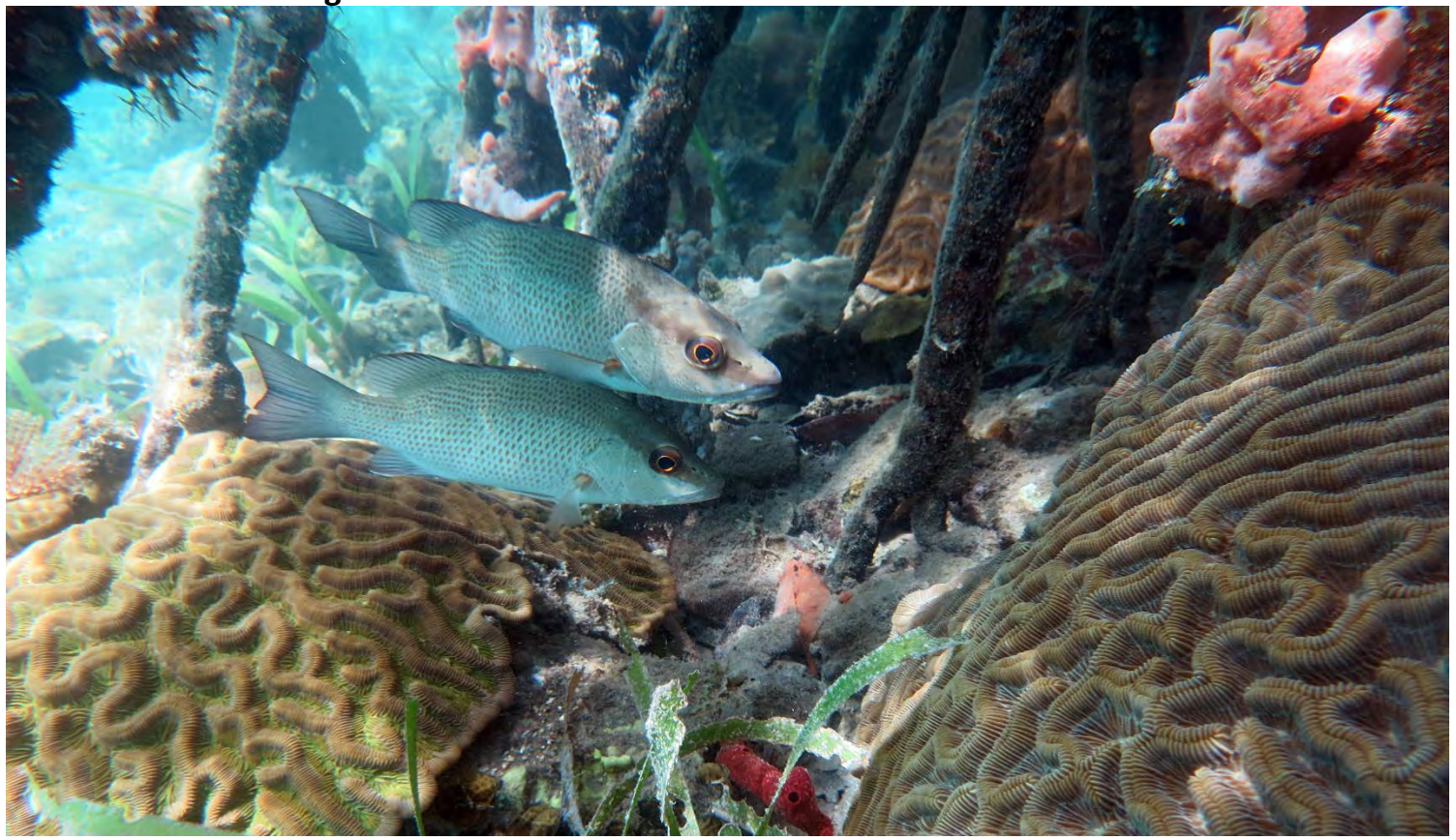
Photo: Caroline S. Rogers



Hurricanes and Mangroves: Structural Impacts of Hurricanes Irma and Maria on the Unique Mangrove Resources of St. John

Ken W. Krauss
U.S. Geological Survey
Wetland and Aquatic Research Center
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with Caroline S. Rogers and Andrew S. From

USGS

National Park Service
Cruz Bay Visitor's Centre
9 December 2019

Structure of this presentation


USGS


NOAA


NY Times


Caroline Rogers

1 General overview of mangroves and hurricanes

2 Influences of Hurricanes Irma and Maria on the mangroves of St John

3 Can we influence recovery, and how?

4 Summary and questions

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General overview of mangroves and hurricanes

What are mangroves?

- Tidal saltwater forested wetlands
- 137,600 km^2
- Losses of mangroves have historically been high

newswatch.na

K.W. Krauss, Kosrae, Micronesia

LETTERS

edited by Etta Kavanagh

A World Without Mangroves?

AT A MEETING OF WORLD MANGROVE EXPERTS HELD LAST YEAR IN Australia, it was unanimously agreed that we face the prospect of a world deprived of the services offered by mangrove ecosystems, perhaps within the next 100 years.

Mangrove forests once covered more than 200,000 km^2 of sheltered tropical and subtropical coastlines (*1*). They are disappearing worldwide by 1 to 2% per year, a rate greater than or equal to declines in adjacent coral reefs or tropical rainforests (*2*–*5*). Losses are occurring in almost every country that has mangroves, and rates continue to rise more rapidly in developing countries, where >90% of the world's mangroves are located. The veracity and detail of the UN Food and Agriculture Organization data (*2*) on which these observations are based may be arguable, but mangrove losses during the last quarter century range consistently between 35 and 86%. As mangrove areas are becoming smaller or fragmented, their long-term survival is at great risk, and essential ecosystem services may be lost.

Where mangrove forests are cleared for aquaculture, urbanization, or coastal landfill or deteriorate due to indirect effects of pollution and upstream land use (*3*, *4*), their species richness is expected to decline precipitously, because the number of mangrove plant species is directly correlated with forest size (*6*, *7*). Examples from other ecosystems have shown that species extinctions can be followed by loss in functional diversity, particularly in species-poor systems like mangroves, which have low redundancy per se (*8*). Therefore, any further decline in mangrove area is likely to be followed by accelerated functional losses. Mangroves are already critically endangered or approaching extinction in 26 out of the 120 countries having mangroves (*2*, *9*).

Deforestation of mangrove forests, which have extraordinarily high rates of primary productivity (*3*), reduces their dual capacity to be both an atmospheric CO_2 sink (*10*) and an essential source of oceanic carbon. The support that mangrove ecosystems provide for terrestrial as well as marine food webs would be lost, adversely affecting, for example, fisheries (*11*). The decline further imperils mangrove-dependent fauna with their complex habitat linkages, as well as physical benefits like the buffering of seagrass beds and coral reefs against the impacts of river-borne siltation, or protection of coastal communities from sea-level rise, storm surges, and tsunamis (*12*, *13*). Human communities living in or near mangroves would lose access to sources of essential food, fibers, timber, chemicals, and medicines (*14*).

We are greatly concerned that the full implications of mangrove loss for humankind are not fully appreciated. Growing pressures of urban and industrial developments along coastlines, combined with climate change and sea-level rise, urge the need to conserve, protect, and restore tidal wetlands (*11*, *15*). Effective governance structures, socioeconomic risk policies, and education strategies (*15*) are needed now to enable societies around the world to reverse the trend of mangrove loss and ensure that future generations enjoy the ecosystem services provided by such valuable natural ecosystems.

Emerging from the embrace of a mangrove tree–lined channel in northern Brazil, these pescadores, like coastal fishers worldwide, know that healthy mangroves mean good fishing and a secure livelihood.

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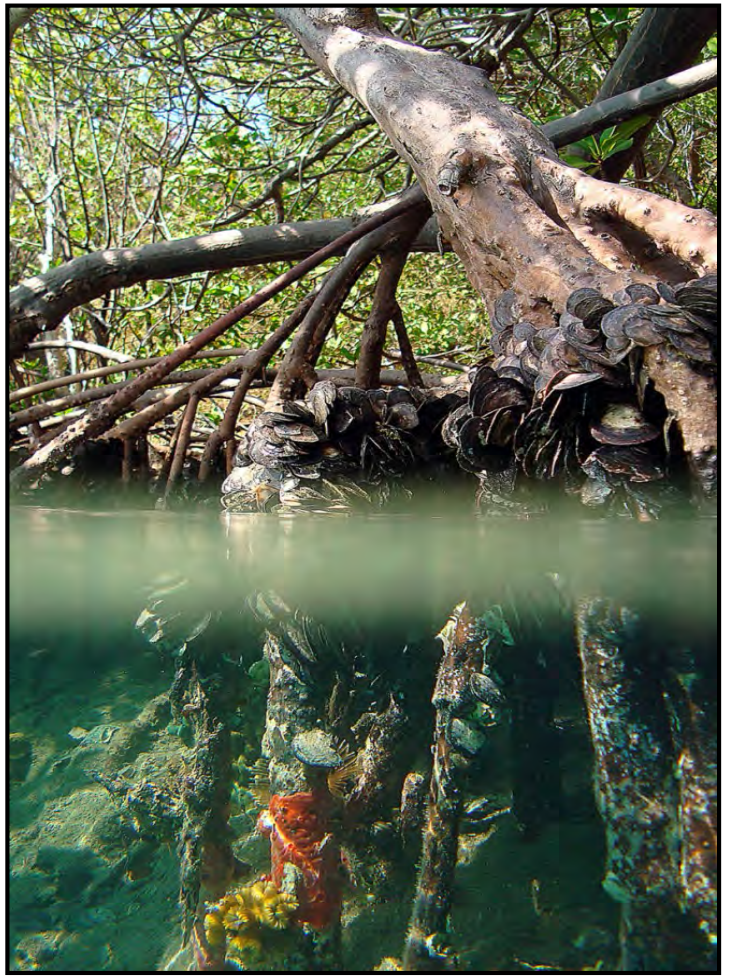
Mangrove ecosystem goods and services

- Timber and forest products
- Fisheries
- Nutrient and sediment removal
- Coastal protection
- Carbon storage



nps.gov

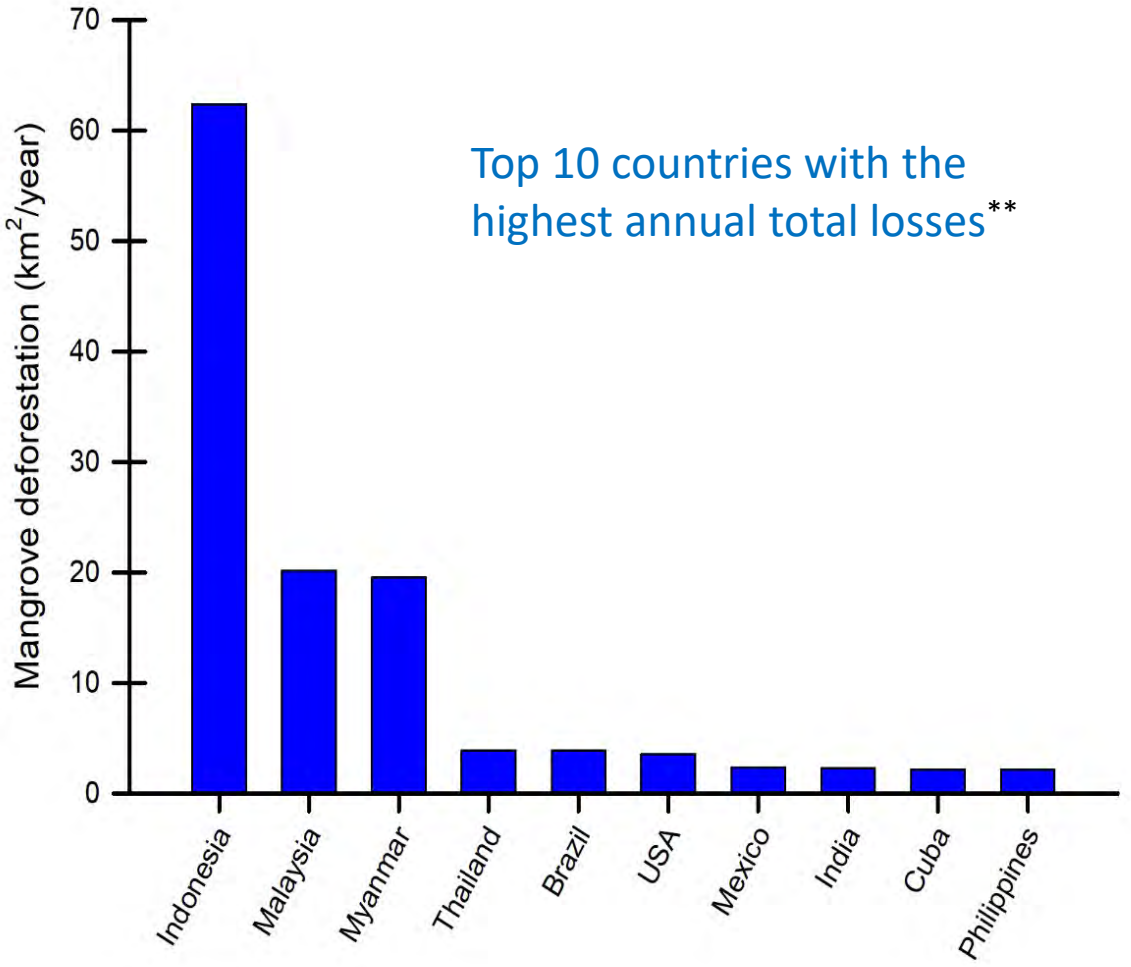
General overview of mangroves and hurricanes

Let's add a positive note…

Valiela et al. (2001) = 2.07 %/year
Duke et al. (2007) = 1-2 %/year
FAO (2007) = 1-3 %/year

However, awareness campaigns, protective measures, and mangrove restoration projects have changed these trends over the last few decades….

1980s = 1.04 %/year*
1990s = 0.72 %/year*
2000s = 0.2 - 0.7 %/year**



Top 10 countries with the highest annual total losses**

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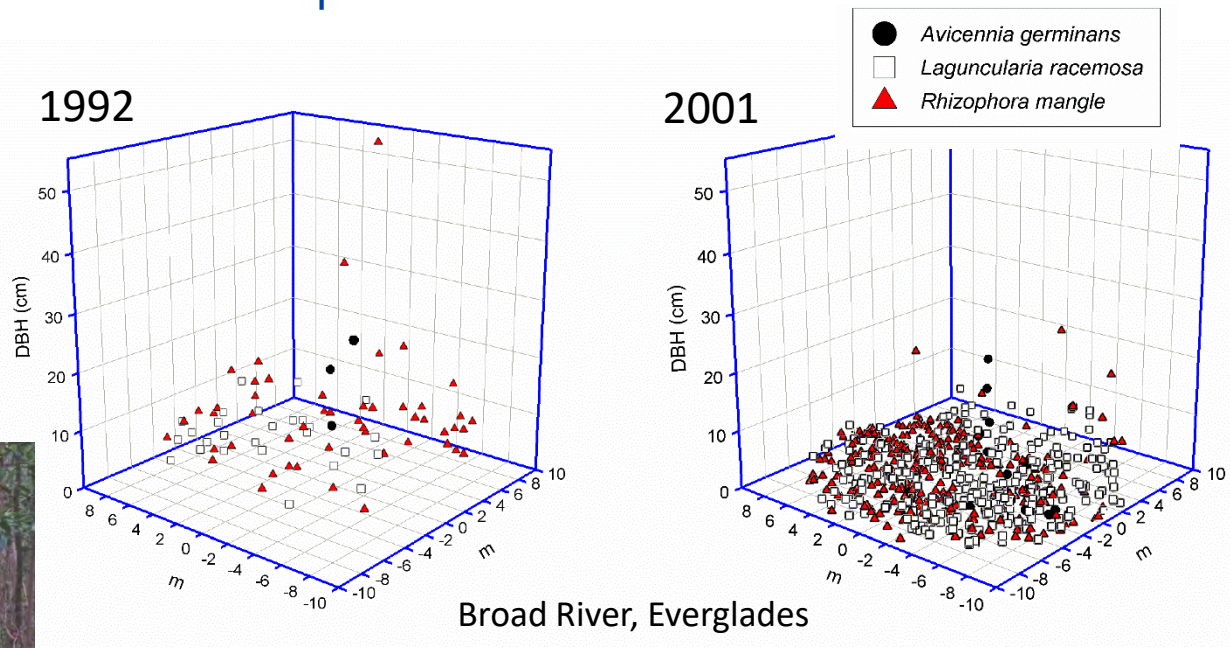
*Spalding et al. (2010) *World Atlas of Mangroves*, **Hamilton & Casey (2016) *Glob Ecol Biogeogr* 25: 729-738

General overview of mangroves and hurricanes

How many of you have heard that mangroves are “disturbance-adapted”?

Possible reasons:

(1) Mangroves often recover over time



Recovery dependent on:

- Intensity of hurricane
- Regeneration
- Soil surface elevation loss/gain

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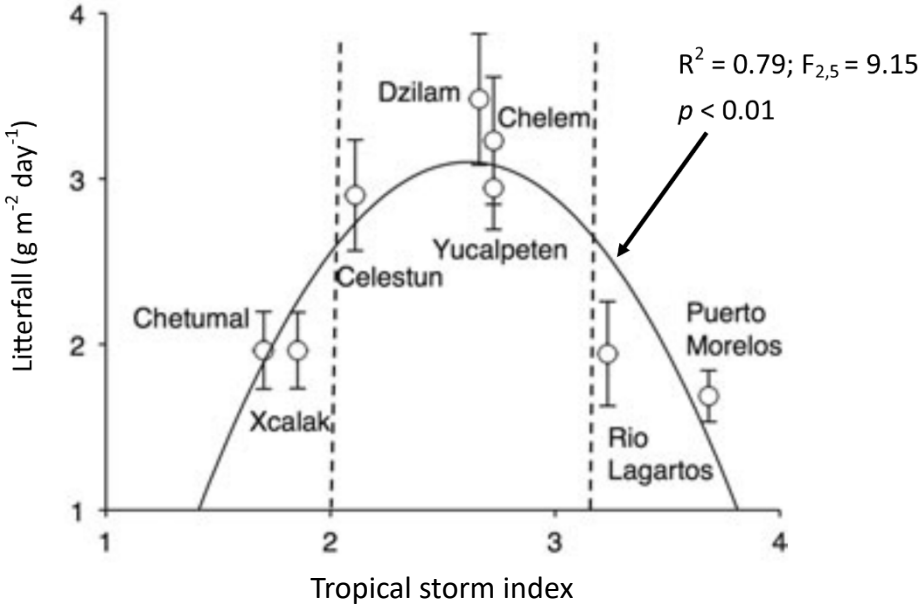
General overview of mangroves and hurricanes

Possible reasons:

(2) Reproductive (and productivity) strategies appear to embrace storms

Some have suggested that peak production of propagules in Neotropical mangroves coincide by design with greater tropical storm activity (Aug – Oct)



Adame et al. 2013. ***Biotropica*** 45, 147–154

https://www.tedleeeubanksphotography.com/Client-Galleries/Jamaica/i-8Dc96L7

https://naturalhistory2.si.edu/smsfp/irlspec/Lagunc_racemo.htm

http://www.mangrove.at/rhizophora-mangle_red-mangrove.html

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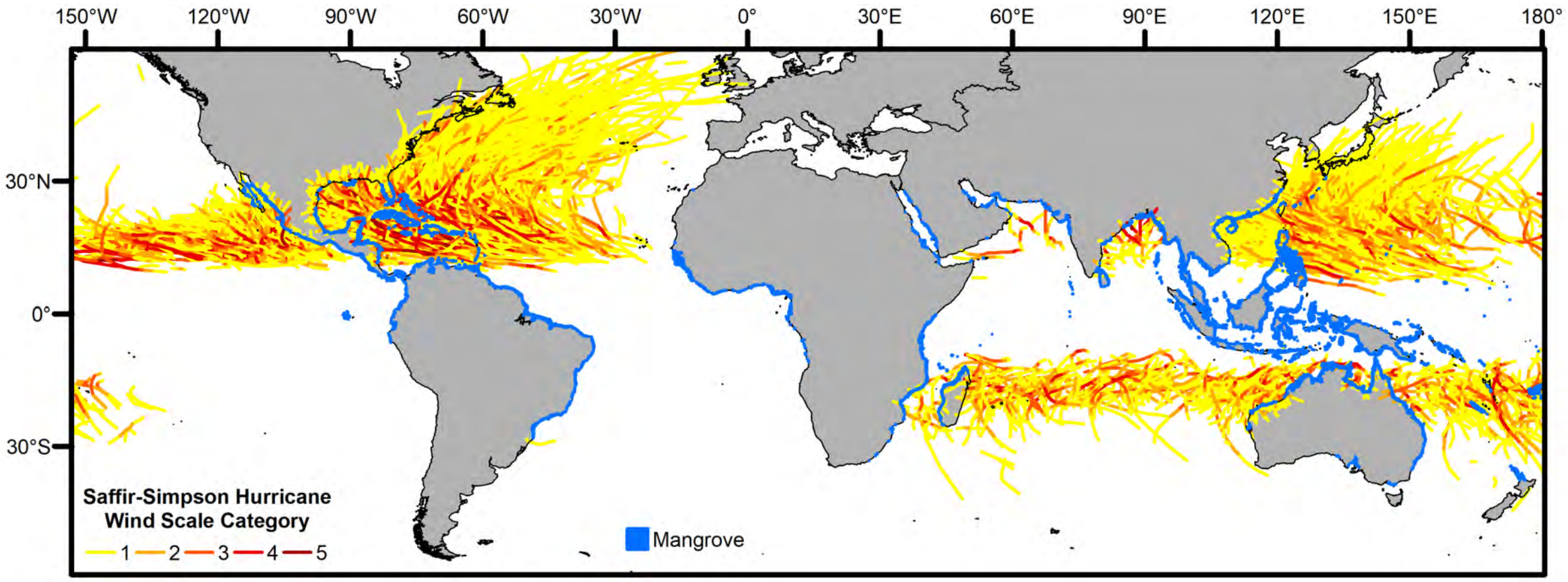
General overview of mangroves and hurricanes



Krauss and Osland 2019. ***Annals of Botany***, in press, doi:10.1093/aob/mcz161

If tropical storms of all intensities are included, Puerto Rico is affected by approximately 50 per century

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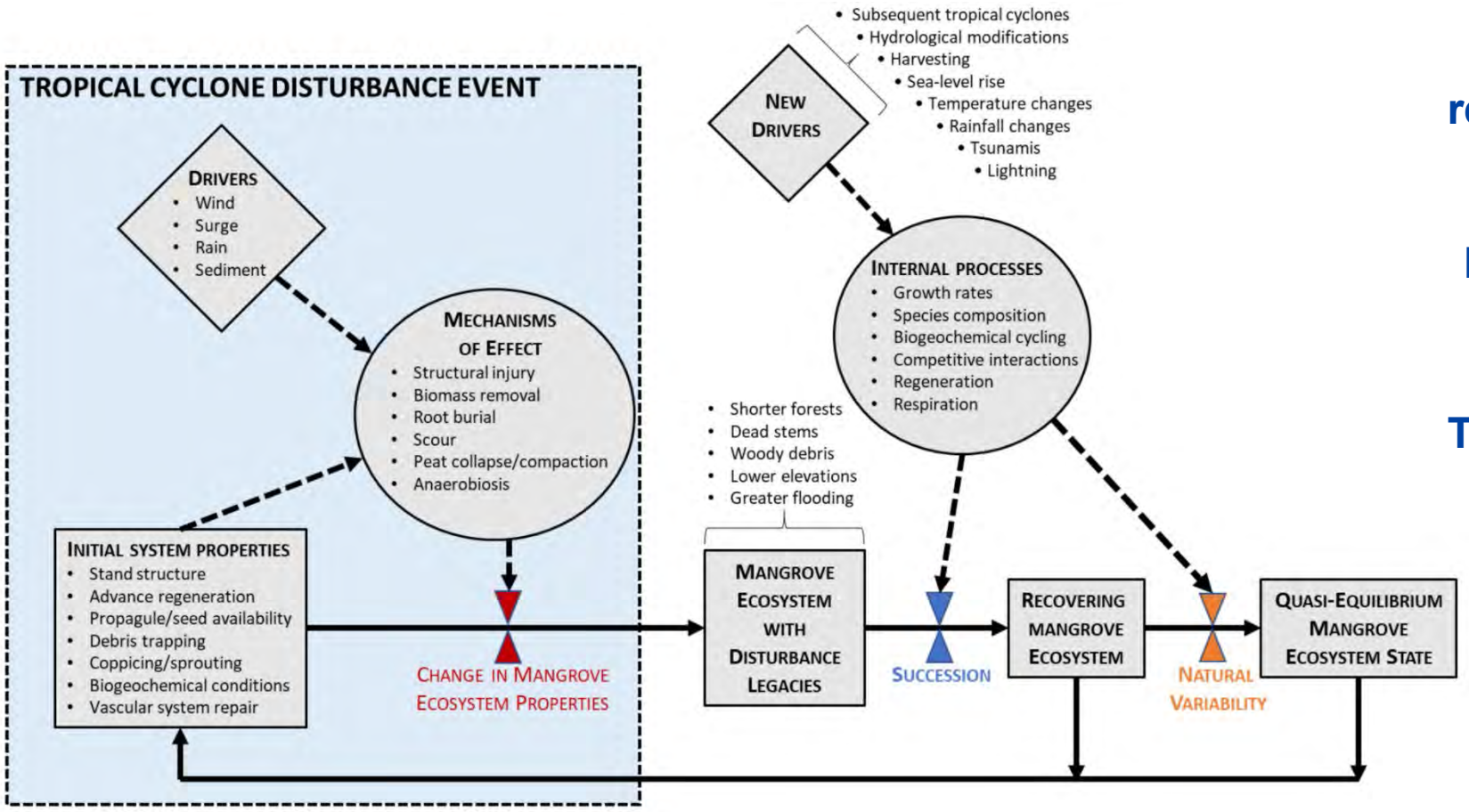
General overview of mangroves and hurricanes

Very important to note, therefore, that mangroves are heavily affected by singular hurricane events



Most mangroves within repetitive storm-track areas have sustained hurricane damage previously and have already recovered to what they are now

This leads to two questions:
(1) What limits recovery?
(2) How can we help?

Krauss and Osland 2019. ***Annals of Botany***, in press, doi:10.1093/aob/mcz161

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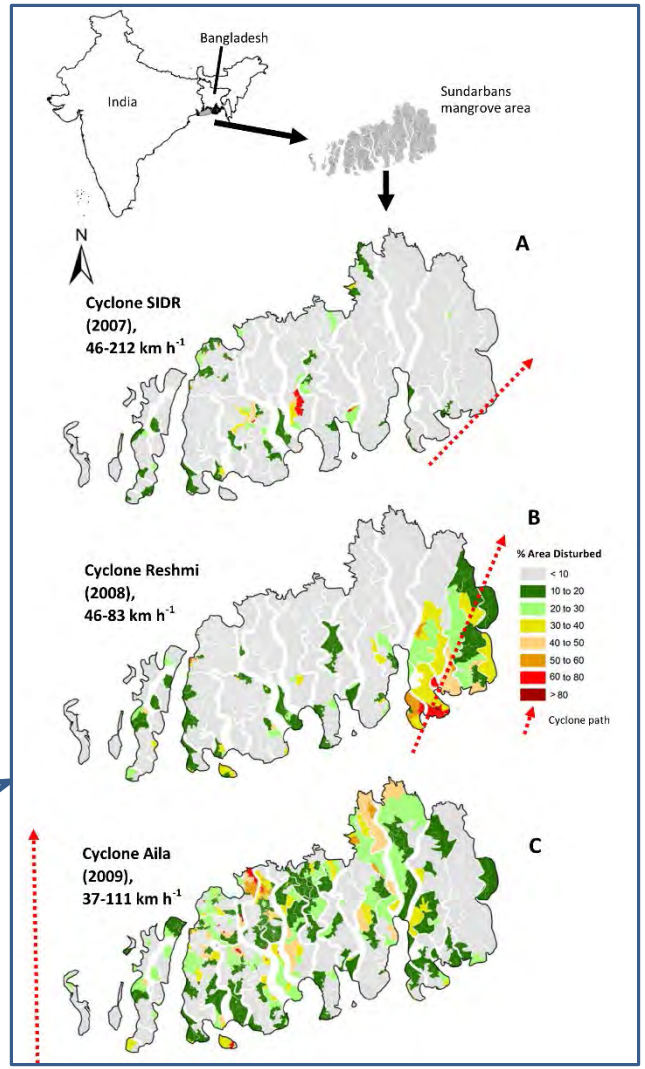
Of concern to us…

What happens if hurricane frequency increases?



after, Dutta et al. 2015. ***Nat. Hazards*** 79, 775–790

What happens if mangroves are not healthy when a hurricane strikes?

aka. “Mangrove Heart Attack”

after, Lewis et al. 2016. ***Marine Pollution Bulletin*** 109, 764–771

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Influences of Hurricanes Irma and Maria on the Mangroves of St. John

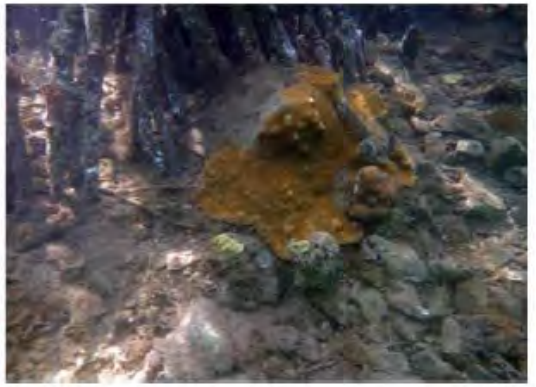
Main focus of this U.S. Geological Survey science program is to assess the damage to the mangrove resource on St. John from the 2017 hurricane season, and assess the potential for recovery.

Before

After

Before

After



We measured characteristics of the mangrove forests and soils in two trips to St. John, 10-14 months after Hurricanes Irma/Maria, and re-constructed pre-hurricane forest structure to determine impact of the hurricanes.

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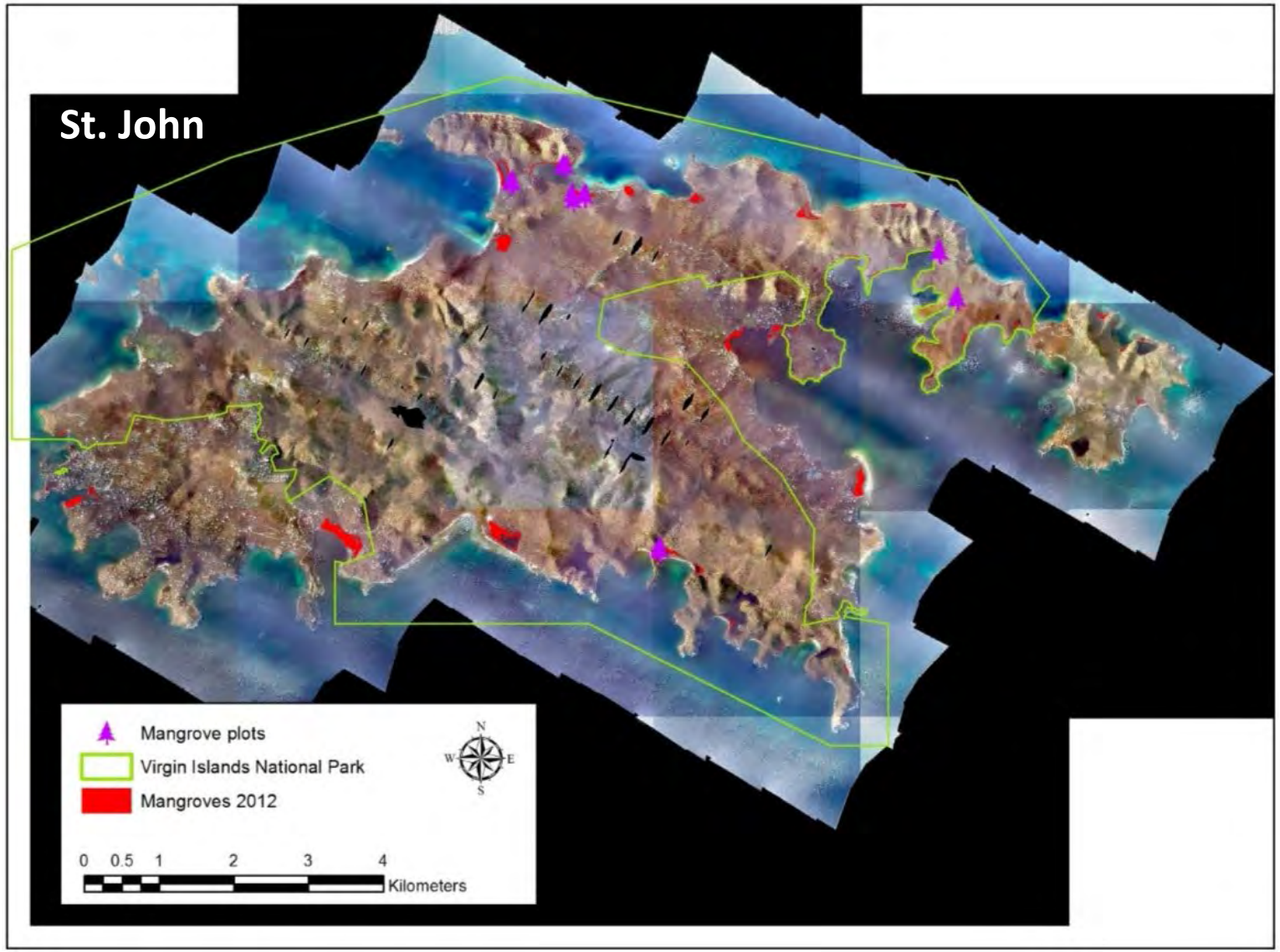
Photos from CS Rogers 2019. ***Diversity*** 11, Article I30

Influences of Hurricanes Irma and Maria on the Mangroves of St. John



- Mangroves cover an area of ~45 ha

- Occupy ~11 km of shoreline (or 12%)

- Height range of 4 – 11 m tall

- At least three different types of mangrove forests on St. John (typology)

  - Isolated basin
  - Salt pond
  - Fringe

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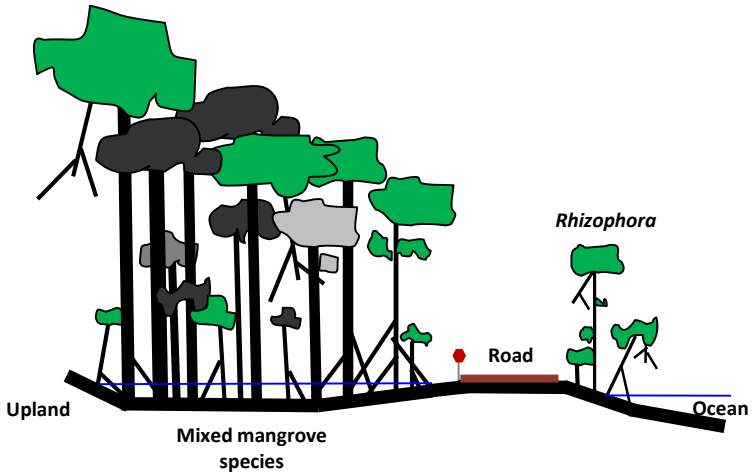
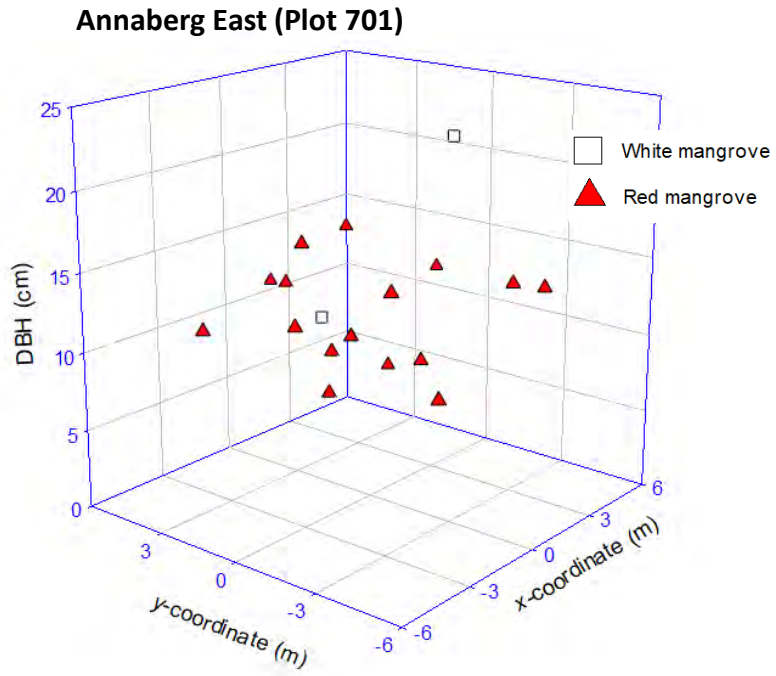
Influences of Hurricanes Irma and Maria on the Mangroves of St. John

Isolated basin



- Two sites, both at Annaberg

- Typically flooded by the highest of tides, or significant rainfall events with water retention



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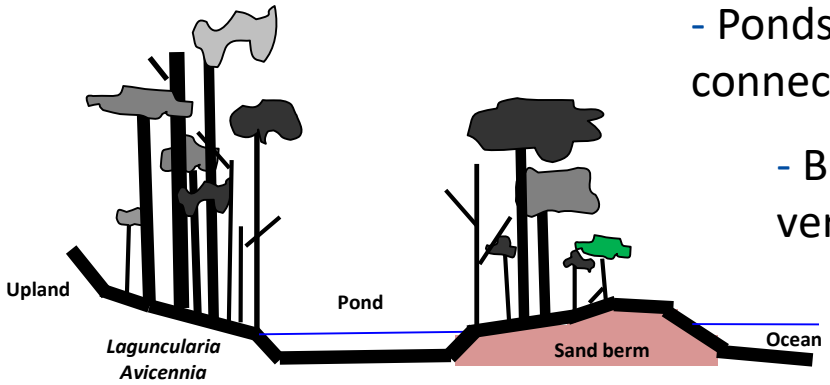
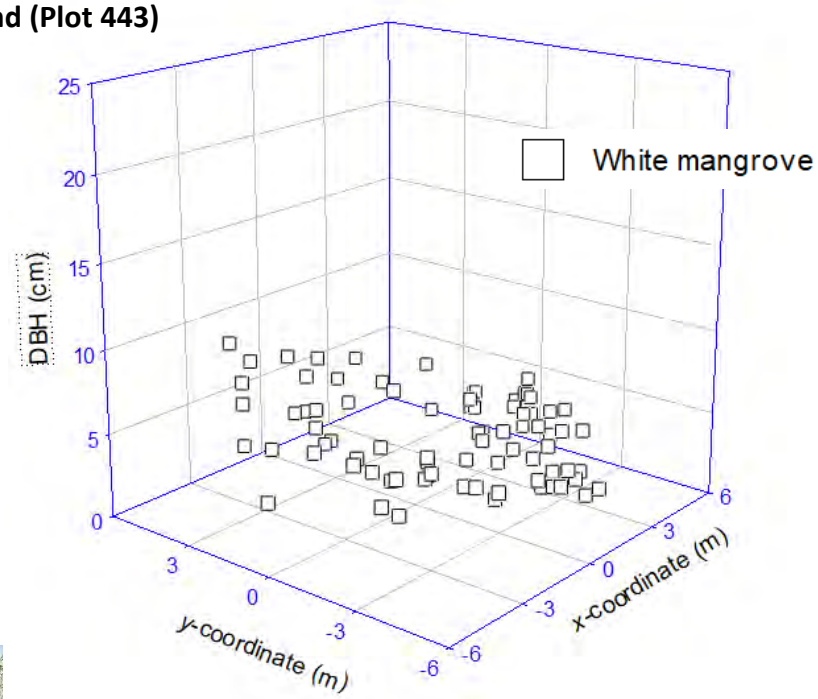
Influences of Hurricanes Irma and Maria on the Mangroves of St. John

Salt pond

- Two sites (Francis Pond, Lameshur)
  - Ponds permanently flooded with various connections to the ocean
    - Both sites selected on St. John were very different; mortality a condition



Francis Pond (Plot 443)



Francis Pond

Lameshur

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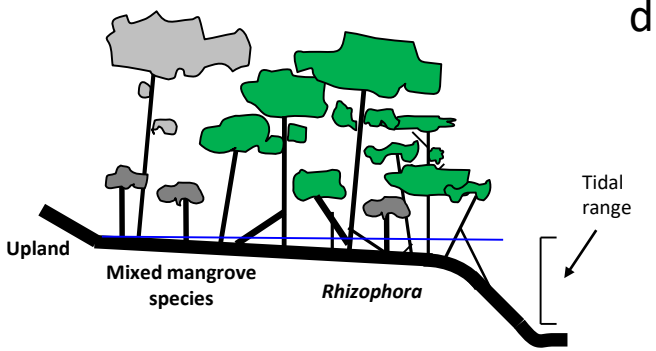
Influences of Hurricanes Irma and Maria on the Mangroves of St. John

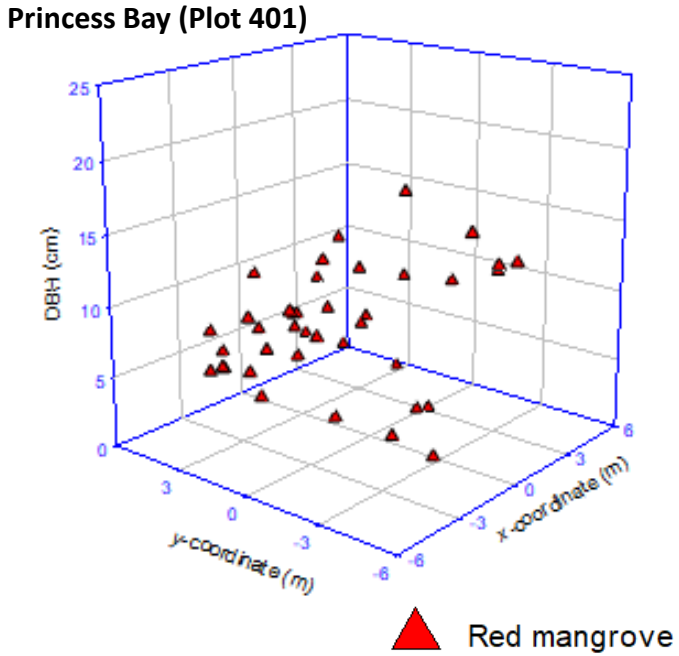
Fringe

- Three sites (Water Creek, Princess Bay, Mary Creek)

- Flooded by nearly every high tide, and most drained at ebb tide

- Mostly comprised of red mangrove, but all species often present





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Influences of Hurricanes Irma and Maria on the Mangroves of St. John

What did we do?

- Established 2, 5.65-m radius plots per site (0.02 ha)

- Measured diameter at breast height (*dbh*, 1.3 m above ground) of live standing, dead standing, and fallen trees.

- Re-constructed pre- and post-storm forest structure. Explain…

- Measured downed wood volume

- Measured regeneration in 1-m^2 sub-plots

- Soil samples to a maximum depth of 50 cm; 3-cm sections

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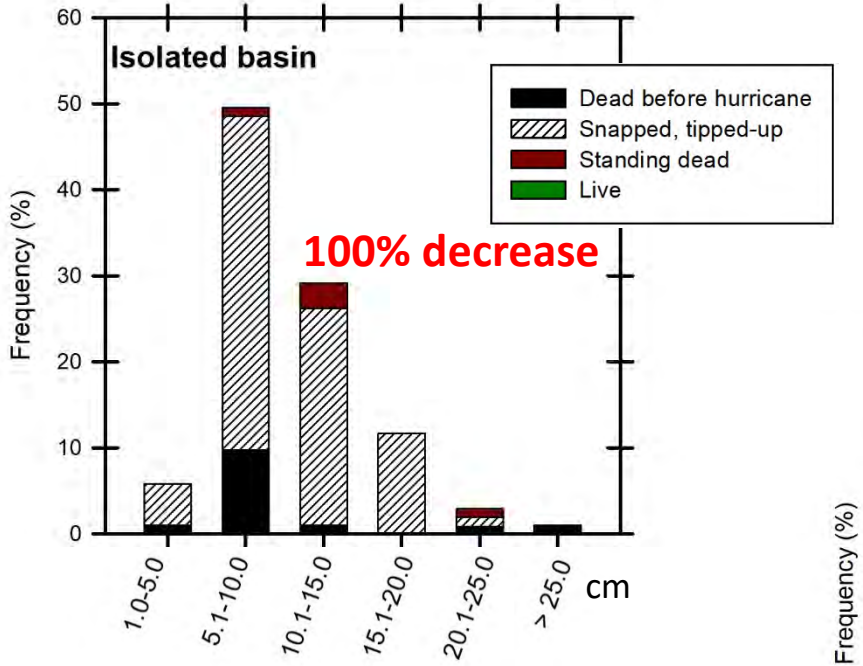
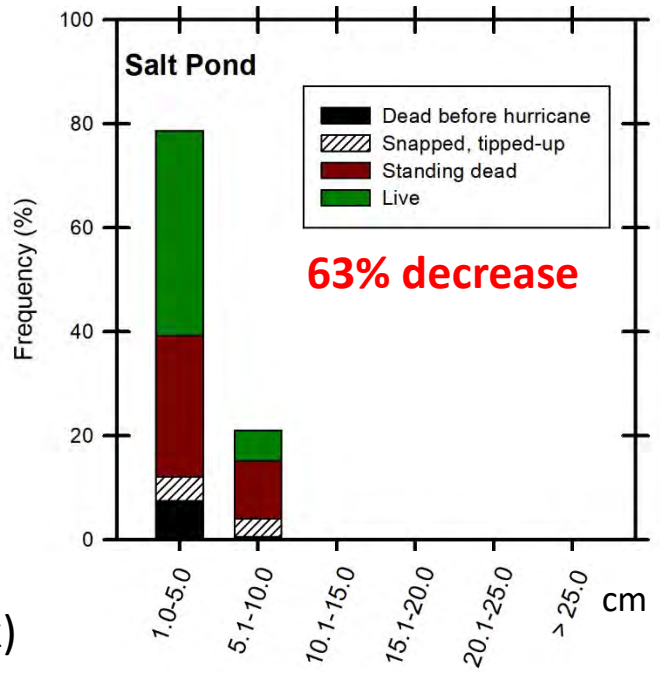
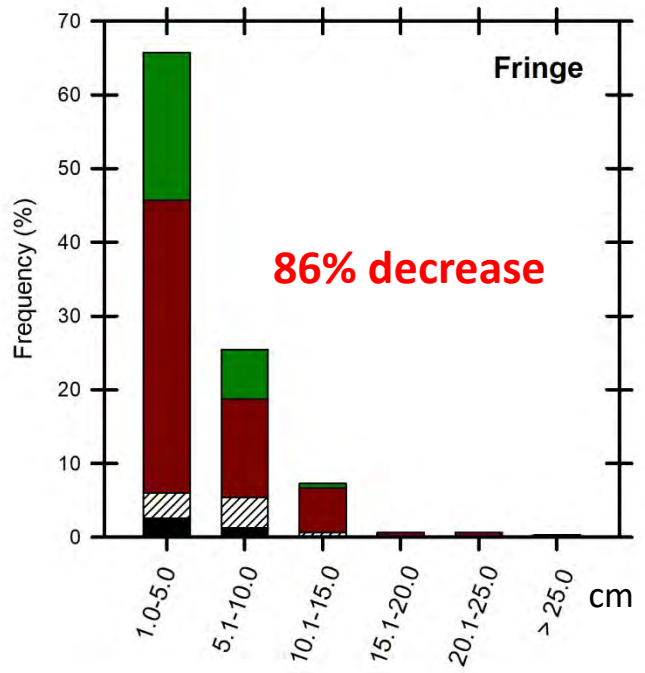
Influences of Hurricanes Irma and Maria on the Mangroves of St. John



- 1600 to 2850 stems/ha before hurricanes
- Diameter distributions (no live trees)
- Missing small diameter class trees and of those present, there were lots of mortality in small diameter classes before hurricanes. Why?





- Diameter distribution typical
- Salt Pond = 6750 to 8100 stems/ha
- Fringe = 3150 to ~13000 stems/ha (Mary Creek)
  - Many more dead standing trees. Trees shorter. But, also some survival.

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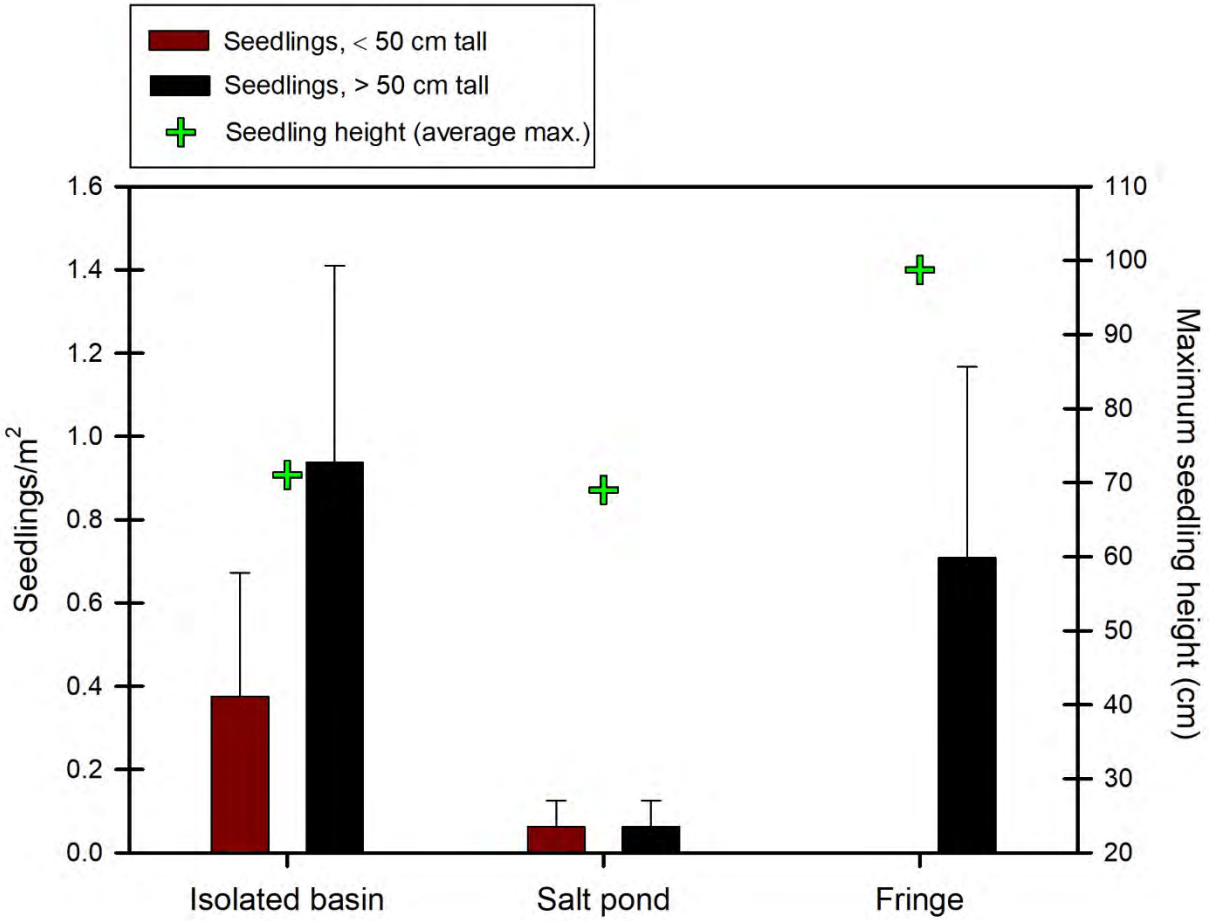
Influences of Hurricanes Irma and Maria on the Mangroves of St. John



- A lot of what we found were seedlings present before the hurricanes

- Regeneration was seemingly fairly low, but variable and not necessarily very different from other post-hurricane regeneration surveys at this point in time (10-14 months).

- 1.8 to 5.3 seedlings/m^2 (Everglades); 0.7 to 2.2 seedlings/m^2 (Nicaragua)

- Regeneration re-surveys on this trip (26 months) ?

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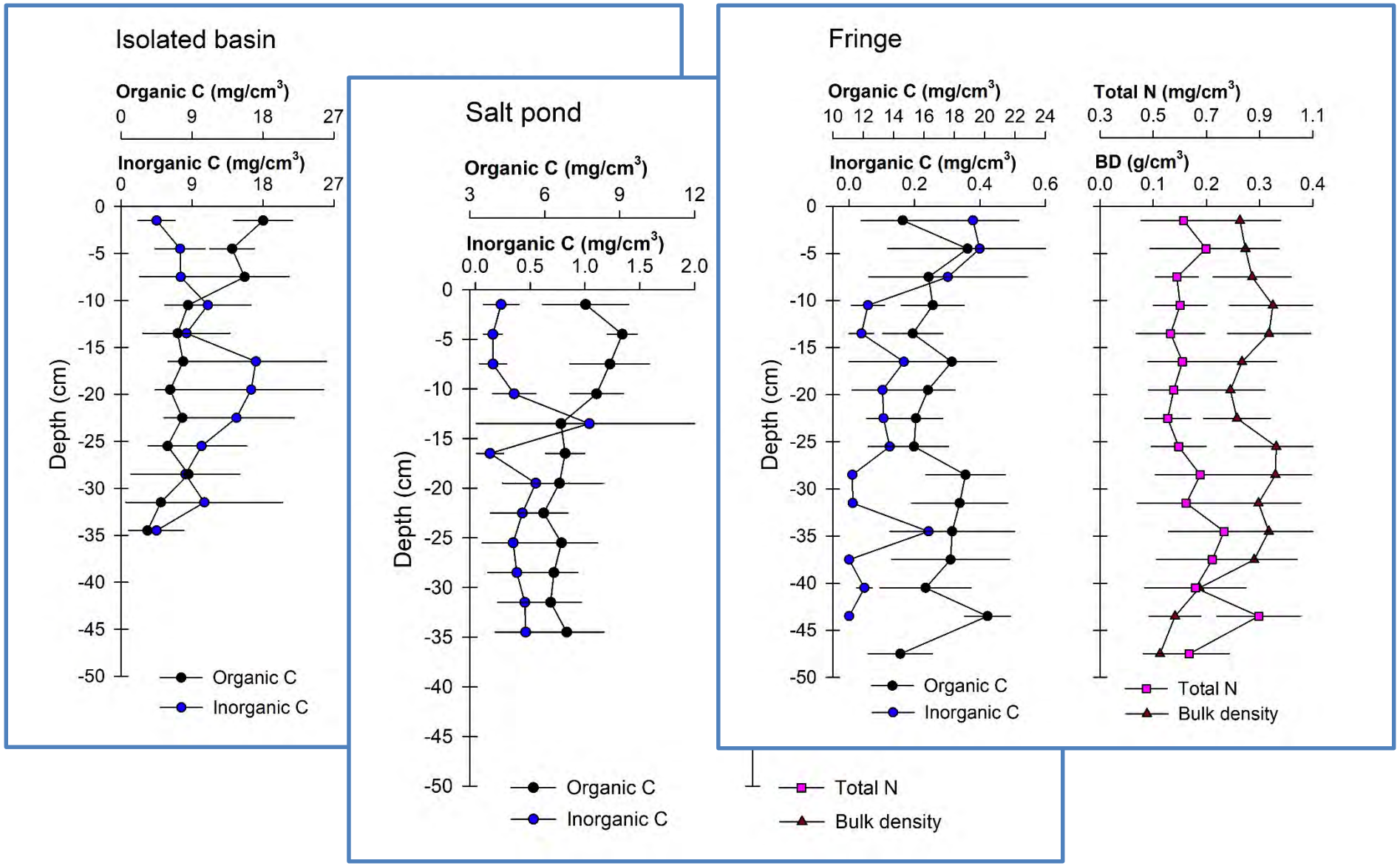
Influences of Hurricanes Irma and Maria on the Mangroves of St. John



- Hurricanes not likely to affect soil structure greatly unless recovery is delayed (peat collapse)

- Nitrogen content fairly low; sign of nutrient conservation in the uplands?

- Inorganic C content high in Isolated basin (>50%). Why?

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Can we influence recovery, and how?

- Mangroves look horrible after hurricanes.

Ten Thousands Islands, Florida

Saipan, Northern Marianas Islands

St. John

What can we do?

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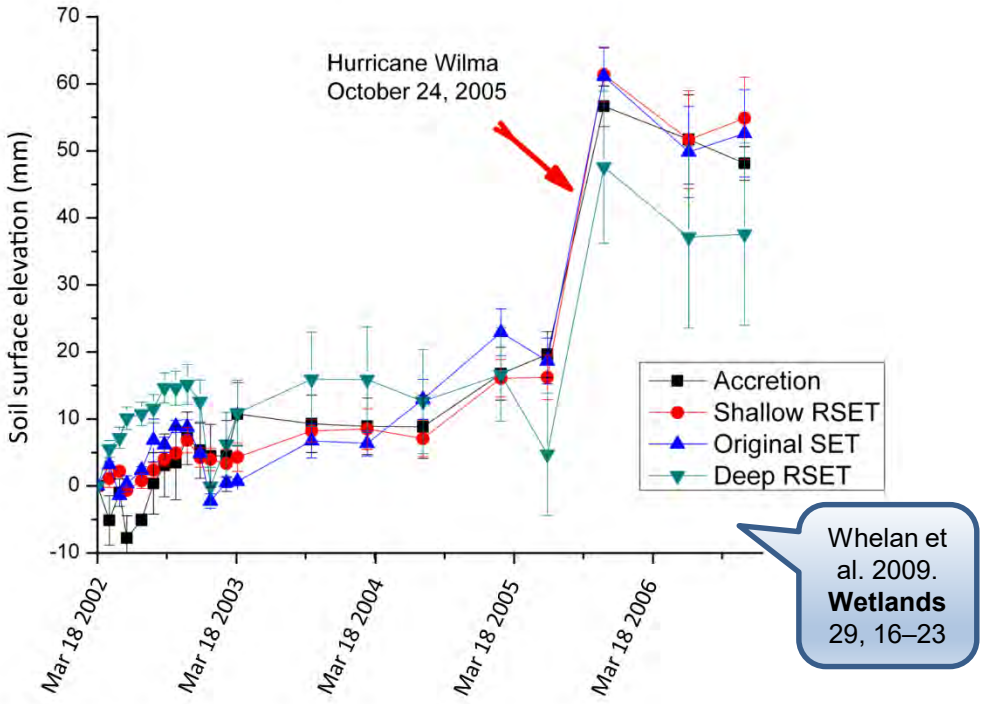
Can we influence recovery, and how?

Embracing the disturbance…



- Hurricane Wilma deposited 37 mm of sediment on to the mangrove soil surface in Everglades National Park.

T.J. Smith III, U.S. Geological Survey

- Reported a 42.8 mm increase in elevation, which decreased by 10.5 mm by June 2006 – due to settling

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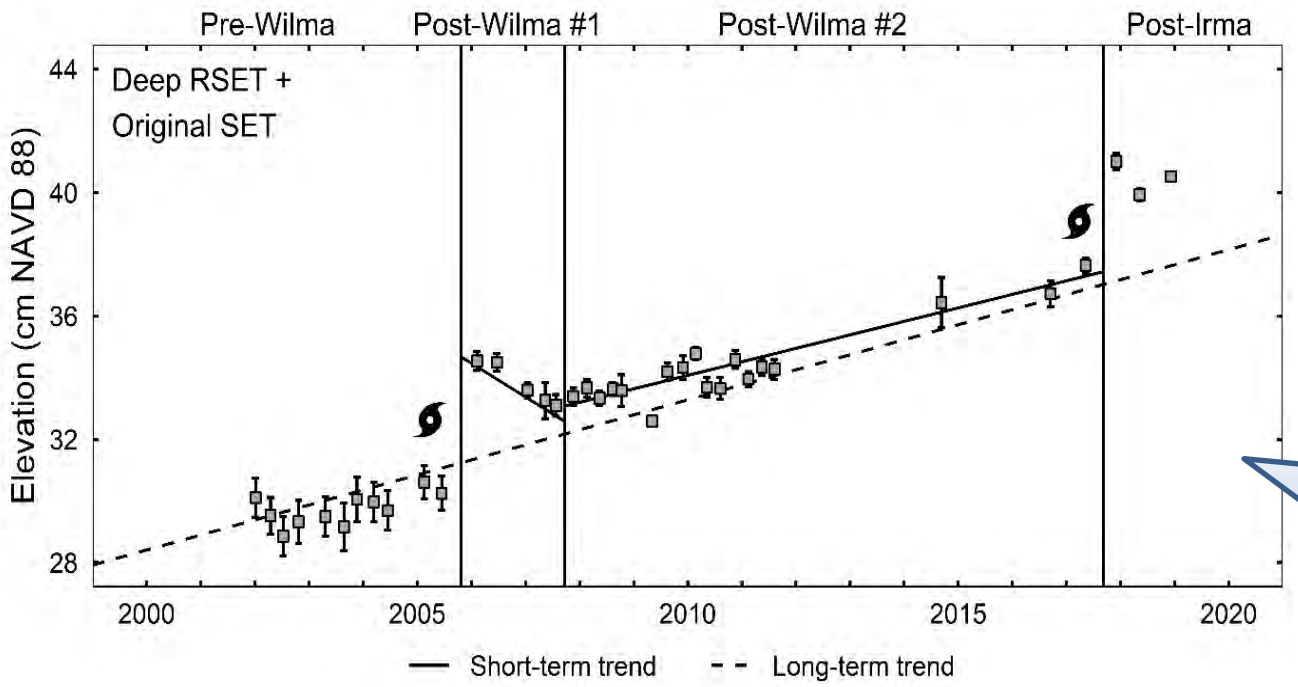
Can we influence recovery, and how?

Embracing the disturbance…



Hurricane Wilma deposited 37 mm of sediment on to the mangrove soil surface in Everglades National Park.

However, is the benefit long-term?

Feher et al. 2019. **Ecosystems,** in press, doi: 10.1007/s10021-019-00446-x

- Reported a 42.8 mm increase in elevation, which decreased by 10.5 mm by June 2006 – due to settling
  - How might physical morphological changes to adjacent nearshore marine and sea floor benthic environments affect mangrove sedimentation patterns on St. John in the future (c.f., Browing et al. 2019, ***Scientific Reports*** 9: *7101*)

T.J. Smith III, U.S. Geological Survey

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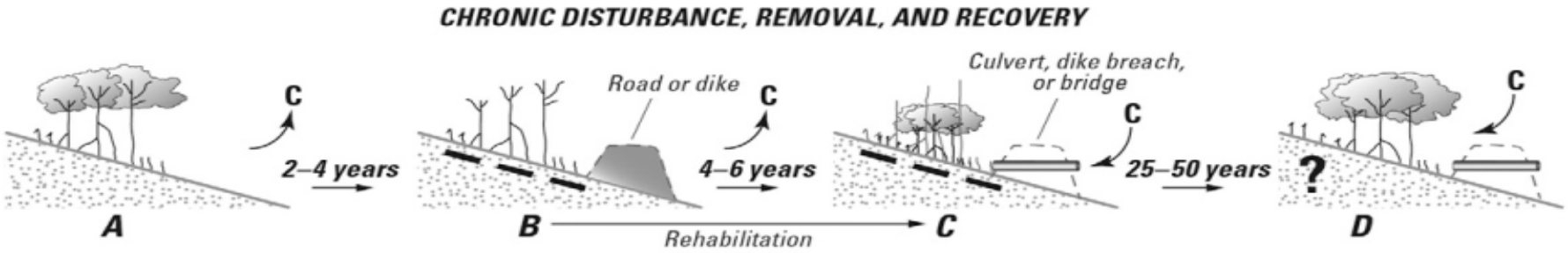
Can we influence recovery, and how?

Ensuring that tidal hydrological flow is maintained…



Lewis et al. (2016) *Mar Pollution Bull* 109: 764-771

Many established mangrove forests are stressed by subtle changes in hydrology brought on by development, and this needs to be recognized globally.

Marco Island, Florida, USA

Dead — **Transitional** — **Full canopy**

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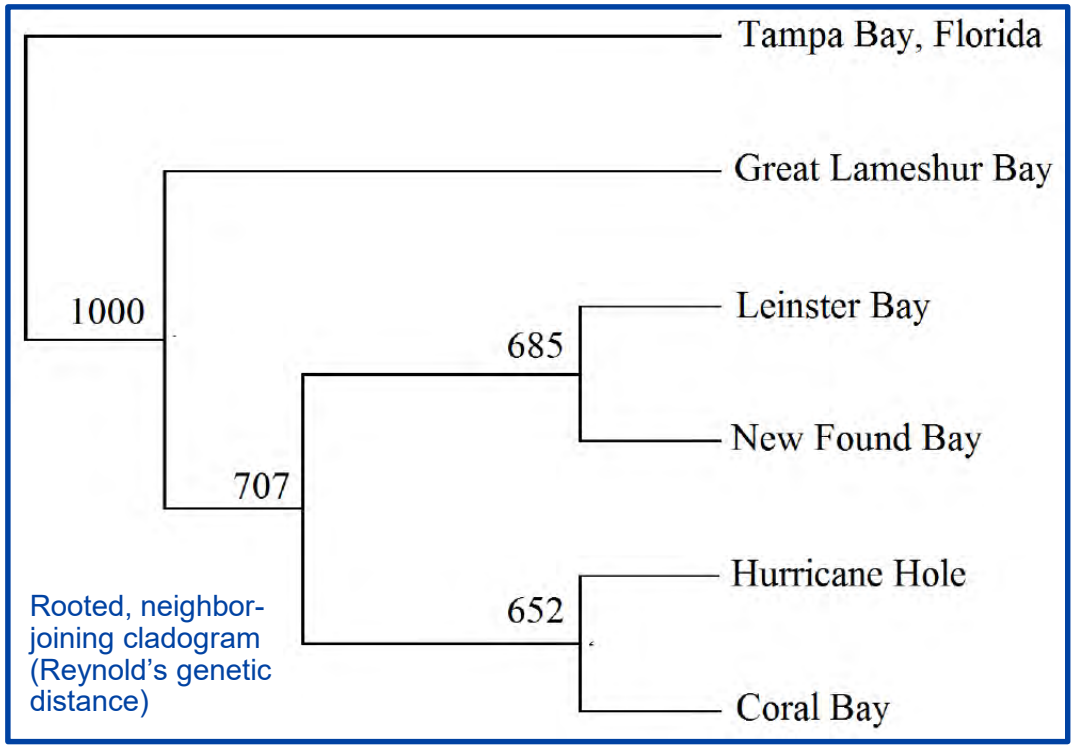
Can we influence recovery, and how?

Actively planting seedlings to facilitate quicker regeneration…

- Maybe a solution, but acceptable sources of propagule material need to be found.

- Limited genetic variability may be a condition of mangrove development on Caribbean islands?



Bologna et al. 2019. ***Diversity*** 11, Article 65

- Genetic relatedness of *Rhizophora mangle* populations after recovery from Hurricane Hugo on St. John.

- How important is this to maintain?

- Ensuring post-planting survival. *E.g., Different environmental conditions, herbivory, browsing.*

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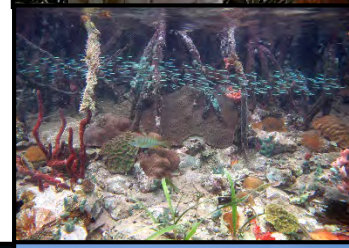
Summary and Questions?

While mangroves are considered stress-adapted ecosystems, there is a limit of that adaptability made more difficult by human-impacts to the landscape, limited regeneration potential in some environments, genetic bottlenecks, and lack of seed/propagule sources to promote expedient recovery.

That said, how the mangroves on St. John appeared before the hurricanes already represented recovery to that stage from past hurricanes. Legacies of past impact are part of being a disturbance-adapted ecosystem.



U.S. Geological Survey
Ecosystems Mission Area
Environments Program

U.S. National Park Service
Virgin Islands National Park
Virgin Islands Coral Reef National Monument