Initial Considerations of Ecological Vulnerability Analysis for Everglades Restoration

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Introduction

- RECOVER Five-Year Plan calls to assess assumptions of current assessment framework in order to more effectively guide restoration planning and implementation.
- Consider knowledge gained over past decade.
- Major components and functions of the Greater Everglades ecosystem have continued to degrade since CERP was authorized (2000).
- The influence of climate change, sea-level rise, and invasive exotic species drivers has accelerated.
- These drivers influence the Greater Everglades concurrently and interactively with strongly managed drivers (hydrology, water quality), affecting restoration progress and prospects.
- Given accelerating ecological threats and evidence of ecosystem degradation, the Five-Year Plan calls for system-wide analysis of the most vulnerable areas, components (habitats, communities, species), and functions.

Why Vulnerability Analysis?

- Provide a systematic basis for assessing ecological risks across the ecosystem for multiple stressors.
- Integrate information and gain knowledge from existing time-series data.
- Identify key uncertainties – a basis for prioritizing research, modeling, monitoring.
- Improve understanding of "tipping points" between alternative system states, typically a product of complex, non-linear ecological dynamics.
- Improve understanding of how best to promote resilience (avoidance of reaching tipping points).
- Improve capability of informing "trade-off" analyses.
- Complementary of current ecological performance measures and indicators, with emphasis on considering restoration effects that interact with the effects of other drivers and stressors.

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 function of:
  - exposure to a stressor
  - sensitivity to this stressor
  - recovery potential (resilience or adaptive capacity)
  - a form of risk analysis, but probabilistic estimates are challenging
- Sensitivity: the degree to which a disturbance (exposure to a stressor) affects structure, composition, or function (antonym of resistance).
- Resilience: the 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

Illustration of Resilience and Tipping Point Between Two System States

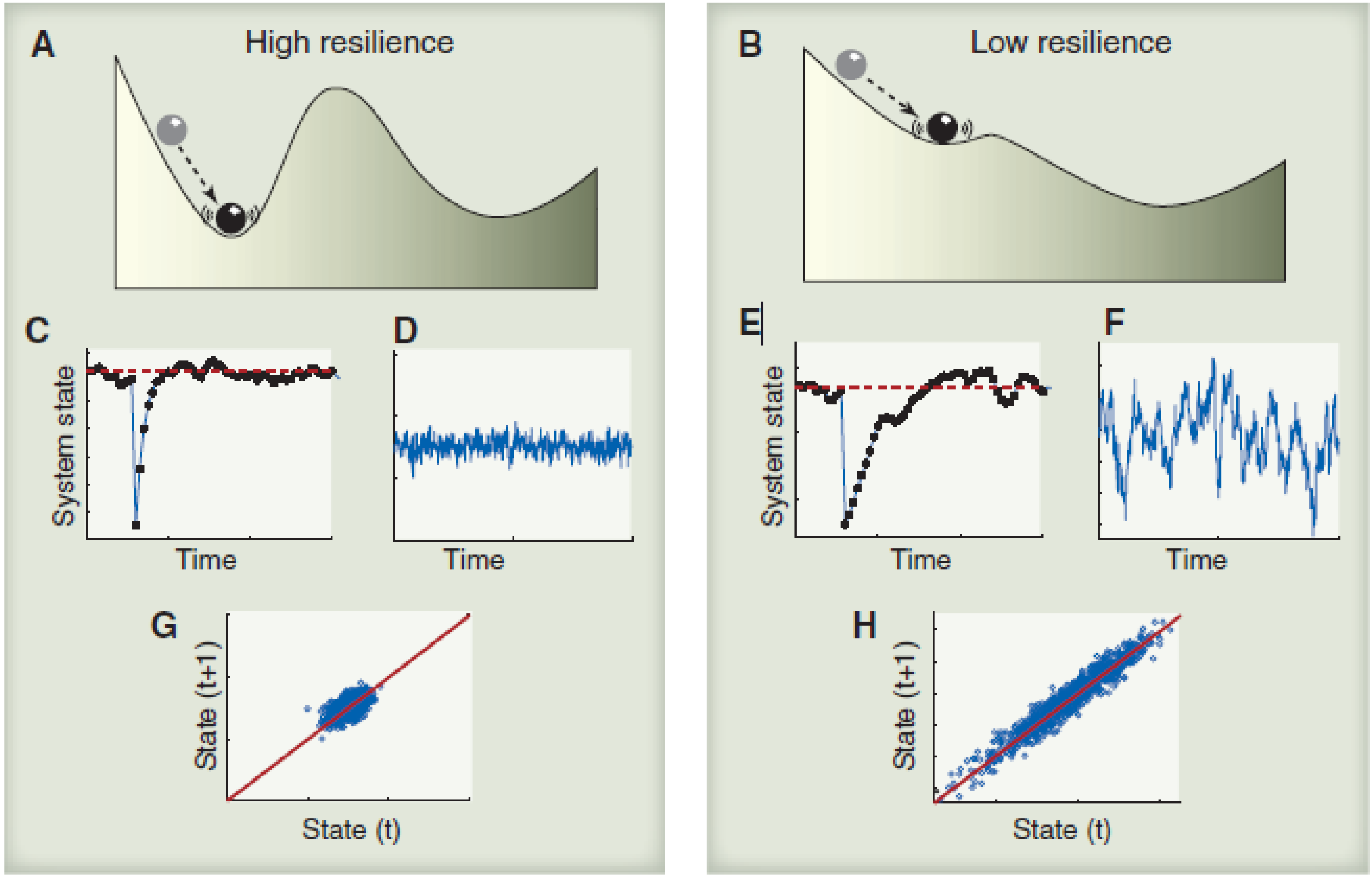


Fig. 2. Critical slowing down as an indicator that the system has lost resilience and may therefore be tipped more easily into an alternative state. Recovery rates upon small perturbations (**C** and **E**) are slower if the basin of attraction is small (**B**) than when the attraction basin is larger (**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

Evidence of Everglades System Vulnerability

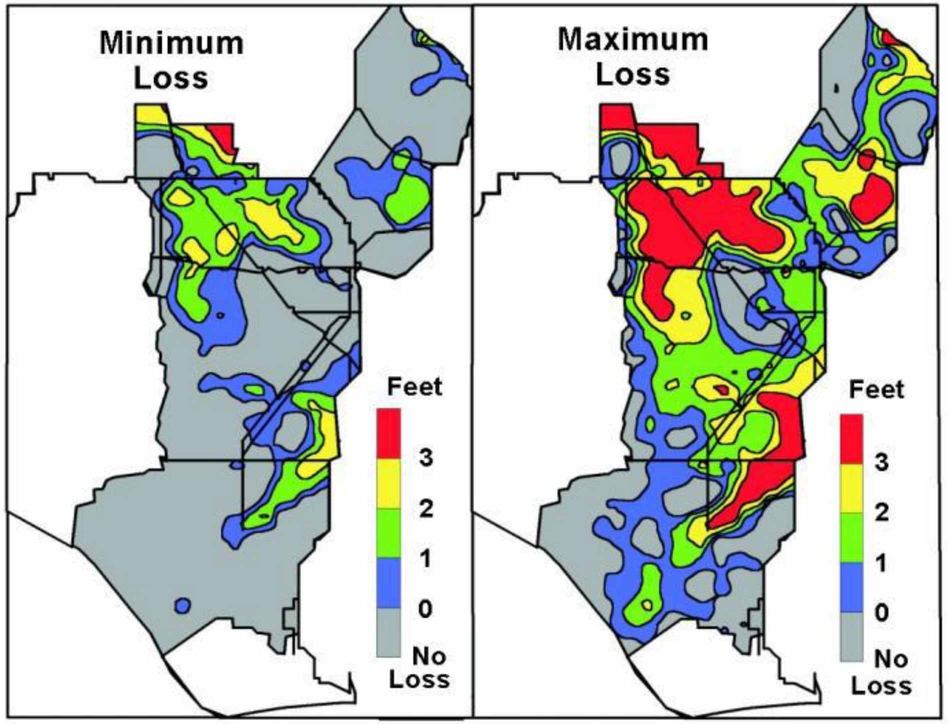
- Soil loss: freshwater peat oxidation (fire, microbial decomposition)

Table 3. Peat volume, peat mass and peat carbon mass for the predrainage and current Everglades and the loss of each.

time period	total area (km^2)	peat volume (m^3)	mass (Mg)	carbon (Mg)
predrainage Everglades totals	1.1×10^4	2.0×10^{10}	2.6×10^9	9.4×10^8
current EPA totals	5.6×10^3	4.7×10^9	4.5×10^8	1.8×10^8
change (loss)	5.4×10^3	1.5×10^{10}	2.2×10^9	7.6×10^8

From Hohner and Dreschel 2015

Mires and Peat, Volume 16 (2015), Article 01, 1–15, http://www.mires-and-peat.net/, ISSN 1819-754X

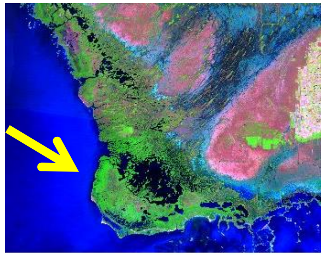


Losses since 1934 (EPA, 2000)

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

Evidence of Everglades System Vulnerability

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



Physical drivers:
- Hurricanes
- Storm surge
- Saltwater intrusion

Mangrove forest mortality and peat loss / collapse after the 1935 hurricane

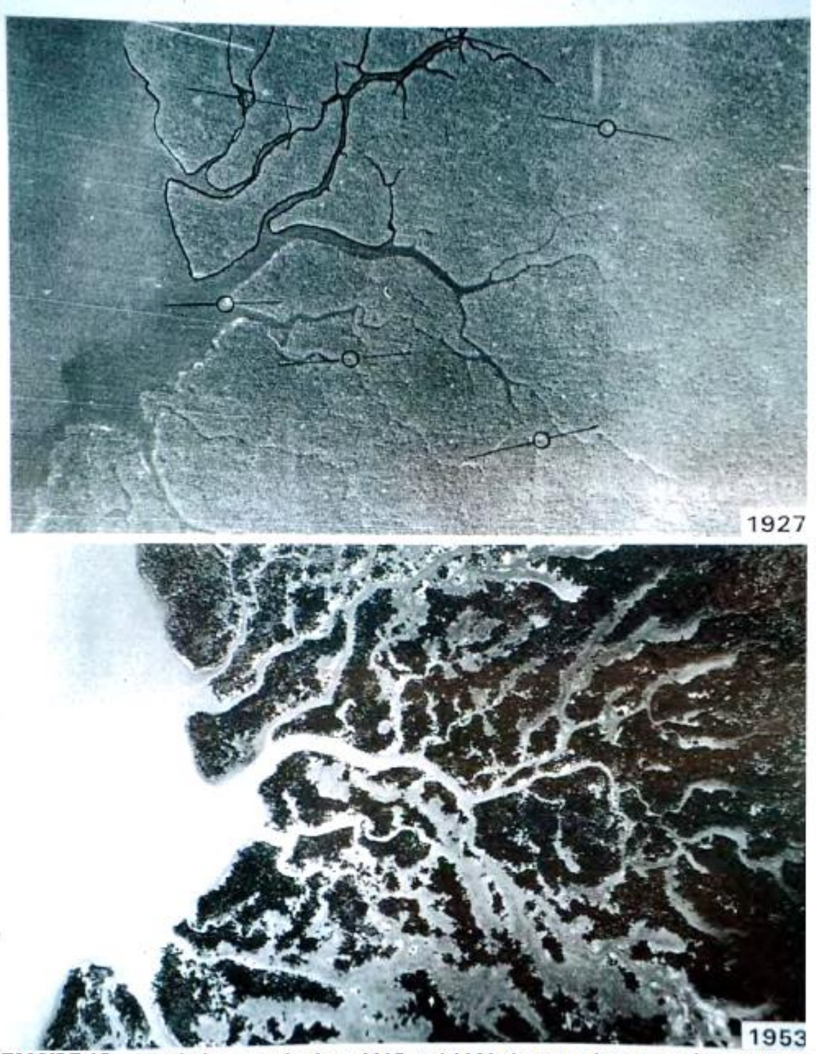
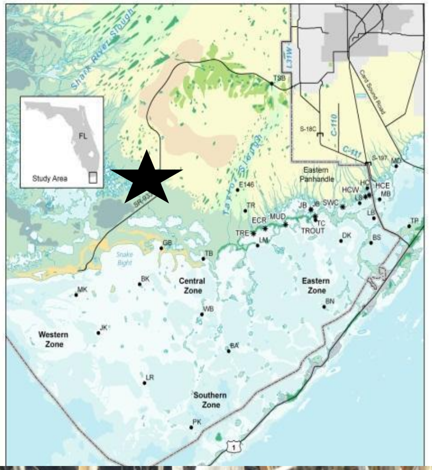


FIGURE 17. Aerial photographs from 1927 and 1953 showing changes in the mangrove wetlands associated with Big Sable Creek. The entire change is thought to be the result of the wind and storm surge of the Labor Day Hurricane of 1935. Mangroves that survived or recolonized in the 18 years between the storm and the lower photograph appear as dark in the photograph. The Gulf of Mexico is to the left. Photographs are 2.5 km in horizontal dimension.

From Wanless and Vlaswinkel, 2005

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

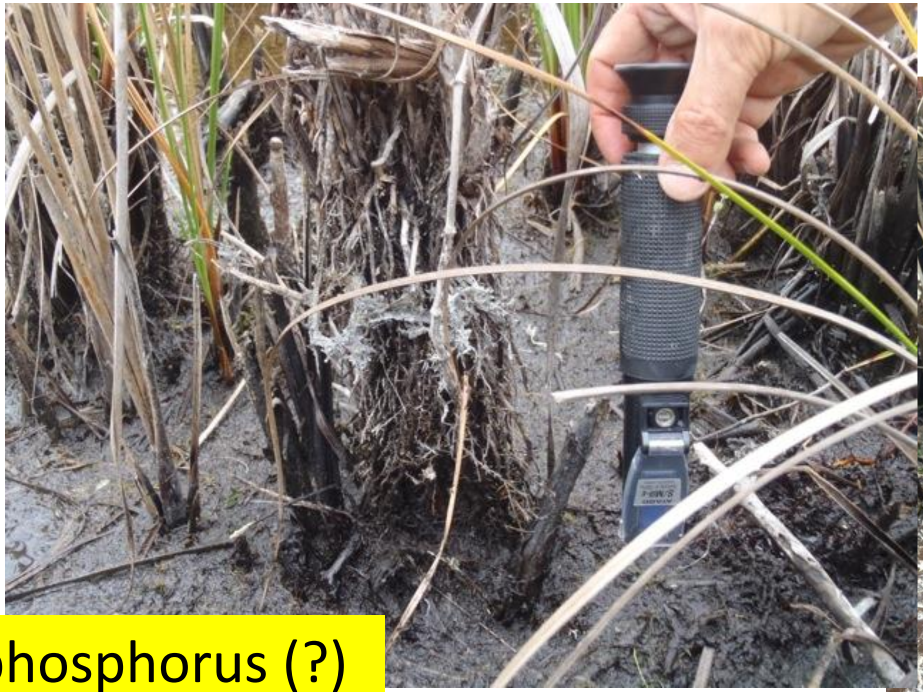
Evidence of Everglades System Vulnerability



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

Physical drivers:

- Saltwater intrusion?

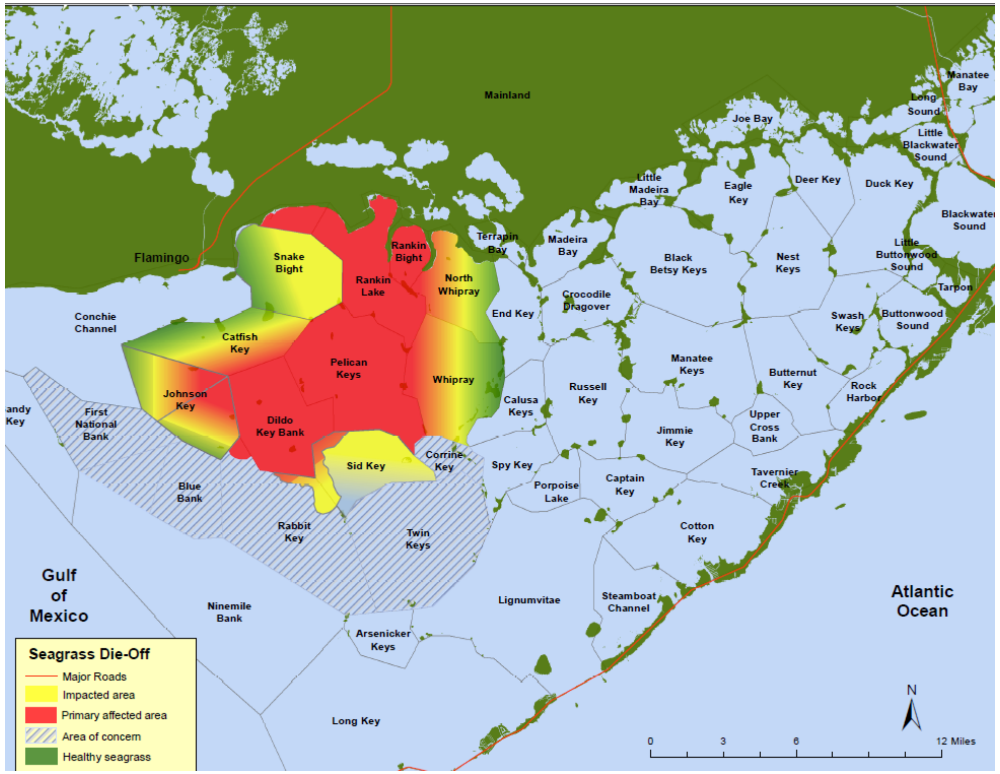


Stressors: salinity, sulfide, phosphorus (?)
Current Exposure: moderate-high
Sensitivity: moderate (?)
Resilience: low

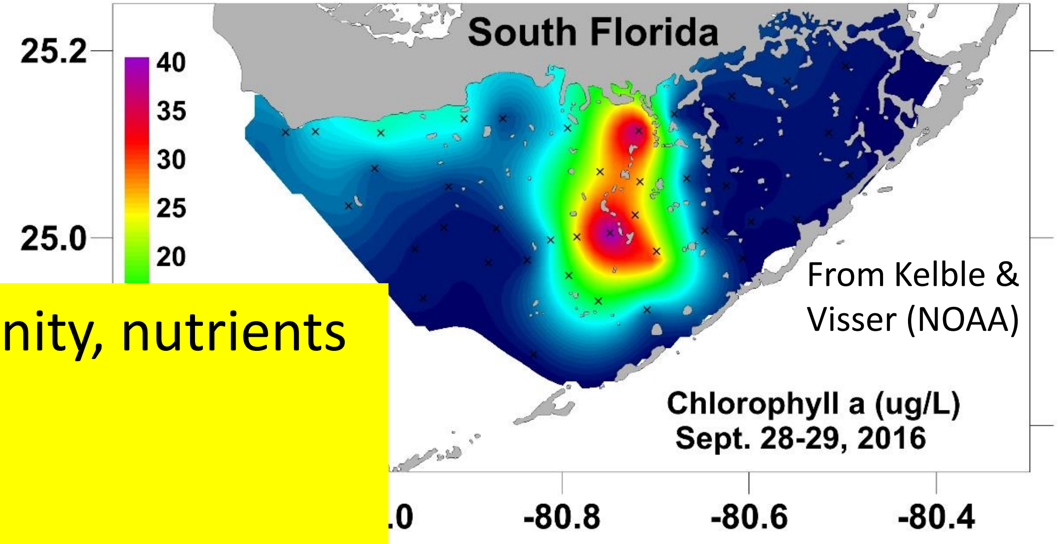
From: S. Davis

Evidence of Everglades System Vulnerability

- Florida Bay seagass mass-mortality and algal blooms



Die-off distribution December 2015



Likely causing intense algal blooms (Sept 2016 to present)

Stressors: low dissolved oxygen, sulfide, salinity, nutrients
Current Exposure: high
Sensitivity: moderate
Resilience: moderate

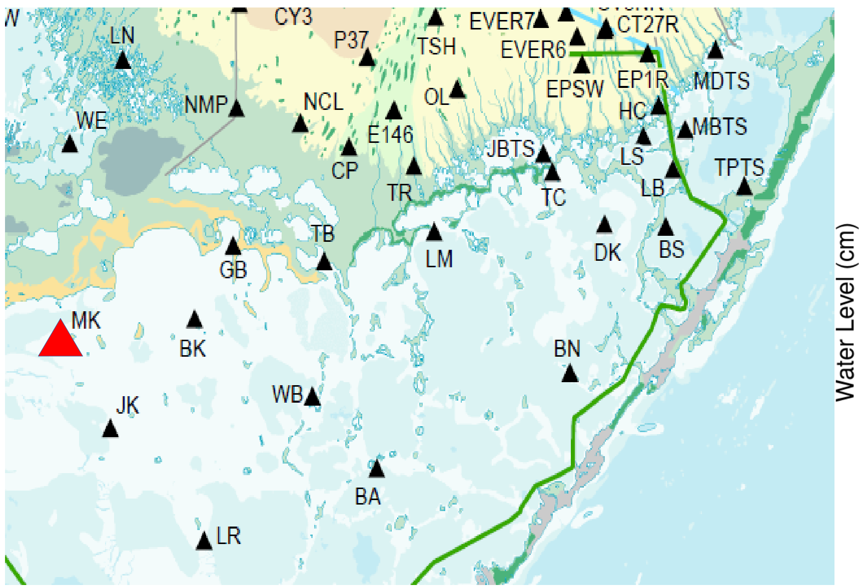
Evidence of Everglades System Vulnerability

Other Examples:

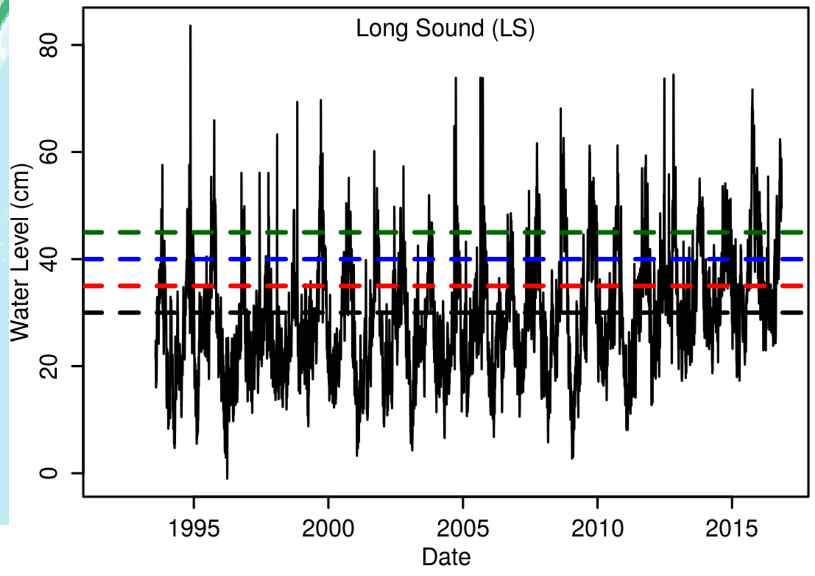
- Tree island mortality
- Ridge and slough landscape loss
- Periphyton loss, cattail expansion
- Mammal mortality
- Threatened and endangered species
- Northern estuaries algal blooms
- Coral reef mortality

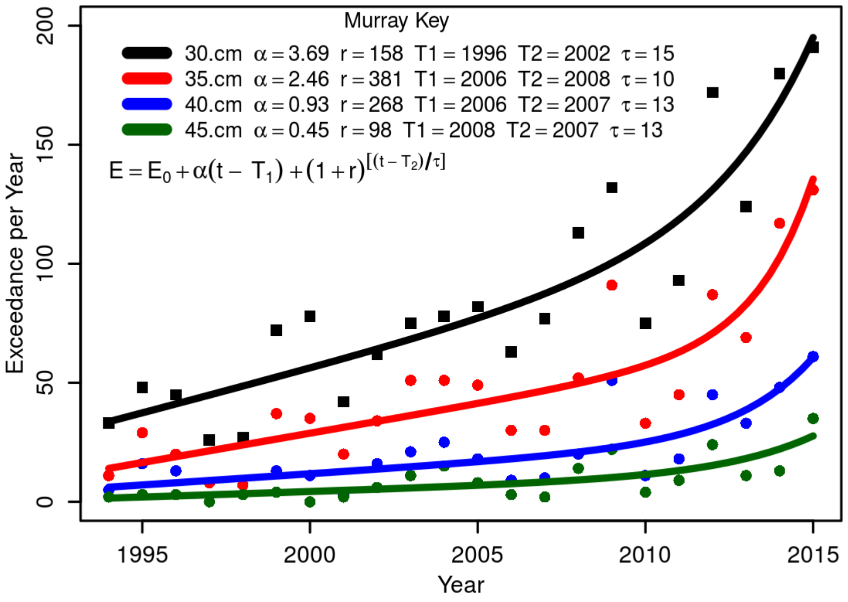
Accelerating Threats

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

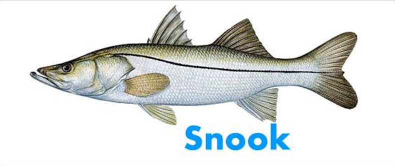


Count number of days per year above 4 threshold water levels



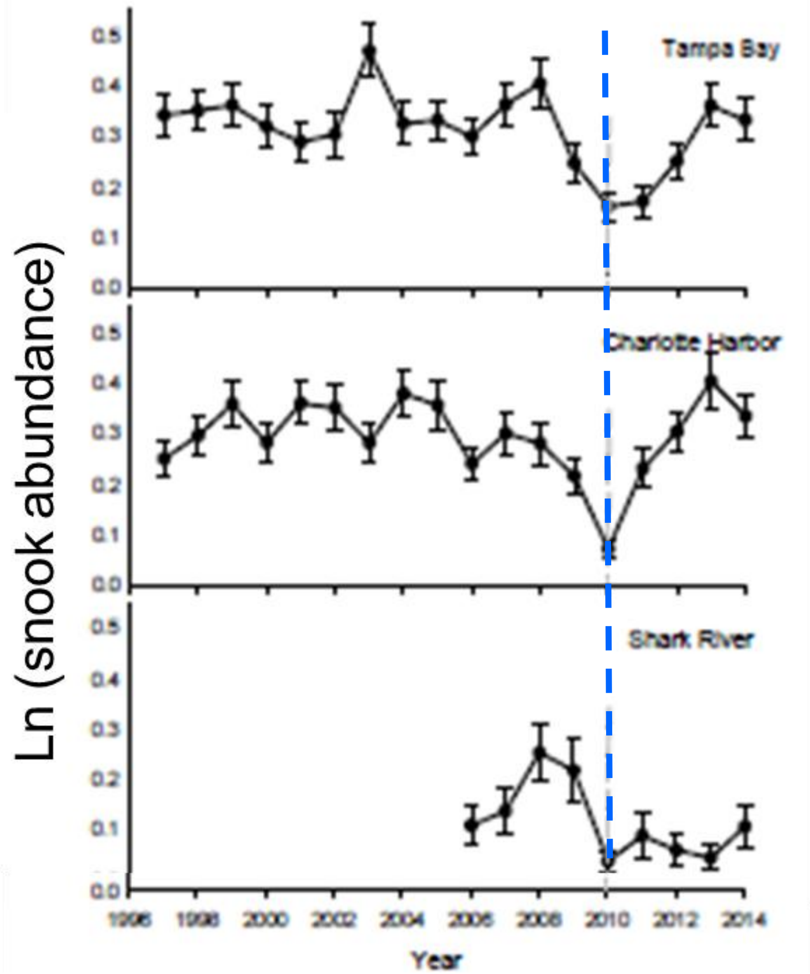


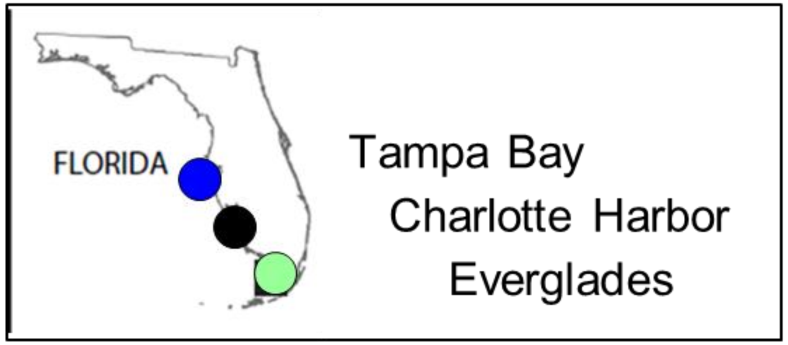
From Sweet and Park, 2014; Park, SFNRC 2016



Variation in resilience across populations: Lowest for Everglades

Inference on resilience from monitoring data





Snook recovered in:
- 3 years
- 1 year
- 4 years - slowest recovery

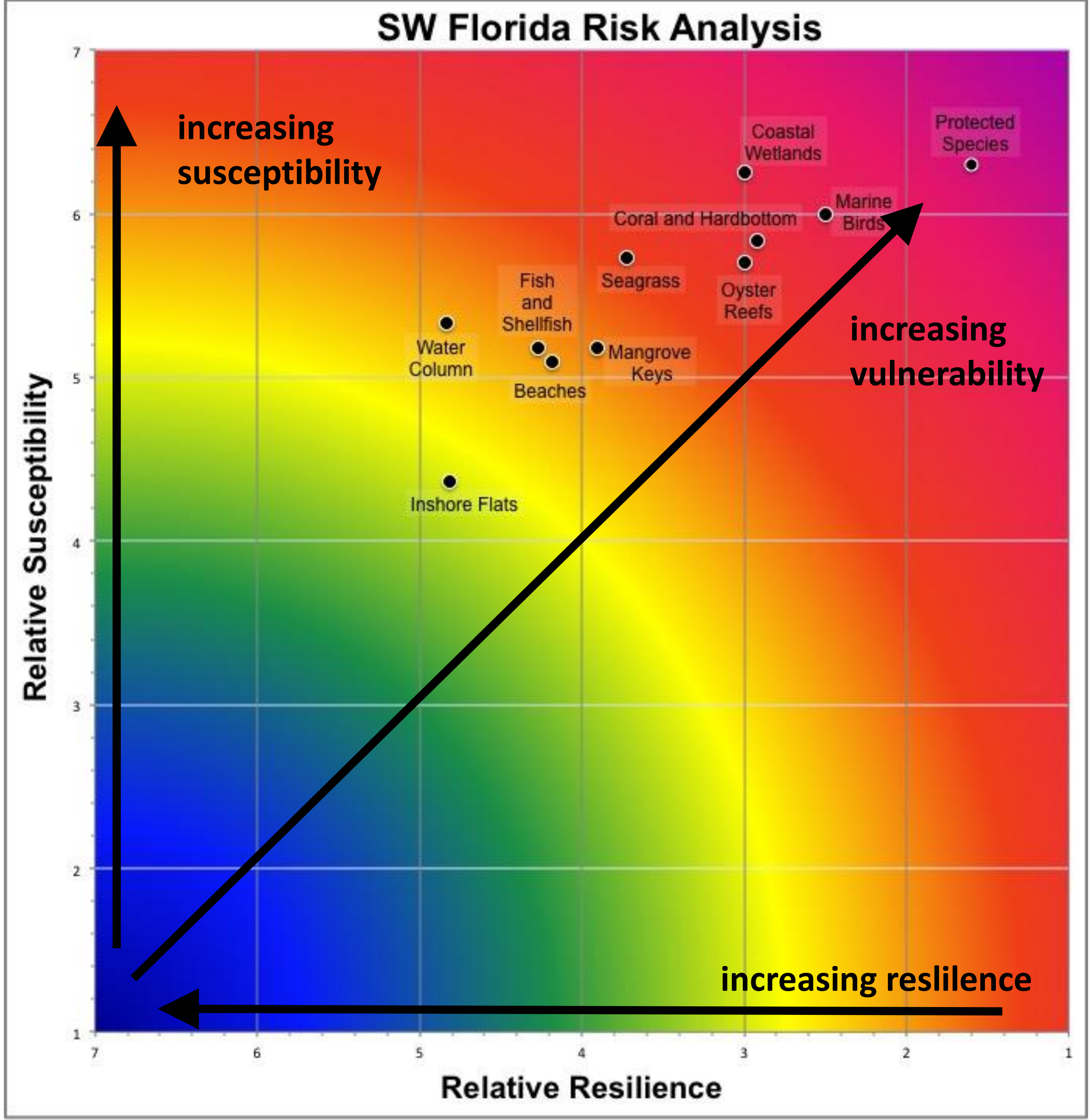
Dead snook, tarpon & goliath grouper, Everglades National Park, Jan 2010

Stevens, Rehage, Boucek et al 2016 Ecosphere

Results from Analysis of the Susceptibility and Resilience of Southwest Florida Coastal Attributes

- Susceptibility includes of stress exposure and sensitivity
- Relative scores are derived from best professional judgement

From Cook et al. 2016, NOAA-COCA



Challenges and Opportunities for Vulnerability Analysis

- Stress exposure and resilience depend on spatial and temporal scale of stressor exposure and ecological attribute.
- Complex, non-linear interactions cannot be modeled with high confidence.
- Much has been and can be learned from rich existing time-series databases and continued monitoring. Spatial analysis should provide further insight.
- Insight regarding relative vulnerability and key uncertainties can be gained from qualitative, best professional judgement.
- Identifying tipping points and level of resilience requires research (recall P threshold effort) and modeling.
- Further development of relatively simple models, combined with research, can improve understanding and forecasting of vulnerability and guide restoration in the face of unmanaged and accelerating ecological threats.