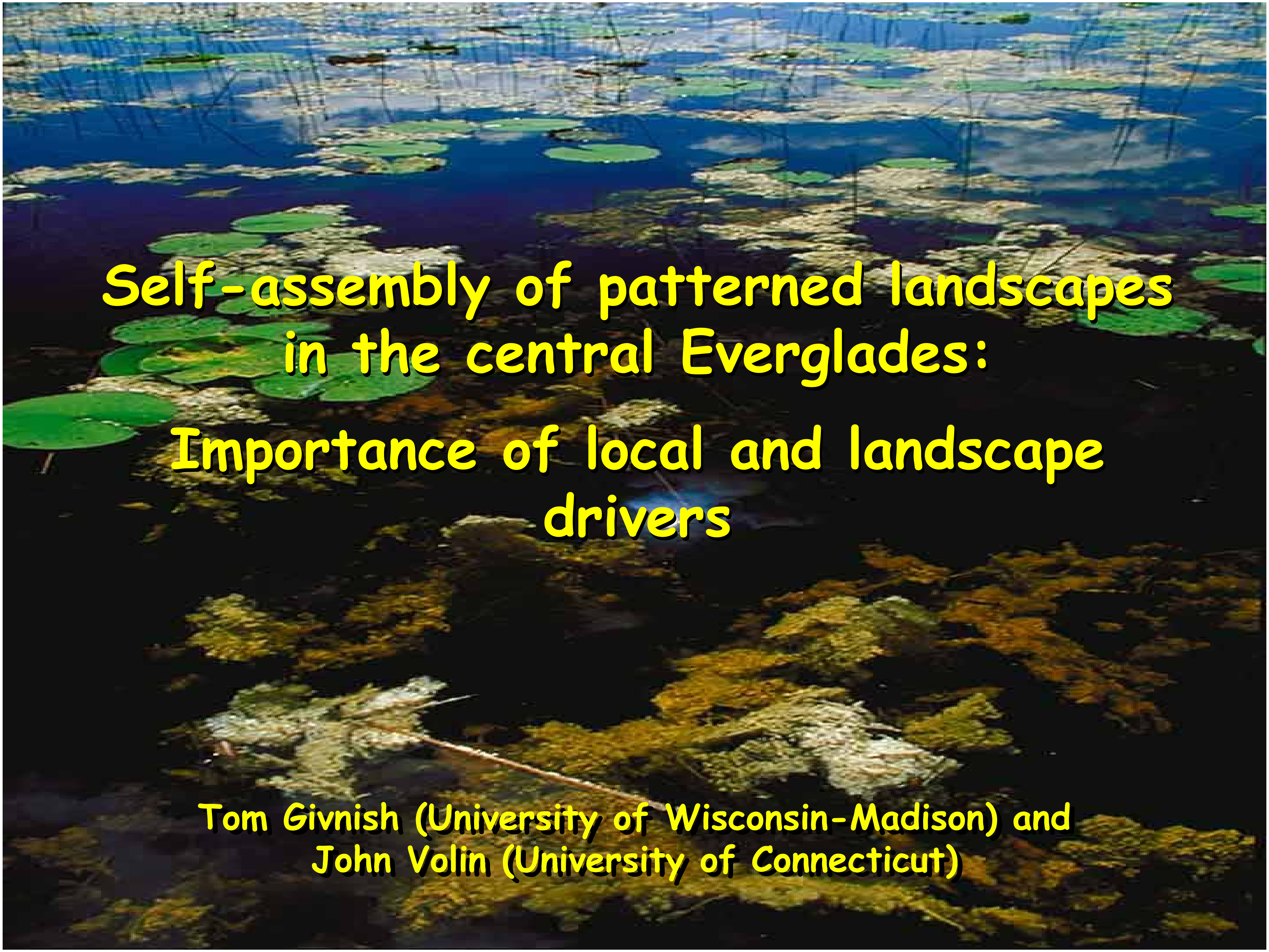

Self-assembly of patterned landscapes in the central Everglades:

Importance of local and landscape drivers

Tom Givnish (University of Wisconsin-Madison) and
John Volin (University of Connecticut)

Conceptual model for development of landscape patterning in the central Everglades

1. Sheetflow over the very gently tilted (< 0.05% slope) bedrock of the central Everglades -> accumulation of peat up to roughly the average water level

Givnish & Volin 2003 (GEER)
Givnish et al. 2007 (Global Ecol Biog)

Conceptual model for development of landscape patterning in the central Everglades

1. Sheetflow over the very gently tilted (< 0.05% slope) bedrock of the central Everglades -> accumulation of peat up to roughly the average water level
2. Random "bumps" above this wet surface should allow greater plant productivity with little initial increase in decomposition -> amplification of bumps into sawgrass ridges, then tree islands

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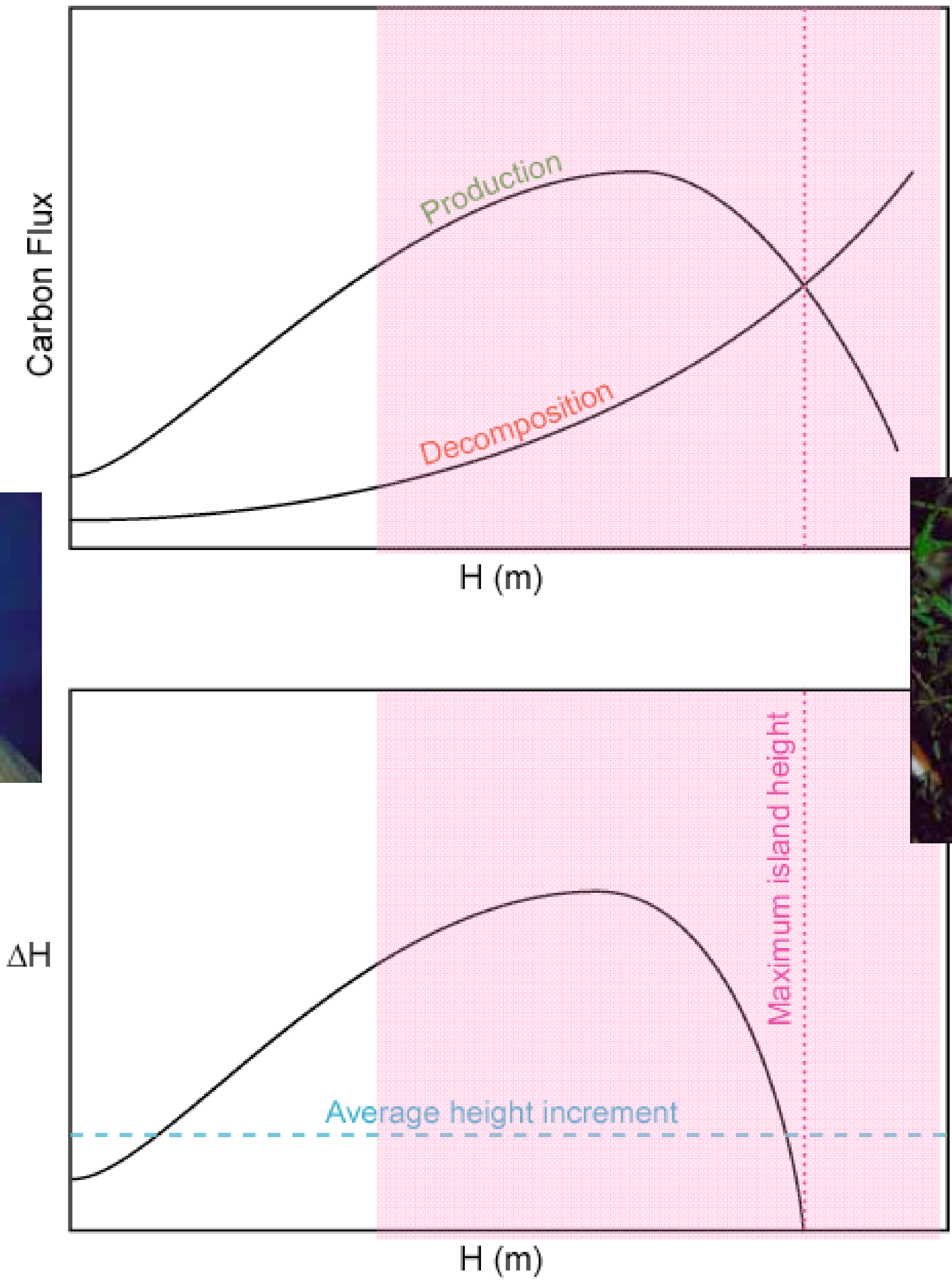
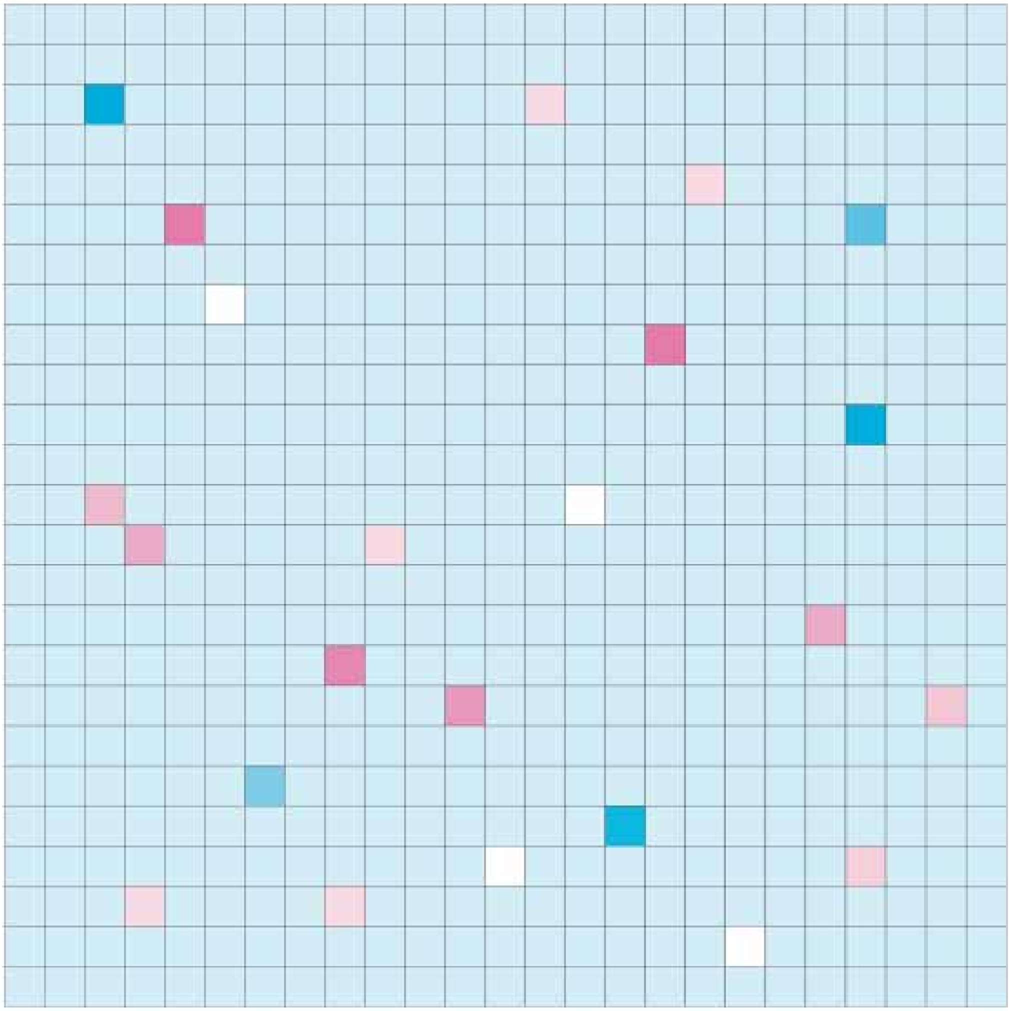
3. As local peat elevation increases, at some point the substrate becomes sufficiently aerated to permit invasion by woody plants, which would provide roosting and nesting sites for wading birds. Guano deposited by these top predators would provide large inputs of P and further accelerate plant growth and peat accretion.

Givnish & Volin 2003 (GEER)
Givnish et al. 2007 (Global Ecol Biog)


Carbon Flux
Production
Decomposition
H (m)
ΔH
Maximum island height
Average height increment
H (m)

Local positive feedback alone …



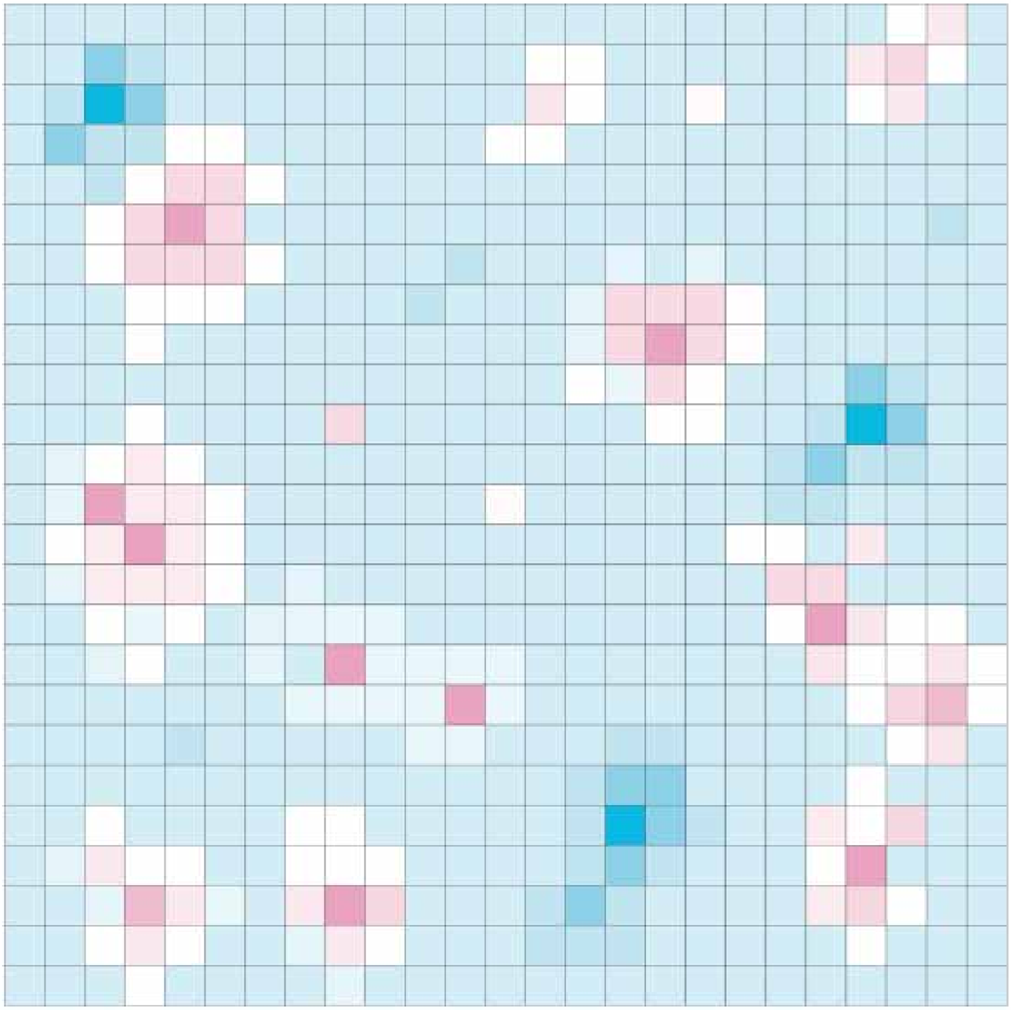
… can only create small-scale features, not large ridges, islands,or sloughs.

Conceptual model for development of landscape patterning in the central Everglades

4. Litterfall outside immediate surroundings -> **lateral expansion,** expansion of incipient ridges, islands

Givnish & Volin 2003 (GEER)
Givnish et al. 2007 (Global Ecol Biog)

Local positive feedback combined with lateral expansion …



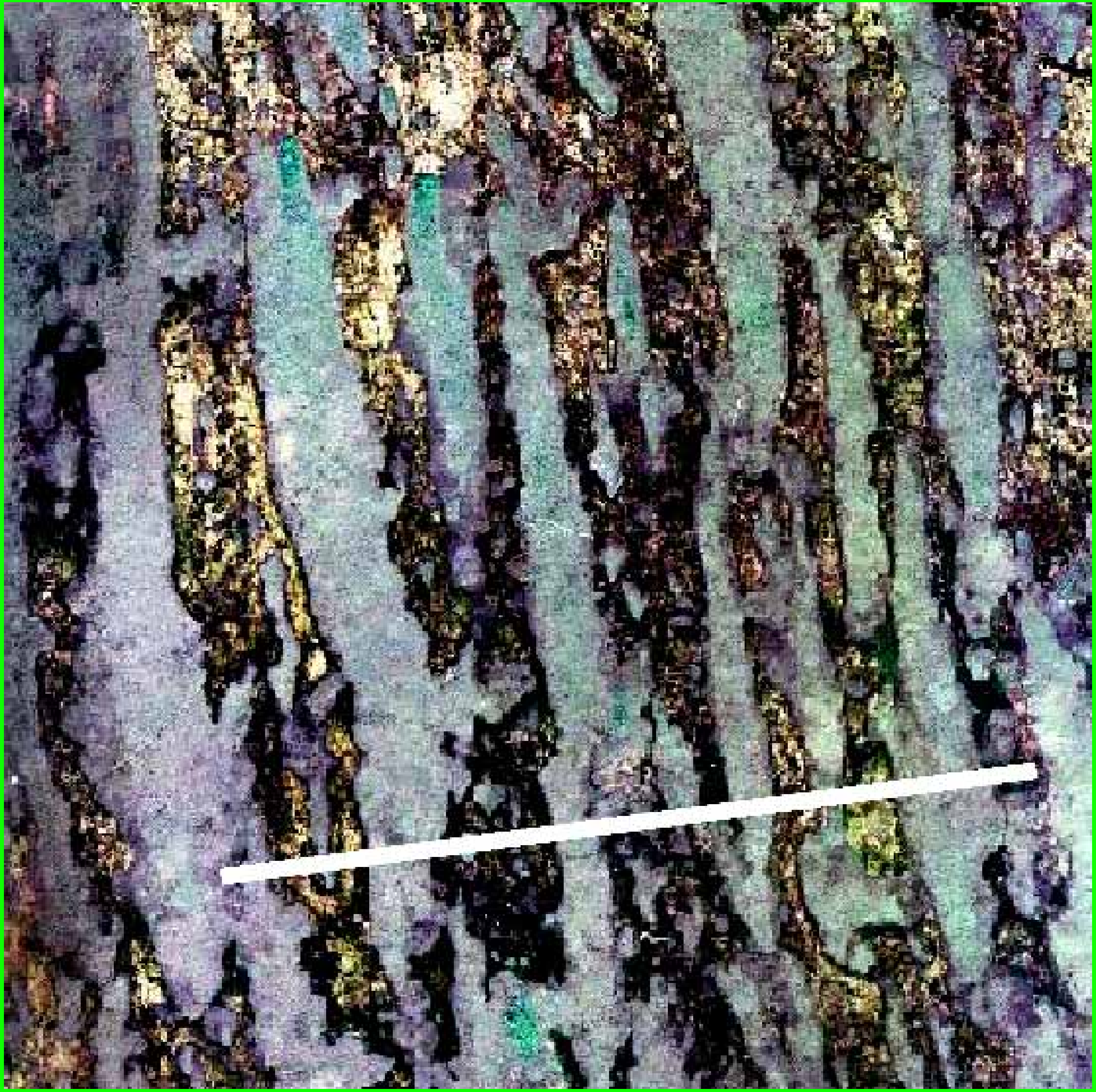
… can create larger-scale islands, ridges, and sloughs – **but** they would not be streamlined, and there would be no limit to the area covered by islands and ridges

Conceptual model for development of landscape patterning in the central Everglades

4. Litterfall outside immediate surroundings -> **lateral expansion,** expansion of incipient ridges, islands

5. Slowing of flow rates in lee of incipient sawgrass foci should lead to deposition there (especially during/after storms) of floc and periphyton -> spatially coupled positive feedback -> downstream propagation of ridges, "healing" of irregularities in outline; ridge peats should be rich in $CaCO_3$ based on floc, periphyton deposition

Larsen et al 2007 (Ecol Monogr)
Givnish et al. 2007 (Global Ecol Biog)



Paul Glaser

Conceptual model for development of landscape patterning in the central Everglades

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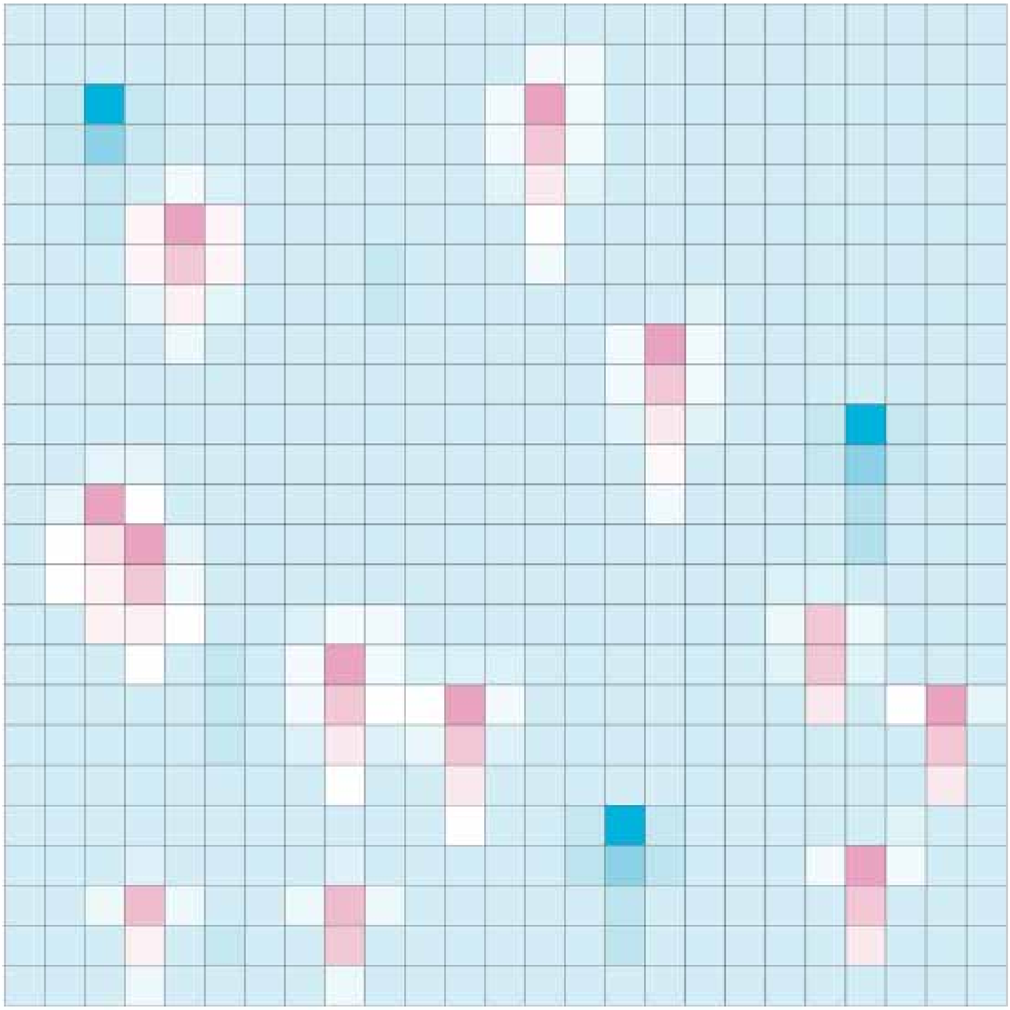
6. **Groundwater transport** of P and other nutrients to periphery of island should accelerate peat accretion there and in island’s lee; this process, combined with relatively rapid transport and dilution of nutrients by surface flow elsewhere, should lead to **self-assembly of elongate, teardrop-shaped tails** downstream, independent of erosive or depositional processes

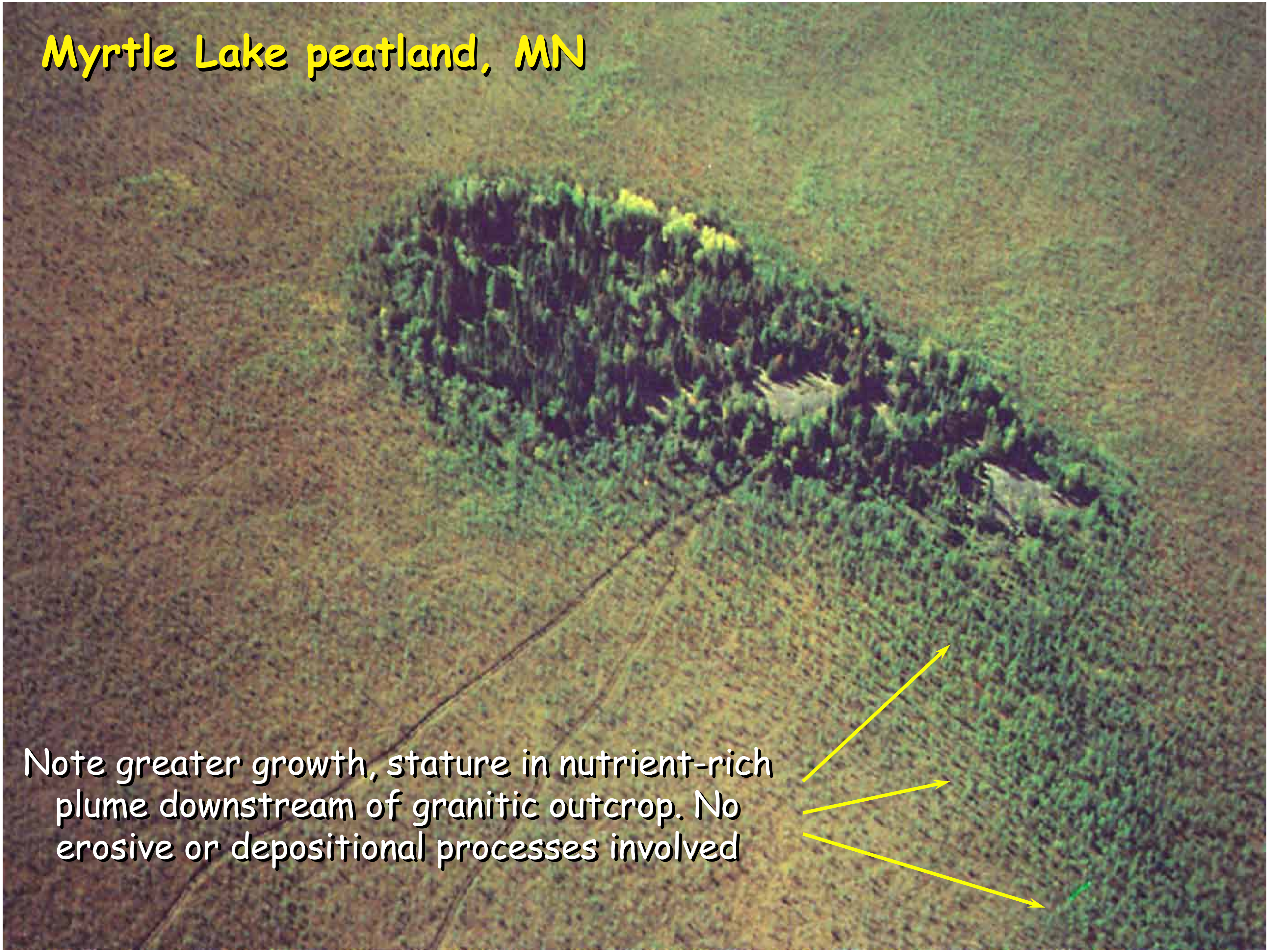
Givnish & Volin 2003 (GEER)
Givnish et al. 2007 (Global Ecol Biog)

Local positive feedback combined with lateral expansion and P transport by ground- and surface-water from island heads can create elongate tails



Self-assembly of high-P, low flow regions and low-P, high-flow regions should lead to teardrop-shaped islands

Myrtle Lake peatland, MN

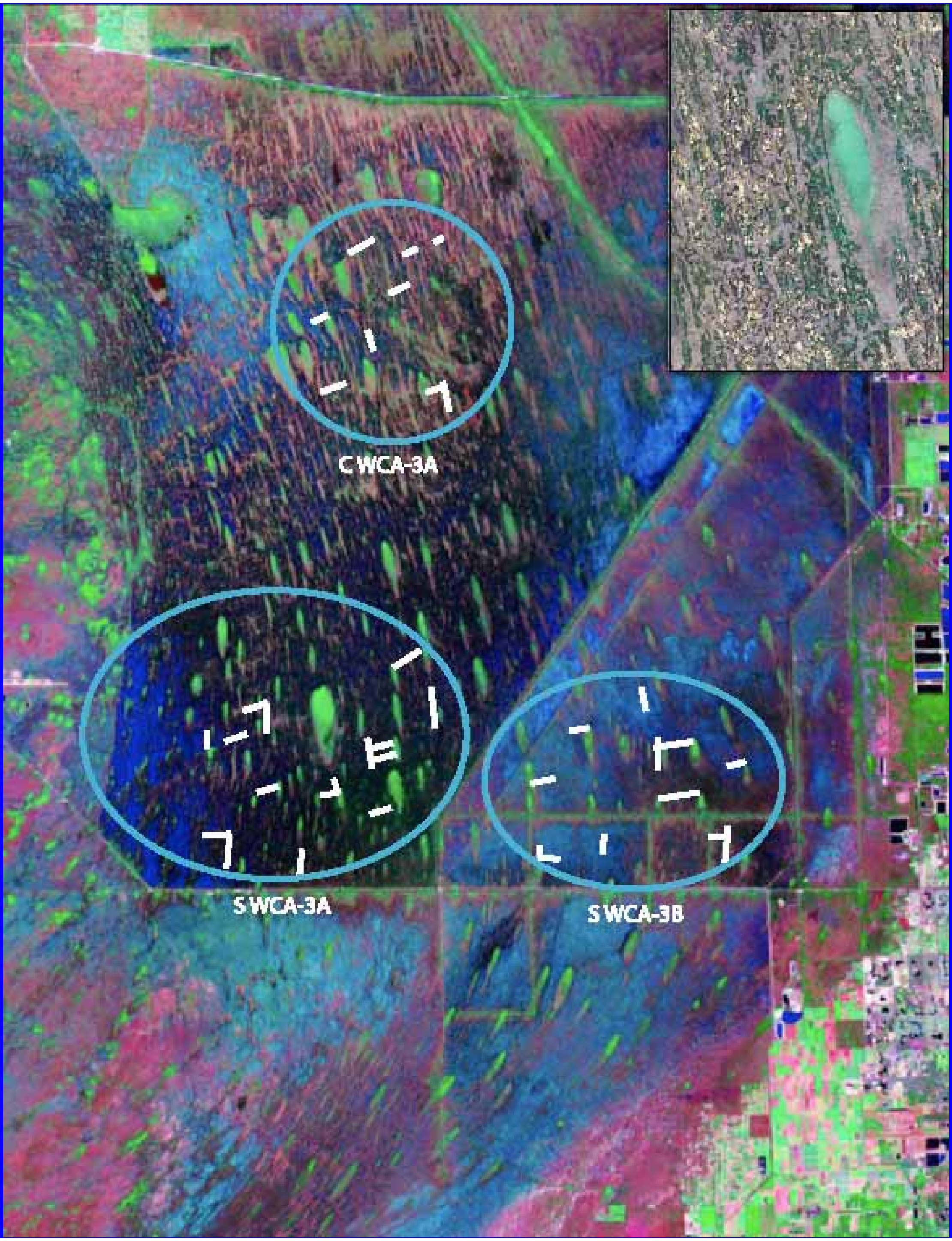


Note greater growth, stature in nutrient-rich plume downstream of granitic outcrop. No erosive or depositional processes involved

Conceptual model for development of landscape patterning in the central Everglades

7. As ridges and tree islands increase in abundance and extent, water must flow more deeply and longer in the intervening sloughs, working against the formation of other ridges or islands via local positive feedback. This spatially coupled negative feedback should limit the areal extent of ridges and tree islands, and prevent loss of sloughs from the landscape. This feedback is strongly dependent on flow, implying loss of sloughs in areas with little net sheetflow

Givnish & Volin 2003 (GEER)
Givnish et al. 2007 (Global Ecol Biog)


C WCA-3A
S WCA-3A
S WCA-3B

Methods

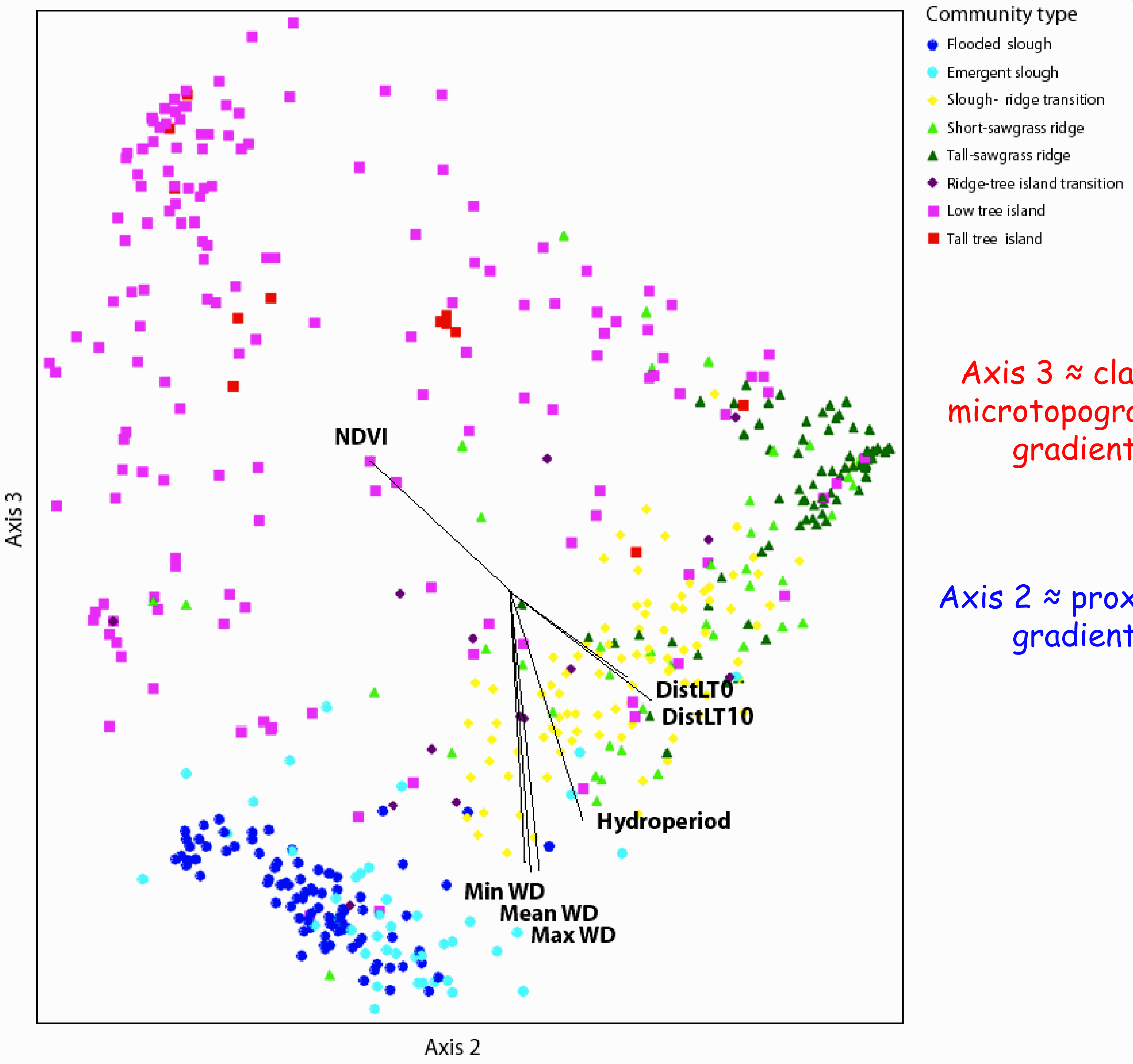
- Quadrats located using Trimble LXR GPS
- Peat thickness measured using metal probe
- NDVI from high-resolution infrared aerial photographs, georectified at 1 pixel = 1'
- Water depth measured, and offset from EDEN data at that time calculated -> generate 5-yr hydrograph for each quadrat (VERY IMPORTANT!) - max, min, mean water depth tabulated
- Calculated distance to nearest quadrat on immediately adjacent tree island whose minimum water depth was at least 0 cm (DistLT0) or -10 cm (DistLT10) - **adjacency metrics**

Primary findings of vegetation analysis

- Water depth and hydroperiod decreased significantly in moving from sloughs to tree islands. Across study regions:
  - Maximum water depth varied from 102 ± 1.9 cm in flooded sloughs to 81 ± 2.4 cm in short sawgrass ridges, 65 ± 2.0 on low tree islands, and 24 ± 12.6 cm on tall tree islands
  - Flooded and emergent sloughs lay ca. 15 cm lower in the landscape than short or tall sawgrass ridges, which in turn lay 15-20 cm lower than low tree islands and 55-60 cm lower than tall tree-island quadrats -> total elevational/water-depth gradient of ca. 80 cm
  - Hydroperiods year-round in sloughs, 10 days less on ridges, and 50-180 days less on short and tall tree islands

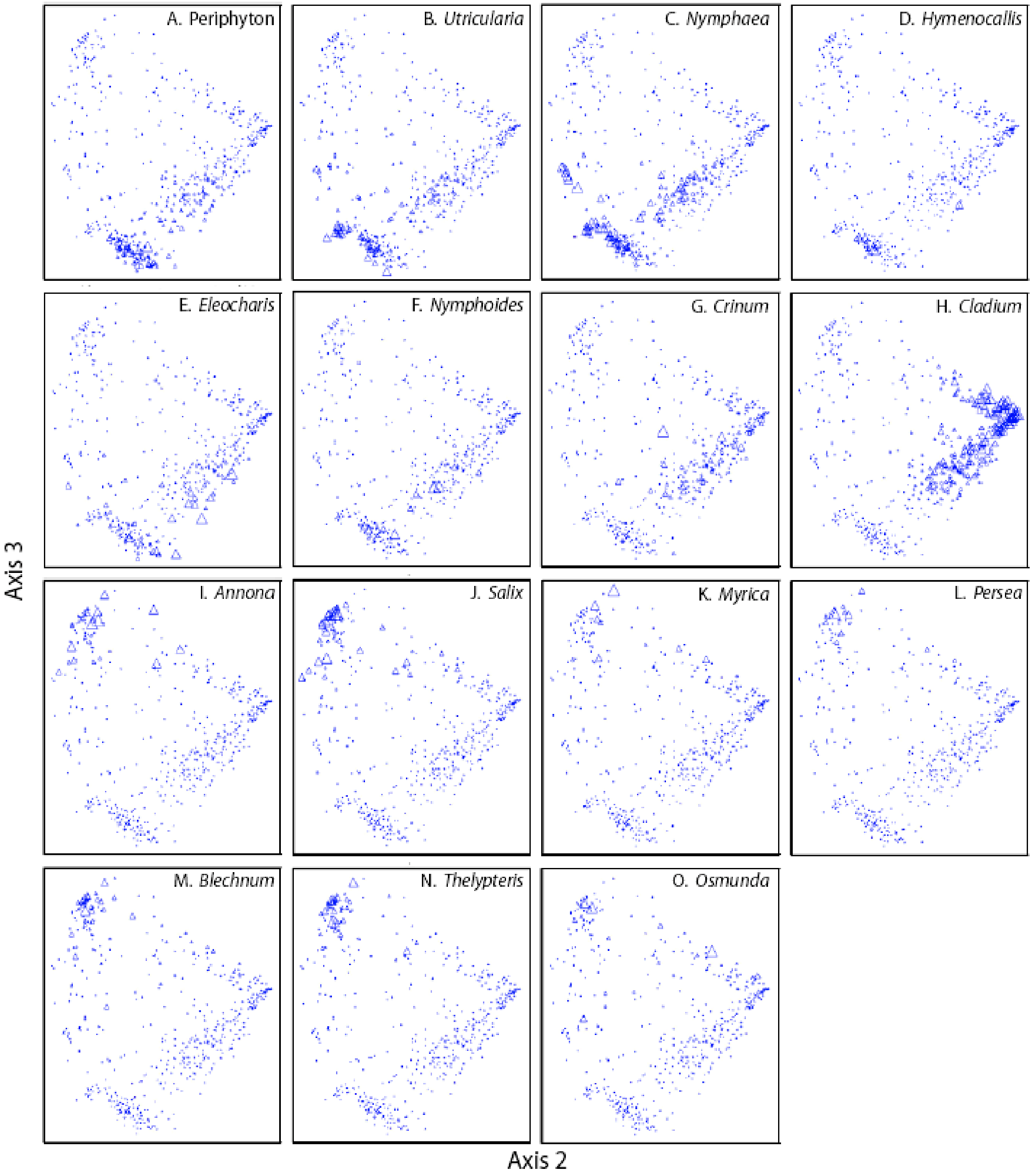
Primary findings of vegetation analysis

- When samples are segregated by study region, many of the environmental differences among community-types persisted
  - Sloughs generally ca. 15 cm lower than ridges, 30 cm lower than low tree islands, and 30-80 cm lower than tall tree islands
  - HOWEVER, differences in each measure of water depth among study regions for a given community-type are substantial relative to those among community-types within a region
  - Quadrats with a particular form of vegetation in s 3A tended to be 15 cm deeper than those in c 3A, and 30 cm deeper than those in s 3B
  - Differences correspond to known shifts in hydroregime in each WCA since the late 1940s and **differences in managed water levels in the last decade**, with surface flow from n and c 3A pooling at the southern end of 3A, and lack of flow (and possible infiltration into the bedrock) in s 3B

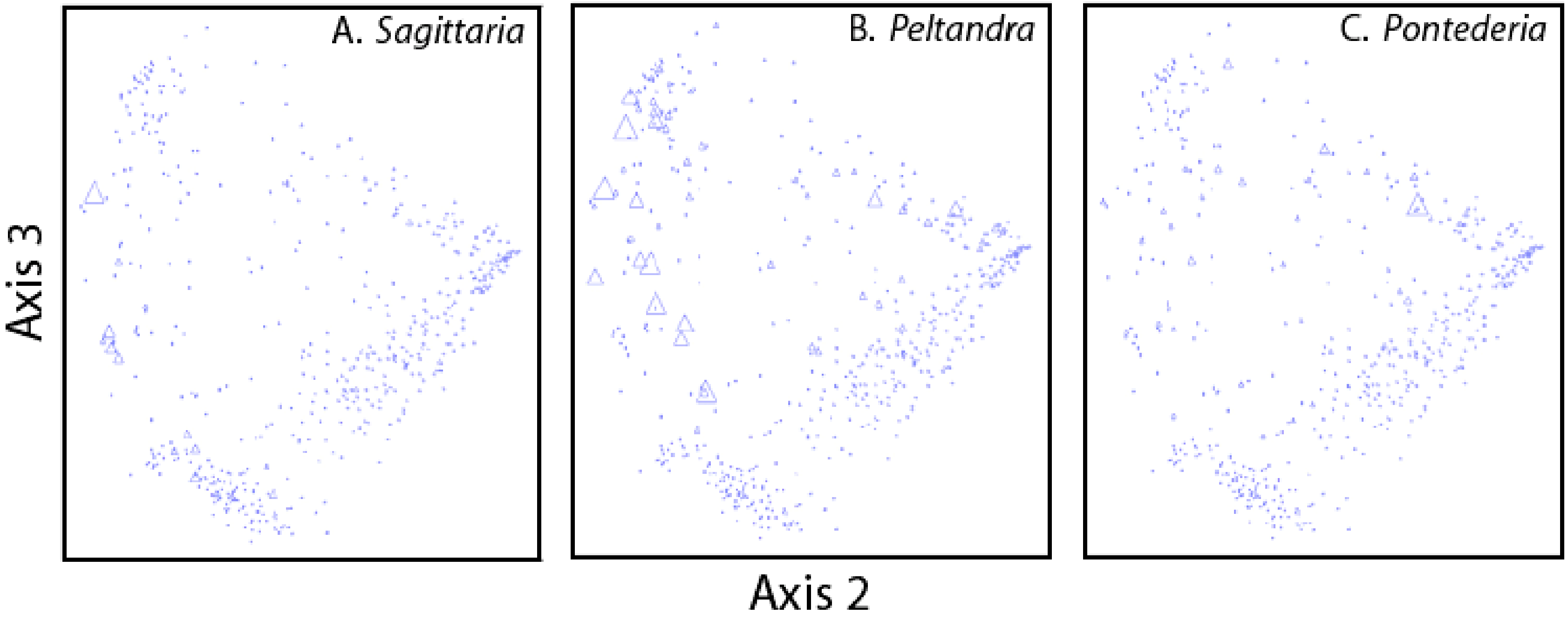


Axis 3 ≈ classic microtopographic gradient

Axis 2 ≈ proximity gradient


A. Periphyton
B. *Utricularia*
C. *Nymphaea*
D. *Hymenocallis*
E. *Eleocharis*
F. *Nymphoides*
G. *Crinum*
H. *Cladium*
I. *Annona*
J. *Salix*
K. *Myrica*
L. *Persea*
M. *Blechnum*
N. *Thelypteris*
O. *Osmunda*
Axis 3
Axis 2

Elsewhere, *Peltandra virginica* and *Sagittaria latifolia* (from the “western” margin) tend to dominate nutrient-rich substrates



By contrast, *Pontederia cordata* and *Cladium jamaicense* (from the “eastern” margin) tend to dominate nutrient-poor substrates

Local vs. landscape-level drivers of vegetation differentiation

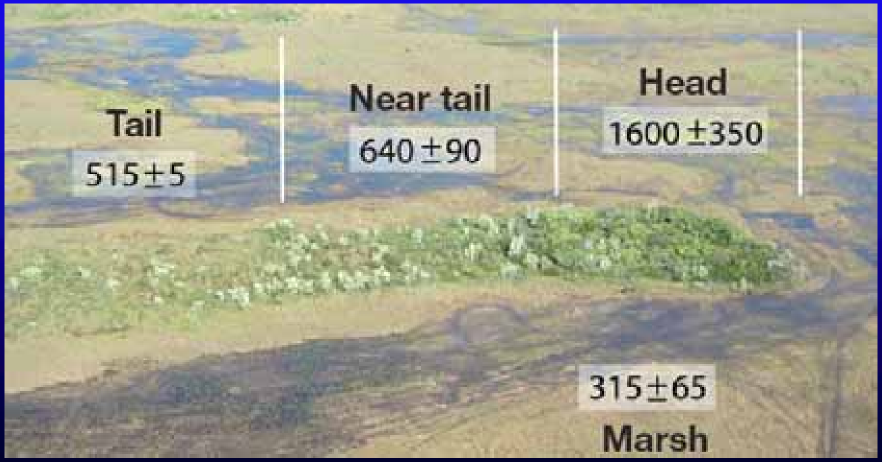
- Detection of two major vegetational gradients in the slough-ridge-tree island province – tied to water depth and proximity to tree islands – points to the operation of **both local and landscape-level drivers**
- Proximity gradient expected based on leakage of P from tree islands into the surrounding ground- and surface-water flows
- Two-dimensional gradient in vegetation composition and structure novel, not recognized or predicted previously

Local vs. landscape-level drivers of vegetation differentiation

- Additional studies/experiments needed to determine whether observed proximity gradient is indeed driven by P-rich groundwater leaking from islands
- But current data tend to support this mechanism:
  - Very high levels of P input to tree islands has been tied to guano deposition, and to soil [P] on islands in a chronically P-limited landscape
  - Effect of P deposition can linger for decades, so that effects of rookeries might be integrated over long periods and persist long after birds have left

Local vs. landscape-level drivers of vegetation differentiation

- Alternative hypotheses that groundwater focusing or higher rates of dry deposition on topographic rises concentrate P seem less plausible but should be tested
- Decline in peat [P] from island head to tail, and higher levels of peat [P] in islands vs. surrounding marshes (e.g., Wetzel et al. 2005, Ross et al. 2006) are consistent with trophic concentration on island heads and ground- and surface-water transport



Wetzel et al. 2005

Local positive feedback

- Previous studies on several species show that plant growth increases in shallower water and at greater [P]
- Our data show that *Cladium* is more than twice as tall on tall vs. short sawgrass ridges / Tall sawgrass ridges occur on substrates 8 cm shallower than short sawgrass / Peat thickness ca. 20 cm thicker under tall sawgrass
- Stratigraphic data of Willard et al. 2006 also consistent with local positive feedback:
  - On Manatee Island in s Shark River Slough, rates of peat accumulation over past 600-2700 years almost four times (0.43 mm yr^{-1}) that in the near-tail (0.11 m yr^{-1})
  - Similar but less divergent behavior at T3 Island in WCA-2A

Model box-score

- Our data and the literature provide support for
  - Positive feedback of peat accretion on higher microsites
  - Trophic P concentration on tree islands
  - Fertilization of areas around and in the lee of tree islands, with subsequent shifts in composition and net peat accretion
  - Local- and landscape-level drivers shape vegetation composition and soil thickness
- Relatively small fluctuation in peat vs. bedrock surfaces across the Everglades provides support for point 1 of the model
- Massive amounts of marl under sawgrass ridges (P Glaser, unpubl. data) supports our scenario for growth and downstream propagation of ridges

Many thanks to CESI and the National Park Service for funding!