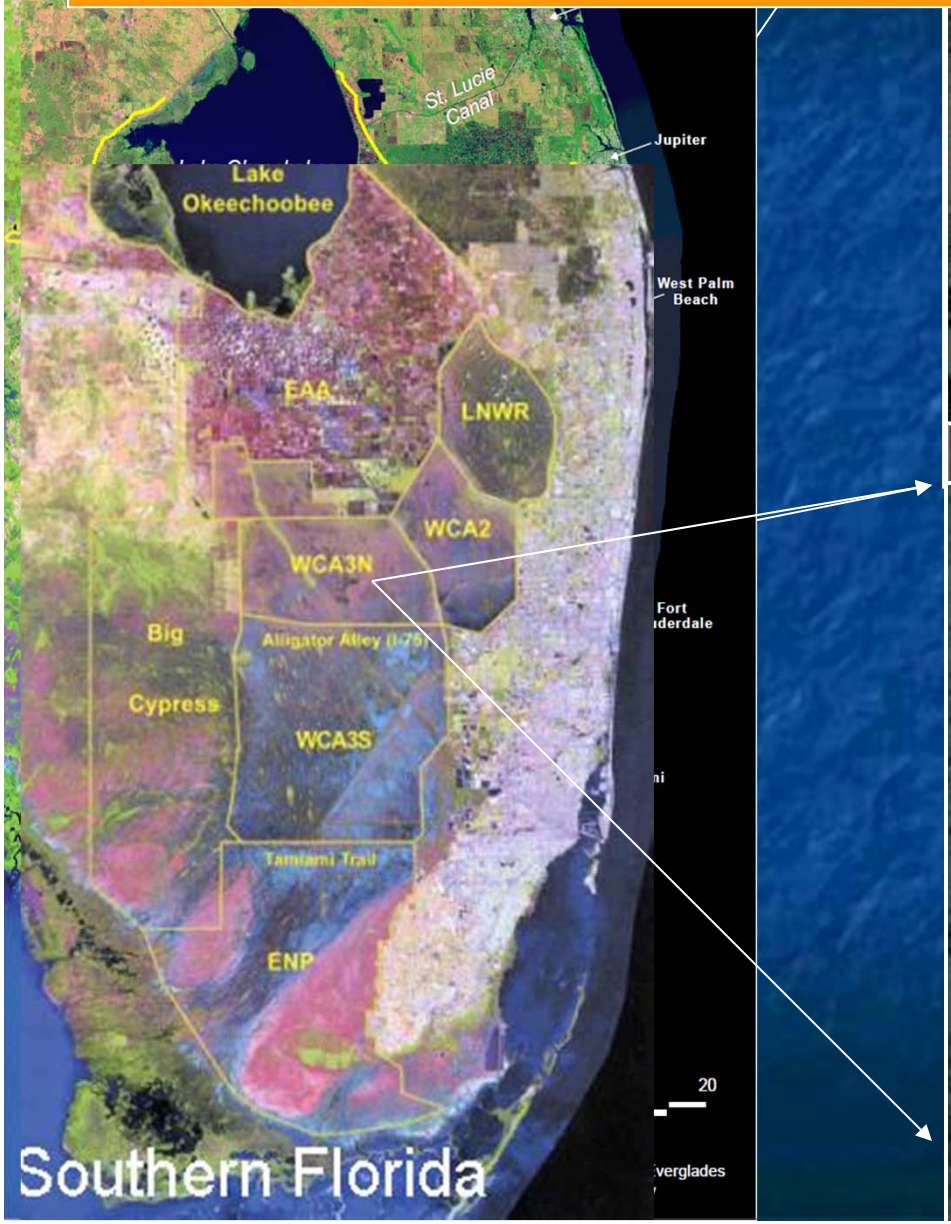
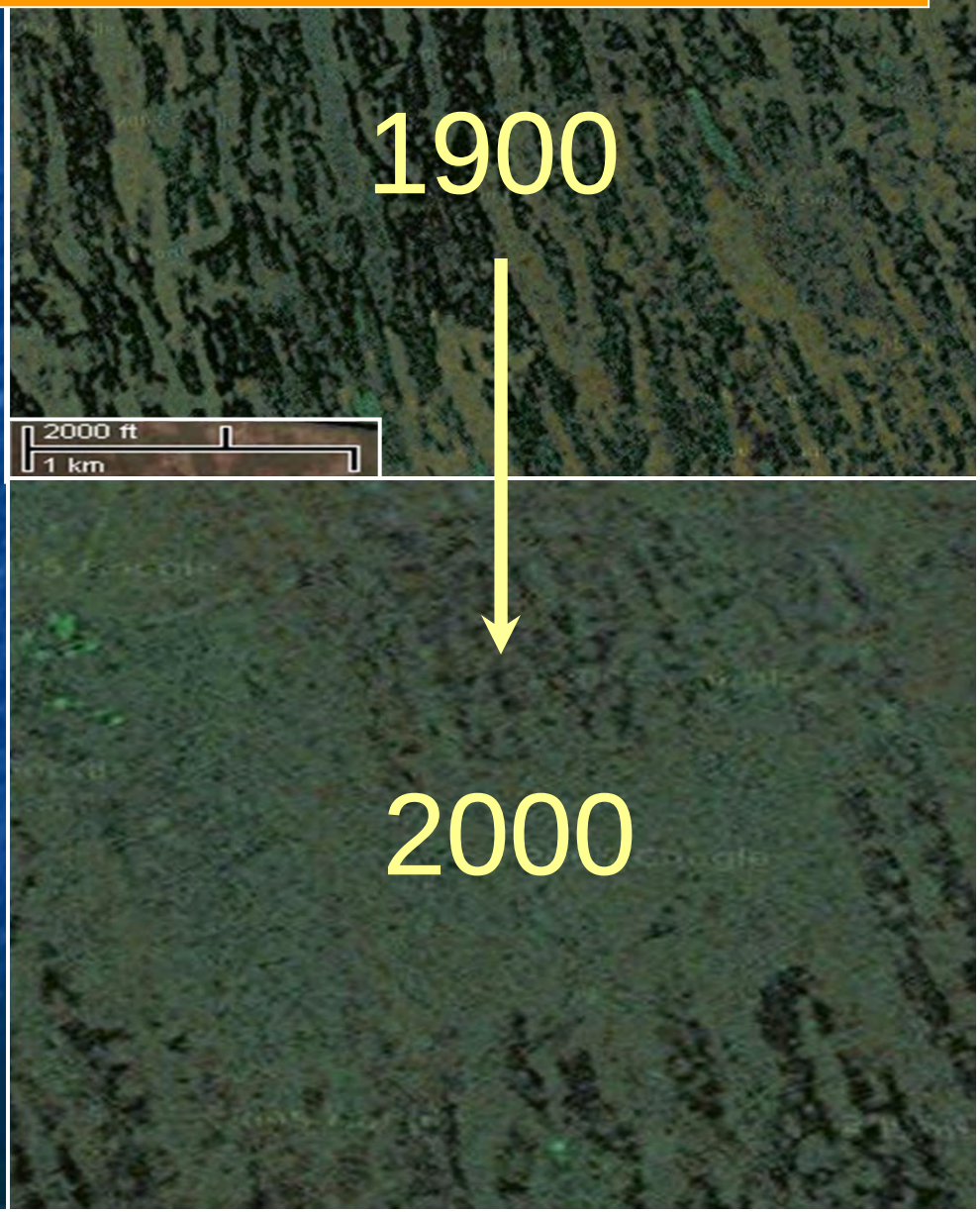
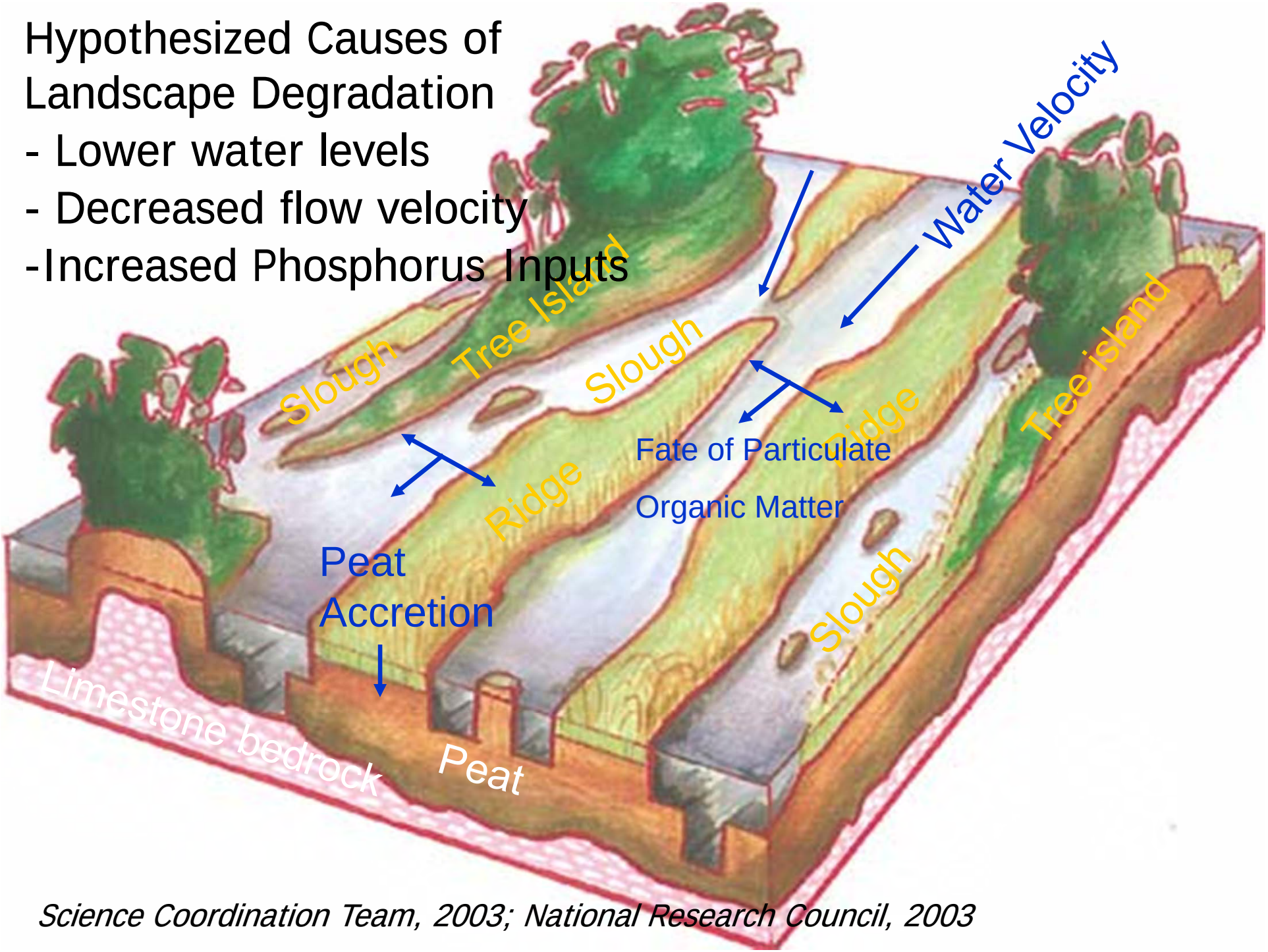
Loss of Ecological Services…hydrologic connectivity, habitat biodiversity, migration/dispersal, freshwater supply to S.E. Florida





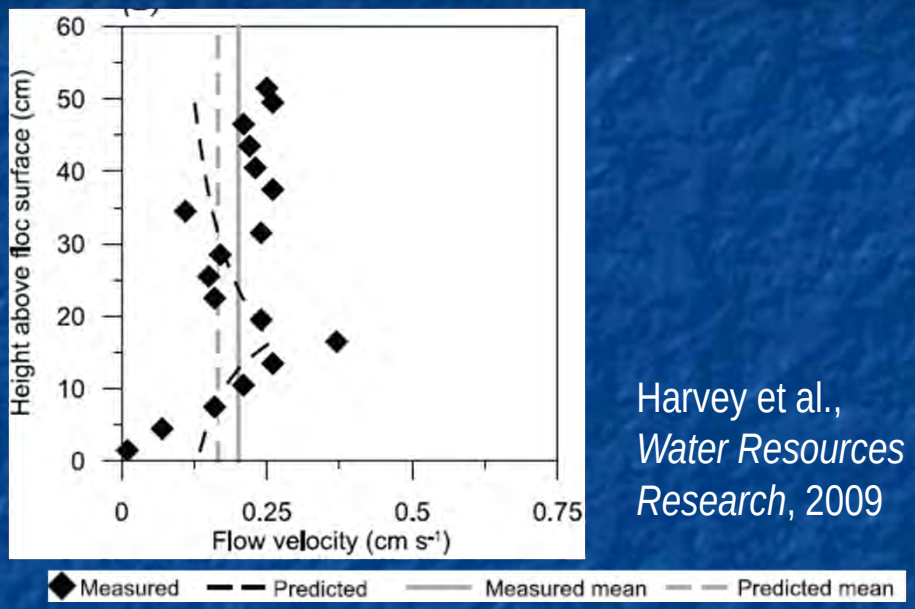
Hypothesized Causes of Landscape Degradation

- Lower water levels
- Decreased flow velocity
- Increased Phosphorus Inputs

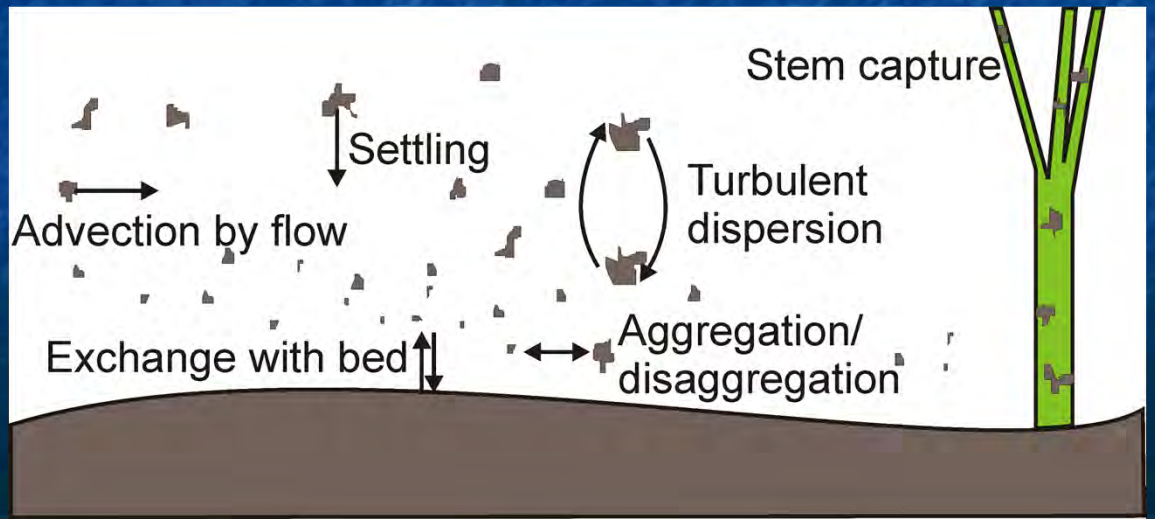


Science Coordination Team, 2003; National Research Council, 2003

Experiments and Modeling to Build a Predictive Framework for Wetland Hydraulics/Sediment Transport



Harvey et al., *Water Resources Research*, 2009



Larsen et al., *Water Resources Research*, 2009a, b; Huang et al., *Water Resources Research*, 2008

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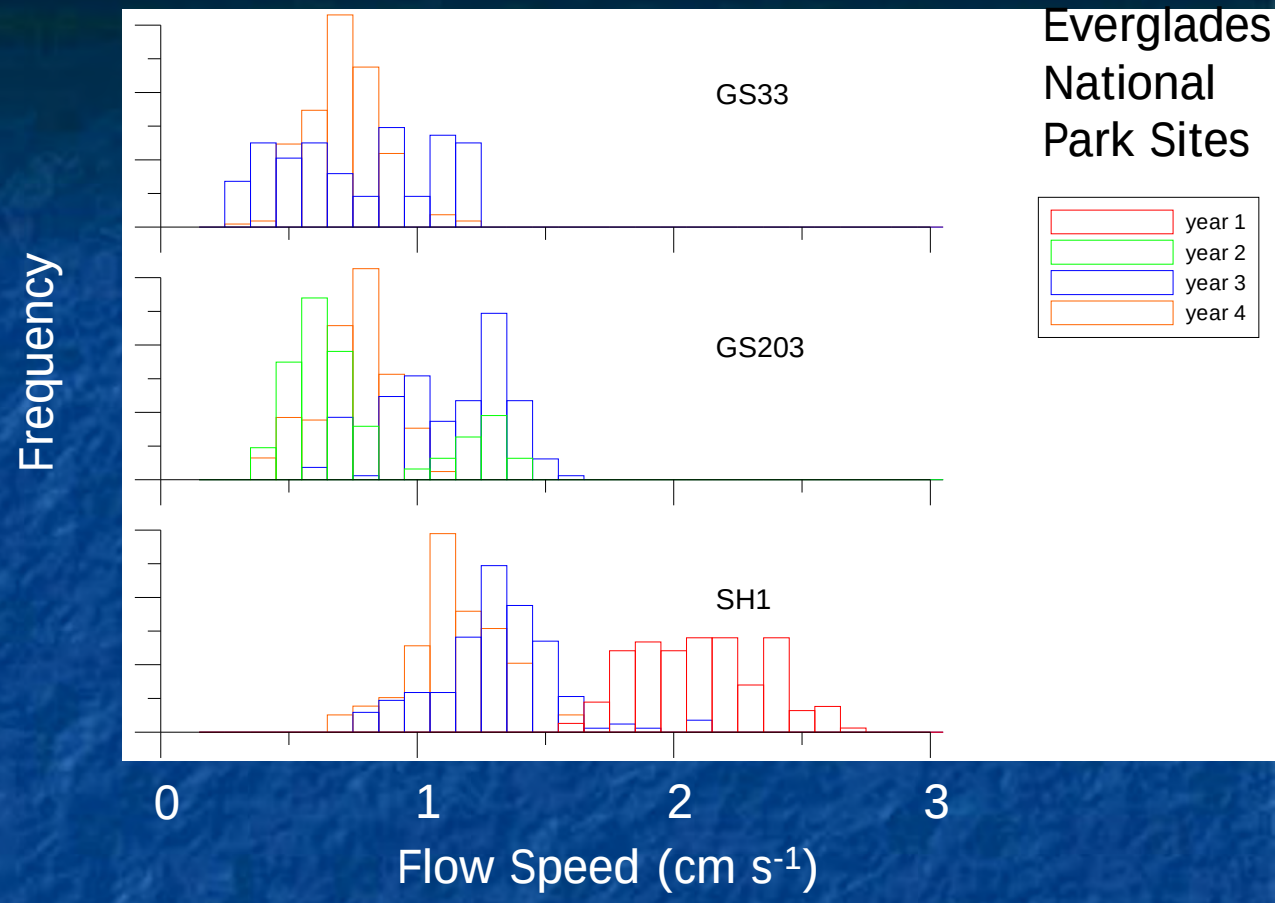
Flow Impoundment in WCAs has decreased velocities relative to unimpounded areas such as Everglades National Park



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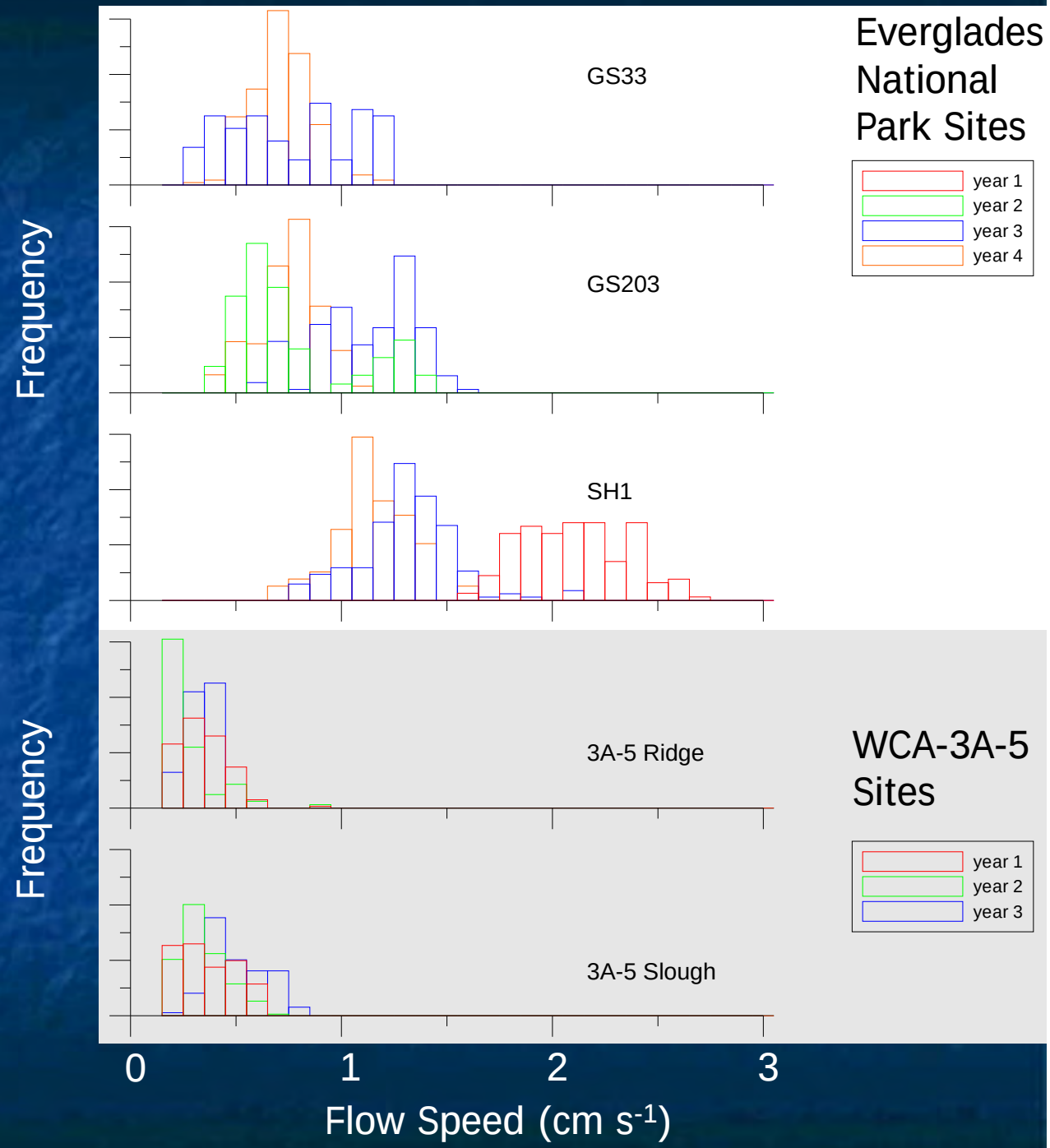

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Need for a Rate Law Describing Sheetflow Through Vegetated Wetlands

- There are two fundamental problems with using Manning's equation to model wetland surface water flows.

1) Manning's equation was developed for turbulent flows where flow resistance is independent of velocity. Flow is typically laminar in wetlands and thus flow resistance depends on velocity

2) Flow resistance in channels can be approximated as drag at the channel boundaries whereas drag in wetlands is distributed vertically in the water column and depends on stem density

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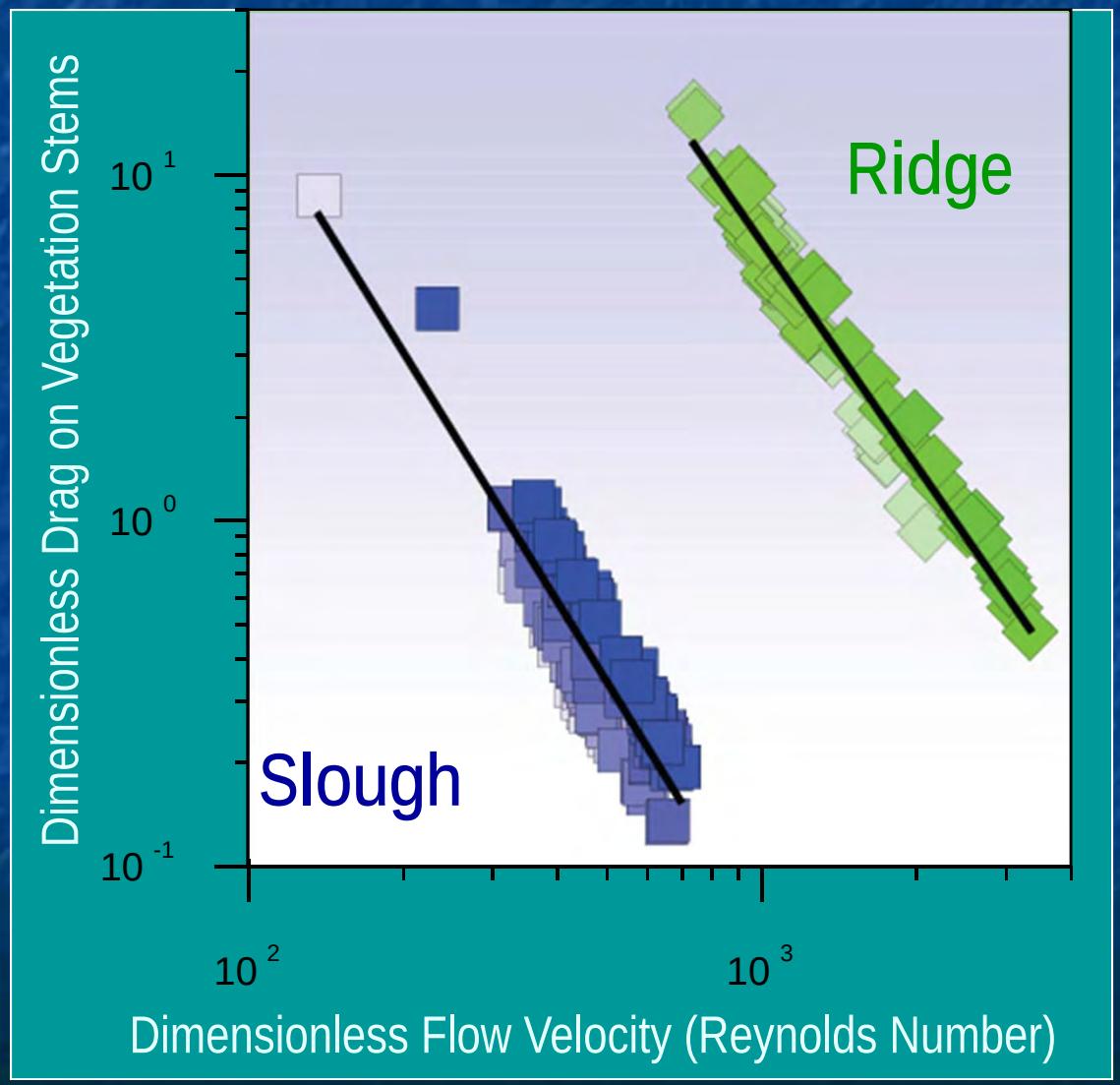
Vegetative Drag is Orders of Magnitude Higher in Sawgrass Ridges Compared with Sloughs



Measurement Date
- 8/7 to 8/21
- 8/22 to 9/5
- 9/6 to 9/20
- 9/21 to 10/5
- 10/6 to 10/20
- 10/21 to 11/4
- 11/5 to 11/19
- 11/20 to 12/4

Harvey et al., *Water Resources Research*, 2009

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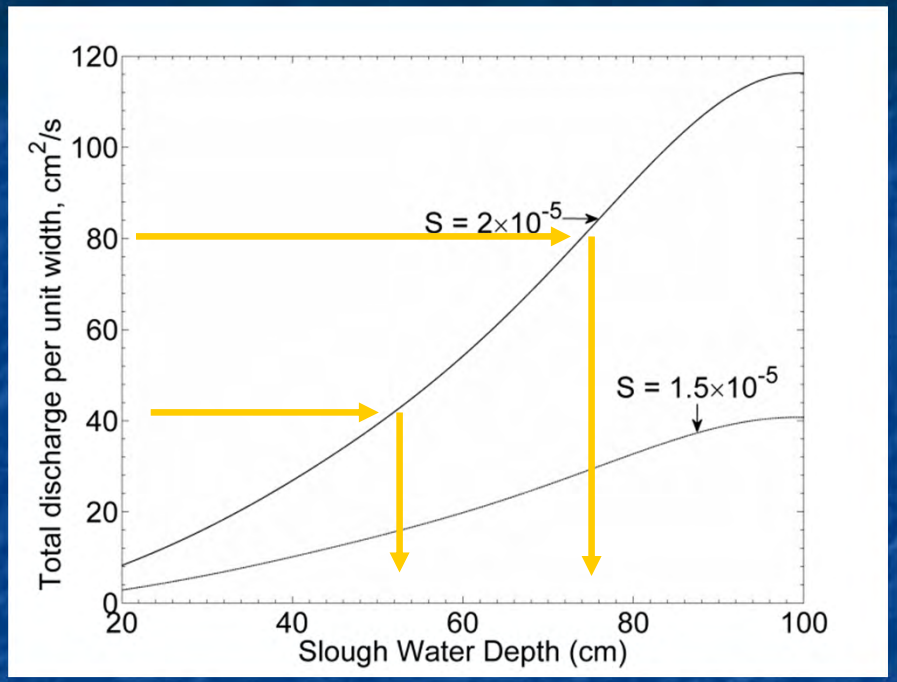
Response of Water Depth to Flow Increase



- Water flow and water depths have decreased and vegetative flow resistance has increased in the managed Everglades. Need predictive tools to achieve restoration targets.
- The new rate law (example above) accounts for both flow change and ecological changes (vegetation type, biomass, and frontal area). For simplified circumstances a doubling of flow results in approximately a 45% increase in water depth

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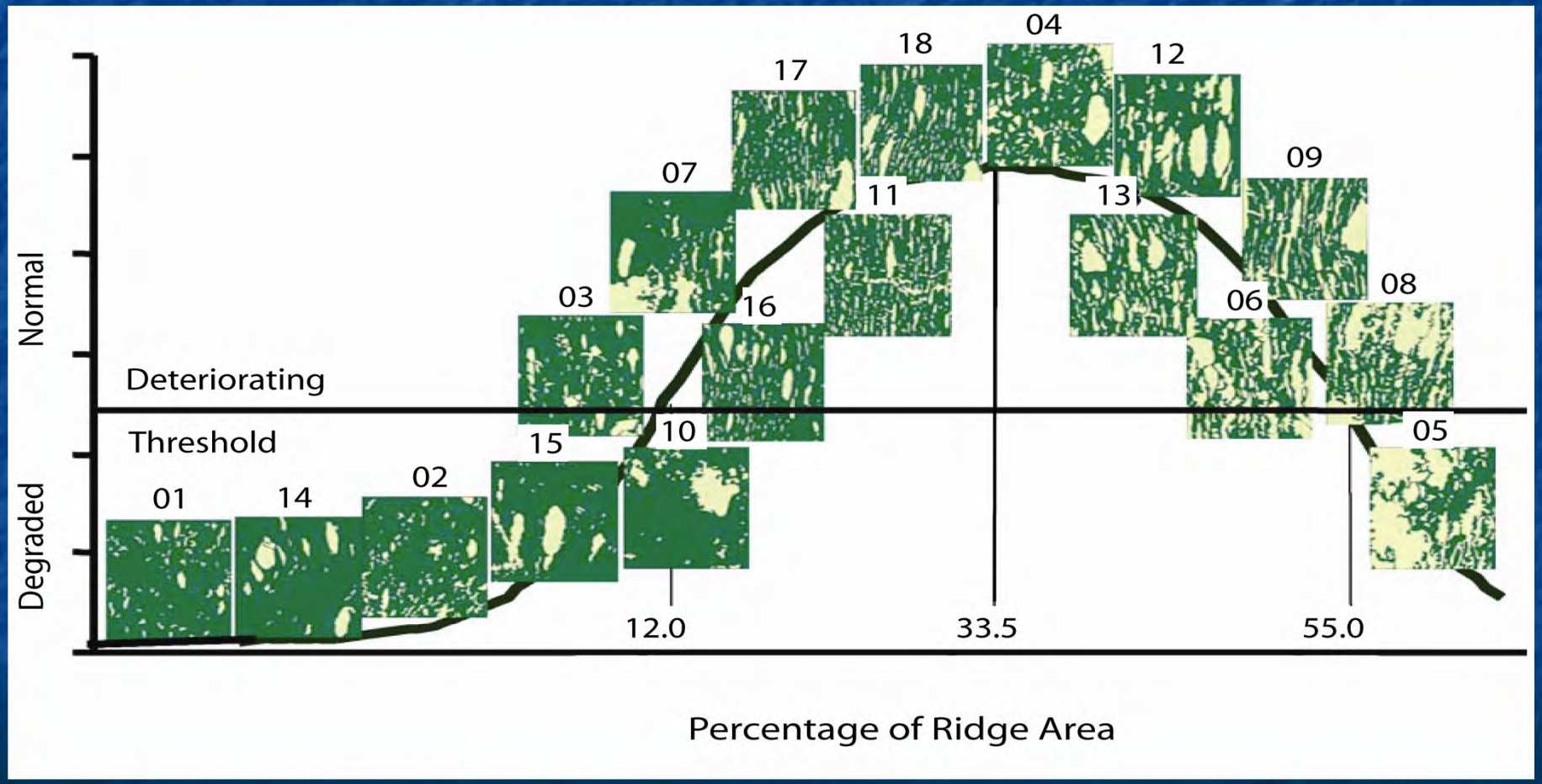
Larsen and Harvey, in preparation

Ridge-Slough Functionality Metrics – Percent Sawgrass Coverage



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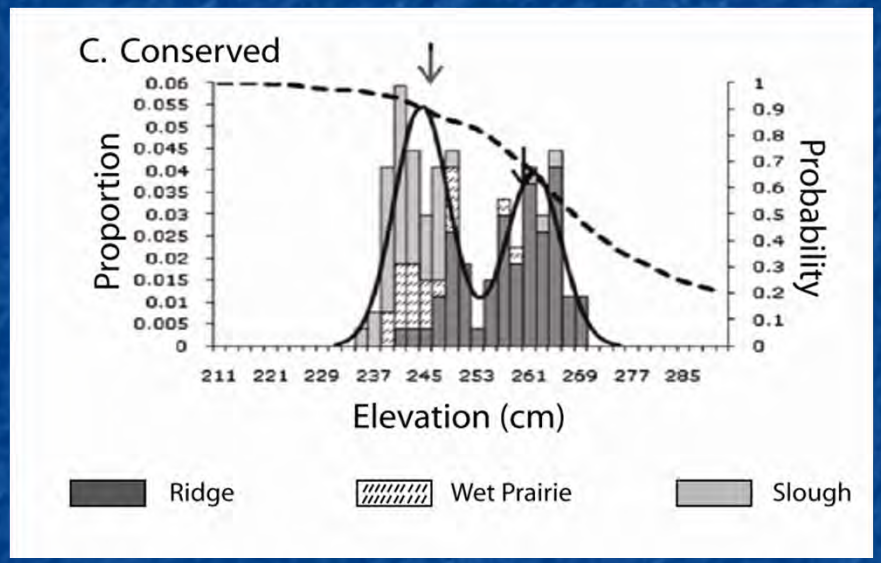
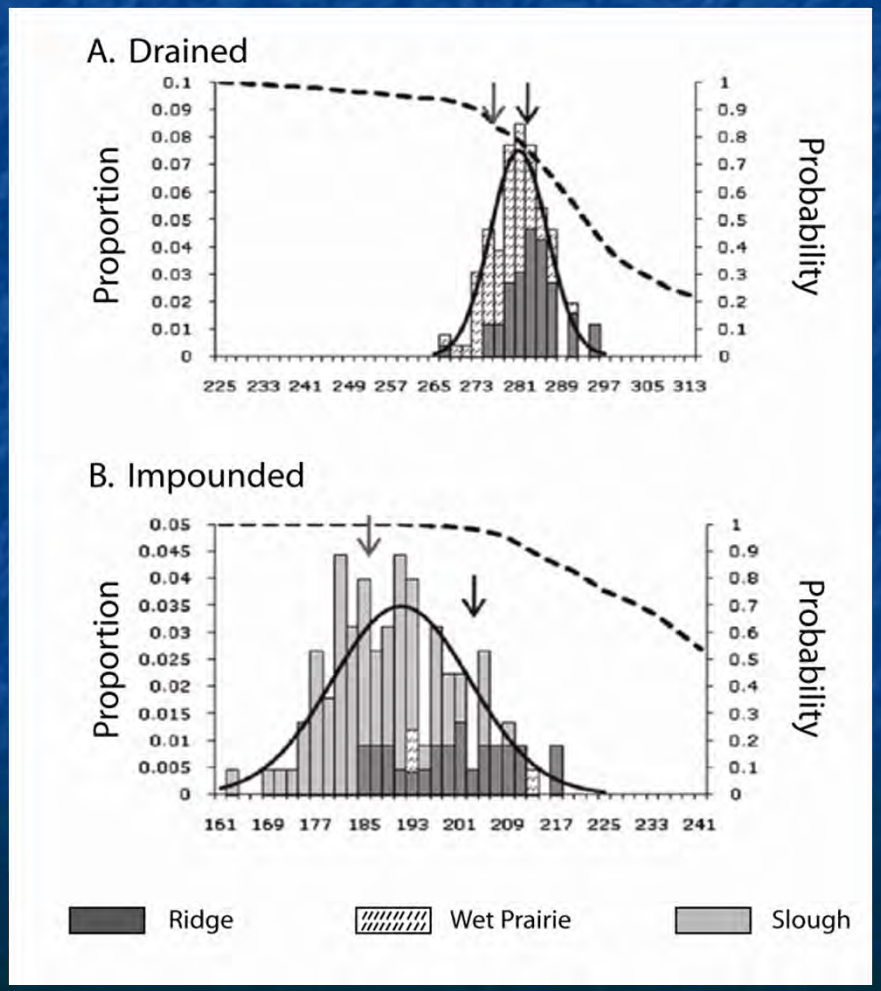
Wu et al., *Ecological Complexity*, 2006

Ridge-Slough Functionality Metrics – Microtopography –Vegetation Distributions

Well Conserved, High-functioning



Degraded, Moderate to Low Functioning



Watts et al., *Ecosystems, 2010*

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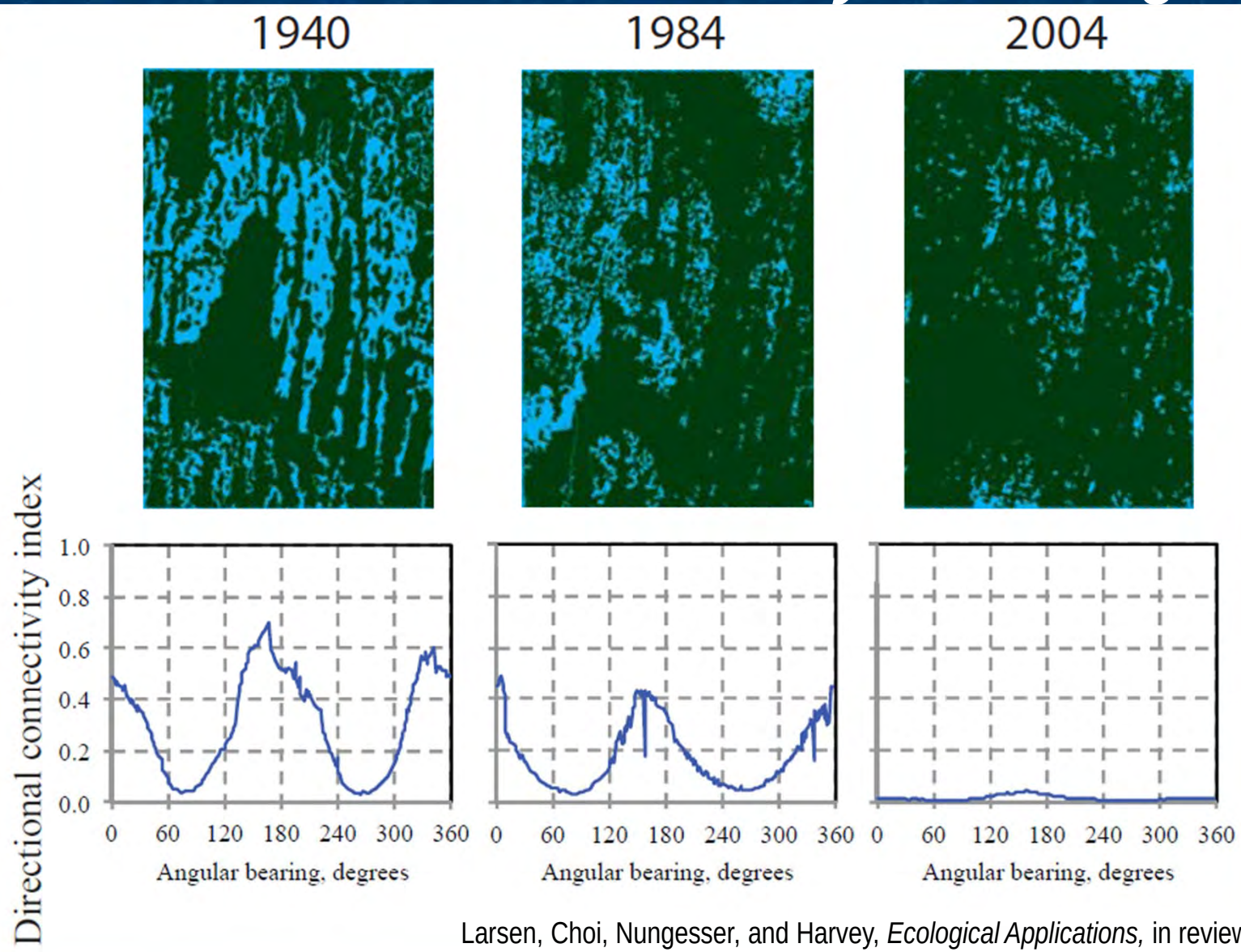
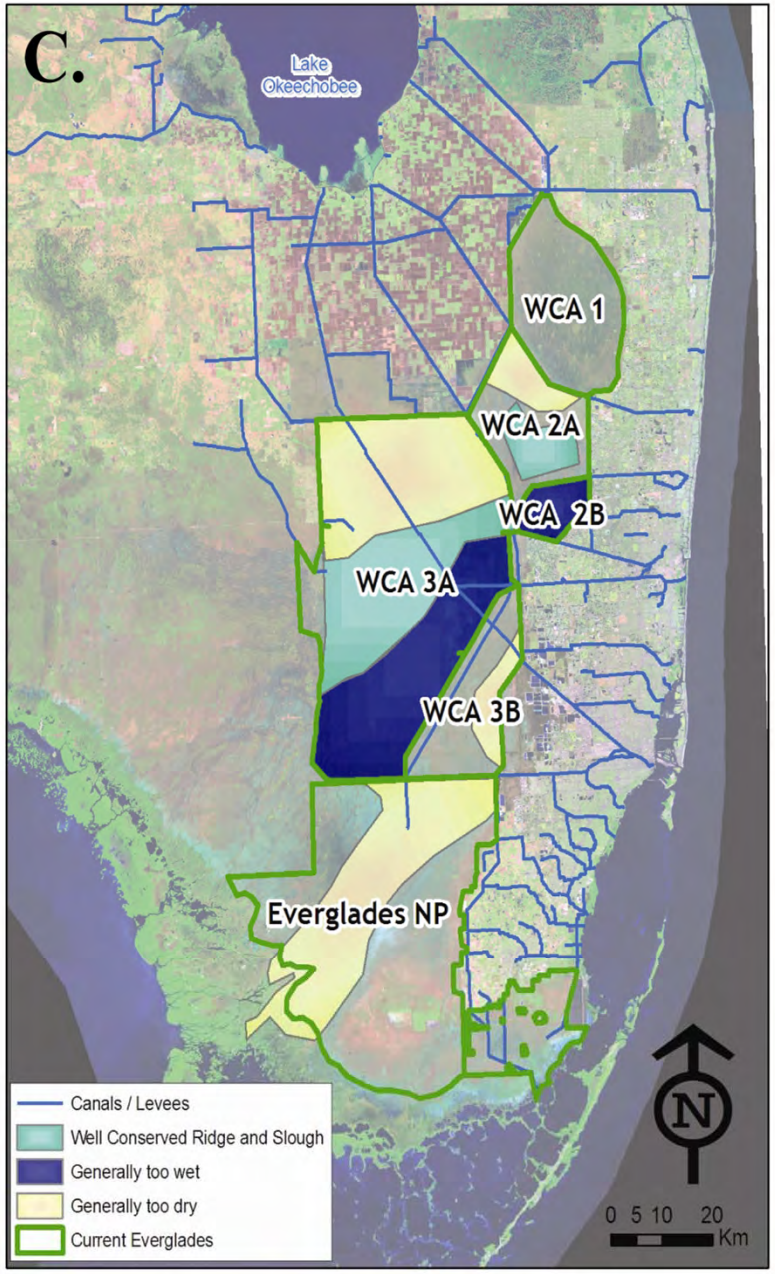
Ridge-Slough Functionality Metrics – Directional Connectivity of Sloughs



Larsen, Choi, Nungesser, and Harvey, *Ecological Applications,* in review



Location of Well Conserved, High-Functioning Ridge and Slough

Note; WCA-1 not considered

Synthesis of Everglades Restoration and Ecosystem Services (SERES), 2011

http://www.everglades-seres.org

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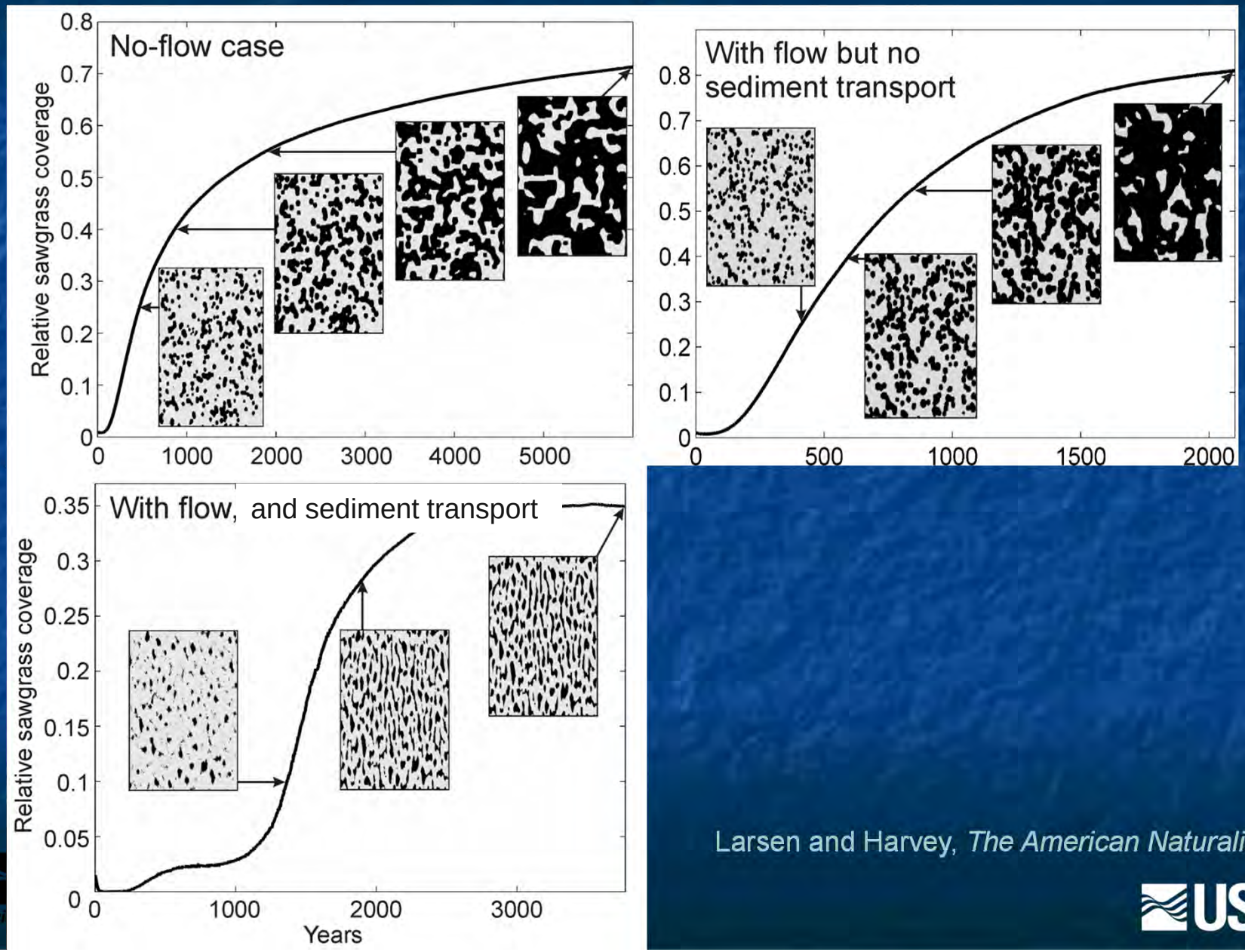
Only Simulations with Flow and Sediment Transport Produced Stable, Well Connected Sloughs



Larsen and Harvey, *The American Naturalist*, 2010

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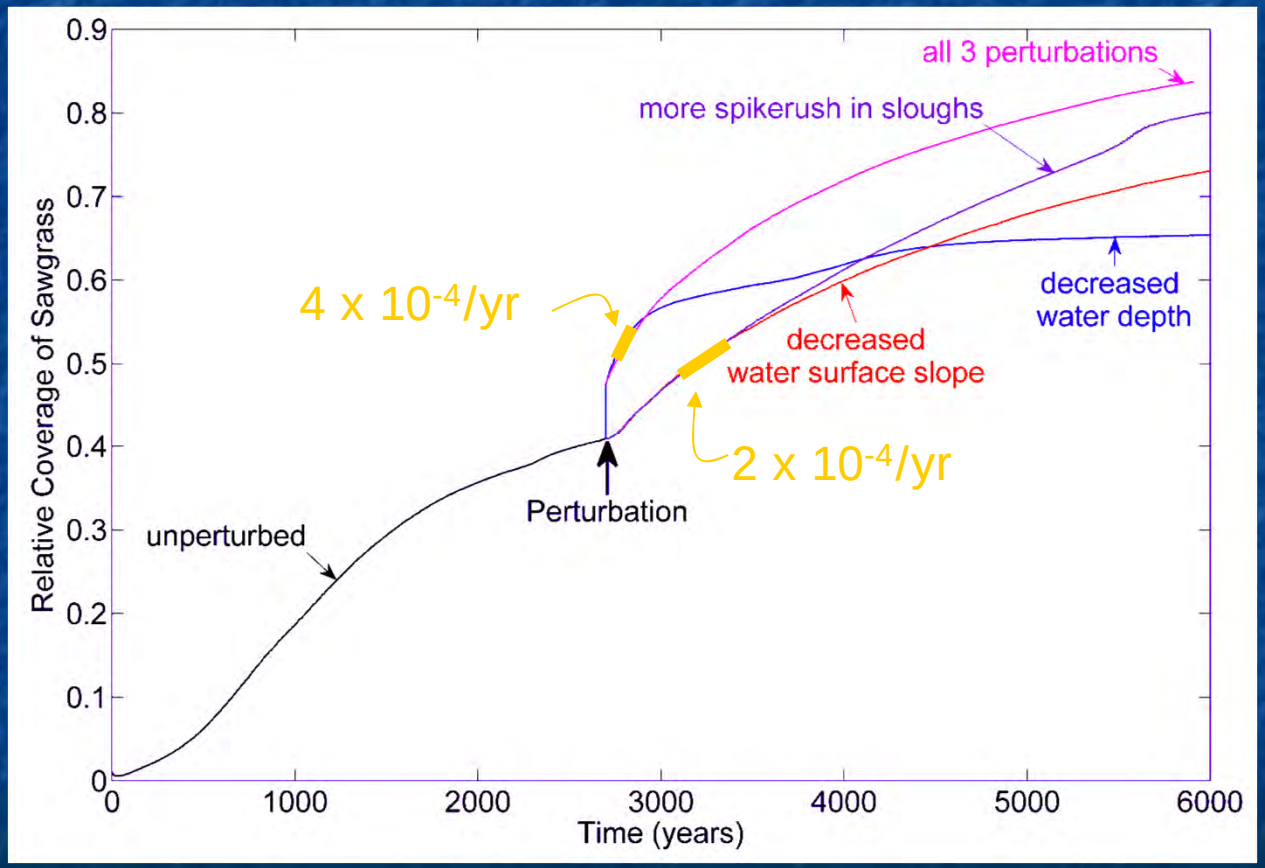
Decreased Water Depth Degrades Pattern the Fastest, Decreased Water Slope and Spikerush Invasion Degrade More Slowly



Compare to data:

- Ridges in WCA-1 expanding 30 cm/yr , or 8 x 10^{-4}/yr

(Paul McCormick, *personal communication*, 2009)

Note: Unit conversion assumes mean ridge dimensions of 500 m x 175 m

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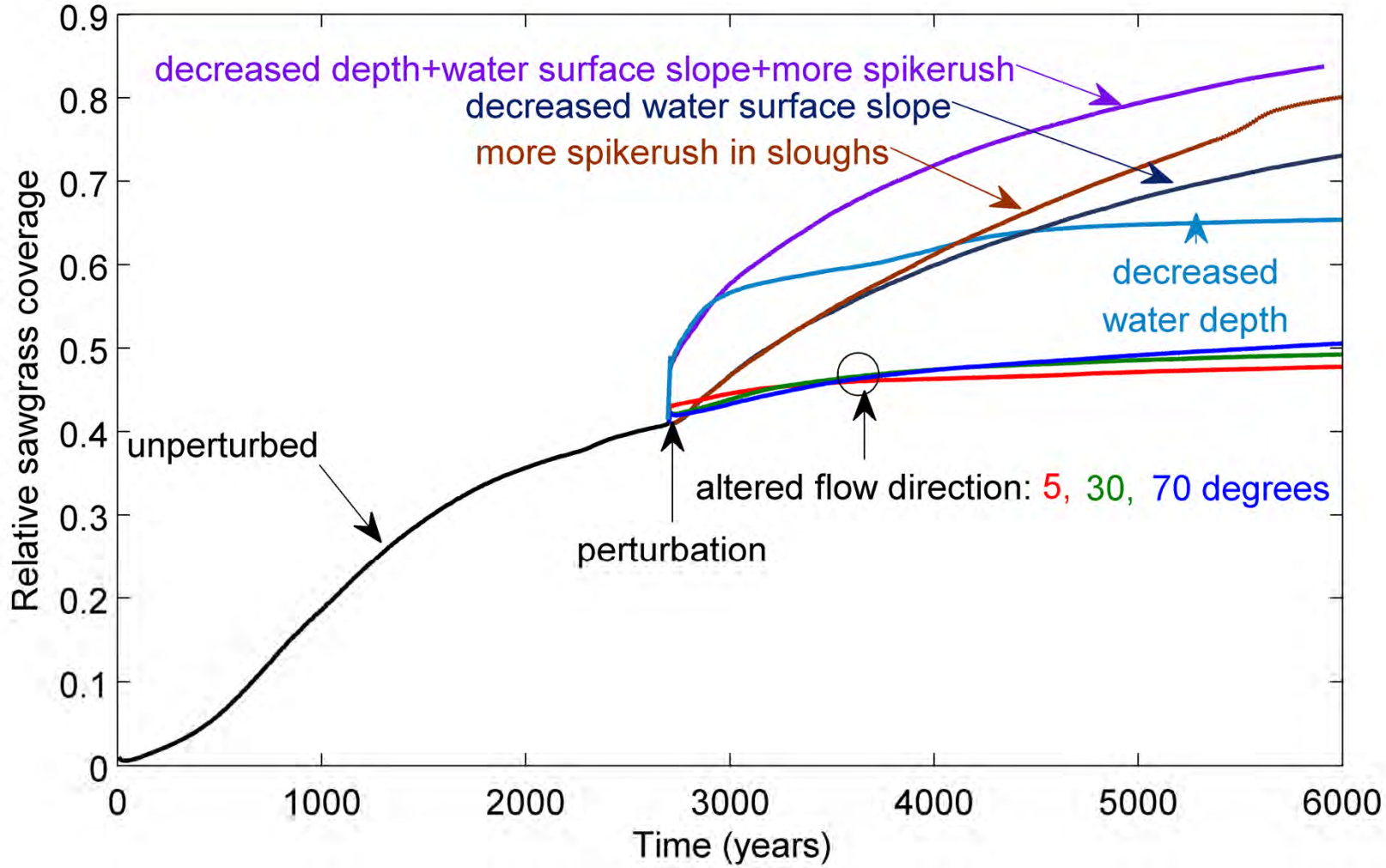
Larsen and Harvey, *Geomorphology,* 2010

In Contrast, Sawgrass Coverage Not Affected as Drastically by Altered Flow Direction



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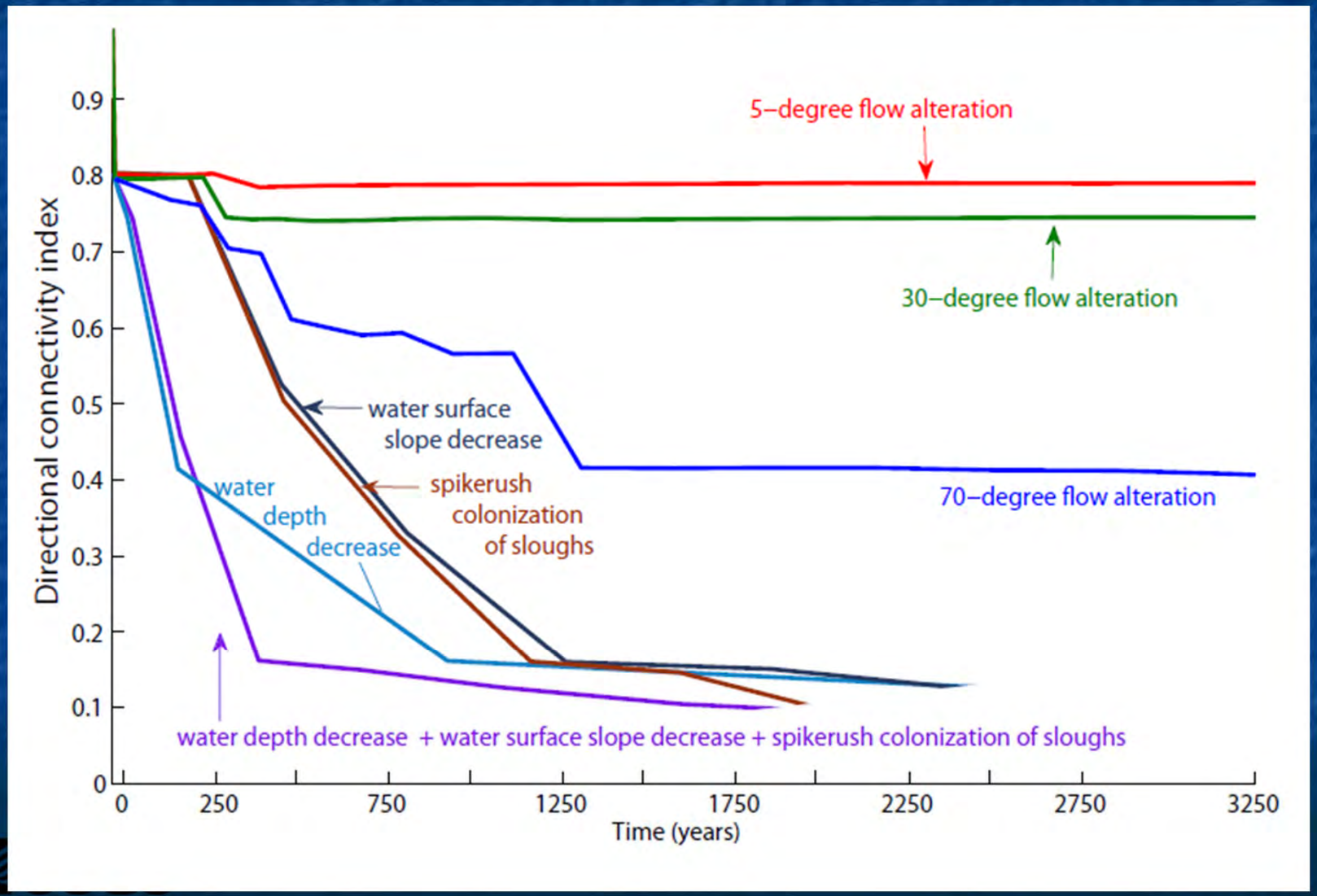
Larsen and Harvey, *Geomorphology,* 2011

Rank Order of Importance of Degradation Similar Using Directional Connectivity Metric



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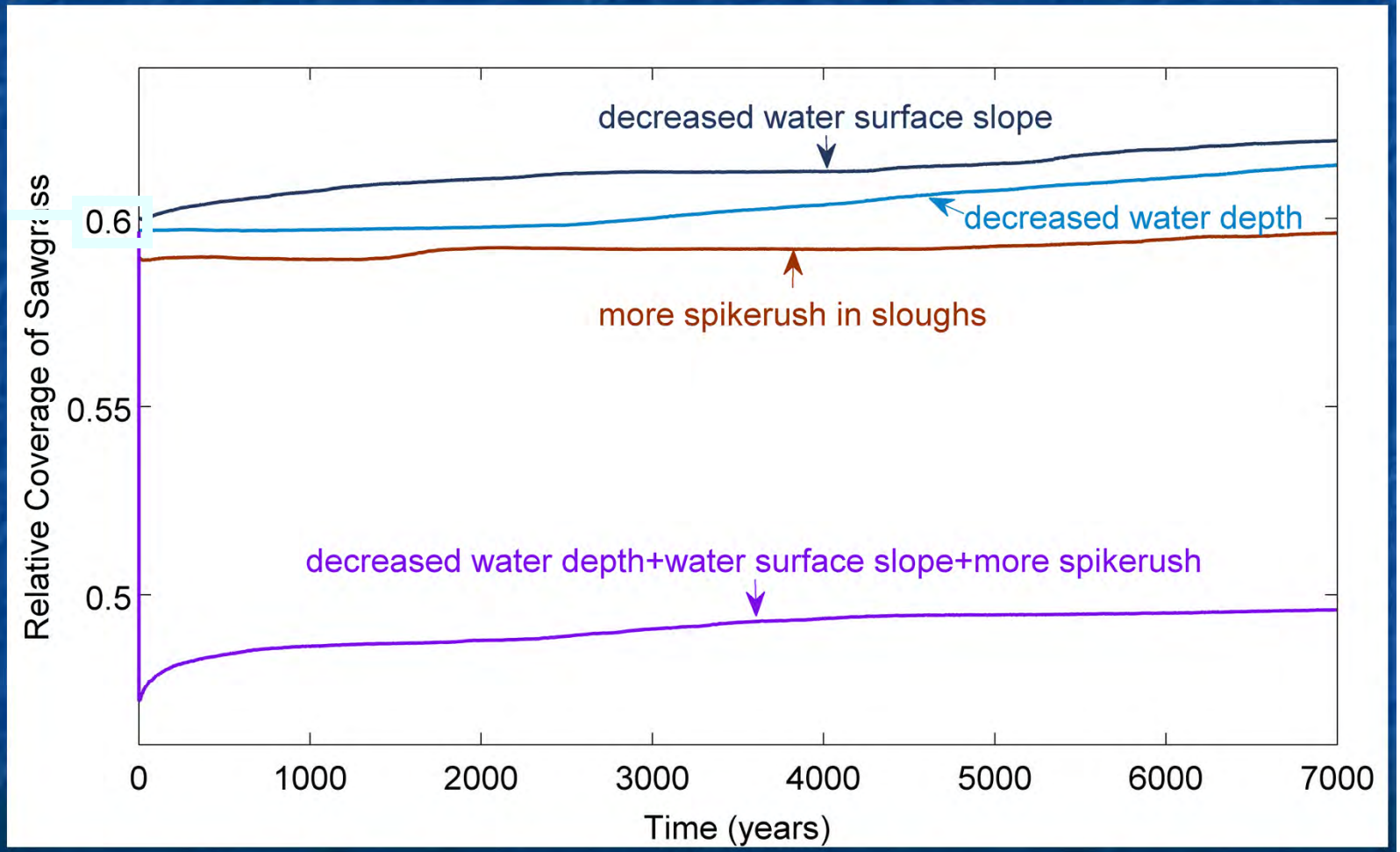
Larsen et al., *Ecological Applications, in review*

Restoration Hard to Achieve in Overly Dry Areas Where Sawgrass Expanded Coverage

"Restoration" was performed on degraded landscapes that had reached 60% sawgrass coverage



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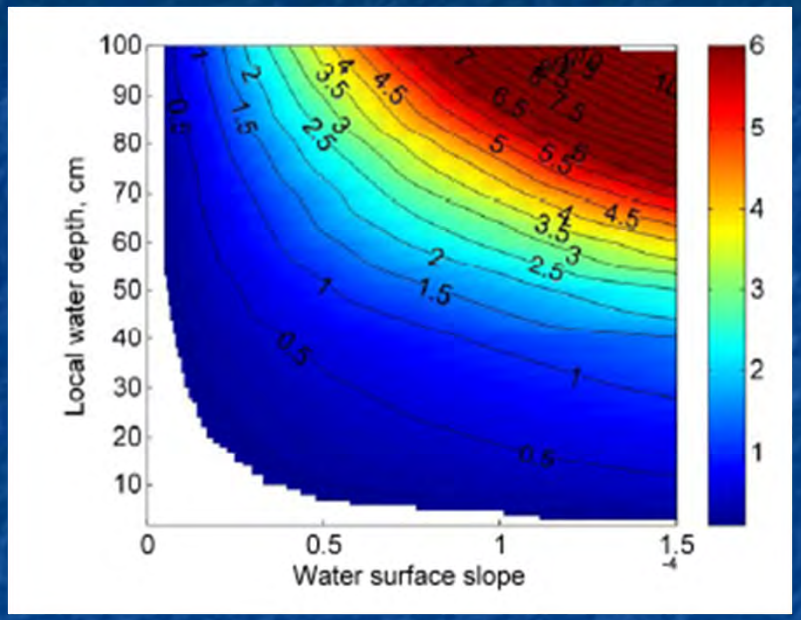
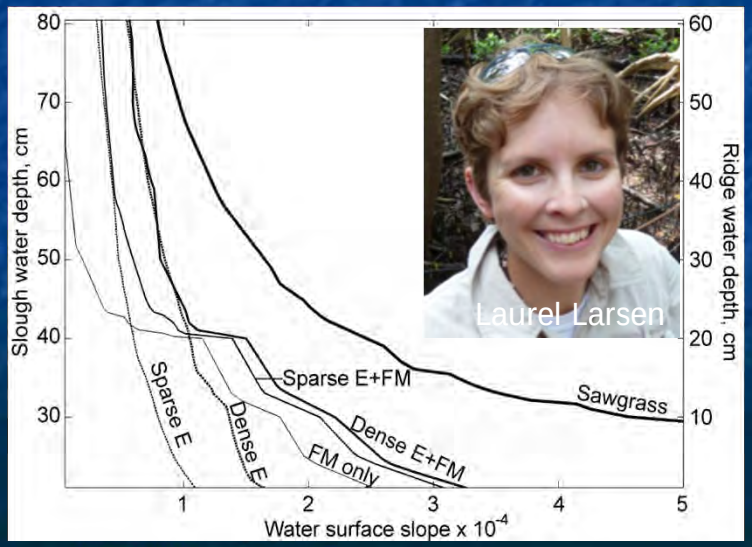
Larsen and Harvey, *Geomorphology,* 2011

Scientifically-based Strategies to Preserve Remaining Ridge and Slough Landscape





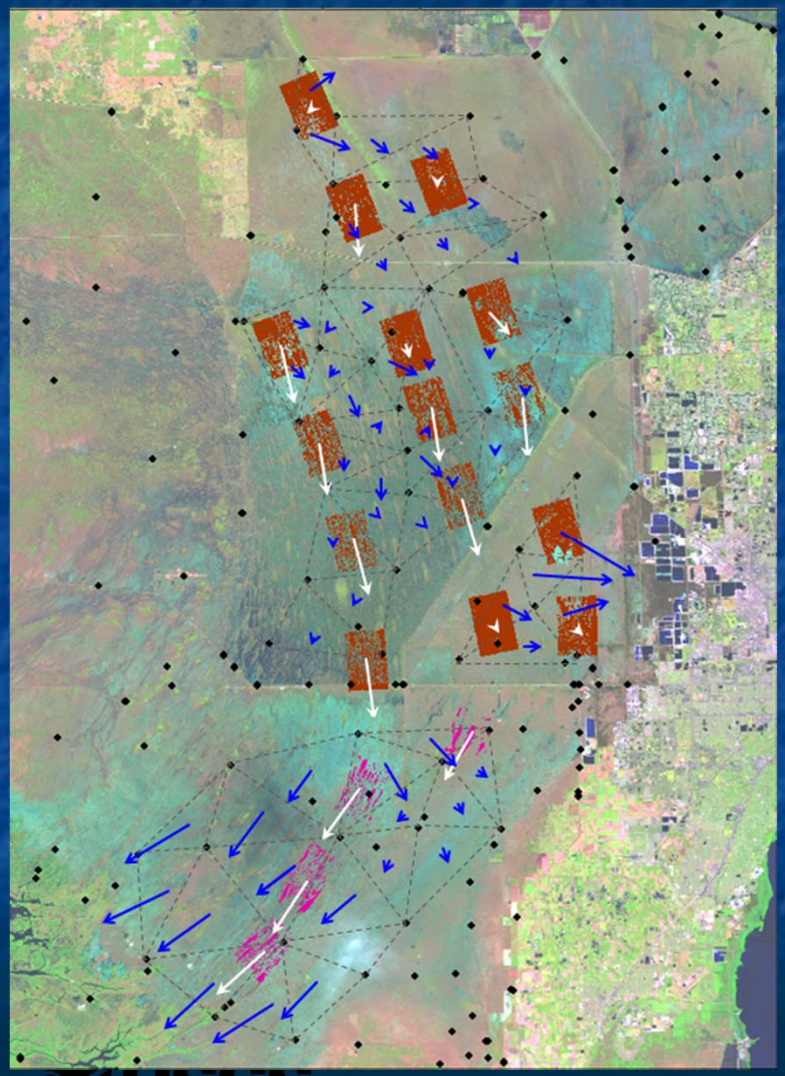
- ❑ Reveals a narrow combination of conditions (water depth, flow velocity, vegetation) that builds and maintains a stable ridge-slough (warm colors).

- ❑ The most effective way to preserve high functioning ridge-slough will be through careful water depth management with pulsed flow releases that maximize water surface slope for weeks per year.

Larsen, Harvey, and Crimaldi, *Ecological Engineering*, 2009

Connectivity of Everglades Landscapes (CEL)

an excel tool for visualizing the landscape



- Fifty-five triangular polygons defined in WCA-3A, 3B, and ENP using USGS-EDEN gaging stations as vertices.
- HAED (high accuracy elevation dataset with 400x400 meter resolution) from USGS-EDEN was planar fitted to calculate *ground slope* (direction and magnitude).
- Water level data (Jan 2007 – Dec 2010) from USGS-EDEN were fitted to calculate *water surface slope* (direction and magnitude)
- 19 digitized ridge-slough landscape patterns were obtained from SFWMD to quantify directional hydrologic connectivity of sloughs

Water surface slope

Landscape connectivity

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Five Reasons Flow Matters

- The ridge-slough landscape is topographically diverse but also highly connected, which supports habitat biodiversity, fish migration, wading bird habitat, etc. Currently, only 22% of current ridge slough landscape is considered highly functional.

- Everglades currently managed by adjusting flows through structures to achieve "optimal" ponding depths. In a decompartmentalized Everglades, water depth will be strongly influenced by sheetflow through vegetation. Do we have a sufficient operations manual?

- Sheetflow through wetlands is not well described by Manning's equation. Our new rate law estimates a doubling of sheetflow will increase water depth by ~ 45% , but the effect is highly dependent on vegetation. The "operations manual " will need to adjust to vegetation changes.

- Achieving water depth-duration targets, velocities > 2.5 cm/s for weeks per year, and flow alignment within ~ 40° will preserve high functioning ridge-slough and improve some degraded areas. Areas that have lost microtopography and/or have crossed a threshold > 60 % ridge coverage cannot be reversed by flow restoration. Consequently, areas that have been overly wet are more likely to be restored than overly dry areas.

- Further challenges of successful restoration include preventing excessive dry downs during drought years and delivering "new" water that meets water quality standards.

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