Discharge competence and pattern formation in peatlands

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Regular Self-Organized Pattern

Diverse ecosystem types, pattern geometries, and scales

Emerge from spatial feedbacks

Local facilitation

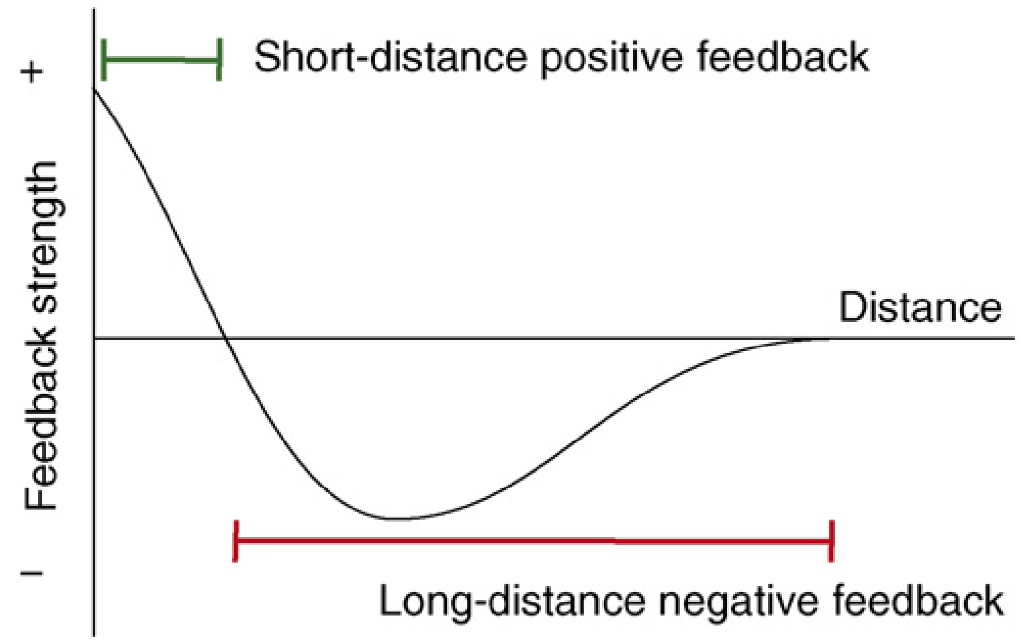
Distal inhibition

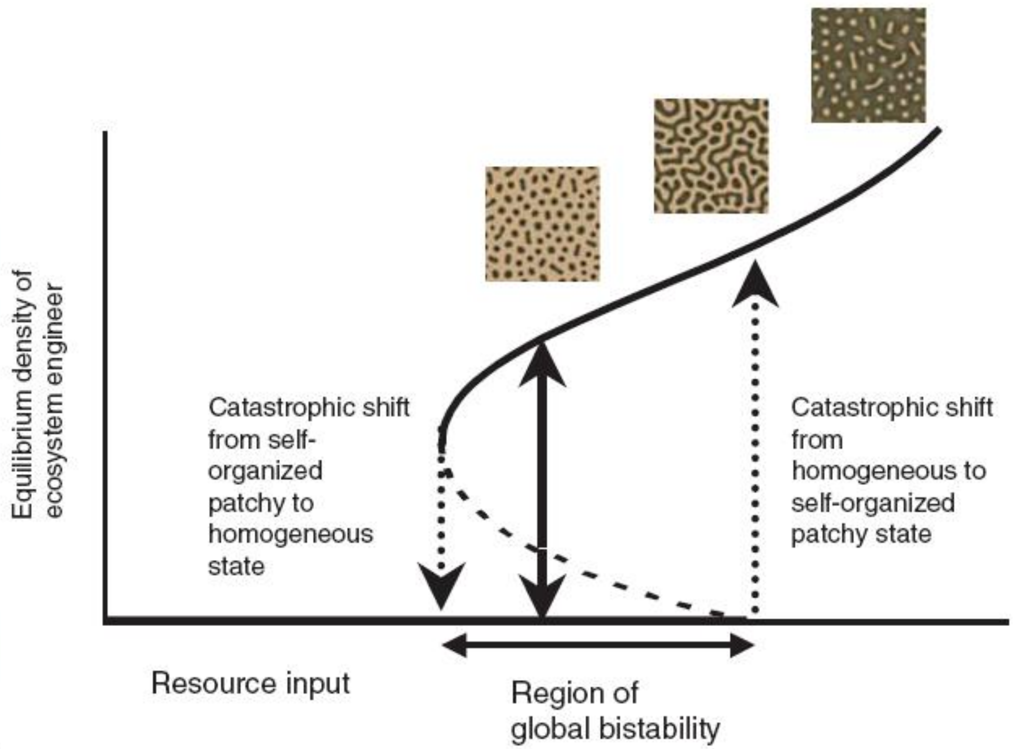
Pattern as alternative stable state

Habitat and biogeochemical function

Management and restoration

Pattern change as leading indicator





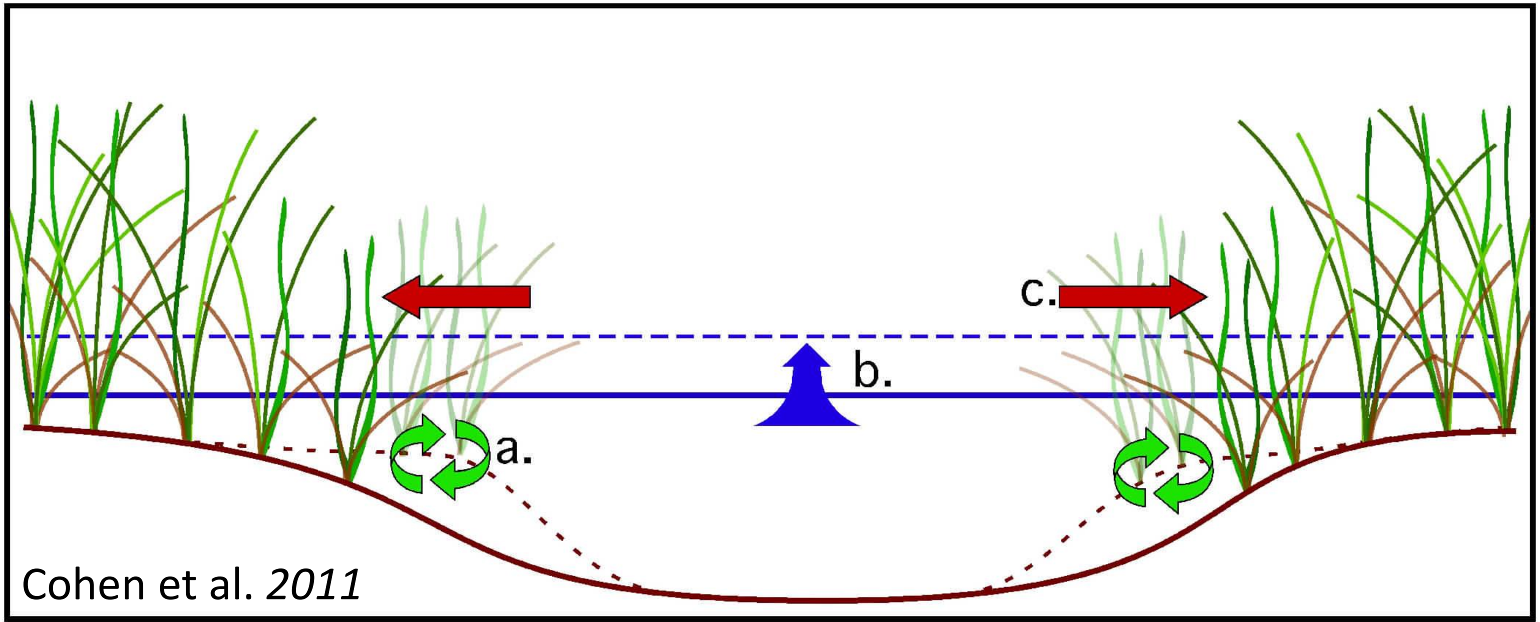
Rietkirk et al. 2004 *Science*

Rietkirk and van de Koppel 2008 *TREE*

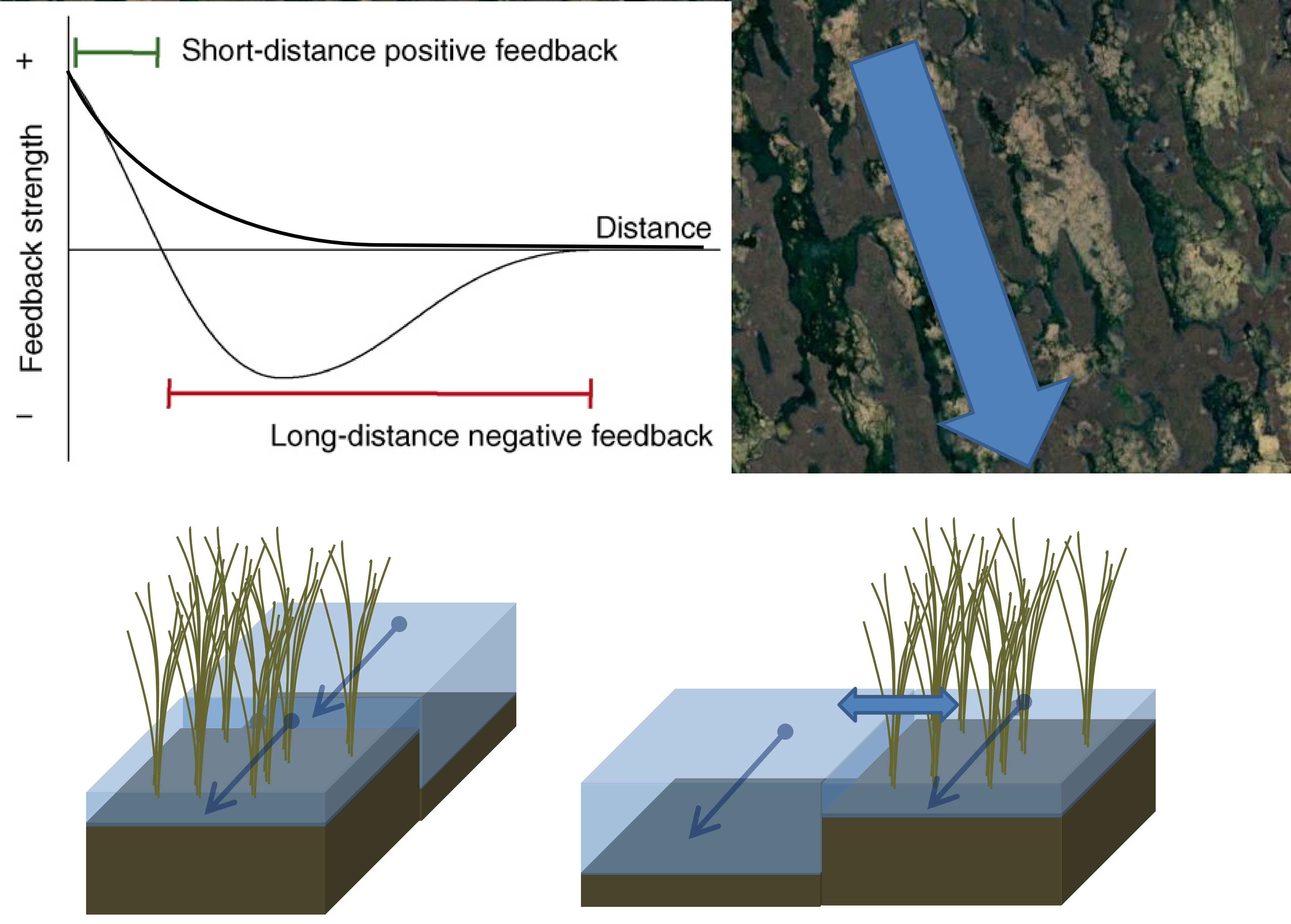

Land Cover Data from SPOT Satellite Classification
Lake Okeechobee
N. PALM BCH. SVC. AREA
EVERGLADES AGRICULTURAL AREA
WCA-1
WCA-3
LEC SVC. AREA 2
BIG CYPRESS BASIN
EVERGLADES NATIONAL PARK
Gulf of Mexico
Florida Bay
Atlantic Ocean
N
Generalized Historical Everglades Boundary
Drained
Impounded

The Self-Organizing Canal Hypothesis

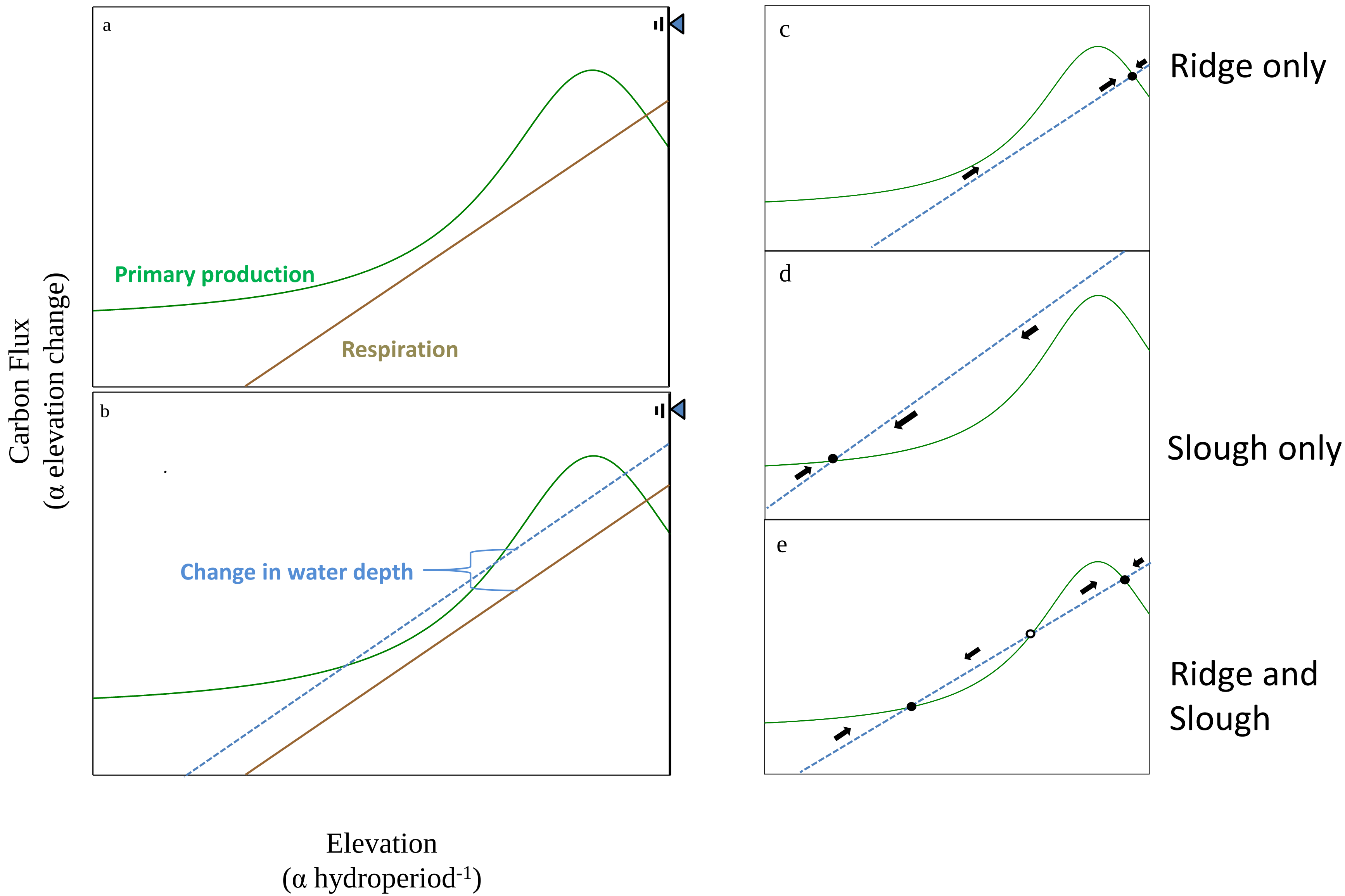
- **75-85% of flow moves through sloughs**
  - Depth 2-3 times that of ridges, marginally greater velocity
- **Lateral expansion of ridges reduces landscape discharge competence**
  - Greater water depth at any given discharge
  - Effect is less for longitudinal expansion
- **Greater depths disfavor further ridge expansion**



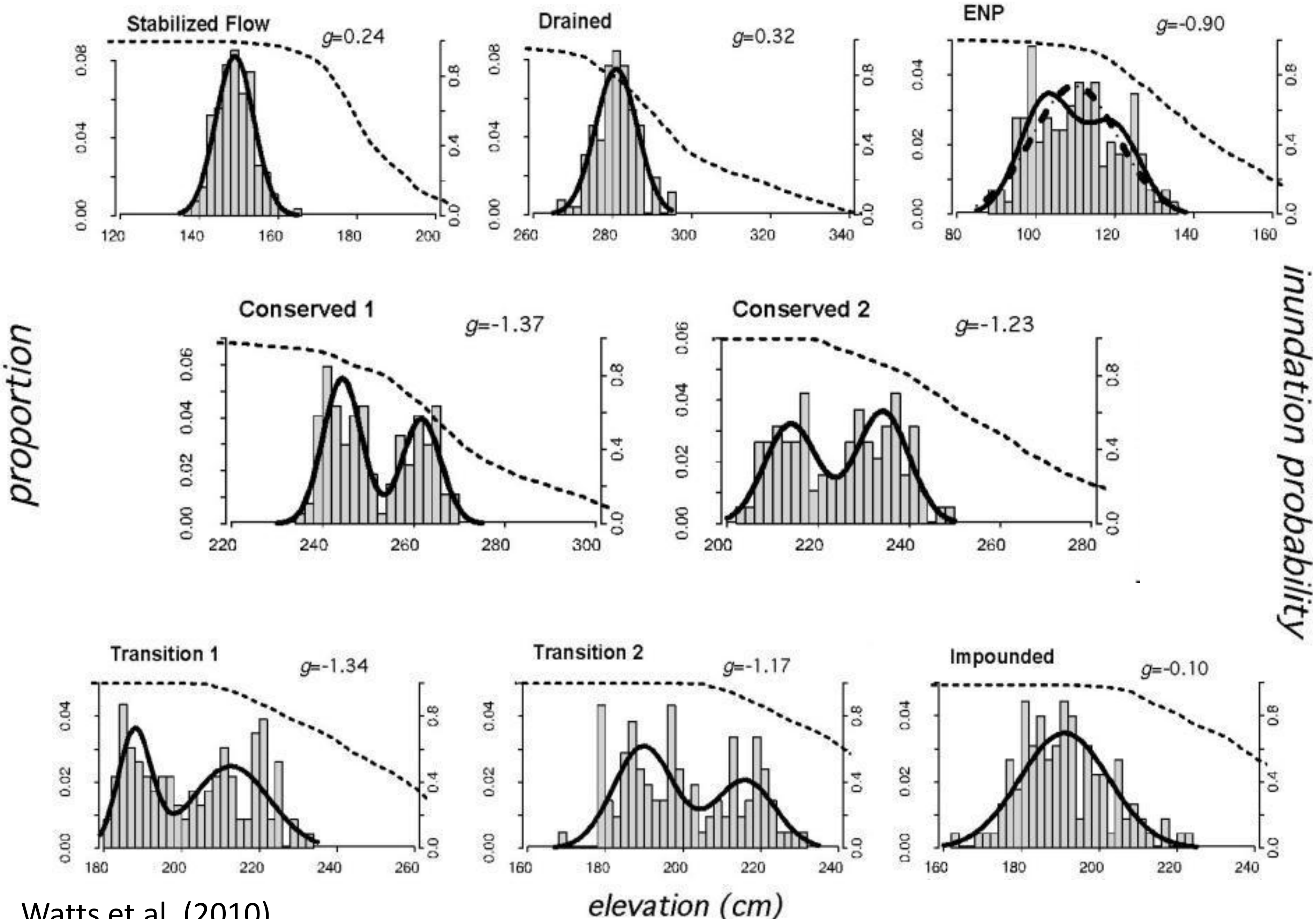
Cohen et al. *2011*



Short-distance positive feedback
+
Feedback strength
Distance
Long-distance negative feedback

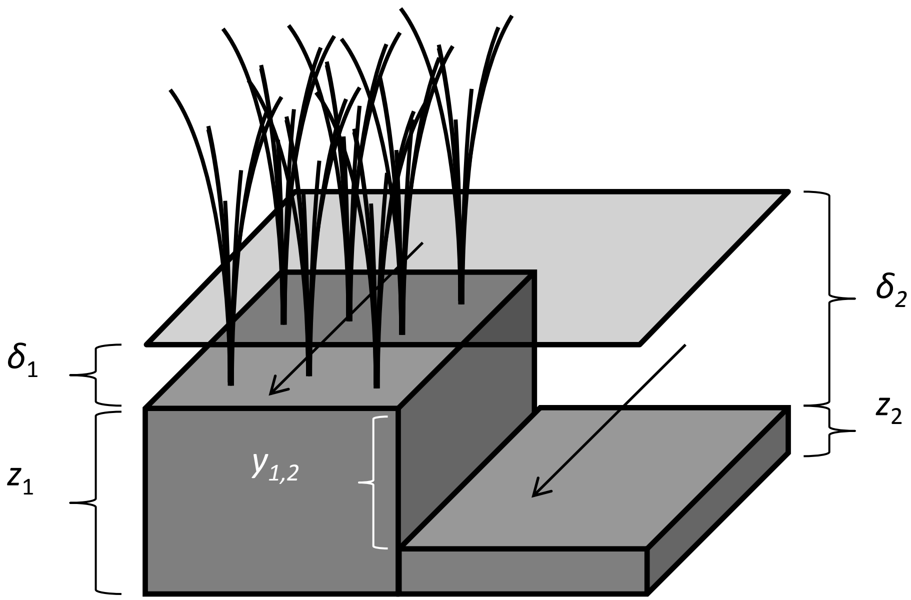


Heffernan et al. *in prep.*



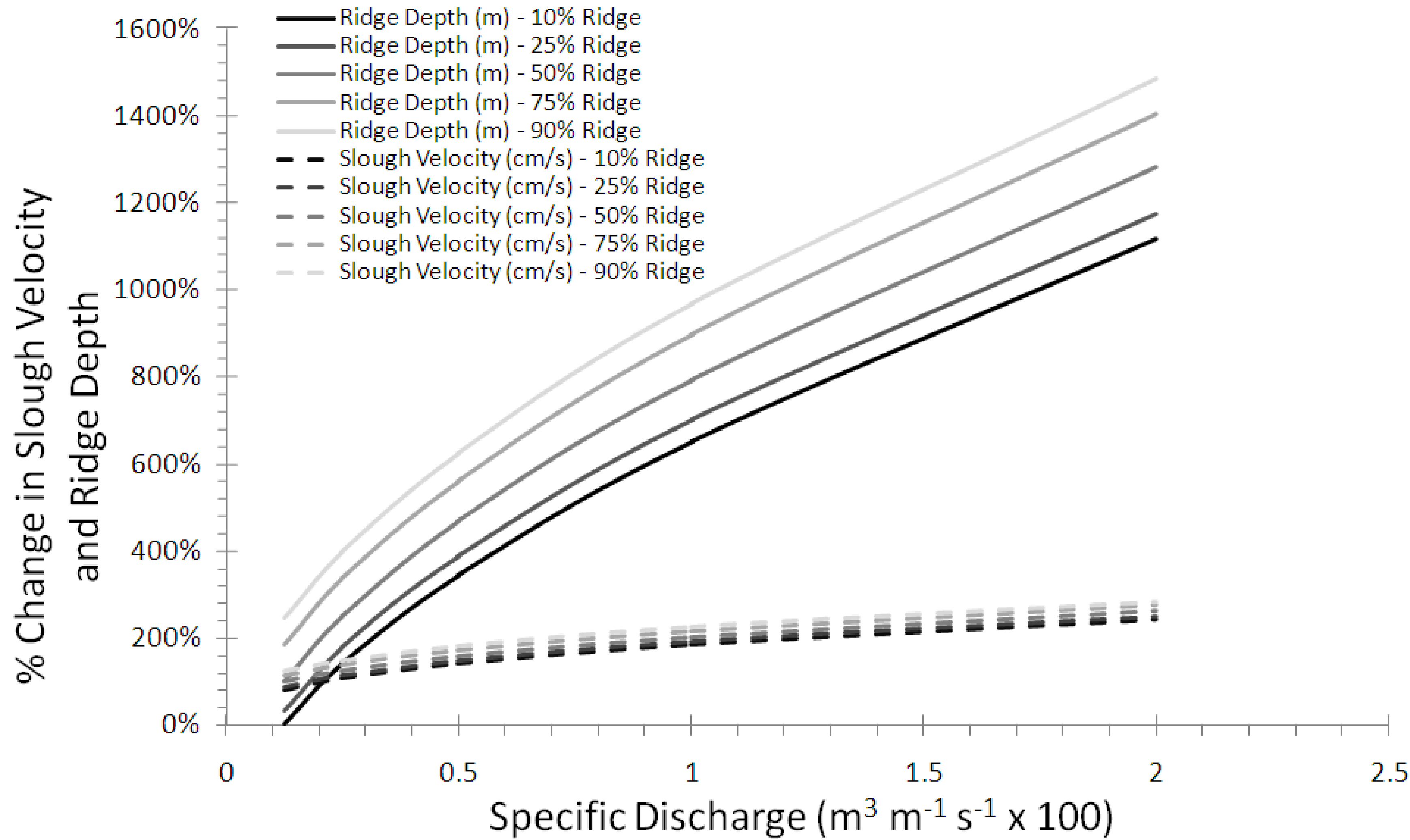
Watts et al. (2010)

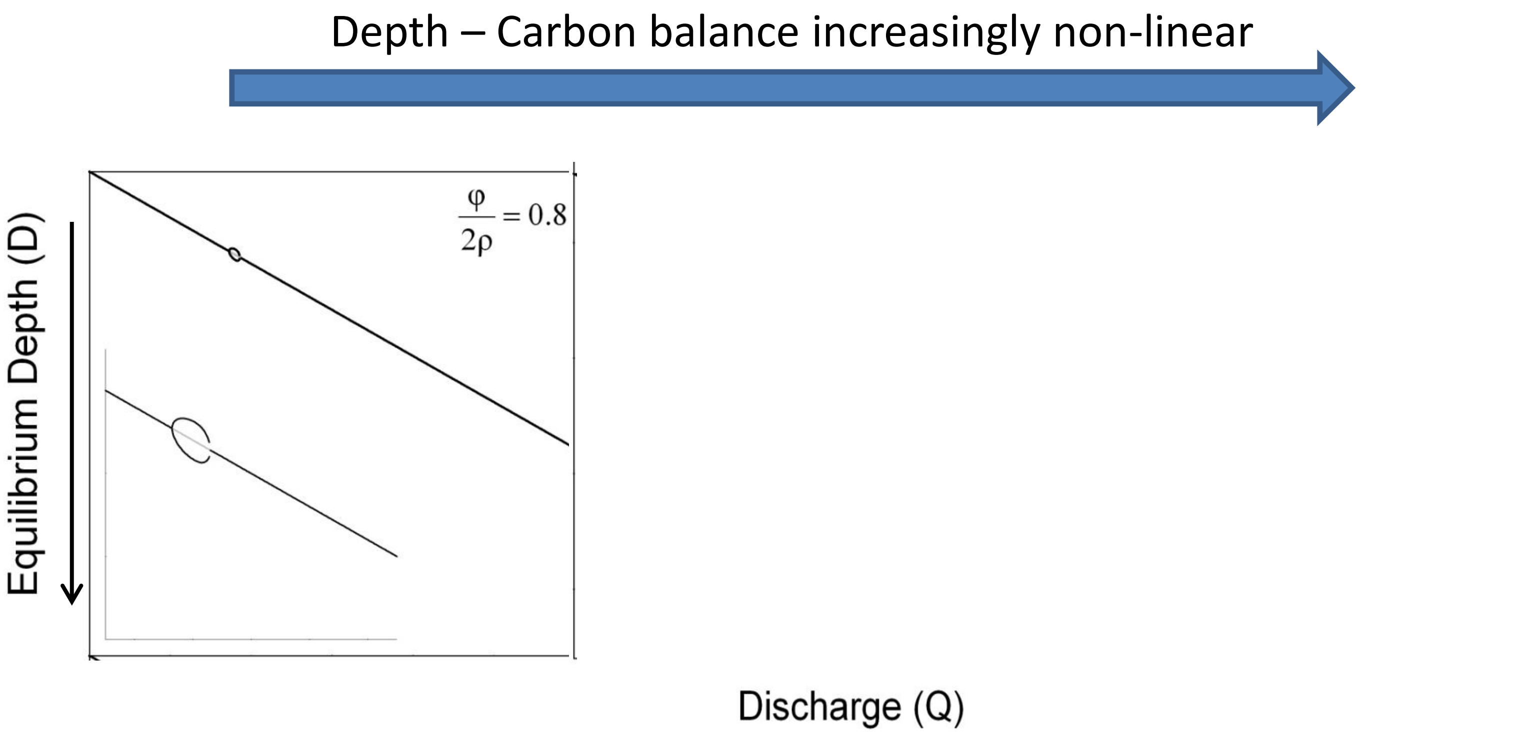
Lateral coupling



- C balance changes non-linearly with depth
- Discharge must be conveyed through shared cross section of 2 patches
  - Water levels equal
- Variation in discharge leads to changes in water elevation
  - Assumes constant velocity
- Equilibrium when all depths are constant

Changes in depth dominate discharge variation

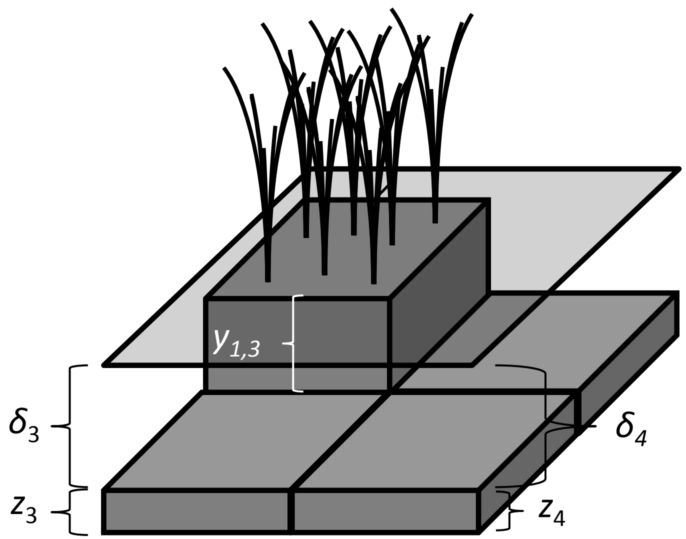




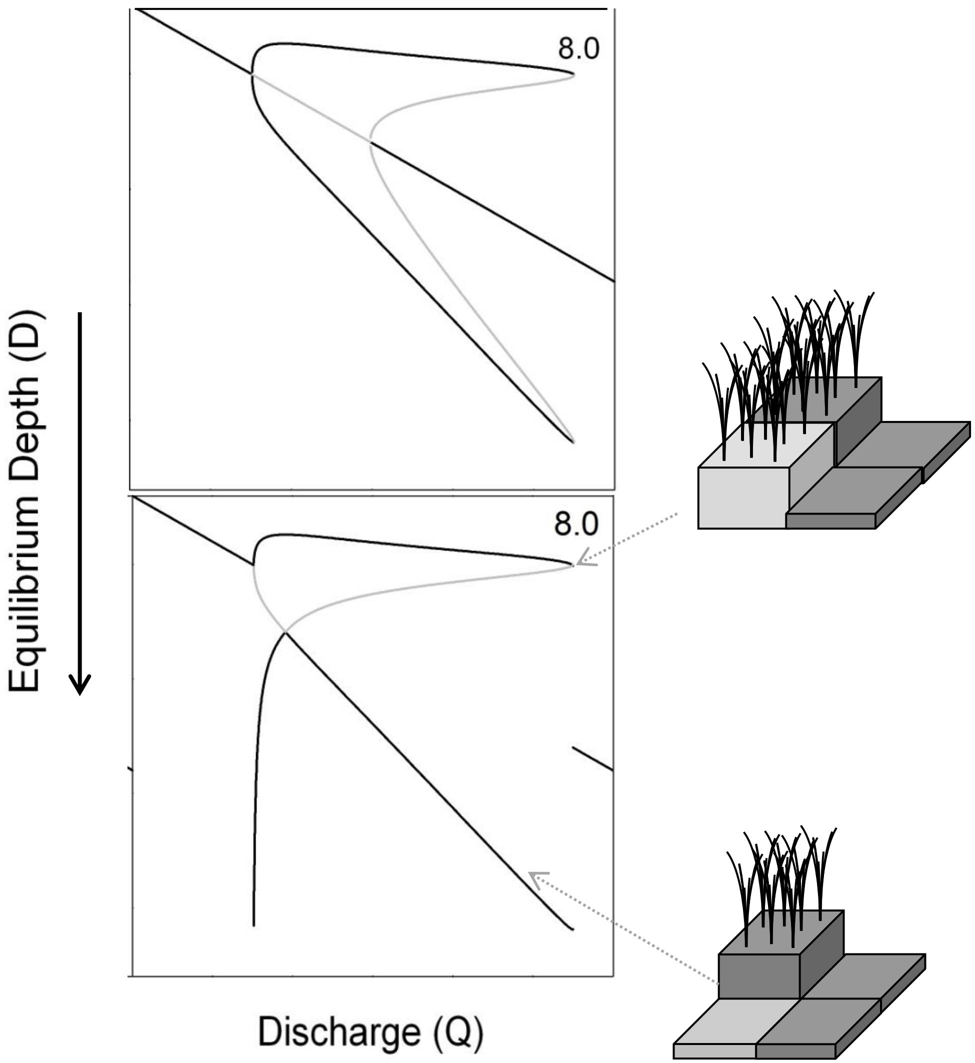
- Ridges and sloughs differentiate spontaneously → Distal negative feedback
- Patterned and homogenous states both stable at some discharges
- Elevation differences and discharge domain increase as depth-C balance relationships become more non-linear

Heffernan et al. *in prep.*

Longitudinal coupling

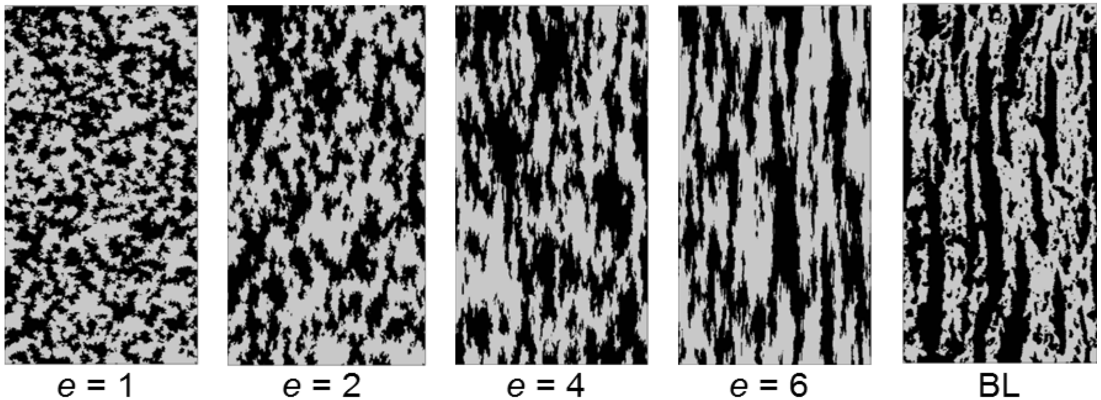


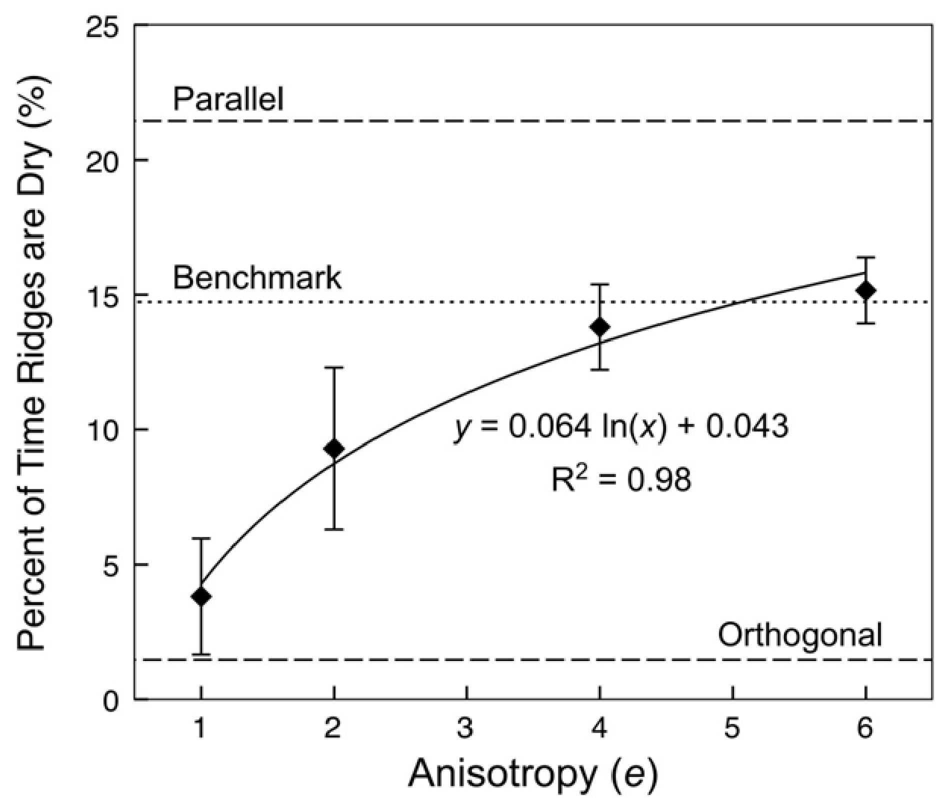
- Upstream patches are shallower and at equilibrium
  - Control water levels
- Downstream patches have same C balance - depth relationships
- Equilibrium when all depths are constant



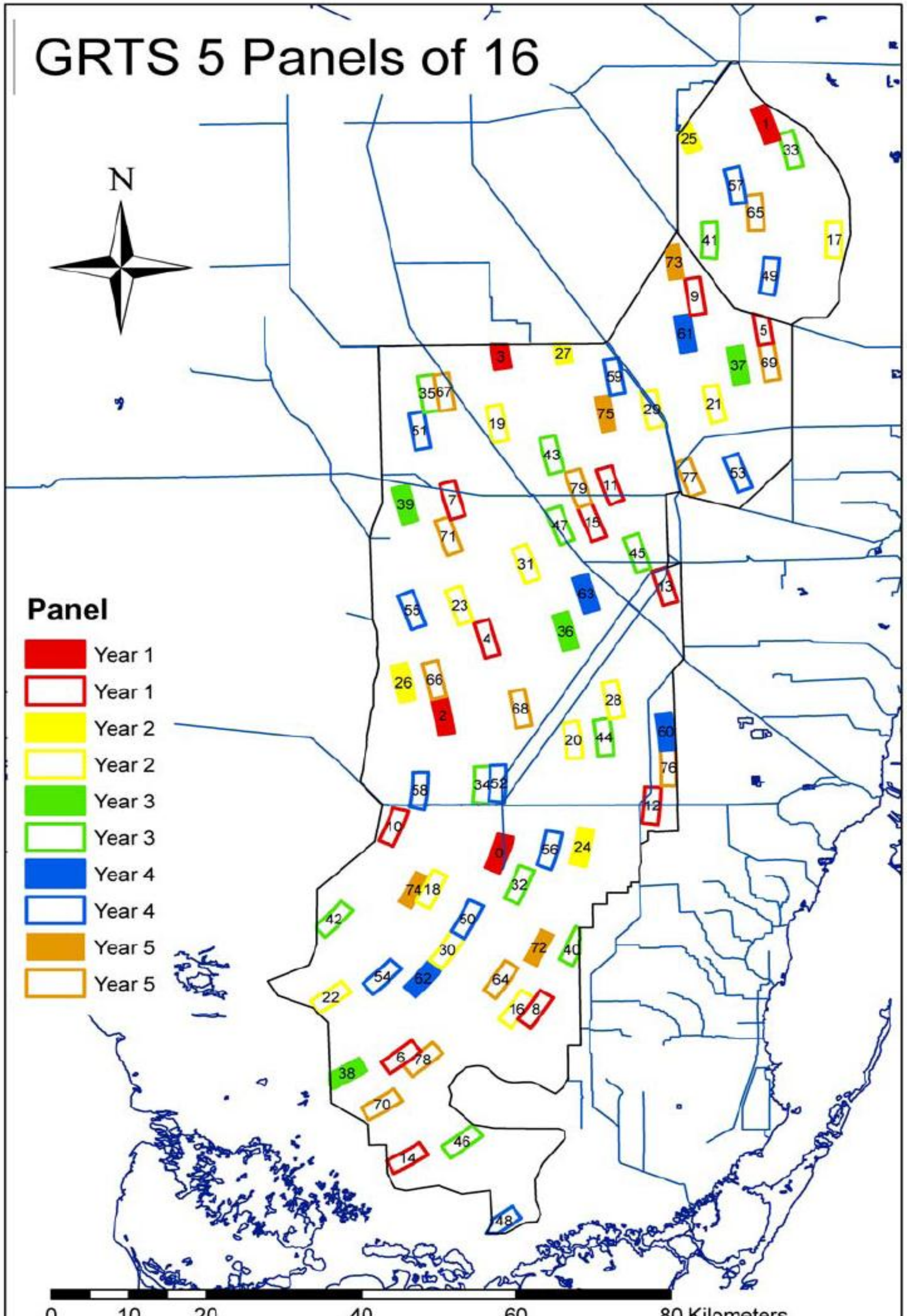
- Downstream of ridge, either ridge or slough is stable
  - No spontaneous divergence →no distal neg. feedback
- Divergence of slough elevation at near dry threshold of patterning
  - Variance signal?

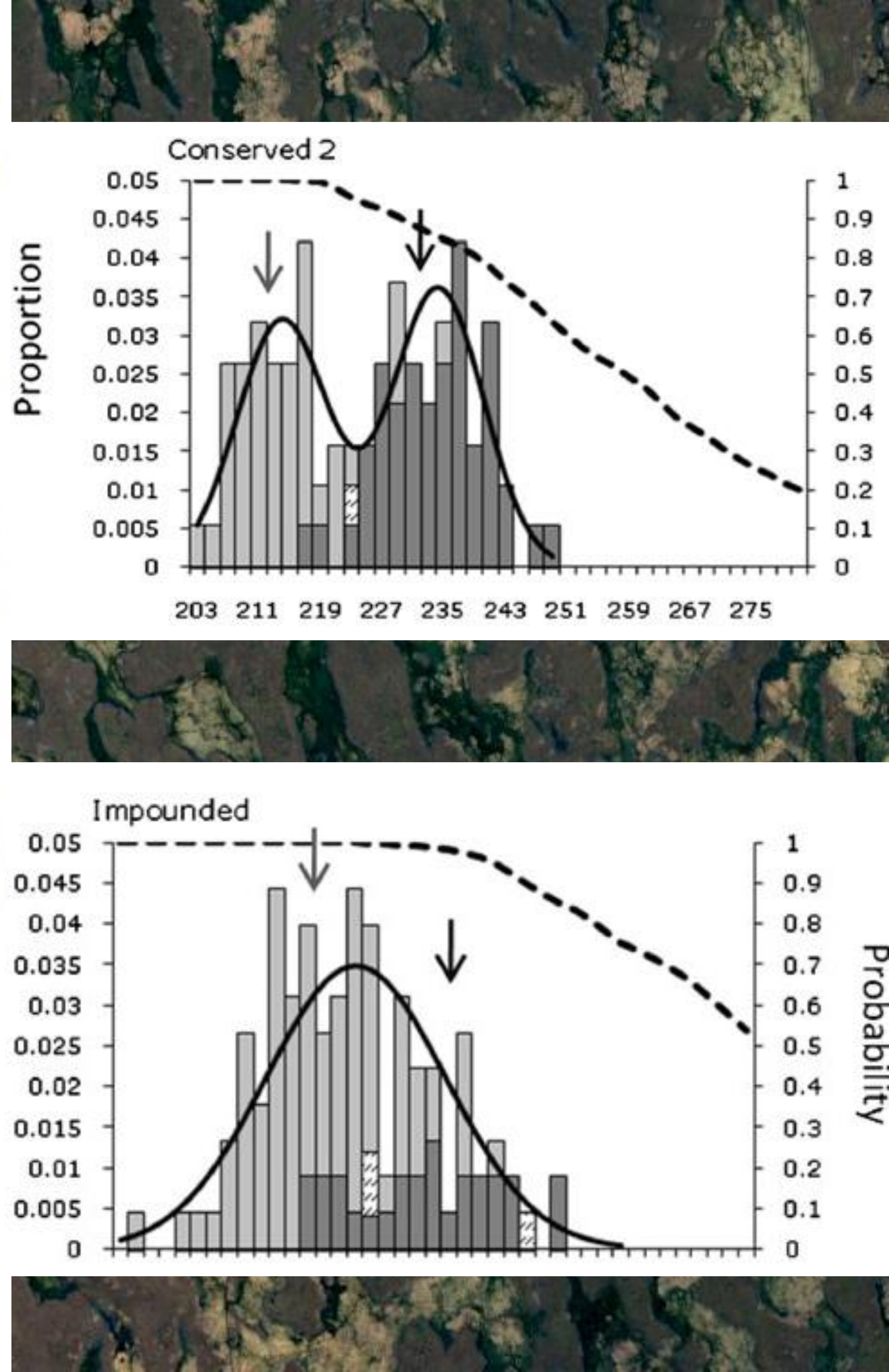
Heffernan et al. *in prep.*





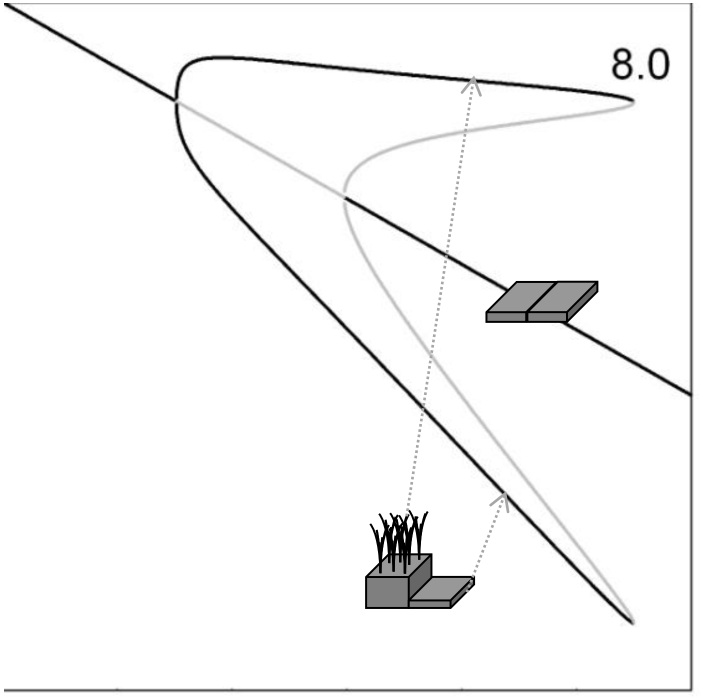
Tomorrow at 2 PM
David Kaplan (UF)
Hydrologic Processes in a Patterned Peatland
Antigua 3&4

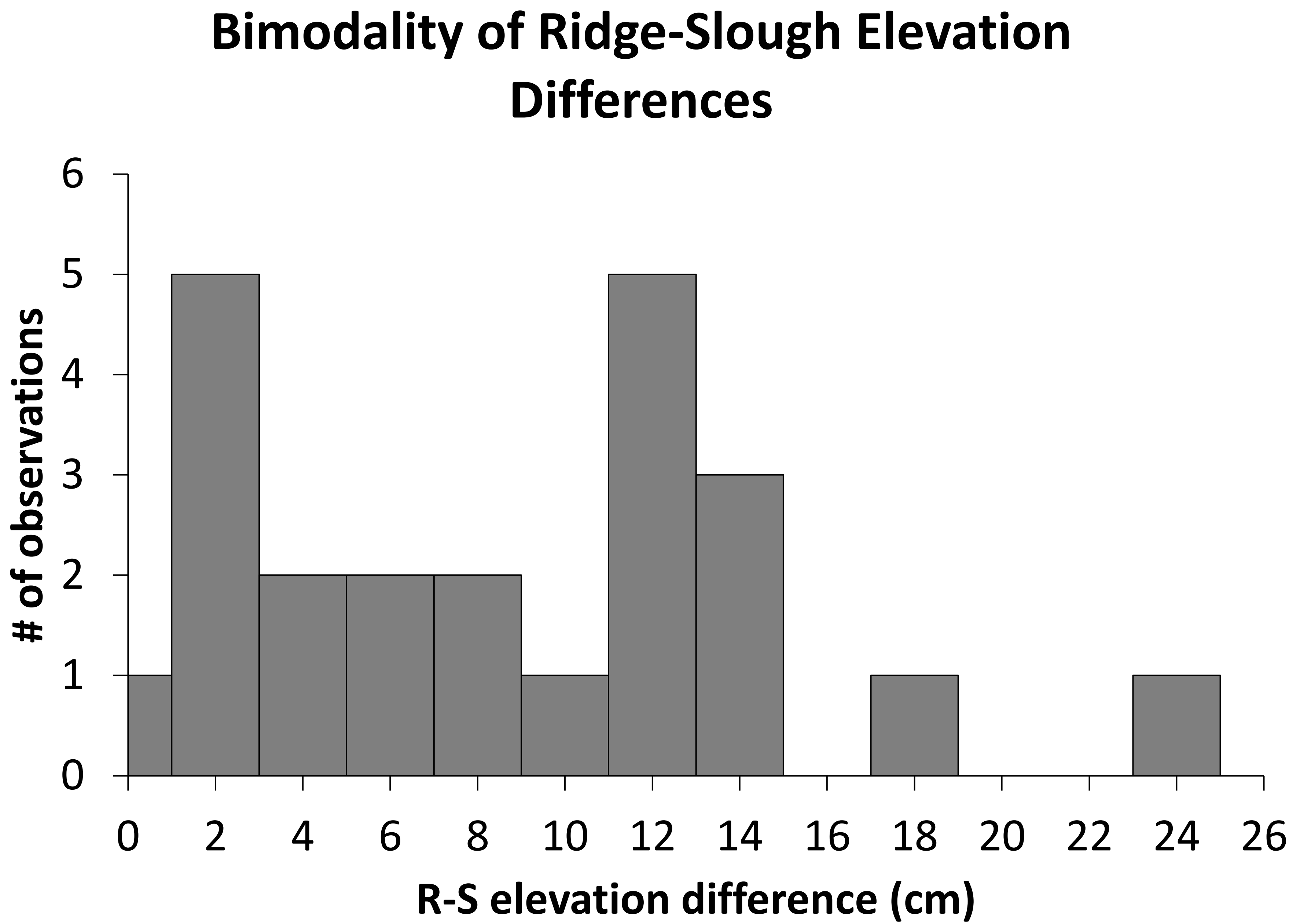

GRTS 5 Panels of 16
N
Panel
Year 1
Year 1
Year 2
Year 2
Year 3
Year 3
Year 4
Year 4
Year 5
Year 5
0 10 20 40 60 80 Kilometers

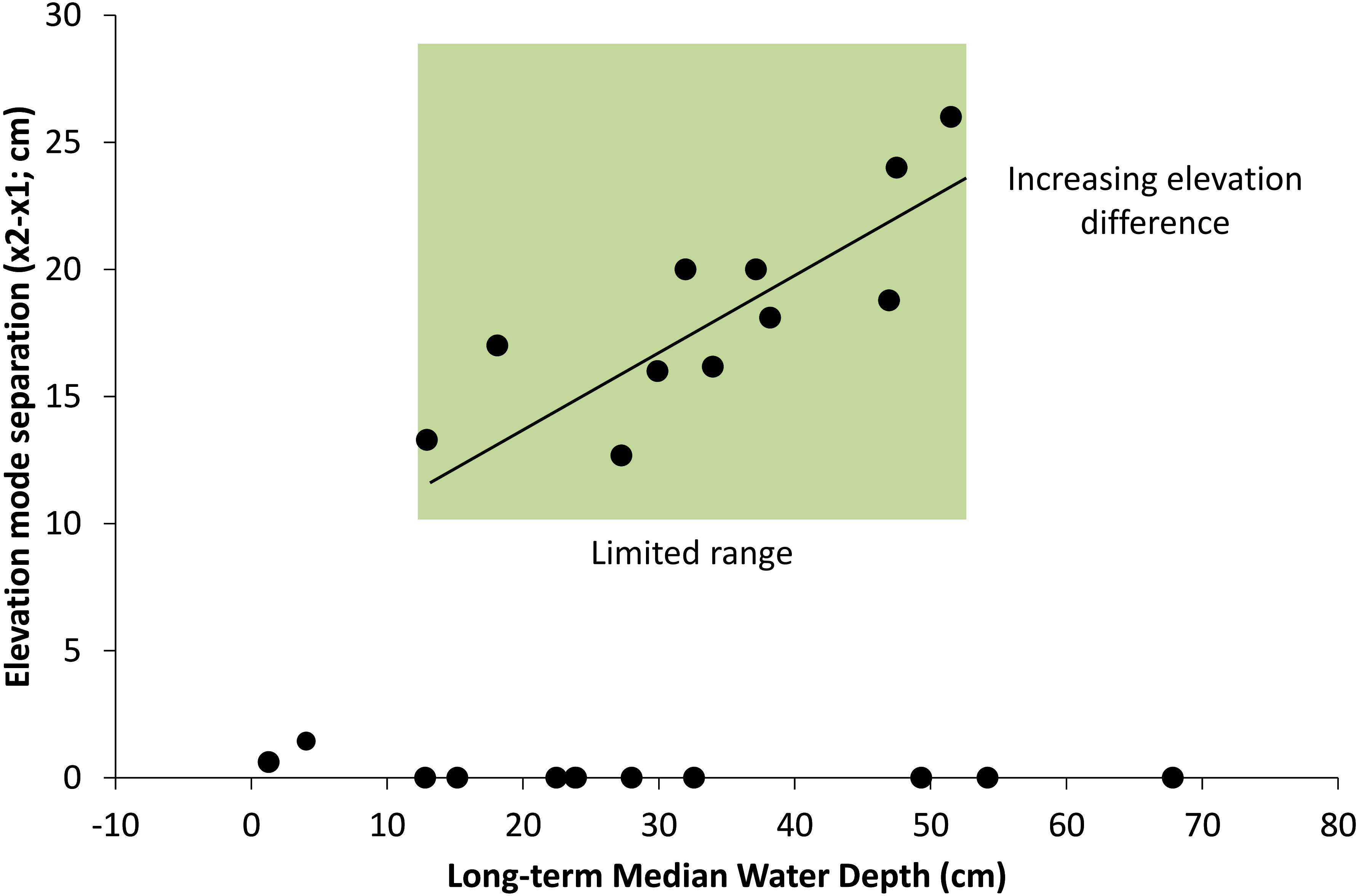

Conserved 2
Proportion
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
203 211 219 227 235 243 251 259 267 275
Impounded
Probability

Predictions

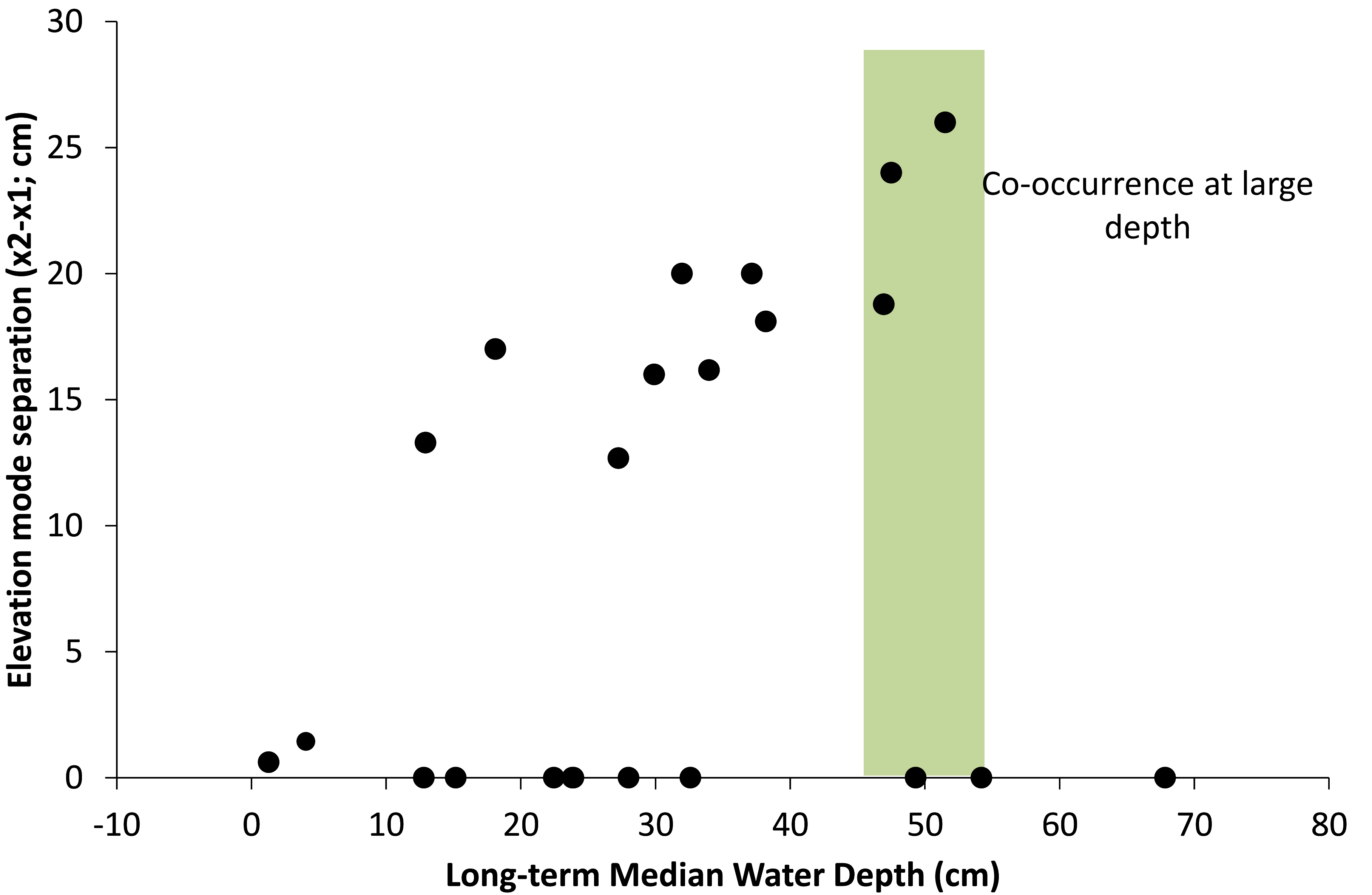
1. Finite hydrologic range for ridge-slough differentiation
2. Increasing ridge-slough differences with greater depth
3. Ridge-slough uniquely stable at moderately low water levels
4. Ridge-slough and unpatterned landscape co-occur at high water levels
5. Bi-modal distribution of ridge-slough elevation differences



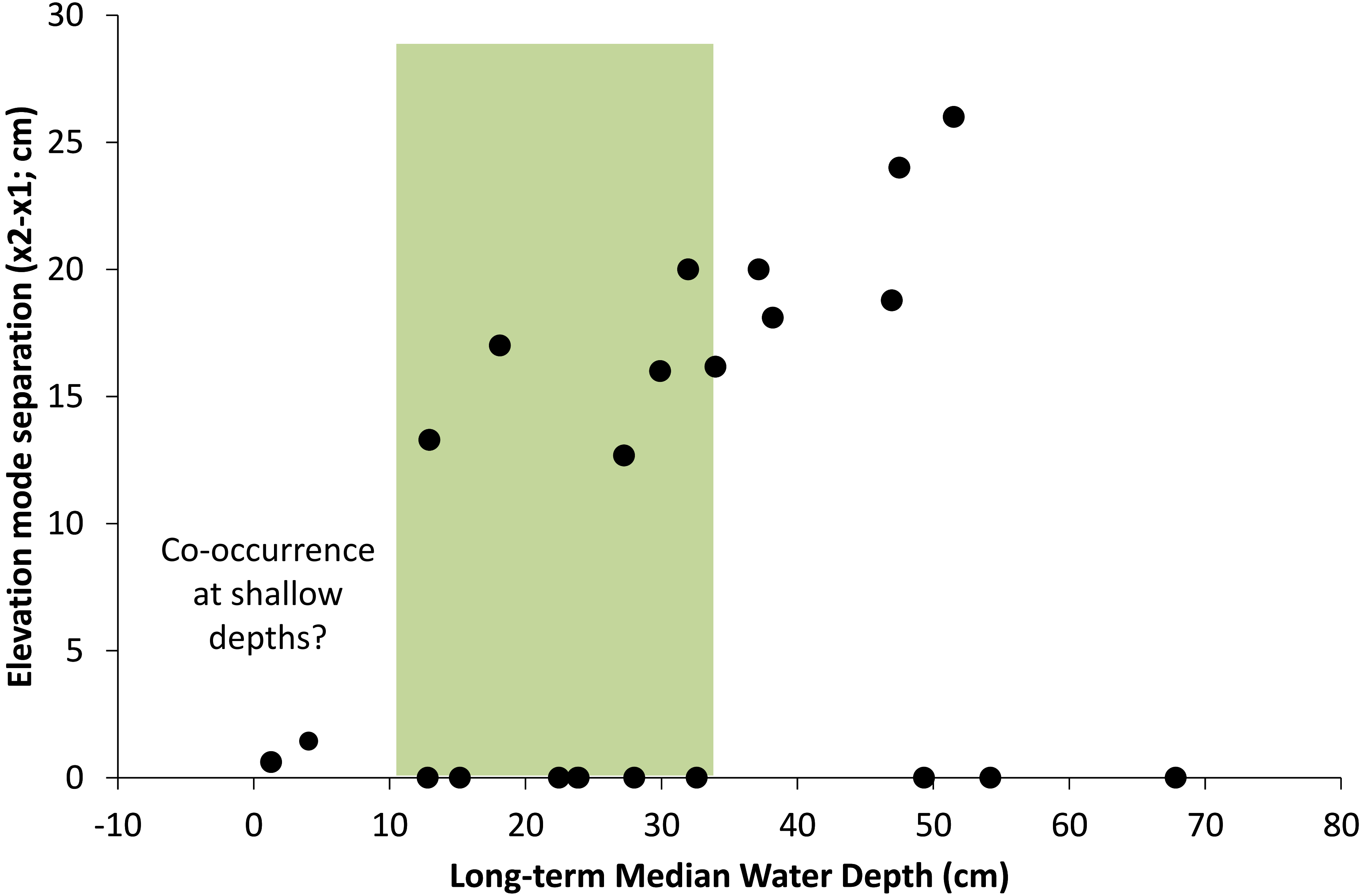

Bimodality of Ridge-Slough Elevation Differences
# of observations
0
1
2
3
4
5
6
0
2
4
6
8
10
12
14
16
18
20
22
24
26
R-S elevation difference (cm)



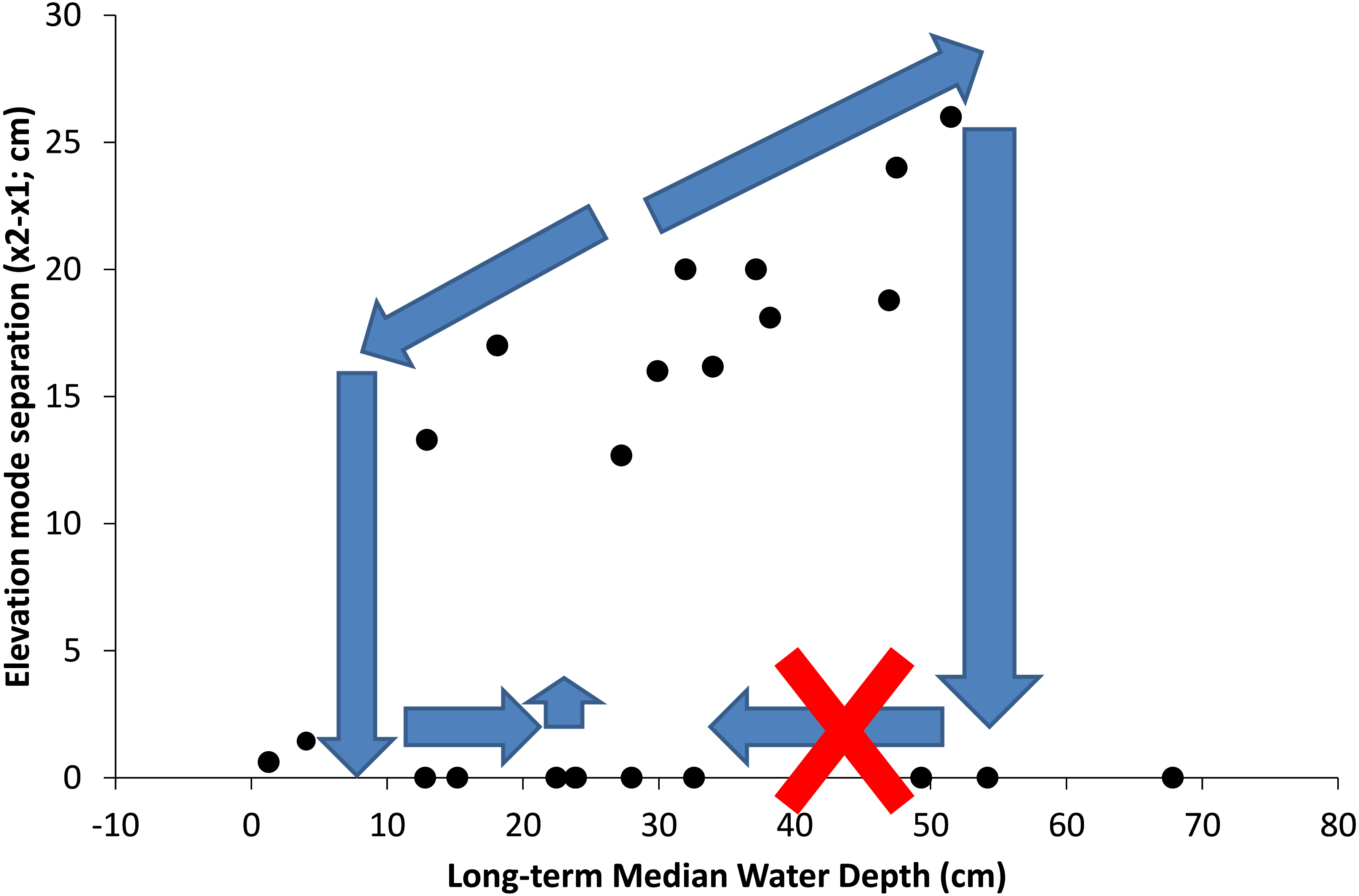
30
25
20
15
10
5
0
Elevation mode separation (x2-x1; cm)
Increasing elevation difference
Limited range
-10
0
10
20
30
40
50
60
70
80
Long-term Median Water Depth (cm)



Elevation mode separation (x2-x1; cm)
30
25
20
15
10
5
0
Co-occurrence at large depth
-10
0
10
20
30
40
50
60
70
80
Long-term Median Water Depth (cm)



Elevation mode separation (x2-x1; cm)
30
25
20
15
10
5
0
Co-occurrence at shallow depths?
-10
0
10
20
30
40
50
60
70
80
Long-term Median Water Depth (cm)



30
25
20
15
10
5
0
-10
0
10
20
30
40
50
60
70
80
Elevation mode separation (x2-x1; cm)
Long-term Median Water Depth (cm)

Conclusions

- **Discharge competence generates anisotropic distal negative feedbacks**
  - Spontaneous differentiation of ridge and slough
- **Need for critical tests where predictions of alternative mechanisms diverge**
  - Discharge competence, sediment and/or nutrient redistribution not mutually exclusive
    - may be synergistic
- **Theoretical and empirical evidence for meta-stability of ridge-slough landscape**
  - Preservation of relict landscapes critical
  - Active restoration needed?

Thanks to…

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- Mike Ross (FIU)
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- South Florida WMD

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- Mario Cisneros
- Alexandra Saldana

US ARMY
CORPS OF ENGINEERS

RECOVER assessment science evaluation integration

SOUTH FLORIDA WATER MANAGEMENT DISTRICT
sfwmd.gov

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