

Lost in Translation: The Role of Coral Reefs in Shoreline Protection in South Florida.

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Common assumption: healthy coral reefs provide shoreline protection.

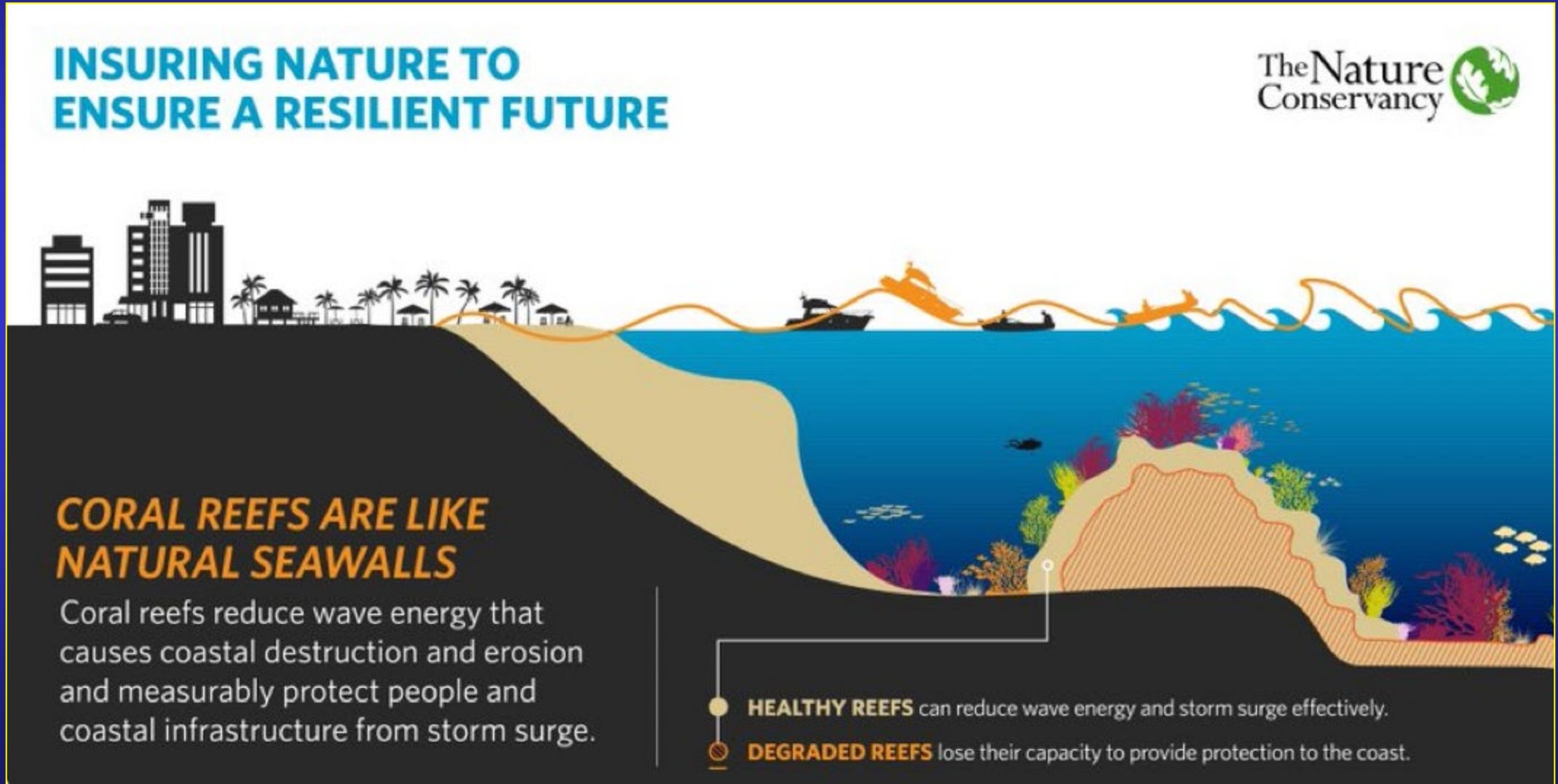
**INSURING NATURE TO
ENSURE A RESILIENT FUTURE**



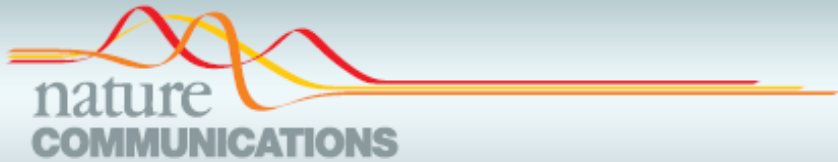
CORAL REEFS ARE LIKE NATURAL SEAWALLS

Coral reefs reduce wave energy that causes coastal destruction and erosion and measurably protect people and coastal infrastructure from storm surge.

- **HEALTHY REEFS** can reduce wave energy and storm surge effectively.
- ⊗ **DEGRADED REEFS** lose their capacity to provide protection to the coast.



Coral Reefs Reduce 97% Incoming Wave Energy



ARTICLE

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DOI: 10.1038/ncomms4794

OPEN

The effectiveness of coral reefs for coastal hazard risk reduction and adaptation

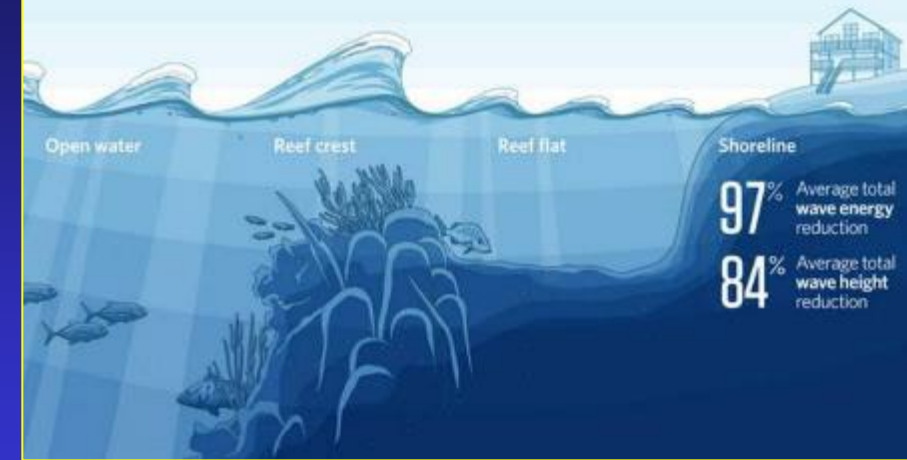
Filippo Ferrario^{1,2}, Michael W. Beck³, Curt D. Storlazzi⁴, Fiorenza Micheli⁵, Christine C. Shepard³ & Laura Airoidi^{1,5}

Over 1015 scientific citations since 2014!

But is this view correct?

Coral Reefs Reduce Wave Energy and Height

Coral reefs lessen wave energy by an average of 97%. The reef crest, or shallowest part of the reef where the waves break first, dissipates 86% of wave energy on its own.



Not all reefs look and function the same!

- Meta-analyses reveal that coral reefs provide substantial protection against natural hazards by reducing wave energy by an average of **97%**. Reef crests alone dissipate most of this energy (86%).
- They identified 255 studies on coral reefs and wave attenuation.
- They could only extract data for their meta-analyses from 27 independent publications

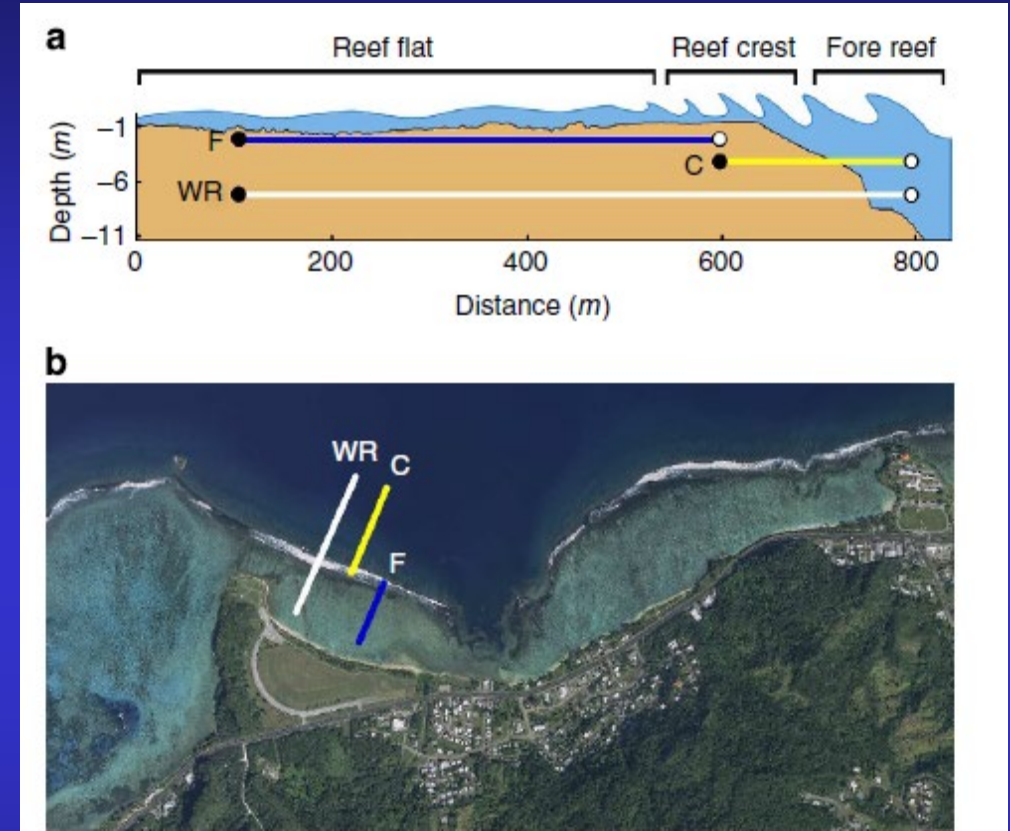


Figure 1 | Example of coral reef environments and sample transects. Transects along which wave attenuation was estimated for the three environments are indicated: reef flat (F), reef crest (C) and whole reef (WR). Measurements of wave parameters were compared between an offshore control (open circle) and a landward treatment (solid circle) in each transect. (a) Cross-section of the Camel Rock, Guam, fringing reef, from US Army Corps of Engineers SHOALS lidar data. (b) Aerial view of Asan Bay, Guam (data available from the US Geological Survey).

They examined wave attenuation across three reef environments: the reef crest, reef flat, and the whole reef.

Although there was usable data for 27 reefs – not all reefs had data for the entire reef

They used “whole reef” data from only 13 reefs

13 out of 255!

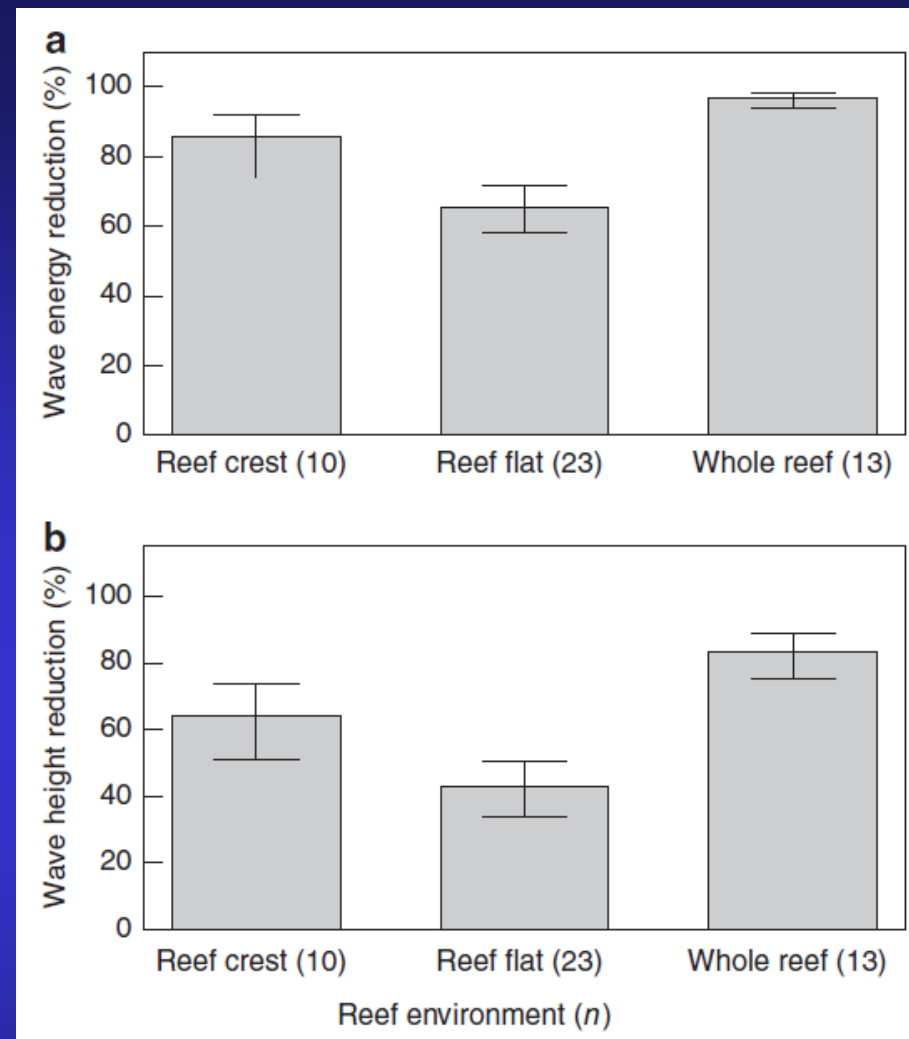


Figure 2 | Coral reef and wave attenuation meta-analysis results. Values are the average percentage of (a) wave energy reduction, and (b) wave height reduction in the three reef environments. Error bars represent 95% confidence interval. When the confidence intervals do not overlap, the averages are considered significantly different from zero ($P < 0.05$). ‘n’ reflects the number of independent experiments.

No reefs from Florida used in study!

Only 2 studies from the Caribbean

Lost in translation!

SMART NEWS

New Research

Coral Reefs Absorb 97 Percent of the Energy From Waves Headed Toward Shore

This finding applies to reefs around the world



Rachel Nuwer

May 15, 2014

> 150 media publications

How and why did the message get lost?


It all started with 97%.

“We knew that reefs break waves and reduce their energy,” said Beck, who was surprised by the findings. **“We were not expecting to see a 97 percent reduction, though. But it really is that consistent and that strong across all the data.”** The team of scientists analyzed more than 255 studies on coral reefs and the buffering effect they have on waves that pass through them. When reefs break waves, they found, the process begins at the reef crest.”

(From Brendan Bane, Mongabay 2014)



NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
UNITED STATES DEPARTMENT OF COMMERCE



NOAA
CORAL REEF
CONSERVATION PROGRAM



HOME > 2019 FEATURED STORIES > THE
VALUE CORAL REEFS PROVIDE AGAINST
HAZARDS

The Value Coral Reefs Provide against Hazards

“Coral reefs protect lives and property by absorbing 97 percent of a wave’s energy while buffering shorelines from currents, waves, and storms. The U.S. is one of the top 10 countries worldwide that benefits from coral reefs in terms of risk reduction.”



Coastal Protection

Because of the reef's ability to dissipate 97% of wave energy from storms and hurricanes, its conservation is critical to the protection of Florida's coastline and interconnected communities.

Florida's Coral Reef buffers adjacent shorelines from wave action and prevents erosion, property damage and loss of life. The reef also protects the highly productive wetlands along the coast as well as ports and harbors and the economies they support.



REEFocus

Nov 18, 2020 • 4 min read



CORAL RESTORATION PROJECT AT EASTERN DRY ROCKS AWARDED \$5 MILLION GRANT

Updated: Apr 20, 2021

The project will strengthen coastal resilience, revitalize critical fish and wildlife habitat, and engage the community as part of NOAA's Mission: Iconic Reefs

Coral reefs are effective in mitigating coastal hazard risks and increasing coastal resilience. They provide substantial protection against coastal storms and storm surges by reducing wave energy by an average of 97 percent. The structural complexity of coral reefs plays a crucial role in dissipating wave energy and protecting coastlines. With its proximity to Key West, the most populous community in Monroe County, the reef at Eastern Dry Rocks provides a natural defense from coastal storms and storm surges.

USCRTF Resolution 47.2

Coral Reefs as National Natural Infrastructure

WHEREAS, the U.S. Coral Reef Task Force (USCRTF), originally established in 1998 by Executive Order #13089, was codified in 2022 by the Reauthorization of the Coral Reef Conservation Act (R-CRCA) to, among other things, coordinate, in cooperation with covered entities and other nongovernmental and academic partners as appropriate, activities regarding the mapping, monitoring, research, conservation, mitigation, and restoration of coral reefs and coral reef ecosystems, and;

WHEREAS, many local, indigenous, and coastal communities have long maintained strong biocultural, spiritual, ecological, and social connections to coral reefs critical to preserving cultures and cultural diversity, and coral reefs, and;

WHEREAS, coral reef-lined communities with small size, low elevation, remote geographical location, and concentration of infrastructure along coastlines have populations denser, growing faster, and composed of more people from lower-middle income groups than the global average, are especially vulnerable to climate change impacts, and;

WHEREAS, coral reef degradation in the US threatens “at-risk” (<16 years old, >65 years old, low-income, and minority) communities, especially in territories. Therefore improving coral reef conservation and restoration will enhance coastal resilience for these vulnerable communities, and;

WHEREAS, healthy coral reefs are among the most biologically diverse, culturally important, and economically valuable ecosystems on Earth, and;

WHEREAS, coral reefs worldwide provide an estimated \$172 billion annually in economic value via tourism, food production, and coastal infrastructure protection. In the US, the estimated economic value of coral reefs is \$3.42 billion annually, not including shoreline protection and hazard reduction values, and;

WHEREAS, coral reefs offer coastal protection services by reducing flooding and erosion through wave breaking and friction. Reefs behave as low-crested, submerged breakwaters, dissipating on average 97% of wave energy before it reaches coastlines. Individual coral colonies induce drag on waves, further reducing wave energy reaching the shoreline and causing coastal flooding. Coral colonies grow together and alongside each other to form a reef, resulting in greater reduction in wave energy and thus greater reduction in adjacent onshore flooding, and;

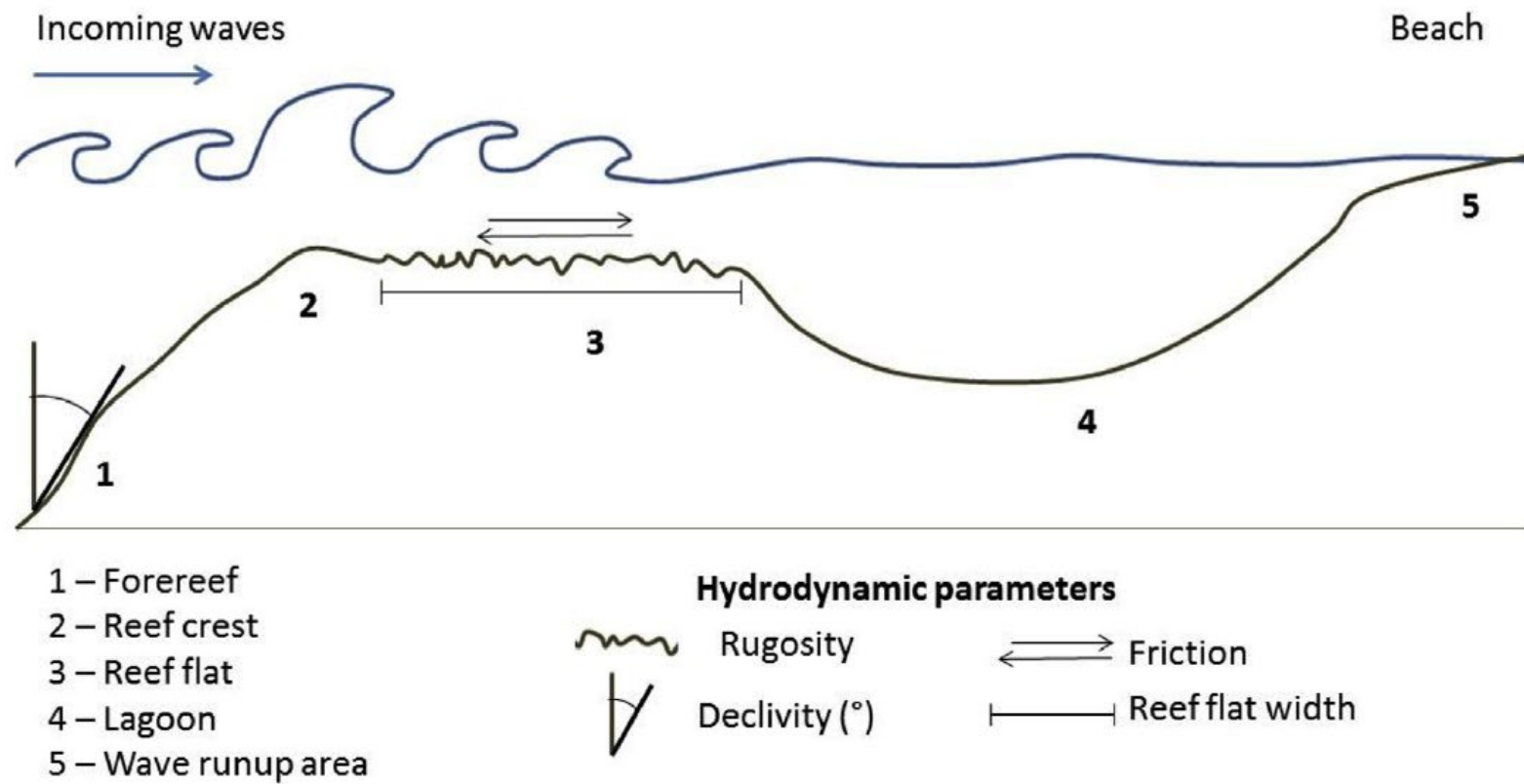


Fig. 1. Reef zones and hydrodynamic parameters involved in the process of wave height and wave energy attenuation.



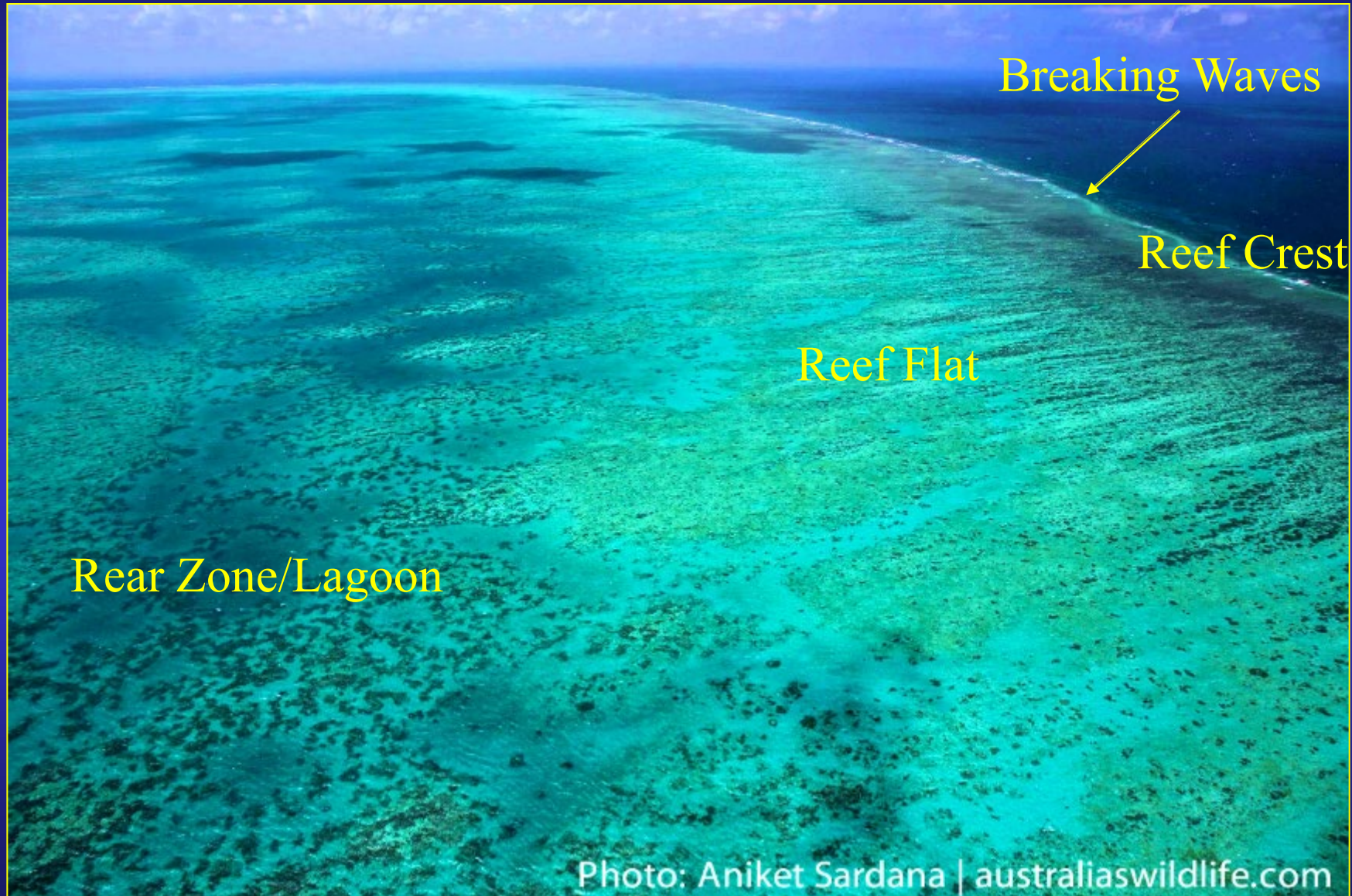
Review

Coral reefs as the first line of defense: Shoreline protection in face of climate change

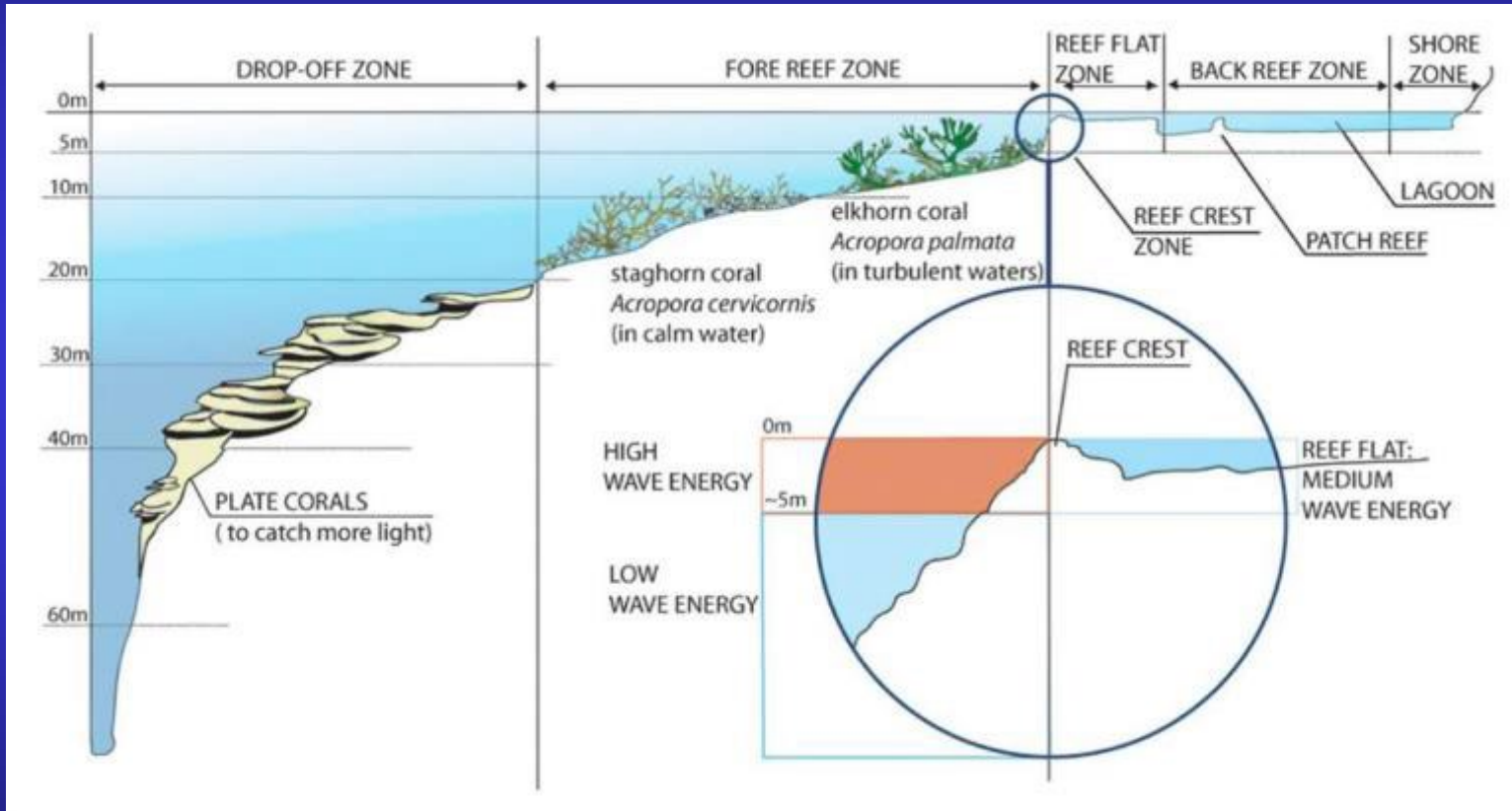
Carla I. Elliff^{a,*}, Iracema R. Silva^b



Prototypical Reef - Great Barrier Reef



Classically Zoned Caribbean Reef



Shallow wave-reef interactions involve dissipative effects of wave breaking, turbulence, and friction, resulting in **measured** wave energy transformations ranging from 72 - 97% depending on reef configuration and water depth.

Roberts, H. H., Wilson, P. A., & Lugo-Fernández, A. (1992). Biologic and geologic responses to physical processes: examples from modern reef systems of the Caribbean-Atlantic region. *Continental Shelf Research*, 12(7-8), 809-834.

Belizean Barrier Reef



Note dissipation of wave energy occurring on the reef crest and inner reef flat.

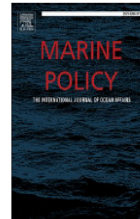


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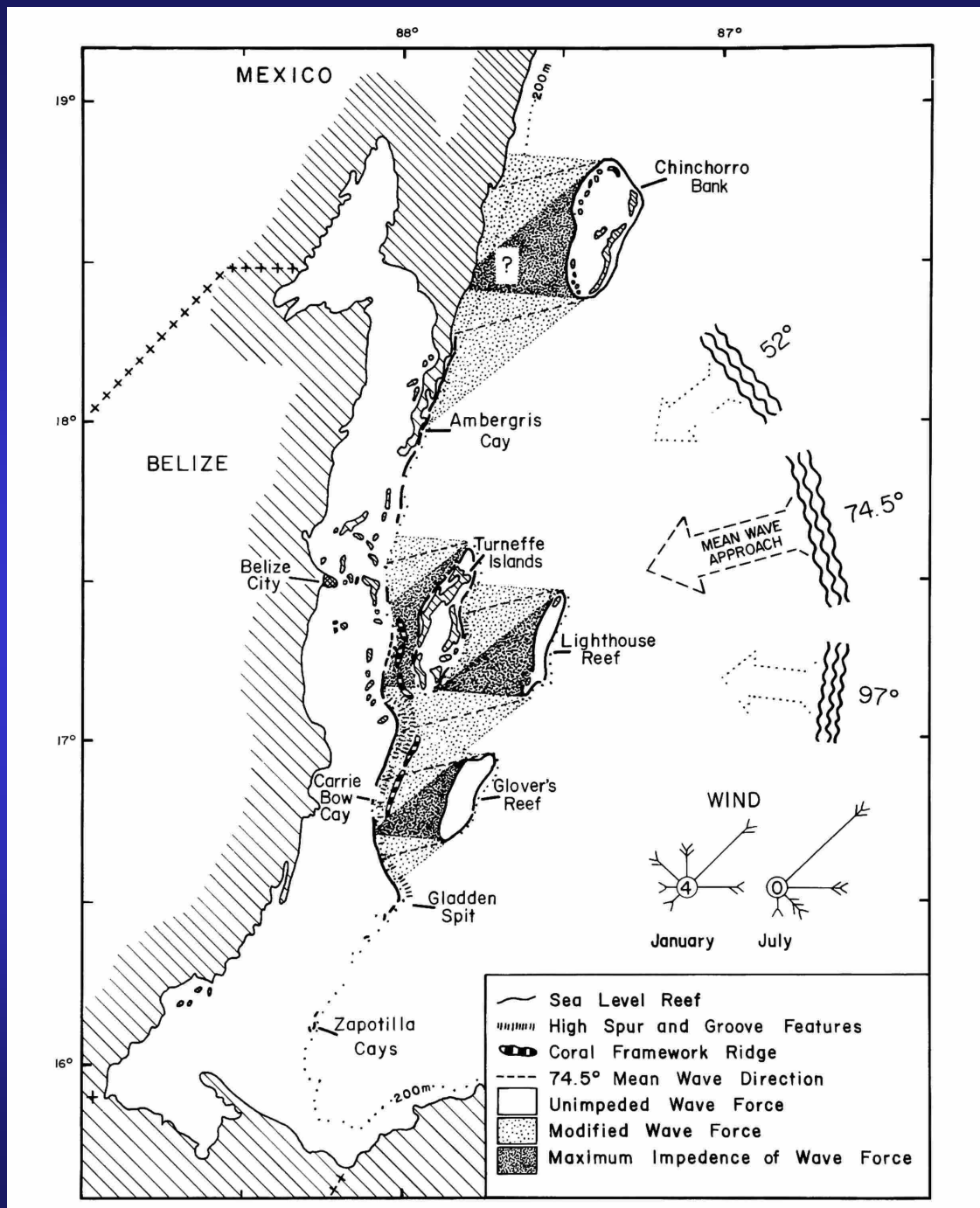
Shoreline protection by the world's coral reefs: Mapping the benefits to people, assets, and infrastructure[☆]

Lauretta Burke^a, Mark Spalding^{b,c,*}



Assumptions in Burke and Spalding

- Although reefs are highly effective at attenuating waves, their effect is most powerful over short distances, particularly during storm events, when wind-driven processes can enable the reformation of waves over relatively short distances. To account for this diminishing level of protection with increasing distance between the reef and shore, three tiers of protective capacity were assigned to coastal grid cells:
 - • within 500 m of a coral reef (high protection)
 - • within 2 km of a coral reef (medium protection)
 - • behind a barrier reef (low protection)
 - • none of the above (no protection)



Wave Shadows

Burke, R.B., 1982. Reconnaissance study of the geomorphology and benthic communities of the outer barrier reef platform, Belize. The Atlantic Barrier Reef Ecosystem at Carrie Bow Cay, Belize I. Structure and Communities, pp.509-526.

How many reefs in Florida have a reef crest and reef flat?

How deep are the reef crests?

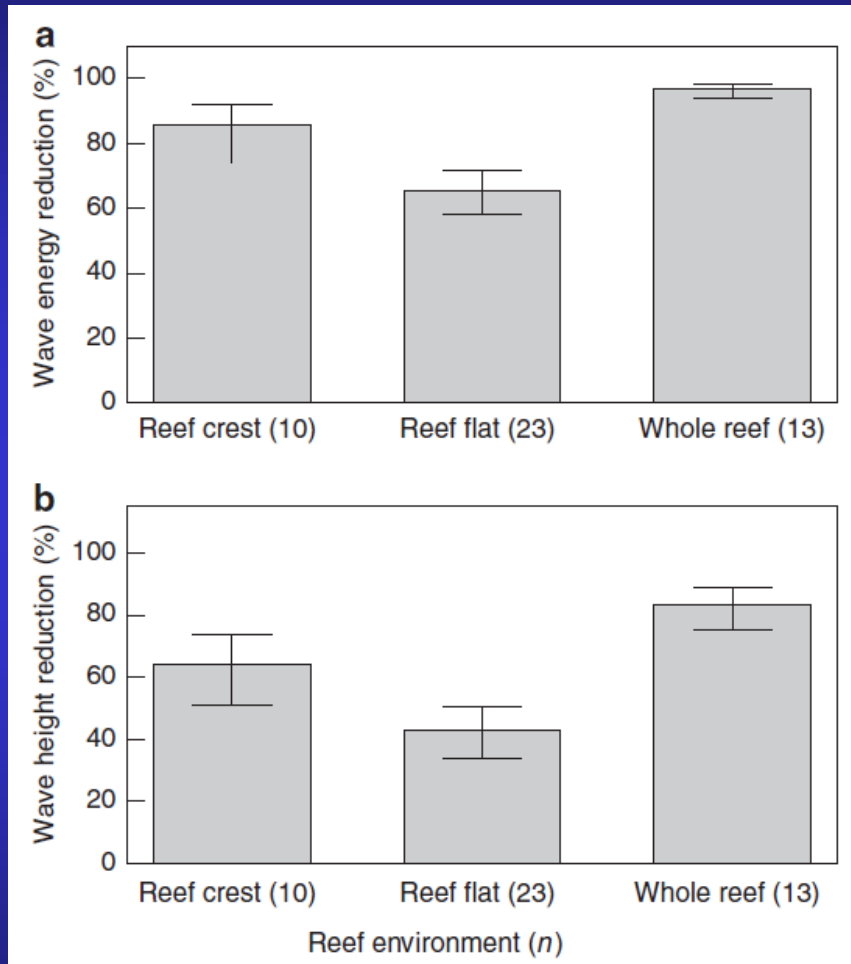
How wide are the reef flats?

How laterally continuous are these reefs?

How far offshore are these reefs?

What is the coral cover?

How about north of the
Fowey Rocks Light?

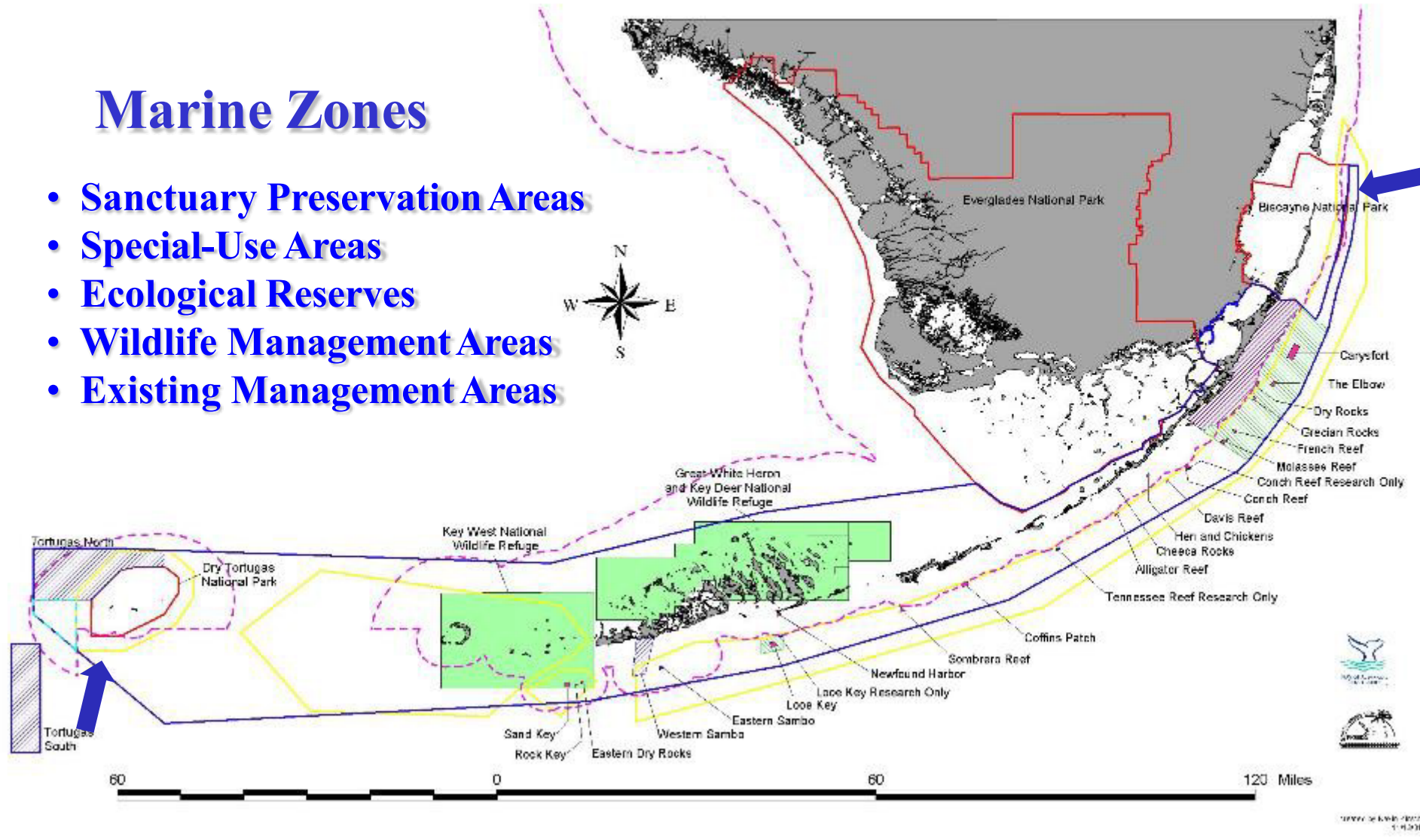


(Ferrario et al. 2014)

Florida Keys National Marine Sanctuary

Marine Zones

- **Sanctuary Preservation Areas**
- **Special-Use Areas**
- **Ecological Reserves**
- **Wildlife Management Areas**
- **Existing Management Areas**



The Florida Reef Tract is discontinuous and extends from the Dry Tortugas to Fowey Rocks

Inimical waters model of Ginsburg & Shinn (1964)

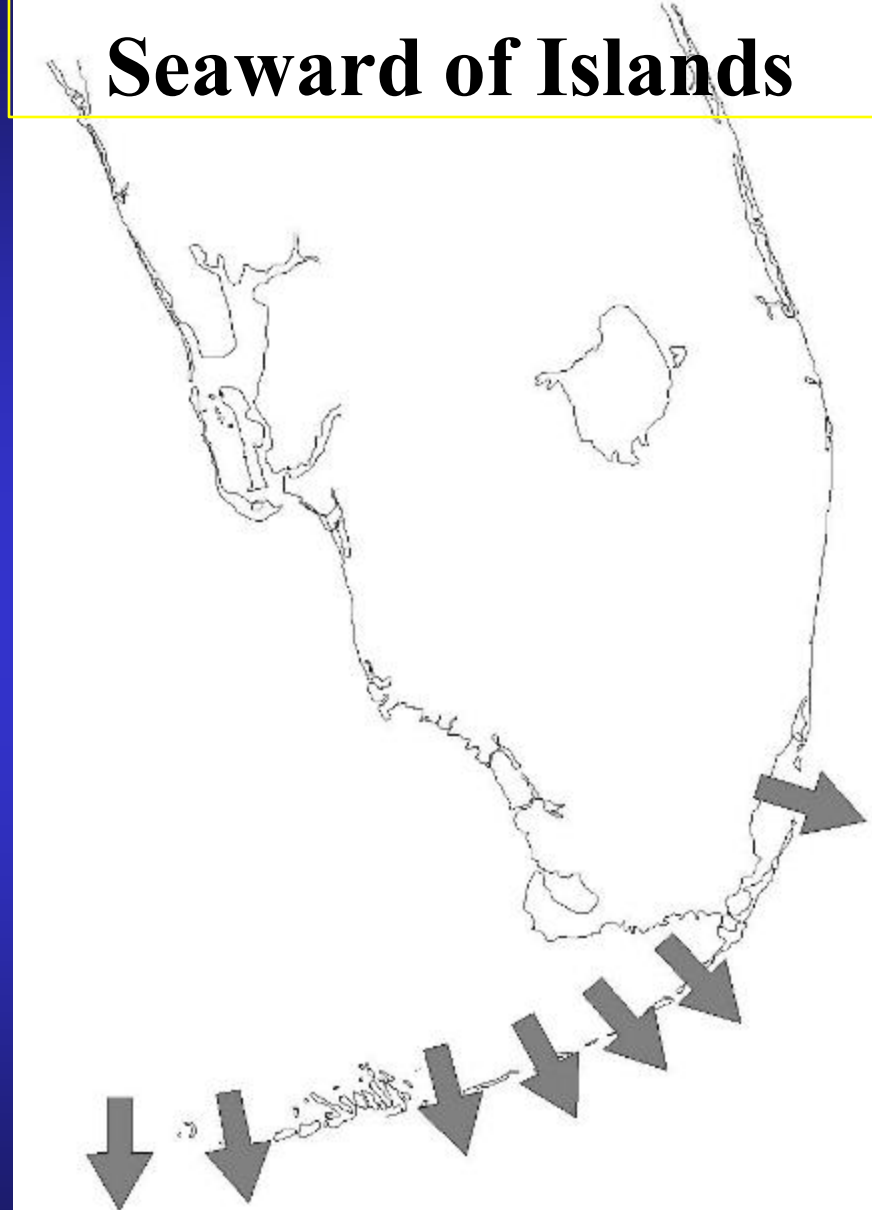
Not a continuous barrier reef.

Only small sections have kept pace with sea level rise through the Holocene and grow to present-day sea level.

“On the basis of their geologic history, the outer reefs are often termed bank reefs (Shinn, 1963) while in their functional aspect they are termed barrier reefs (Ginsburg, 1956). As Ginsburg stated, while they are barrier reefs, they are of little individual extent, have wide, non-reef areas between them and are only somewhat more consolidated within the Sanctuary and northward to Fowey Light.”

(From Voss, 1983)

Named Reefs are Found Seaward of Islands



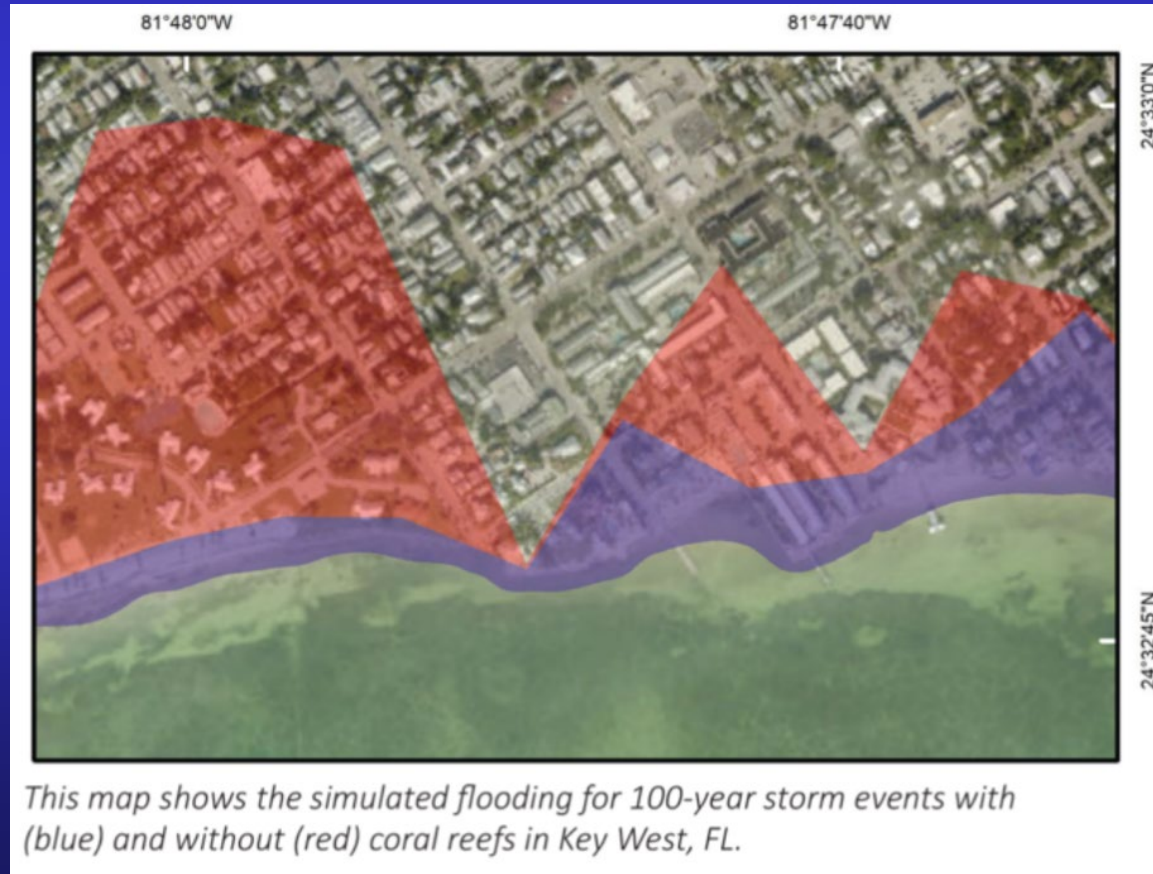
Do the coral communities off Key West provide expected benefits?



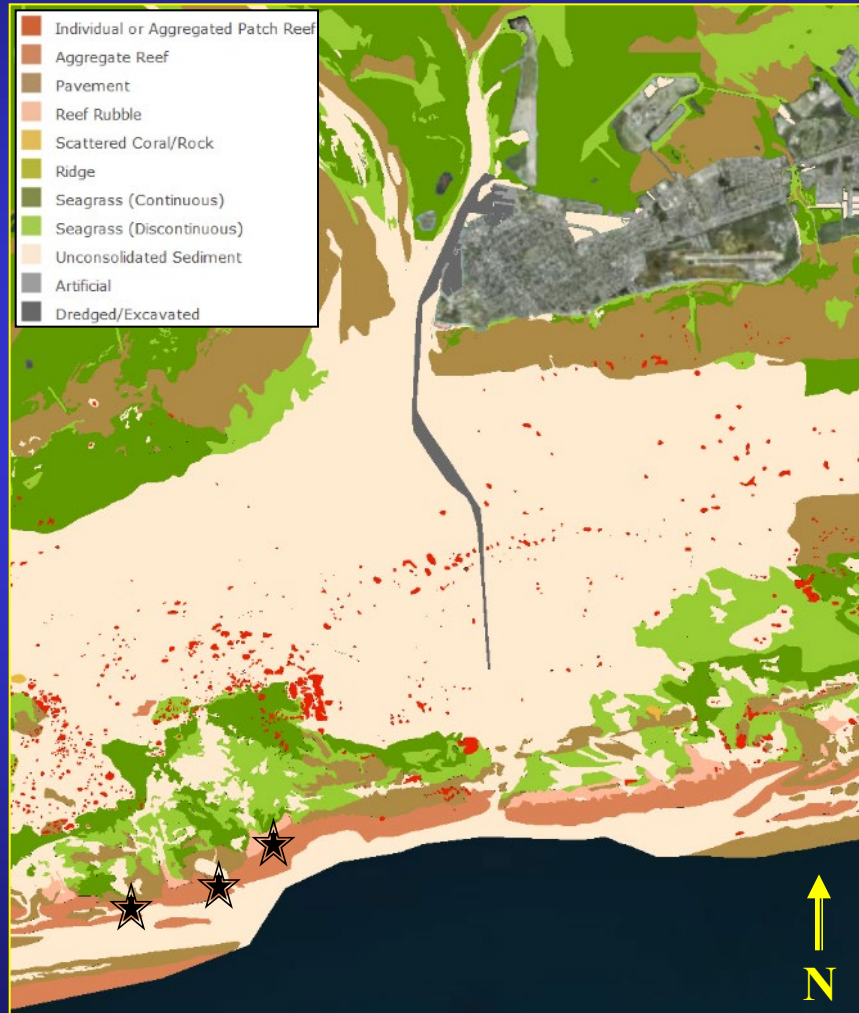
Reguero, B.G., Storlazzi, C.D., Gibbs, A.E., Shope, J.B., Cole, A.D., Cumming, K.A. and Beck, M.W., 2021. The value of US coral reefs for flood risk reduction. *Nature Sustainability*, 4(8), pp.688-698.

The Value of U.S. Coral Reefs for Risk Reduction

FACTS FOR FLORIDA



Reefs off Key West



Wave Shadow - Individual Reefs

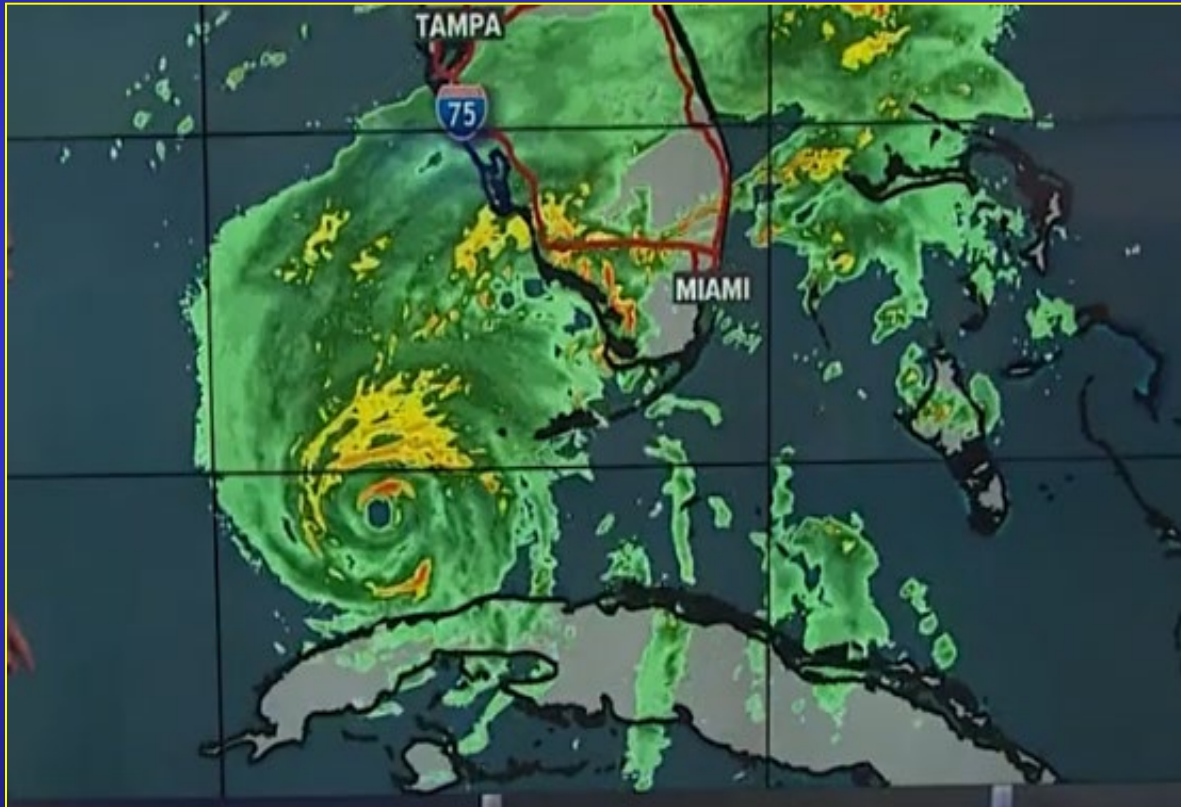


Sand Key



Rock Key

Hurricane Ian – Key West (2022)



Hurricane Ian – Key West (2022)

‘Came through the floor.’ Seawater from Hurricane Ian pours into historic Key West area

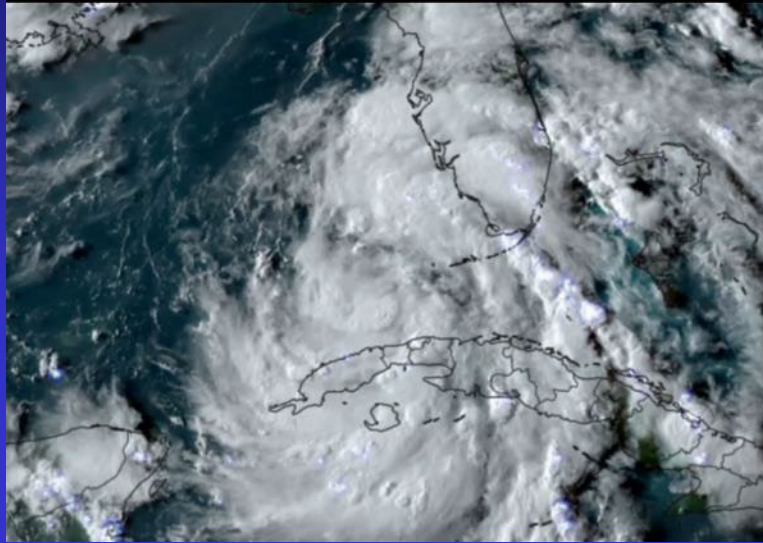
BY DAVID GOODHUE

UPDATED AUGUST 10, 2023 11:01 AM | 



This is what it looked like in Key West with the “with reefs” scenario.

Storm Impacts - Key West (2024)



Hurricane Debby

Hurricane Helene

Hurricane Rafael

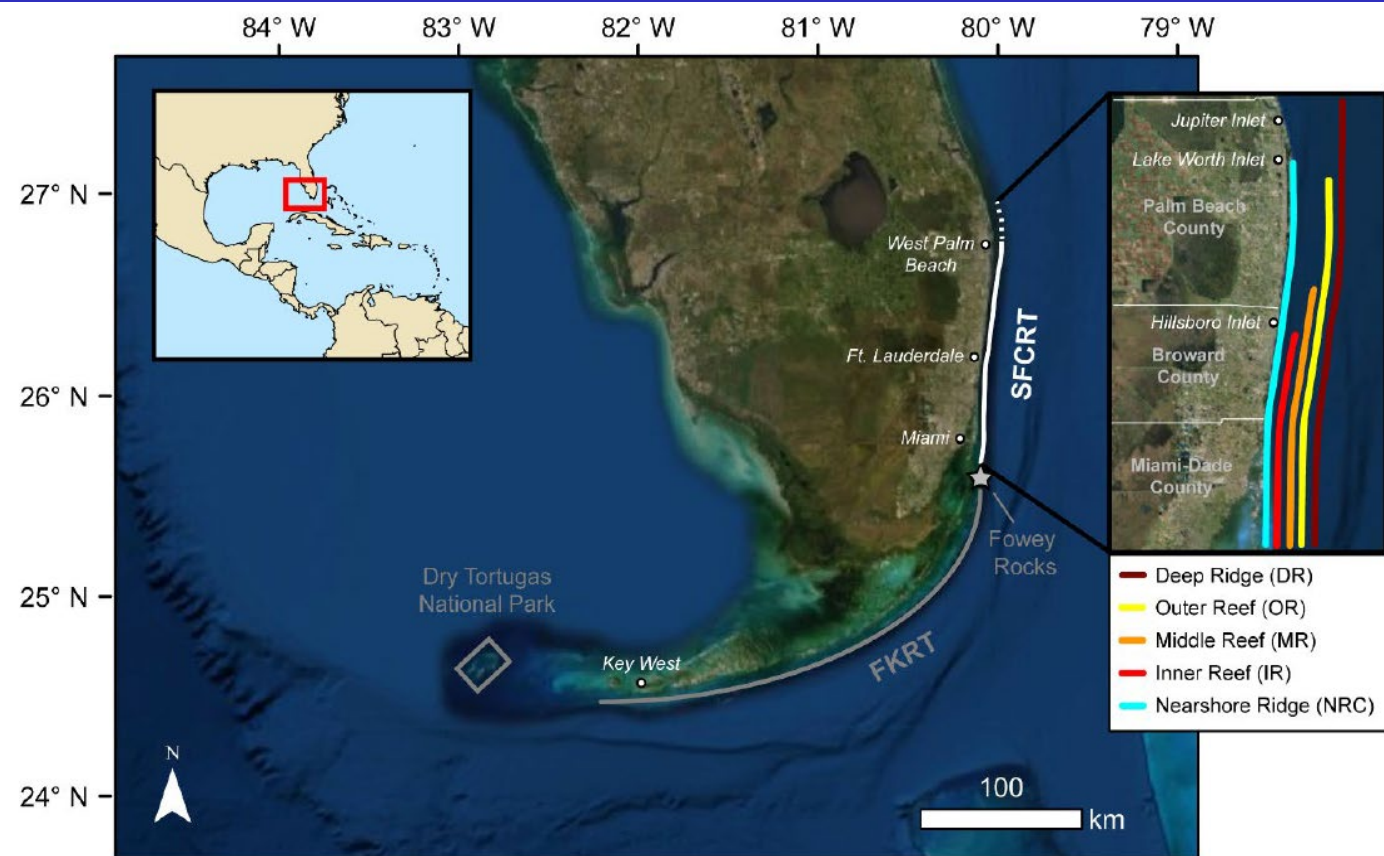
Detail Study Area

- This study was undertaken on the coral reefs in southeastern Florida, which are at the northern extent of reef growth along America.
- Lying off southeast Florida are a series of submerged, shore-parallel, fossil reef terraces. These relict reefs are the remains of a nearly continuous, 150 km long, barrier-reef system that extended northward from Miami to Palm Beach County in the early to middle Holocene.
- The two main terraces are referred to as the inner and outer reefs; closer to shore a fossilized coquina beach deposit is apparent and is known as the nearshore ridge complex.
- Modern-day assemblages of stony corals and octocorals have colonized these relict reefs and nearshore hardbottom structures.
- Coral cover has been low on these features since the middle Holocene.
- Historically, coral cover has routinely been measured at <3%.

OPEN

Climate and the latitudinal limits of subtropical reef development

Lauren T. Toth^{1,2,3}, William F. Precht², Alexander B. Modys³, Anastasios Stathakopoulos¹, Martha L. Robbart^{2,4}, J. Harold Hudson⁵, Anton E. Oleinik³, Bernhard M. Riegl⁶, Eugene A. Shinn⁷ & Richard B. Aronson⁶



How we define a reef is important!



How we define a reef is important!

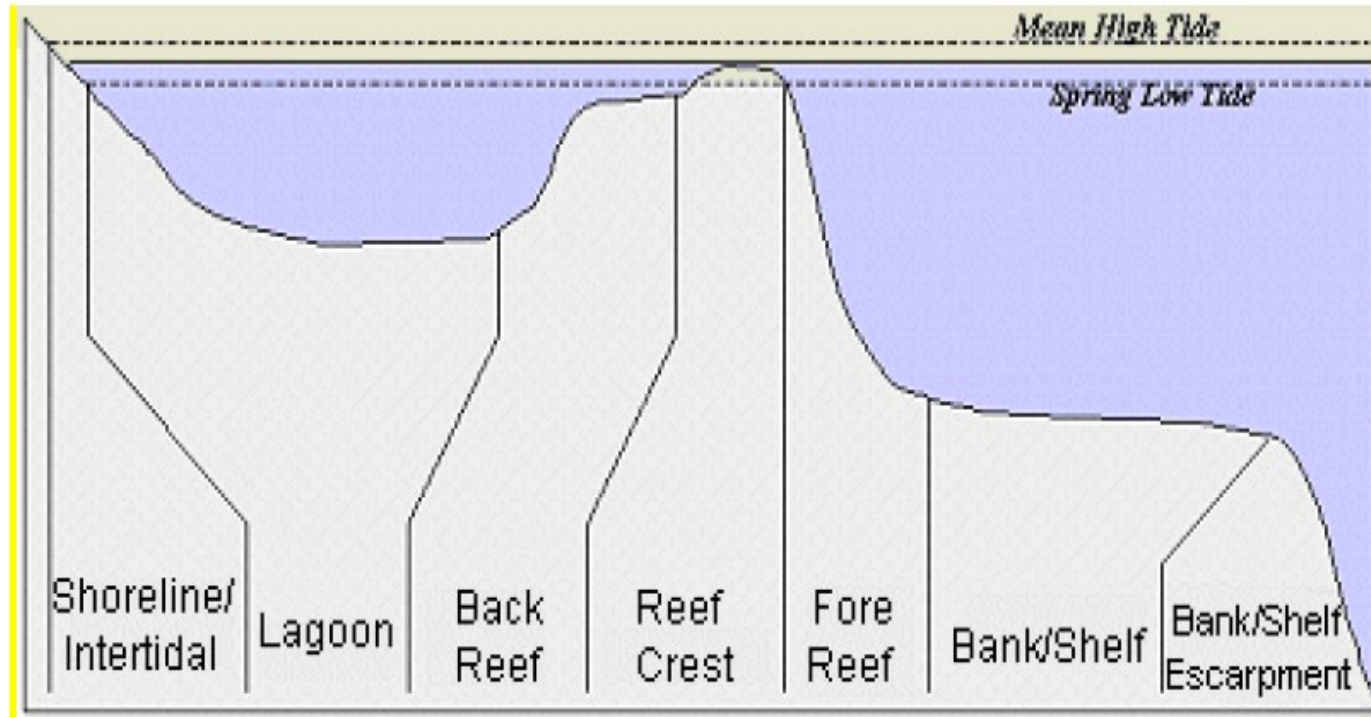


Figure 1. Coral Reef Zones (Graphic courtesy of NOAA NCCOS)

No 'coral reefs' in
southeast Florida look like this graphic.



Coral Reefs are Important: Coastal Protection



Waves break twice on inner reef and nearshore ridge, dissipating much of their destructive energy



Both these wave breaks are in the nearshore ridge complex which are comprised of Pleistocene-age coquina beach ridges. Most shoreline protection in Miami-Dade, Broward, and Palm Beach is provided by these rock ridges. These are NOT coral reefs!



Do the coral communities off SE Florida provide expected benefits?



Reguero, B.G., Storlazzi, C.D., Gibbs, A.E., Shope, J.B., Cole, A.D., Cumming, K.A. and Beck, M.W., 2021. The value of US coral reefs for flood risk reduction. *Nature Sustainability*, 4(8), pp.688-698.

Any \$\$\$ benefits are provided by the nearshore ridge complex and nearshore hardbottom habitats

While they have some living coral on their surfaces these are not coral reefs

Do the coral communities provide
expected benefits?



NO, they do not!

There are no shallow
water reefs
north of
Fowey Rocks

More of the same?

SCIENCE ADVANCES | RESEARCH ARTICLE

15 January 2025

ENVIRONMENTAL STUDIES

Hybrid coral reef restoration can be a cost-effective nature-based solution to provide protection to vulnerable coastal populations

Curt D. Storlazzi^{1*}, Borja G. Reguero², Kristen C. Alkins¹, James B. Shope^{2†},
Camila Gaido-Lassarre², T. Shay Viehman³, Michael W. Beck²

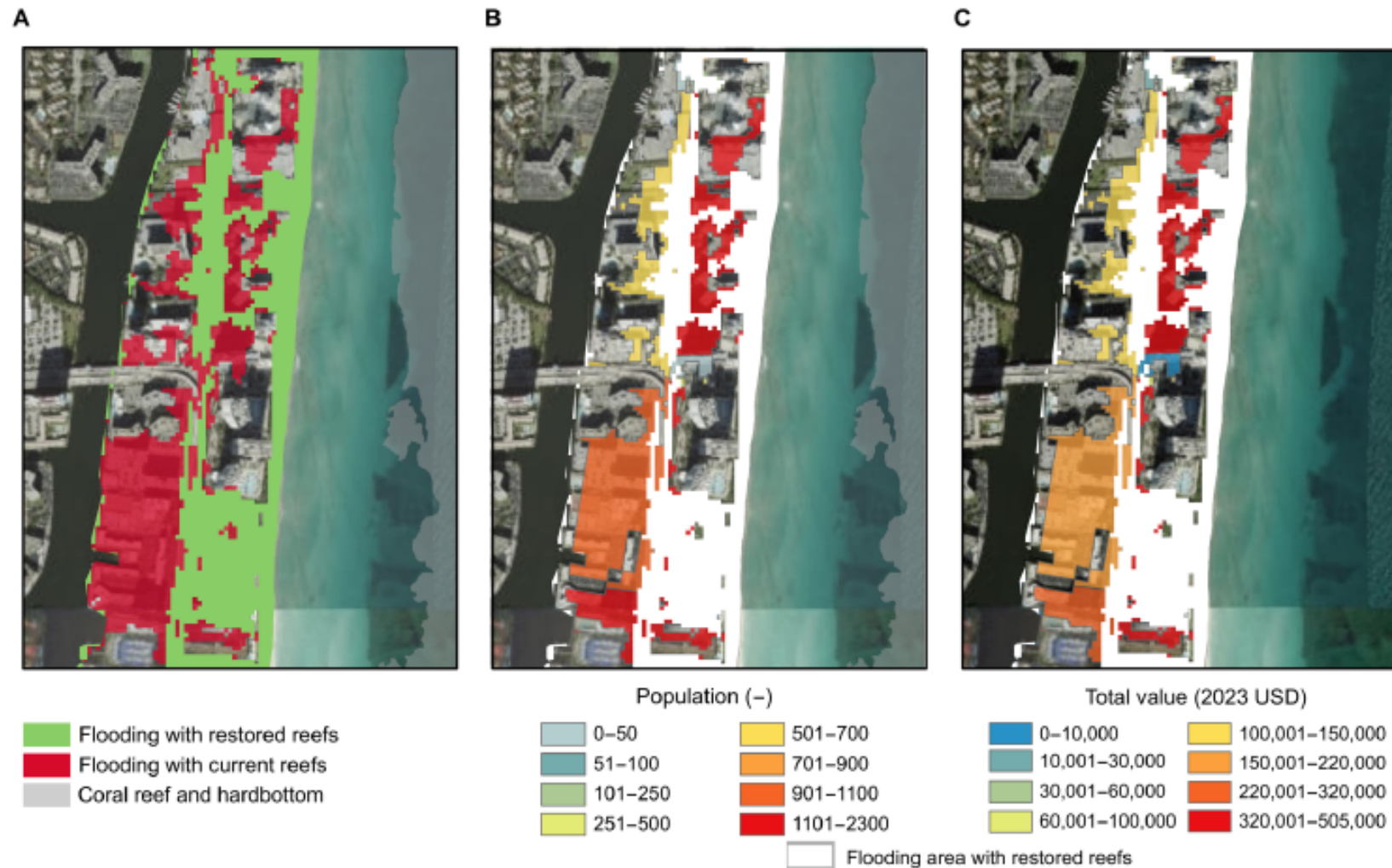


Fig. 1. Example maps of modeled coastal flooding in Miami, Florida, during the 100-year storm with current coral reefs and potentially restored coral reefs. (A) Flood extents with current reefs (red) and restored reefs (green). Thus, the red area denotes the region protected by potential reef restoration. (B) Number of people protected by reef restoration (colors). (C) Total value, in 2023 US dollars, of building damages and economic disruption averted by reef restoration (colors). The storm-induced coastal flooding with restored coral reefs is smaller in area, thus affecting fewer people, buildings, and associated economic activity. USD, US dollars.

Legend

Site Location

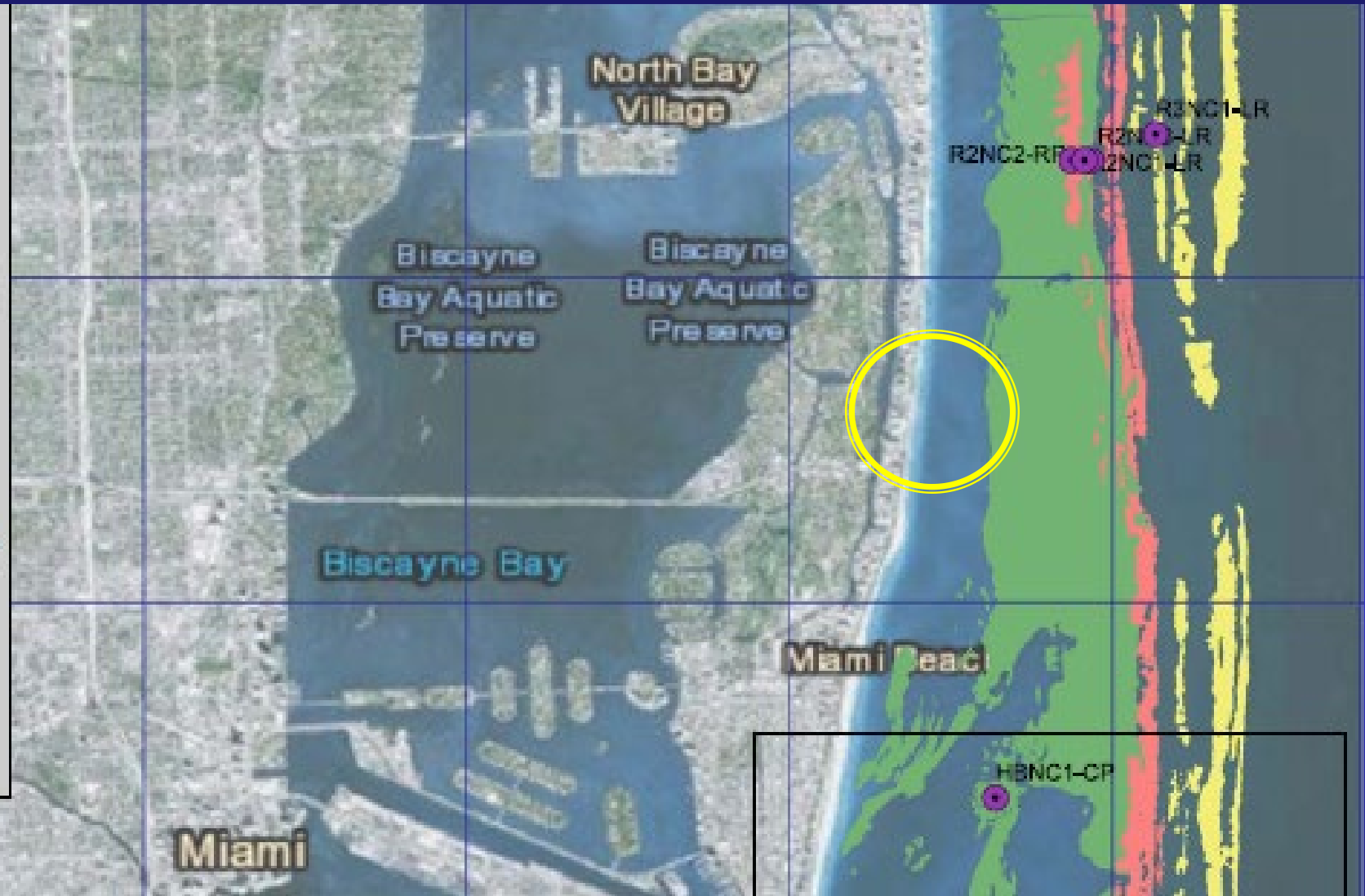
- DCA
- CSI
- ▲ DERM
- NOAA



Reef Habitat

- Nearshore Ridge Complex
- Inner Reef
- Outer Reef

0 1 2 4
Kilometers



Wave Dissipation Analysis – SE Florida

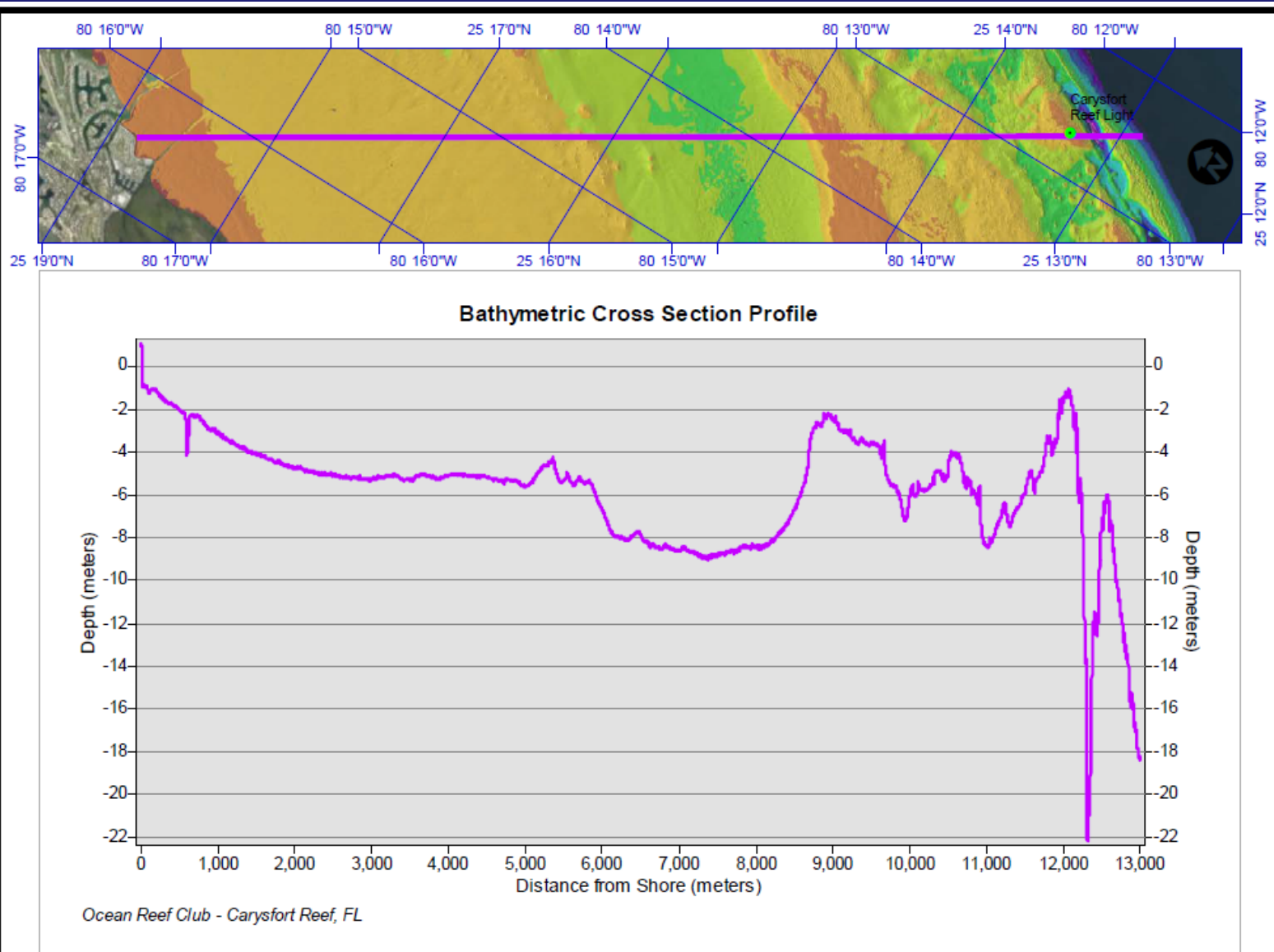
- Wave height and energy dissipation was estimated using XBEACH 1D numerical model.
- Hurricane Irma boundary conditions acquired from NOAA WaveWatch III were propagated along 1D cross-shore transect starting at offshore boundary in 200 meters water depths.
- Profile transects were acquired from NOAA NCEI 1/9th arc second and 1/3rd arc second digital elevation models.
- XBEACH numerical model was run for 3600 seconds in one-dimensional hydrostatic mode
- Spatially varying wave and current friction coefficients were applied to each transect based on habitat data.
- Friction coefficients used were from Storlazzi et al. (2012).
- Reef habitat was simulated over 100-m cross sectional sections at the reef crests of each transect.
- Elevation was added to coral coverage areas based on coral cover.

Best developed “modern” coral reef along the Florida reef tract



Even Carysfort Reef is small when compared
with proto-typical barrier reefs

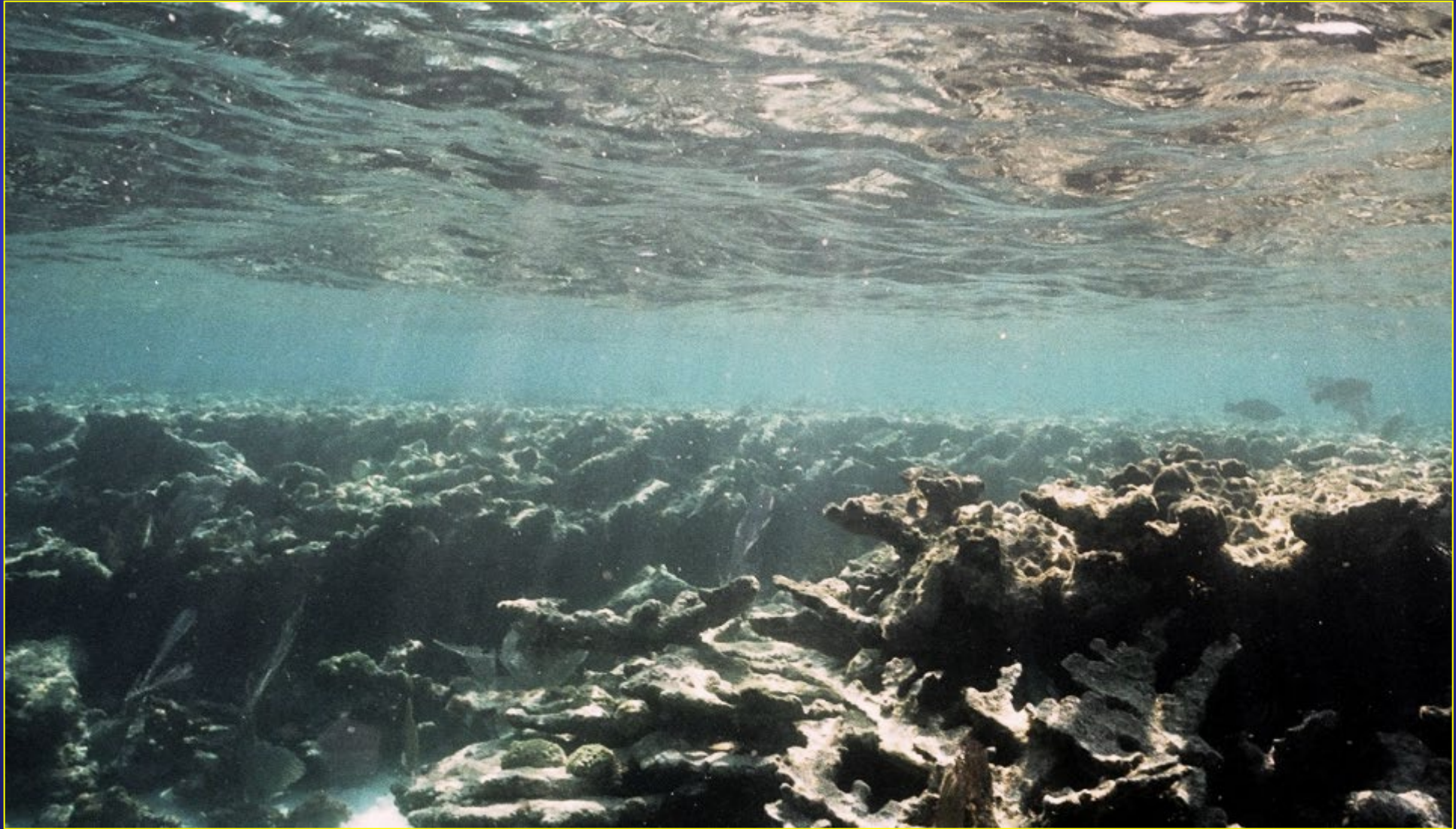
Carysfort Reef



Dead in-situ *Acropora palmata* at the seaward edge of the reef crest, Carysfort Reef



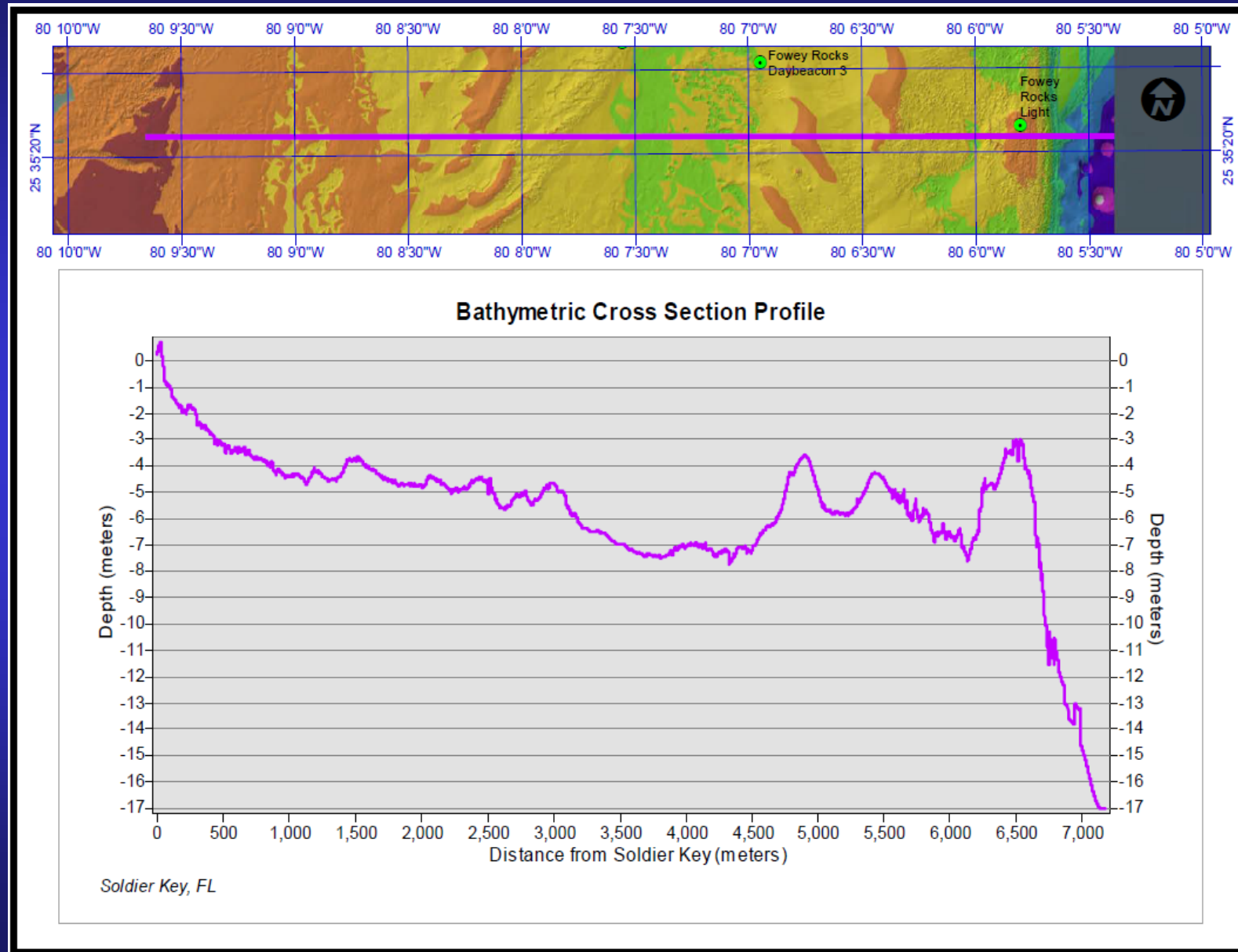
Dead in-situ *Acropora palmata* on the reef crest



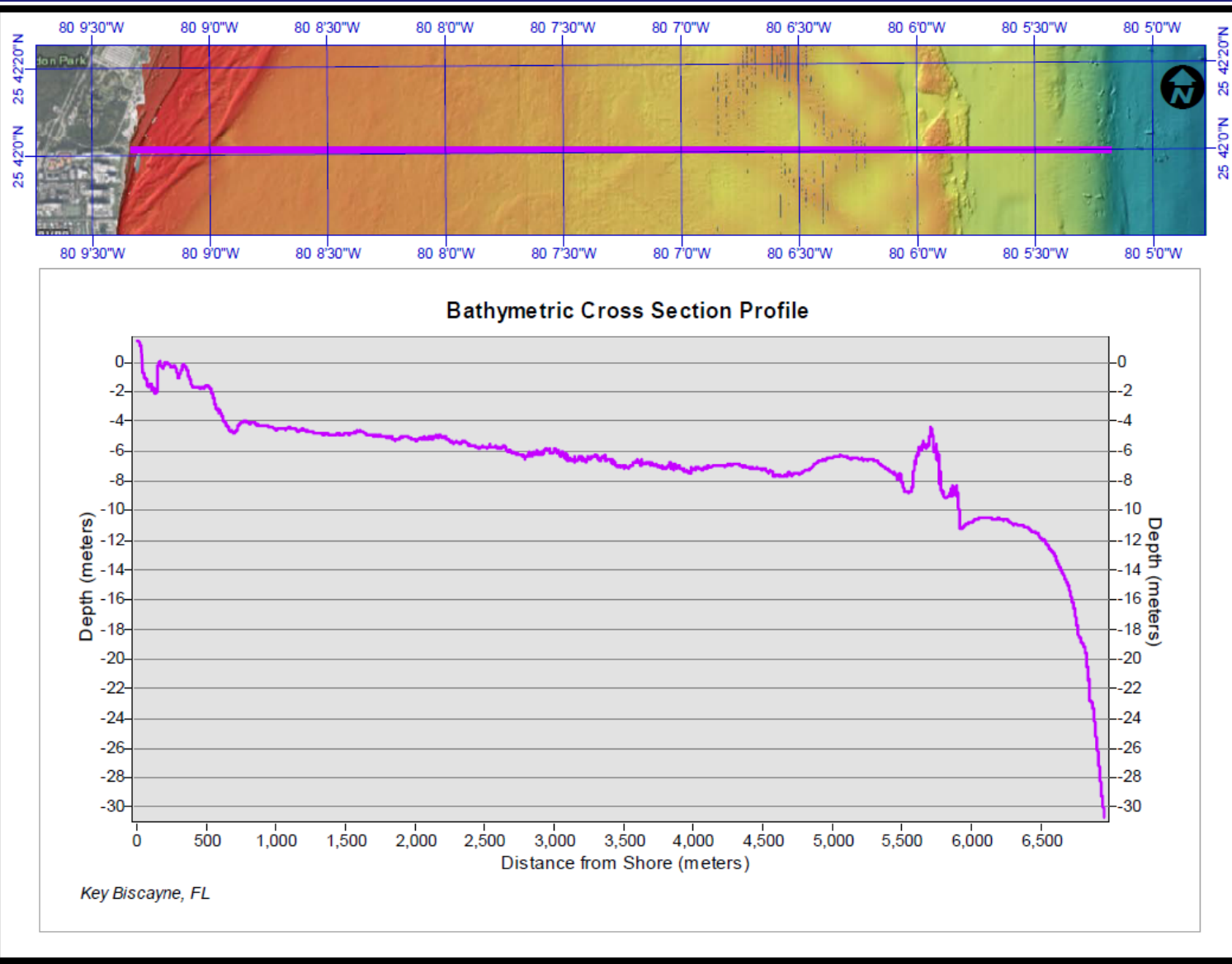
Acropora palmata rubble on the reef flat



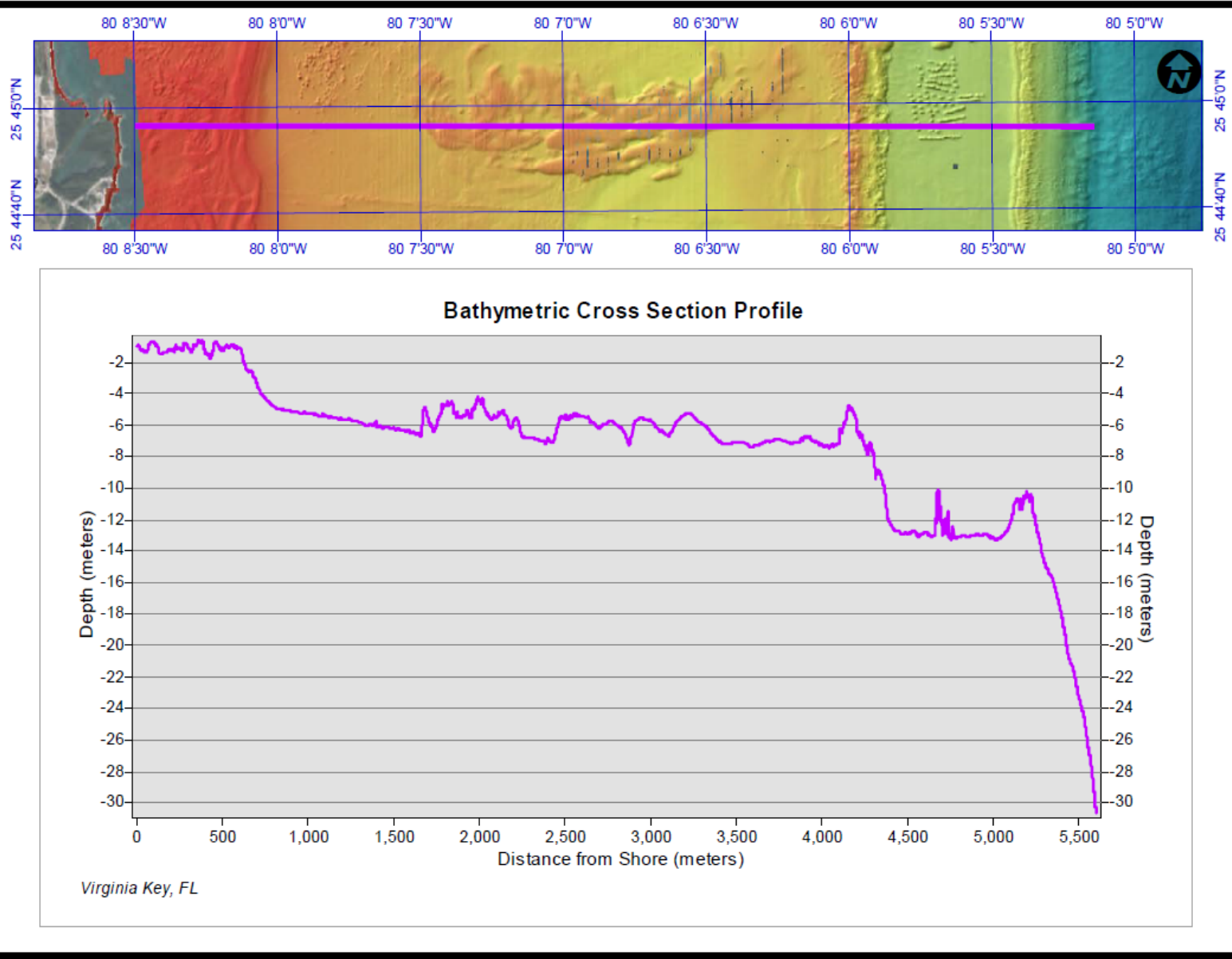
Soldier Key – Fowey Rocks



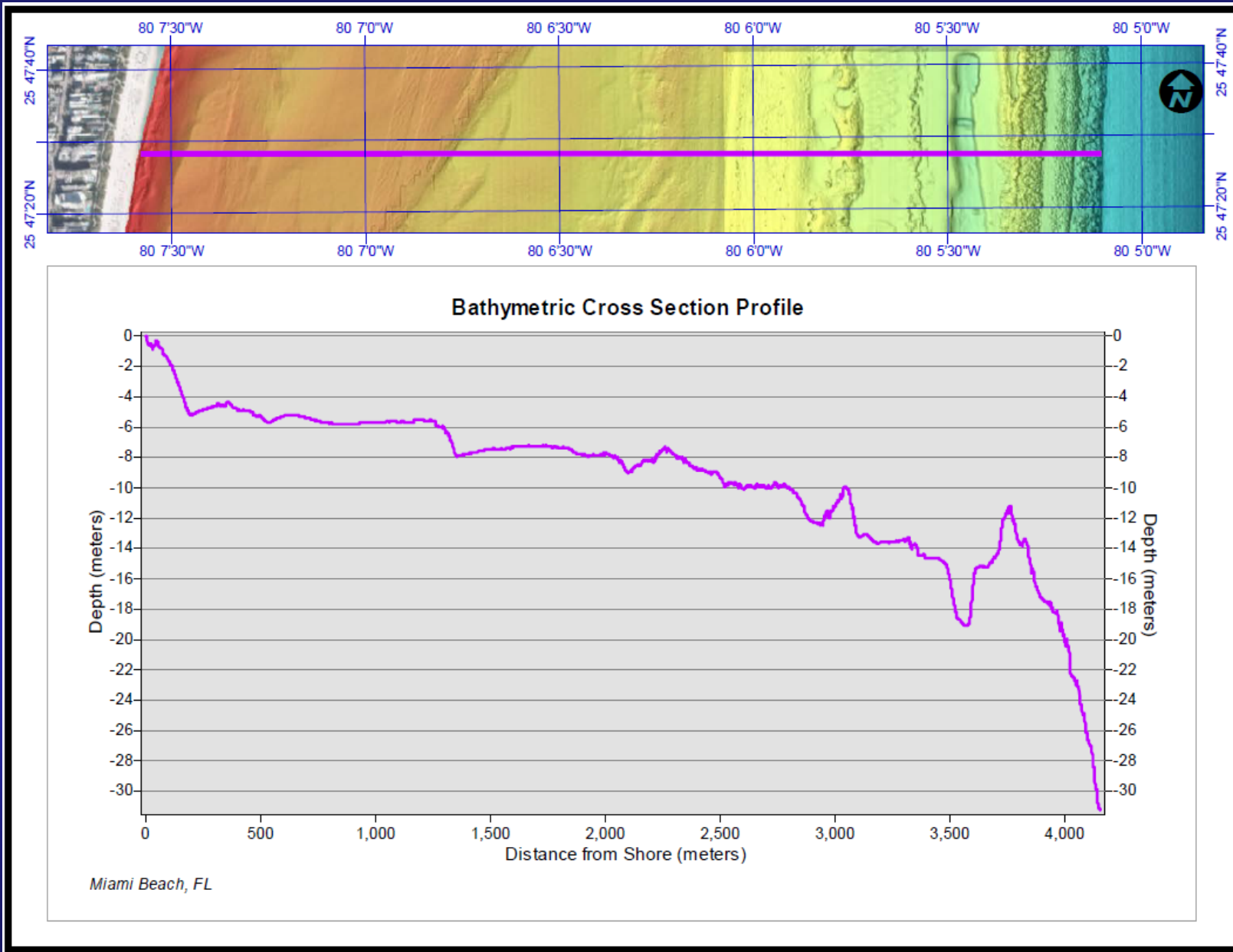
Key Biscayne



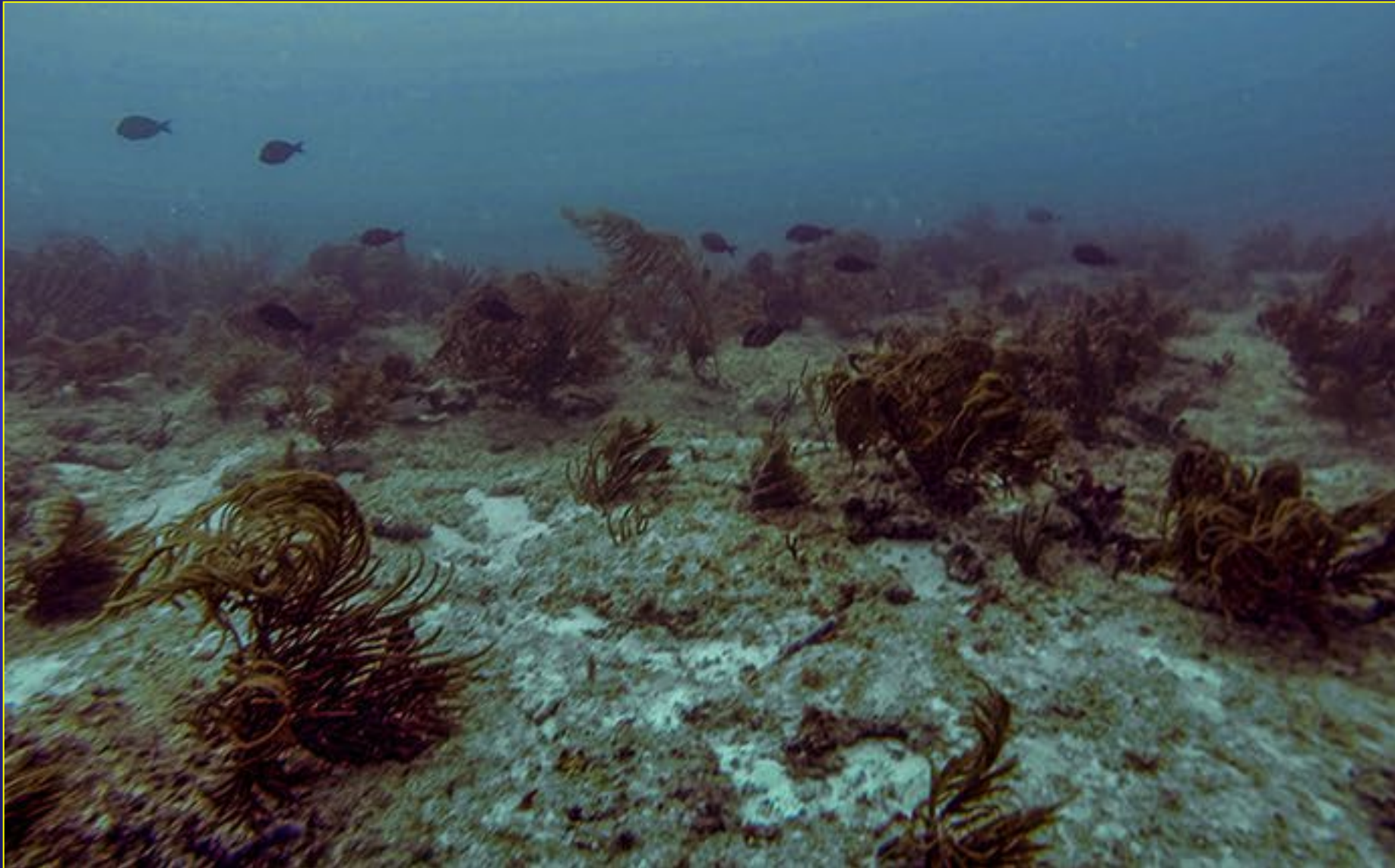
Virginia Key



Miami Beach

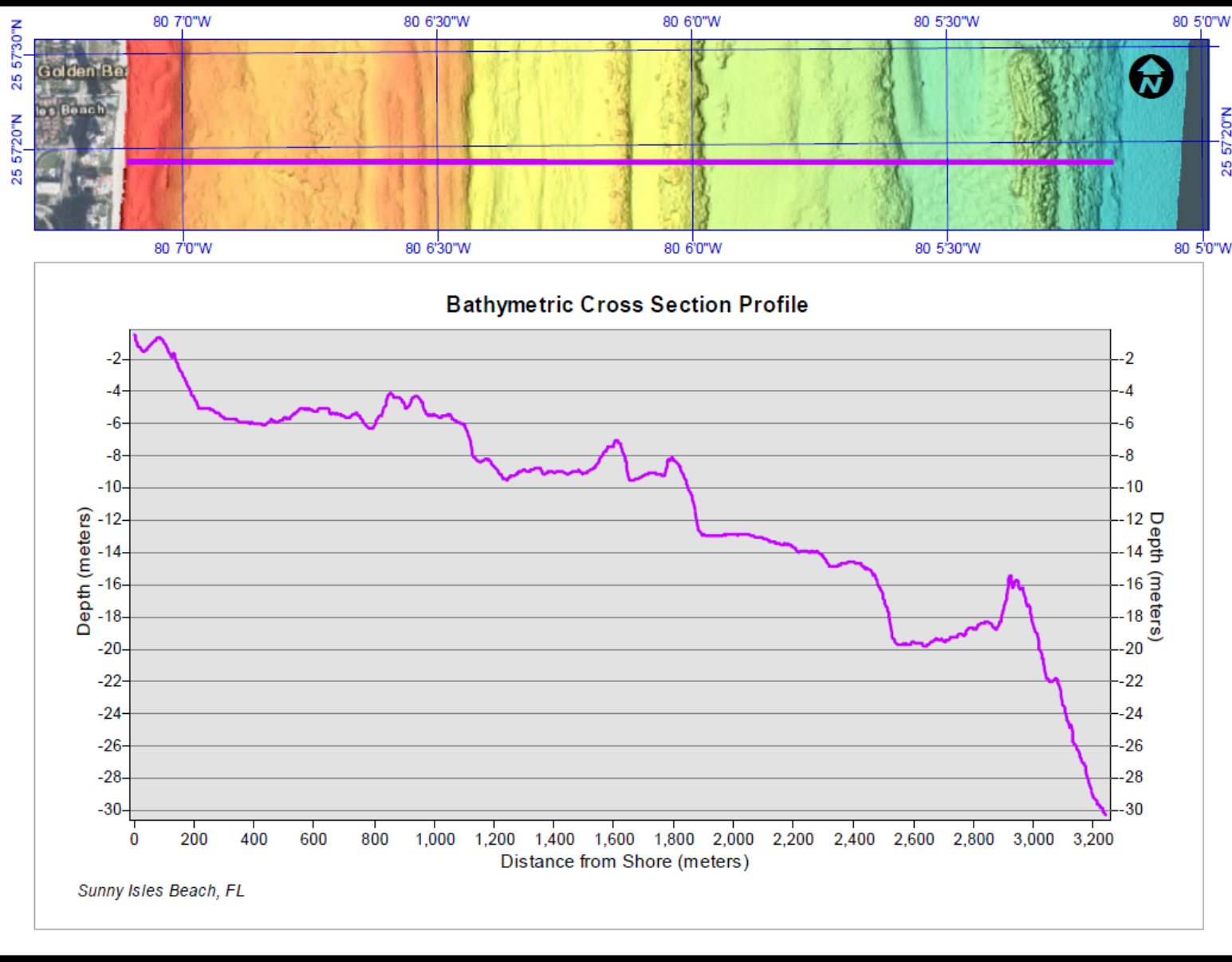


Outer reef off Miami Beach

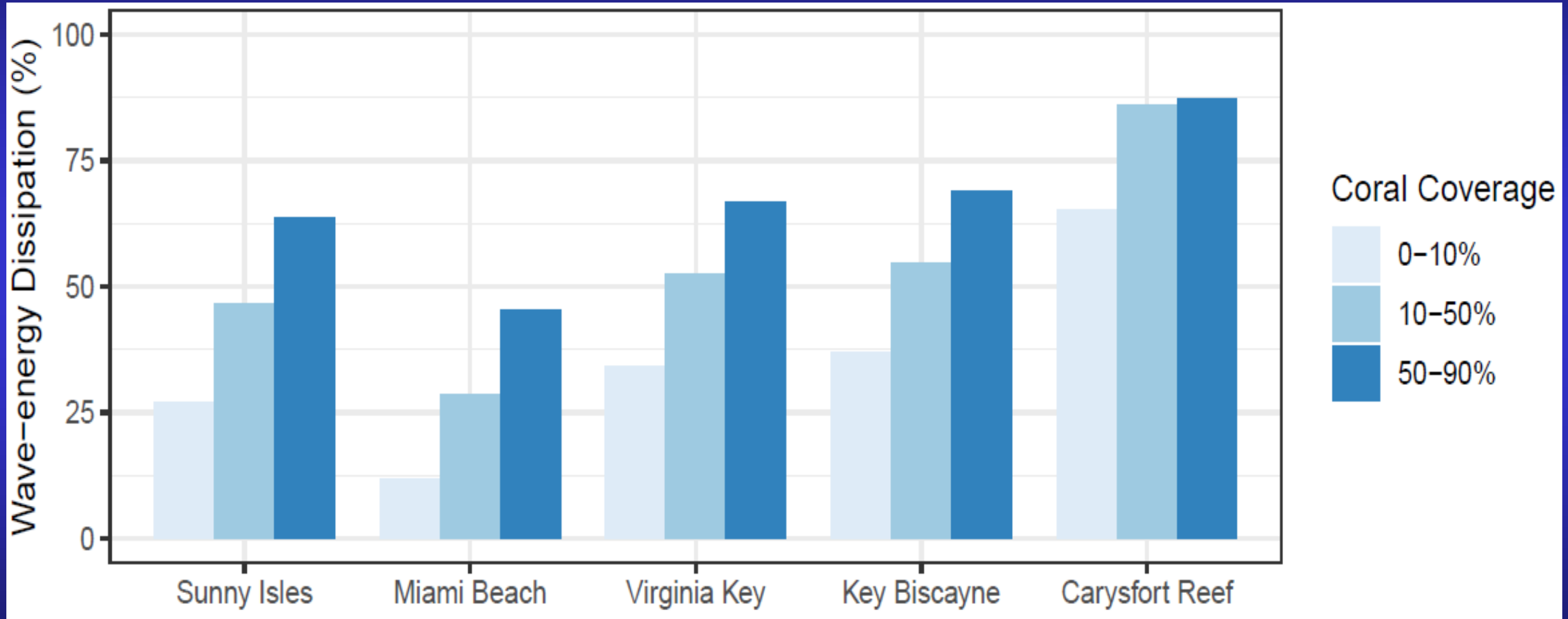


- Depth ~11 meters
- Coral cover < 1%
- Low-relief colonized pavement

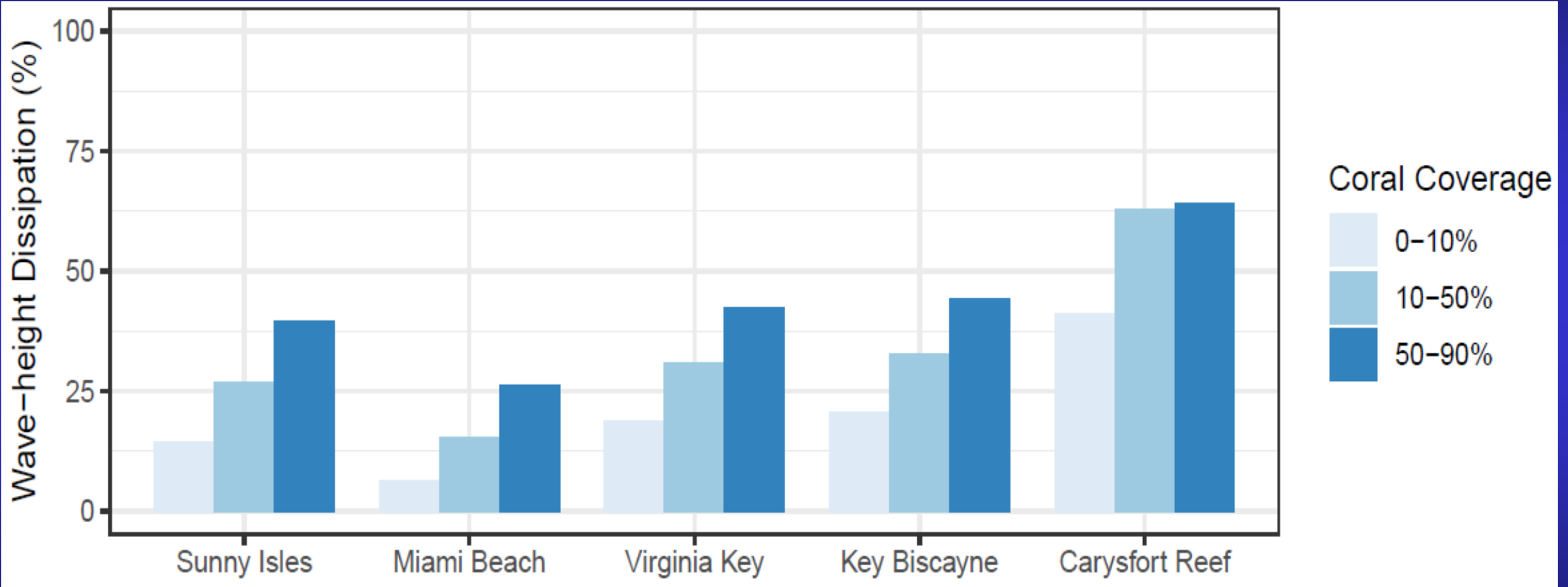
Sunny Isles



Wave Energy Reduction



Wave Height Reduction



Florida's Reefs Do NOT Provide the Energy Diminution Services as Purported

- Why is this important?
 - Science actually matters
 - Actual site conditions should guide restoration/coastal resilience options
 - Failure to understand these basic principles has led to overpromising and ultimately underperforming restoration project goals

Punchline to the Story



Sept. 10, 2017

Large waves produced by Hurricane Irma crash into the end of a pier Sunday in Fort Lauderdale, Fla. At the same time this photo was being taken, the hurricane was making landfall in the Florida Keys as a Category 4 storm.

Chip Somodevilla/Getty Images

From a wave attenuation point of view –
coral reefs in Florida aren't what they are
cracked up to be.