INTEGRATION AND REFINEMENT OF EVERGLADES SCIENCE: ANALYSIS OF ECOLOGICAL VULNERABILITY

David Rudnick[1], Jed Redwine[1], Agnes McLean[1],
Patti Gorman[2], Fred Sklar[2],
Jenna May[3], Gretchen Ehlinger[3], Kelly Keefe[3], Melissa Nasuti[3]

Greater Everglades Ecosystem Restoration Conference
April 19, 2017

1 2 3

Introduction

- RECOVER Five-Year Plan element: integrate restoration science knowledge gained over past 15 years; reassess RECOVER assessment assumptions & priorities.
- Greater Everglades ecosystem has continued to degrade since CERP authorized (2000).
- Accelerating Influence of climate change, sea-level rise, and invasive exotic species.
- Five-Year Plan task: system-wide analysis of the most vulnerable areas, components (habitats, communities, species), and functions.

Vulnerability Analysis Objectives

- Determine which Everglades attributes or areas are most vulnerable to ecological collapse.
- Improve understanding of "tipping points" between alternative system states.
- Improve understanding of how best to <u>promote resilience</u>.
- Inform CERP regarding restoration project planning and sequencing (regarding restoration triage and system-wide "trade-offs").
- Identify key scientific uncertainties and needs, informing prioritization of future research, modeling, monitoring.
- Timeline: 2017-2019

Vulnerability Analysis Definitions

- Vulnerability: the degree to which a system or system attribute is susceptible to, and unable to cope with injury, damage, or harm (stress).
- Vulnerability is a form of risk analysis and a function of:
  - exposure to a stressor
  - sensitivity to this stressor
  - recovery potential (resilience or adaptive capacity)
- Sensitivity: degree to which a disturbance (exposure to a stressor) affects structure, composition, or function (antonym of resistance).
- Resilience: ability to recover after being impacted by a disturbance (exposure to stress).
- Tipping point: a critical threshold between alternative system states.

Definitions modified from Delange et al. 2010, Gitay et al. 2011, Miller et al. 2010, Nimmo et al. 2015, Scheffer et al. 2012

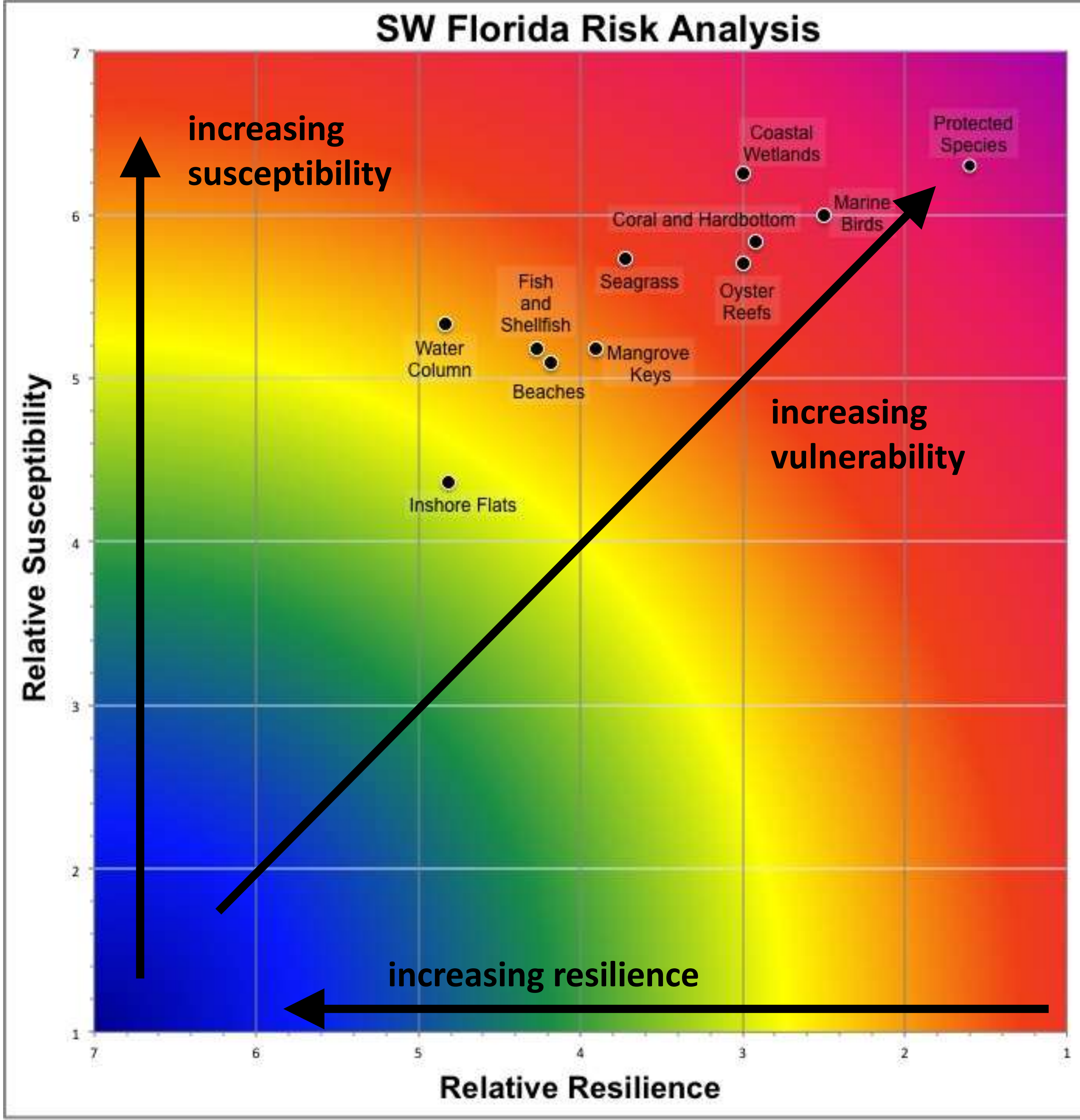
Vulnerability Analysis Approaches

- Inference from analysis of long-term monitoring data; spatial analysis (increasing availability of spatially extensive data).
- Insight of vulnerability and key uncertainties from qualitative, best professional judgement.
- Insight from simple models (existing and potentially developed).

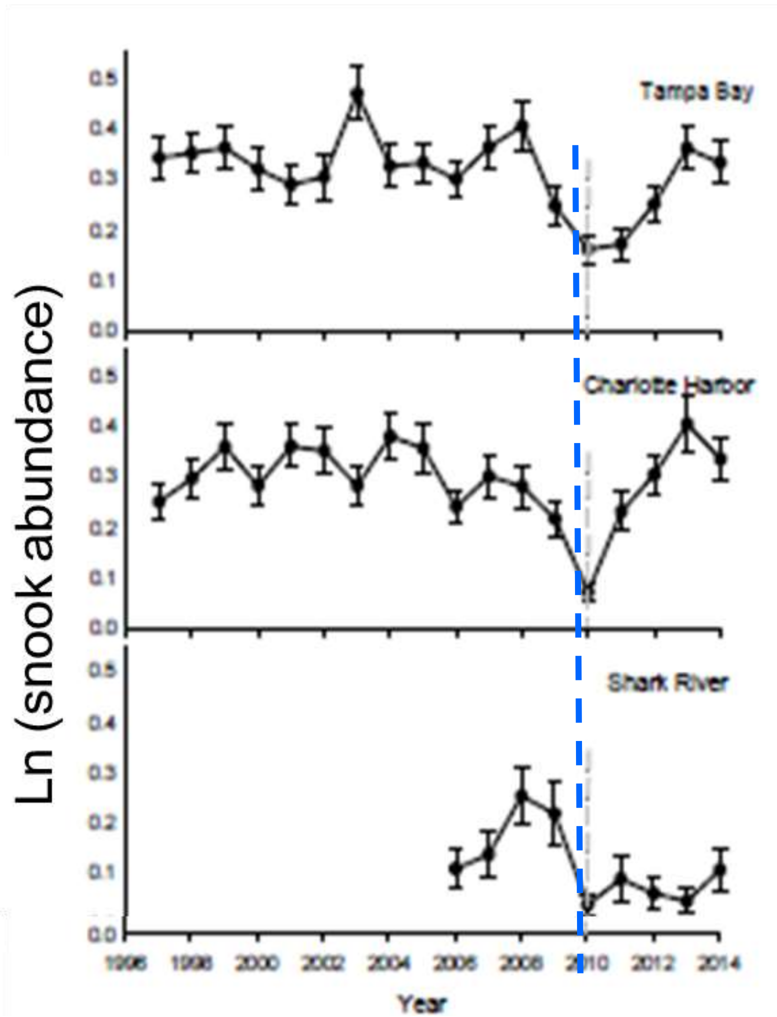
Susceptibility and Resilience of Southwest Florida Coastal Attributes

- Susceptibility includes stress exposure and sensitivity
- Relative scores from expert opinion polling

From Cook et al. 2016, NOAA-COCA



Inference on Resilience from Monitoring Data: Variation Among Snook Populations



Stressor: low temperature
Current Exposure: moderate (variable)
Sensitivity: high
Resilience: high (1-4 years)

Snook recovered in:

- 3 years
- 1 year
- 4 years

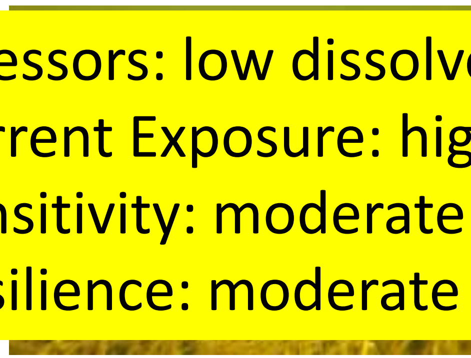
Dead snook, tarpon & goliath grouper, Everglades National Park, Jan 2010

Stevens, Rehage, Boucek et al. 2016 Ecosphere

Evidence of Everglades System Vulnerability

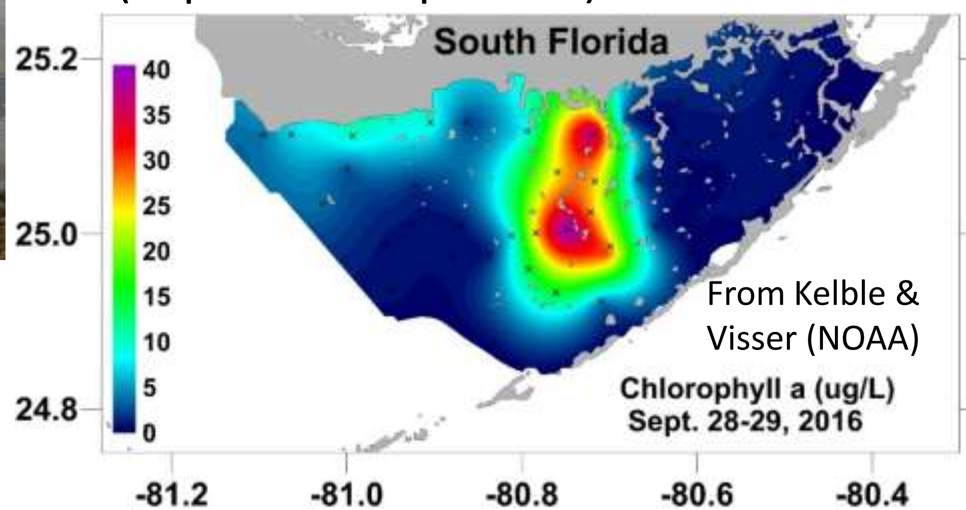
- Florida Bay seagrass mass-mortality and algal blooms

Die-off distribution December 2015



Stressors: low dissolved oxygen, sulfide, salinity, nutrients
Current Exposure: high
Sensitivity: moderate
Resilience: moderate (25 year recovery from last die-off)

Likely causing intense algal blooms (Sept 2016 to present)

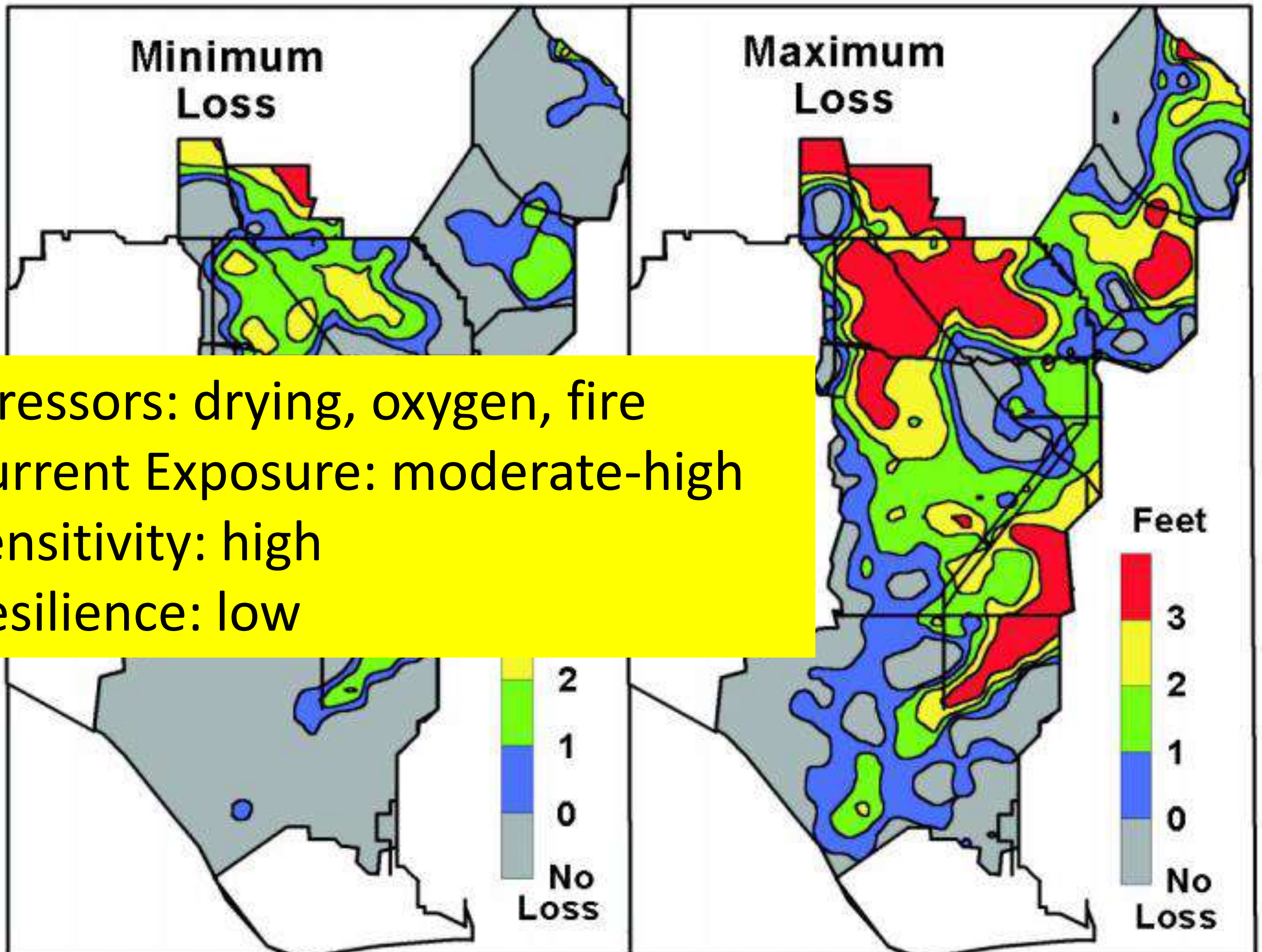


From Kelble & Visser (NOAA)

Evidence of Everglades System Vulnerability

- Soil loss: freshwater peat oxidation (fire, microbial decomposition)

From Snyder (2004)

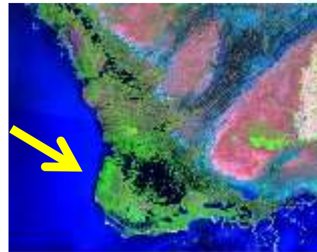


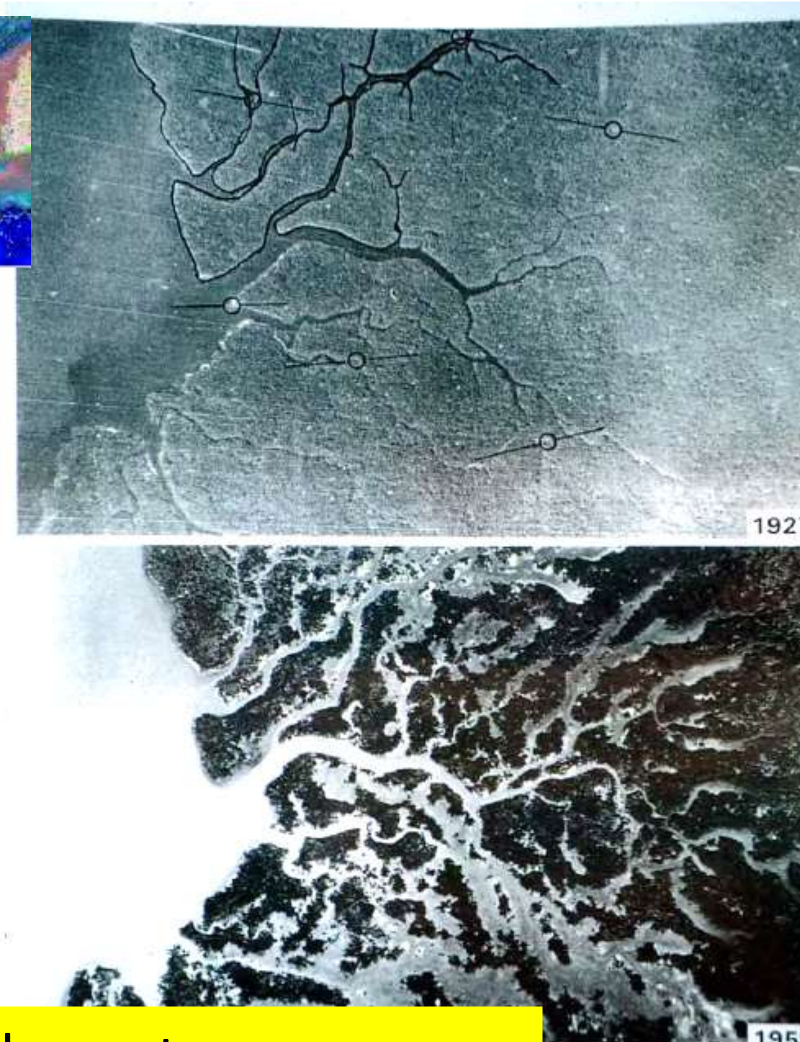
Stressors: drying, oxygen, fire
Current Exposure: moderate-high
Sensitivity: high
Resilience: low

Losses since 1934 (EPA, 2000)

Evidence of Everglades System Vulnerability

- Soil loss: coastal wetland peat collapse in relatively high ocean energy areas





Mangrove forest mortality and peat loss / collapse after 1935 hurricane

FIGURE 21. The peat substrate level beneath surviving mangroves in about one meter higher than the surface of the mangrove forest dest Labor Day Hurricane. About 75 per cent of the elevation loss is the compaction and decay subsidence.

wing changes in the mangrove nge is thought to be the result ne of 1935. Mangroves that m and the lower photograph the left. Photographs are 2.5

nkel, 2005

Stressors: salinity, sulfide, wave energy/shear stress
Current Exposure: high
Sensitivity: low
Resilience: low

Evidence of Everglades System Vulnerability

- Soil loss: peat collapse in oligohaline-freshwater ecotone marsh

Physical drivers:
- Saltwater intrusion?

Stressors: salinity, sulfide, phosphorus(?)
Current Exposure: moderate-high
Sensitivity: moderate (?)
Resilience: low

Photos: S. Davis

Evidence of Everglades System Vulnerability

Other Examples:

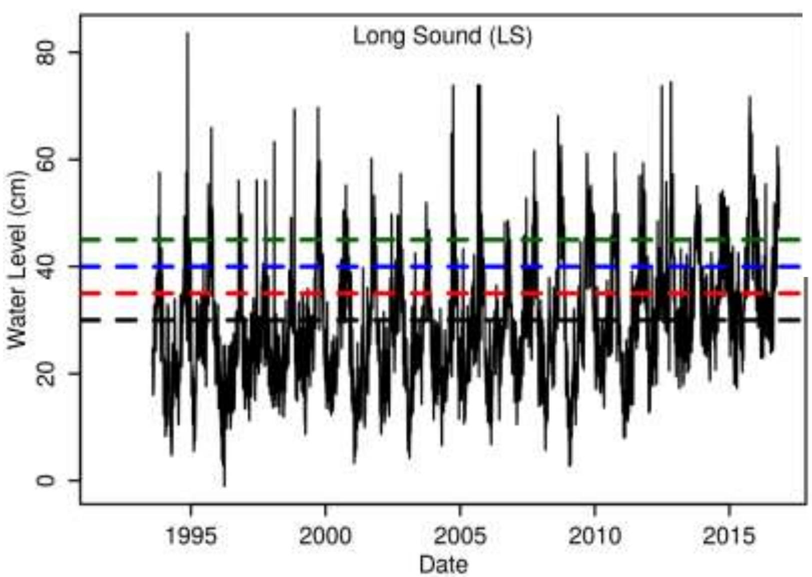
- Tree island mortality
- Ridge and slough landscape loss
- Periphyton loss, cattail expansion
- Mammal mortality (predation by pythons)
- Threatened and endangered species
- Northern estuaries algal blooms
- Coral reef mortality

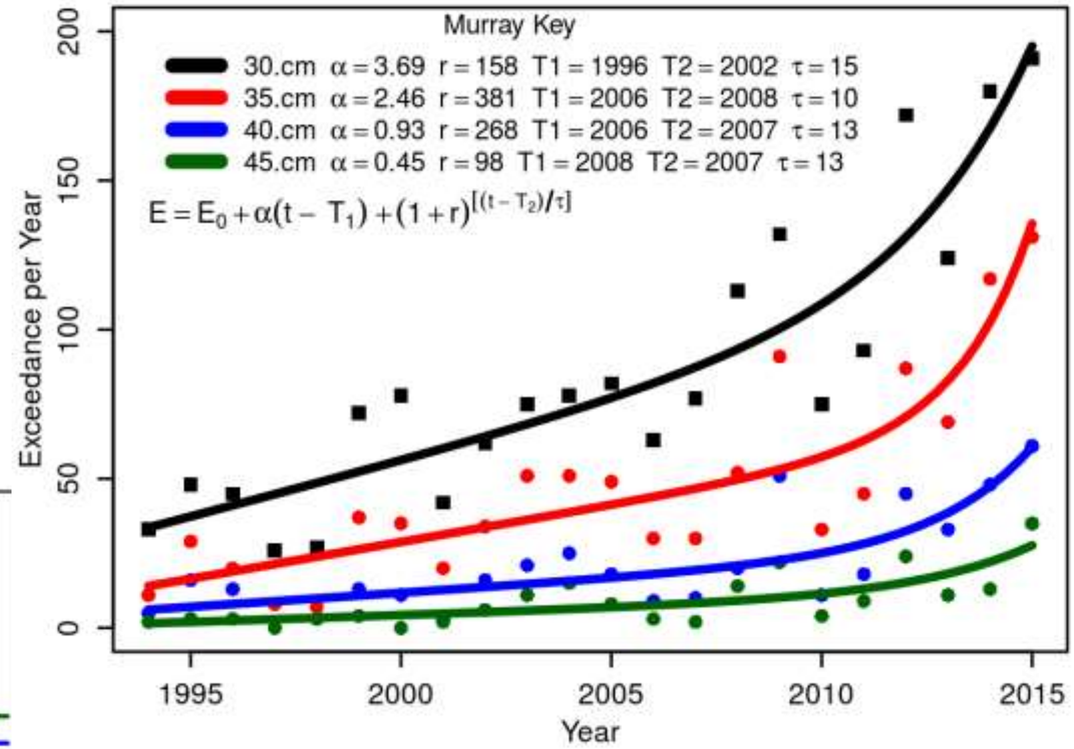
Vulnerability Analysis Summary: Need, Hurdles, Prospects

- Many Everglades attributes now appear highly vulnerable because of accelerating threats (sea-level rise, climate change, and invasive exotic species) and slow restoration progress.
- Urgent need to focus restoration / management vulnerabilities (= triage for adaptive management)
- Complexity and data limitations:
  - stress exposure and resilience occur on multiple scales
  - alternative state changes entail non-linear dynamics
- We are data-rich (and getting richer), which can inform relatively simple, rapid analysis.

Accelerating Threats

- Exotic invasive species (number of species, extent of impact)
- Rate of sea-level rise and extent of salt-water intrusion (including sulfate)





Count number of days per year above 4 threshold water levels

From J. Park, SFNRC 2016

Everglades Inundation with 0.6 m sea-level rise by 2100

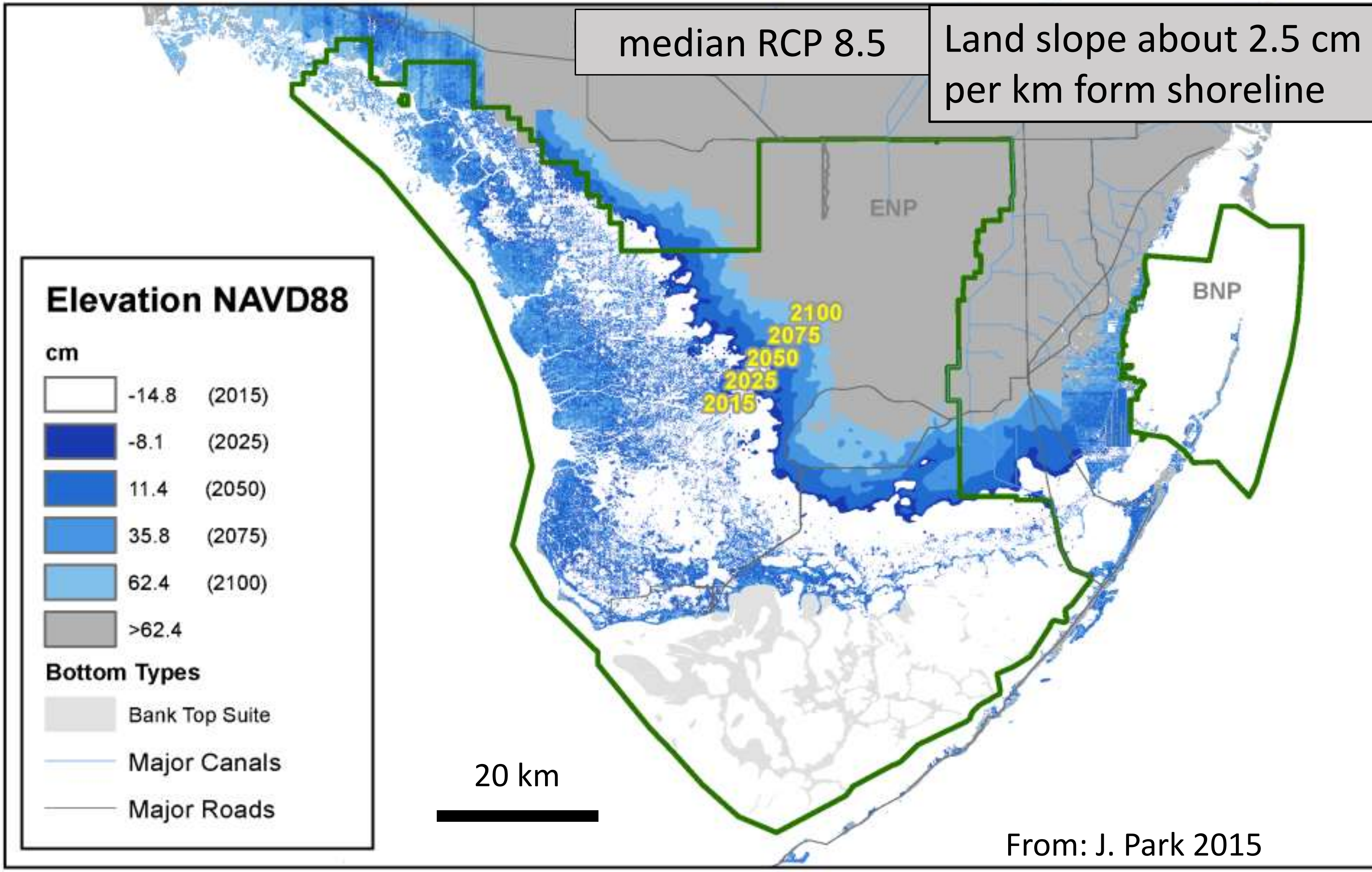


Illustration of Resilience and Tipping Point Between Two System States

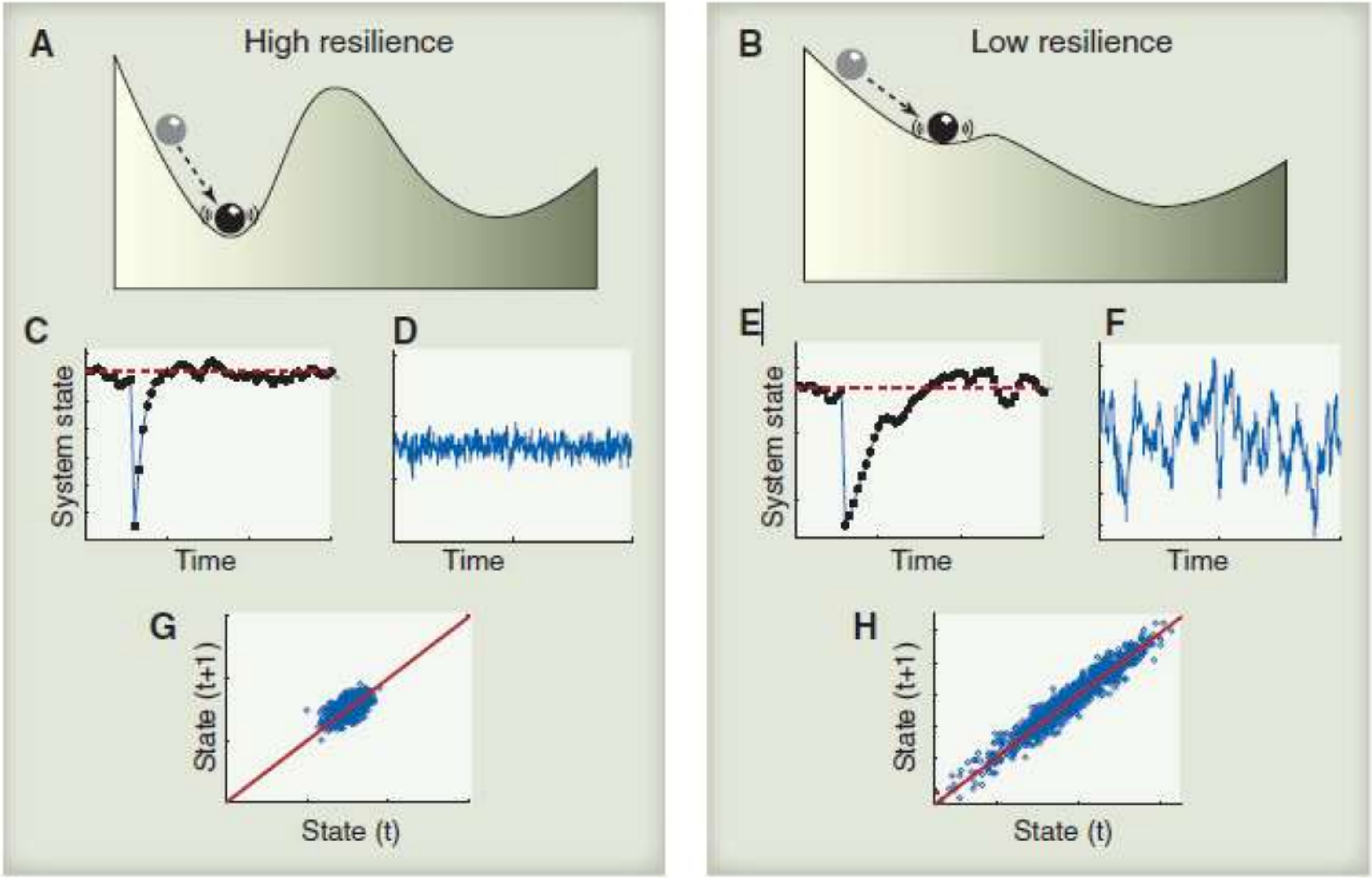


Fig. 2. Critical slowing down as an indicator that the system has lost resilience and may therefore be tipped more easily into an alternative state. Recovery rates upon small perturbations (**C** and **E**) are slower if the basin of attraction is small (**B**) than when the attraction basin is larger (**A**). The effect of this slowing down may be measured in stochastically induced fluctuations in the state of the system (**D** and **F**) as increased variance and "memory" as reflected by lag-1 autocorrelation (**G** and **H**).

From Scheffer et al. 2012

Illustration of Resilience and Tipping Point Between System States

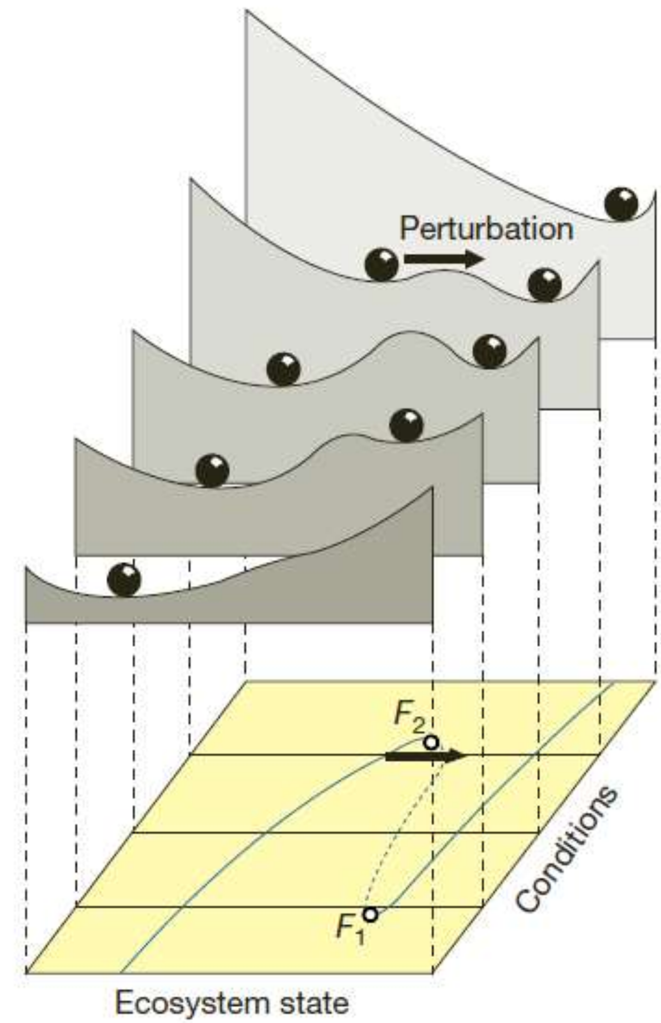


Figure 3 External conditions affect the resilience of multi-stable ecosystems to perturbation. The bottom plane shows the equilibrium curve as in Fig. 2. The stability landscapes depict the equilibria and their basins of attraction at five different conditions. Stable equilibria correspond to valleys; the unstable middle section of the folded equilibrium curve corresponds to a hill. If the size of the attraction basin is small, resilience is small and even a moderate perturbation may bring the system into the alternative basin of attraction.

http://www.nature.com/nature/journal/v413/n6856/pdf/413591a0.pdf

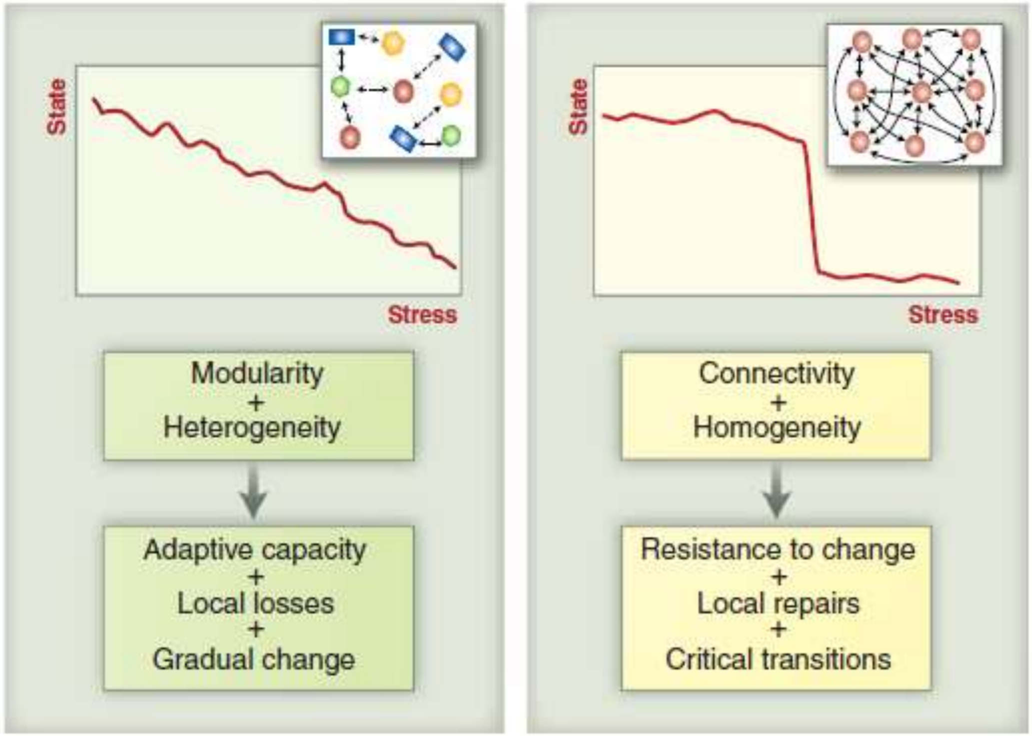
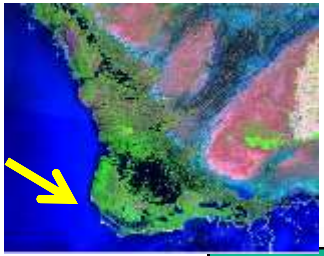
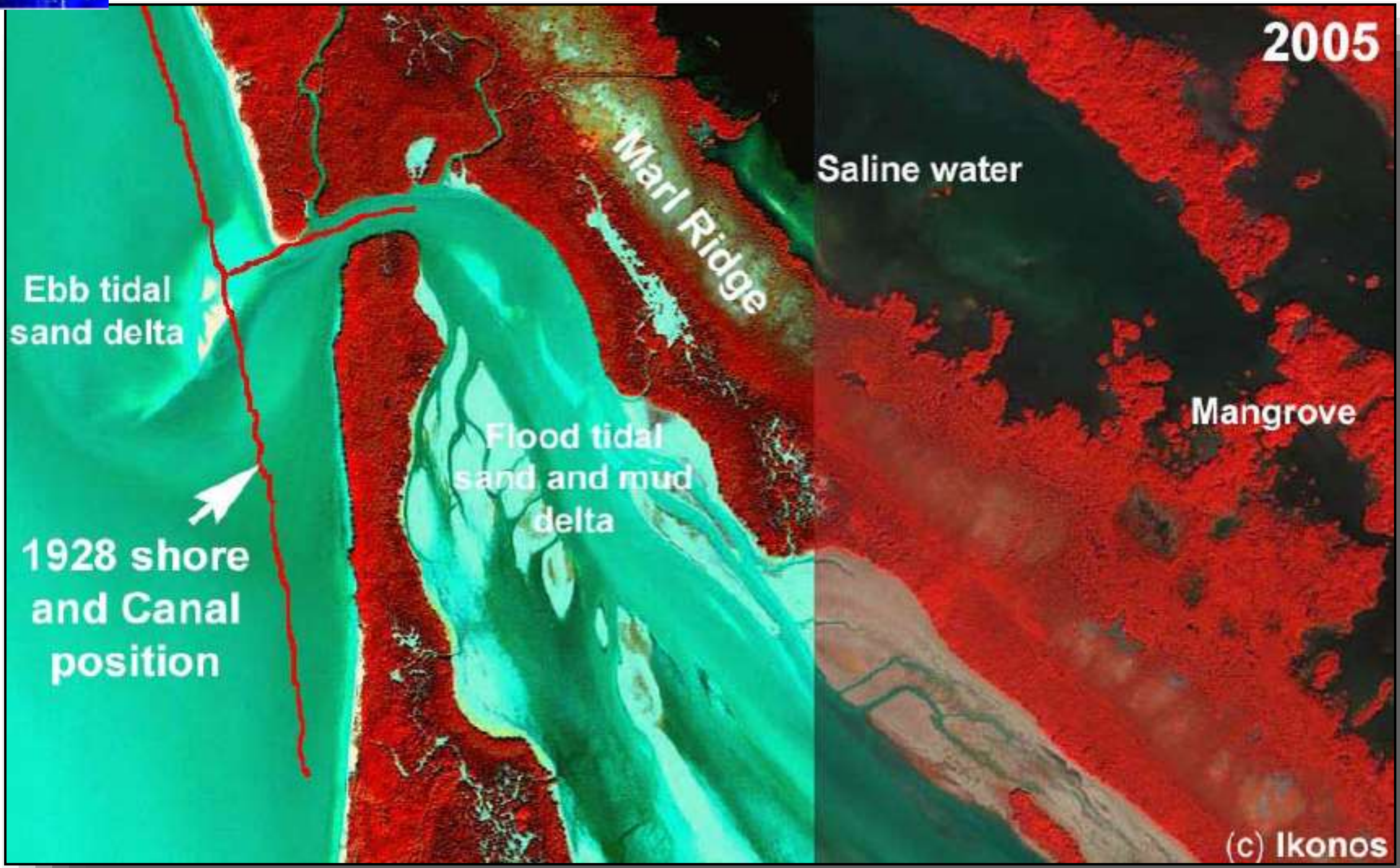
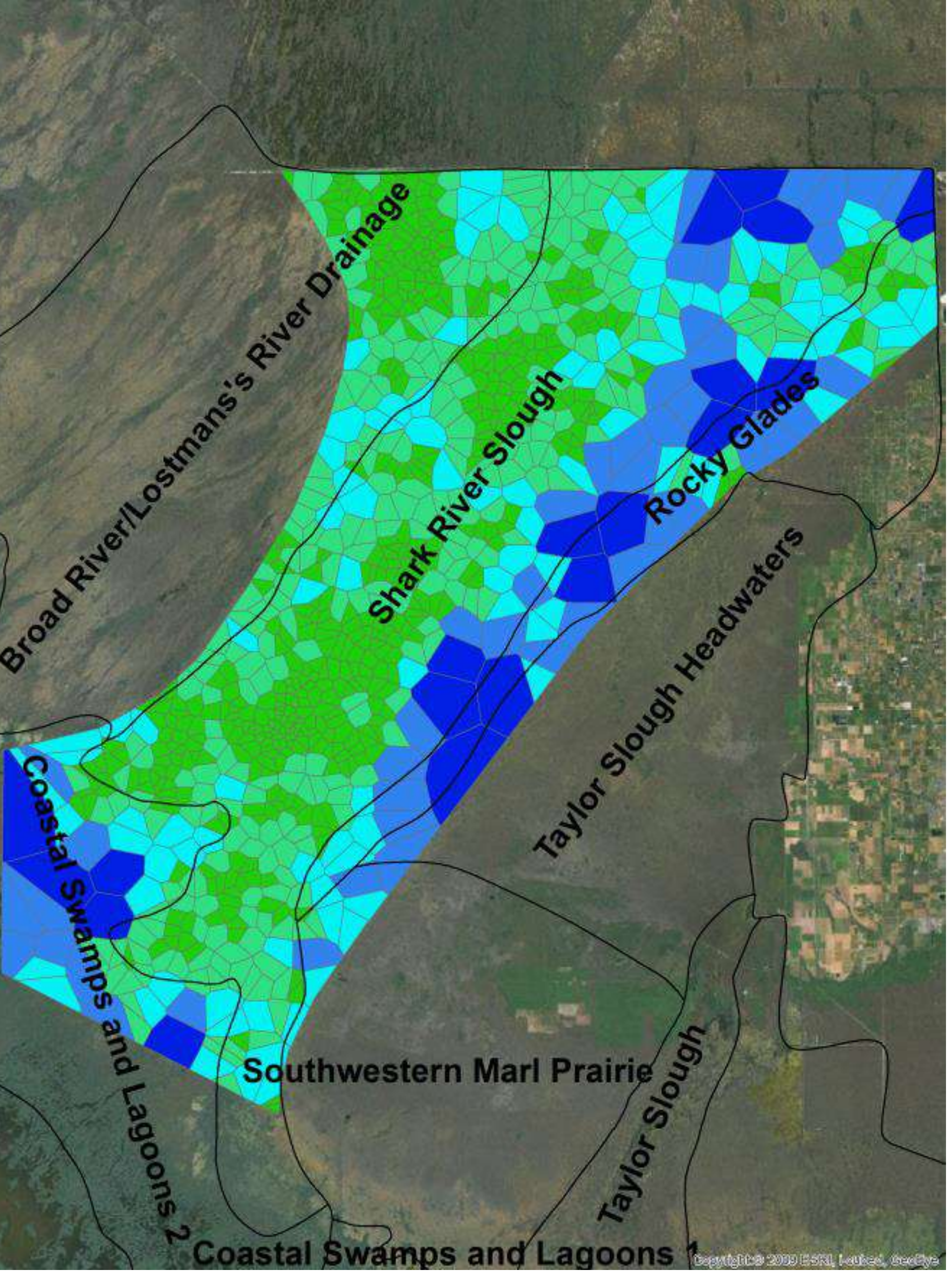


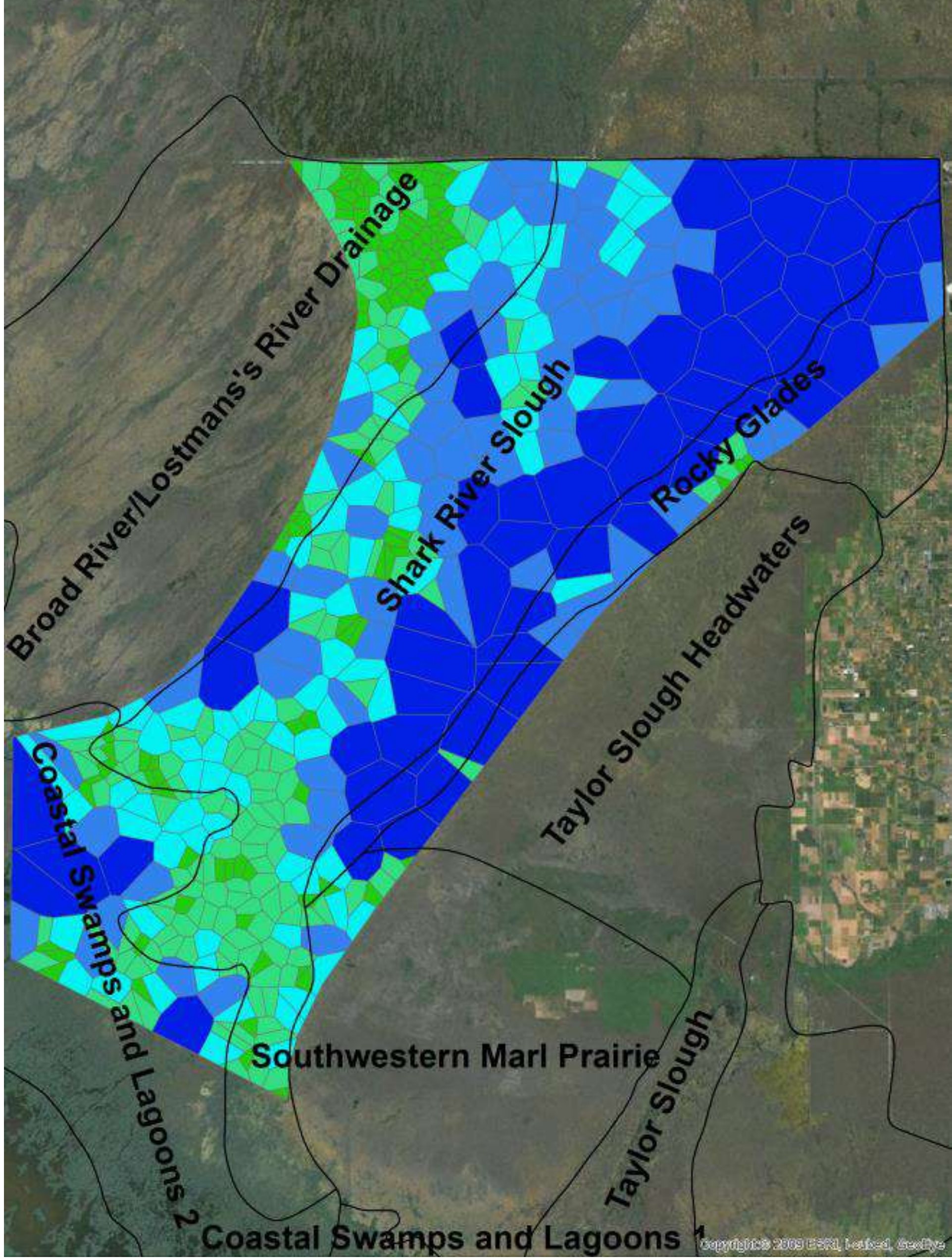
Fig. 1. The connectivity and homogeneity of the units affect the way in which distributed systems with local alternative states respond to changing conditions. Networks in which the components differ (are heterogeneous) and where incomplete connectivity causes modularity tend to have adaptive capacity in that they adjust gradually to change. By contrast, in highly connected networks, local losses tend to be "repaired" by subsidiary inputs from linked units until at a critical stress level the system collapses. The particular structure of connections also has important consequences for the robustness of networks, depending on the kind of interactions between the nodes of the network.

Coastal Erosion and Subsidence





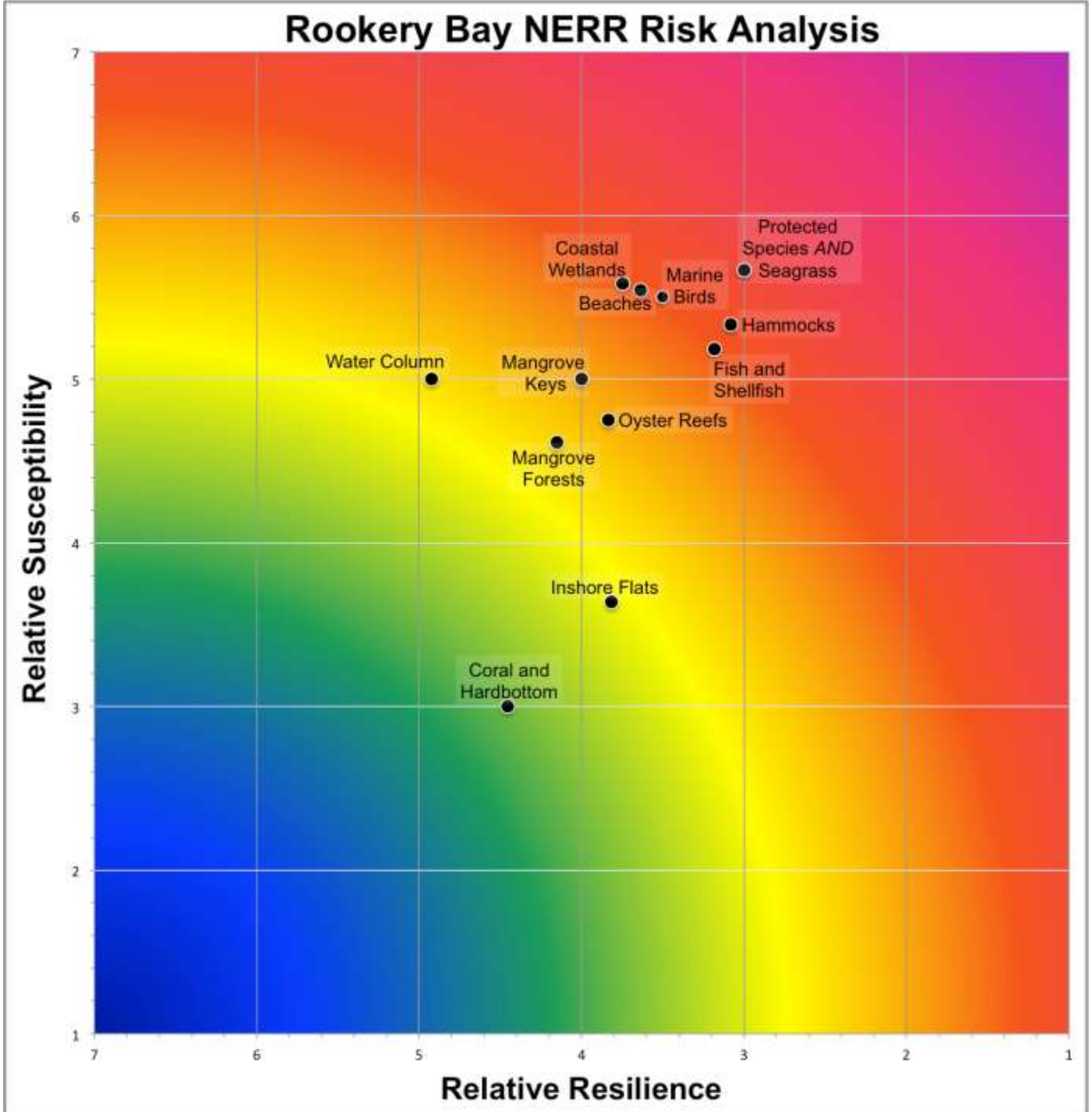




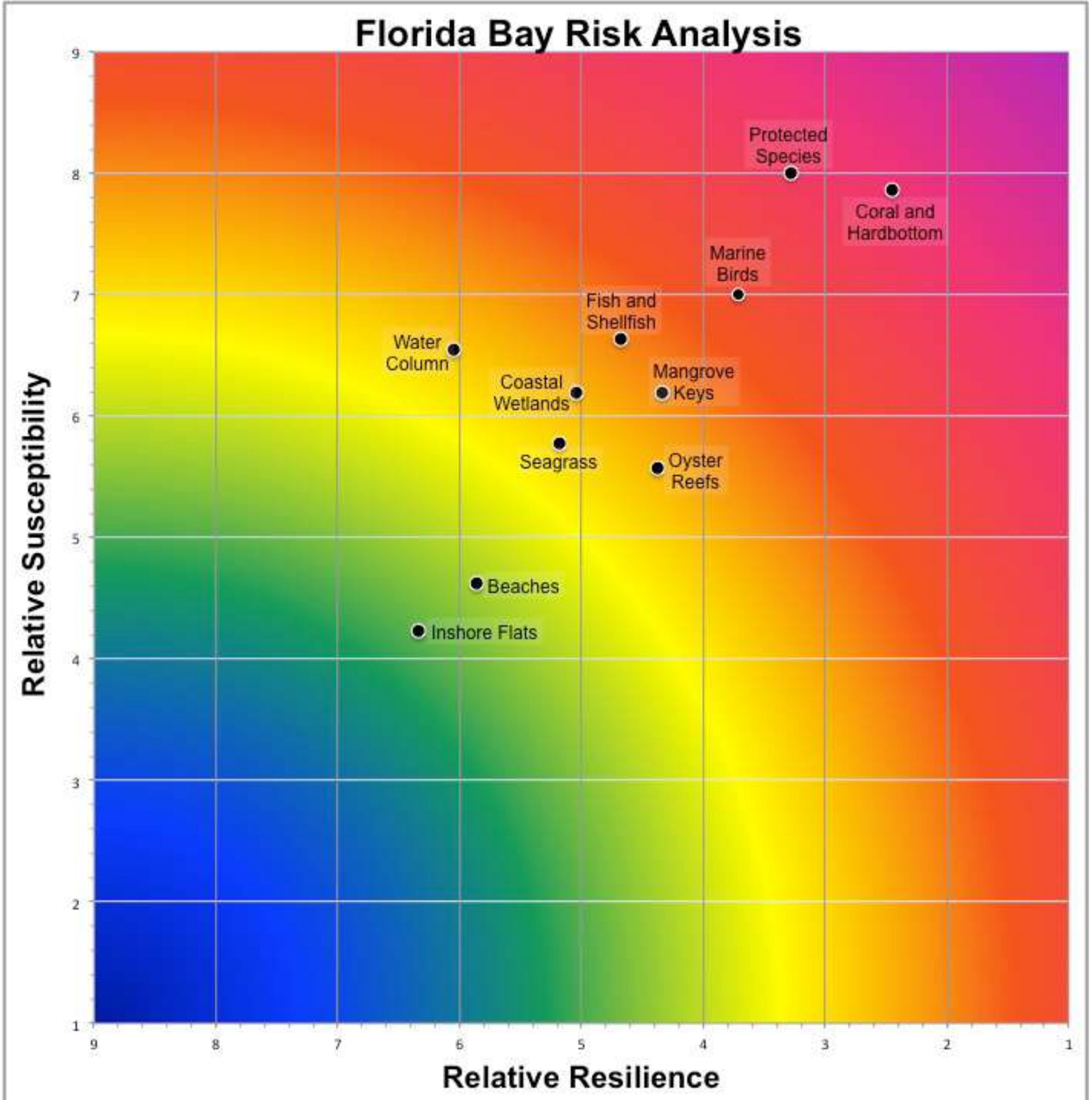
1952 Tree island neighborhood areas

2004 Tree island neighborhood areas

From Redw



Rookery Bay NERR Risk Analysis
Relative Susceptibility
Relative Resilience
7
6
5
4
3
2
1
Protected Species AND Seagrass
Coastal Wetlands
Marine Birds
Beaches
Hammocks
Water Column
Mangrove Keys
Fish and Shellfish
Oyster Reefs
Mangrove Forests
Inshore Flats
Coral and Hardbottom



Florida Bay Risk Analysis
Relative Susceptibility
Relative Resilience
Protected Species
Coral and Hardbottom
Marine Birds
Fish and Shellfish
Water Column
Coastal Wetlands
Mangrove Keys
Seagrass
Oyster Reefs
Beaches
Inshore Flats
9
8
7
6
5
4
3
2
1