# ARTIFICIAL REEFS

# A POTENTIAL NATURE-BASED SOLUTION TO PROTECT THE RI SHORELINE FROM EROSION

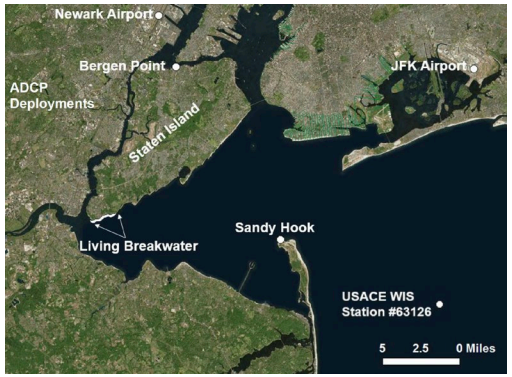
Annette Grilli & Stephan Grilli

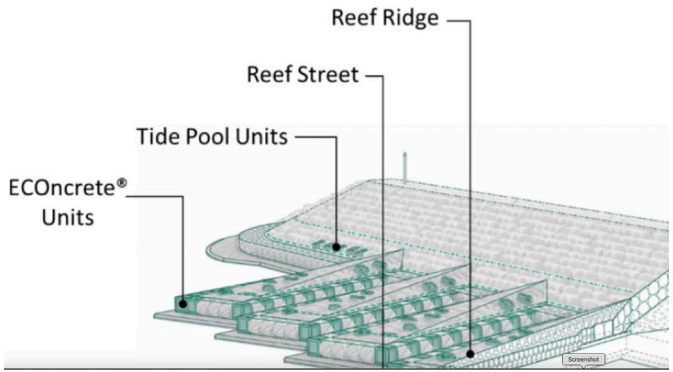
Elin Schuh, and many others

March 4, 2025

# BACKGROUND

- *Artificial Reefs/submerged-detached breakwaters* have been successfully implemented worldwide to protect eroding shorelines, including in the US, sometimes in combination with beach renourishment ("*perched beaches*")
- See, e.g., New York "*Living Breakwaters Project*" (design/implementation, 2019-2024)



# SUCCESS STORIES

- Rome-Ostia : perched beach since 1990 [Ferrante et al., 1993]
  *"Beach stabilized for 3 decades"*
- Pellestrina-Venice: perched beach since 1995 [Bellotti, Franco, diRisio,1999]
  *"Beach stabilized for 3 decades"*
- Gold Coast, Australia: Artificial Reefs [Tuner, 2002, 2006]: *+20 m beach width attributed to reef between 2002-2003.*
- Barbados: submerged breakwater [Agardi, ICCE 2022] *"Grey becomes Green in the Blue"*

## References


Agardi, T., 2022. Gray leads to green in the blue: building infrastructure to enhance c habitat. Conference Coastal Engineering, Sidney, December 2022

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Reguero et al. ,2024. Reefense: REEFS: hybrid biological and engineered reef structure Nature-based Coastal Defense. ICCE2024, September 2024 Rome, IT.

Turner, I.L., 2006. Discriminating modes of shoreline response to offshore structures. *Journal of waterway, port, coastal, and ocean engineering*, *132*(1), pp. 1-8.

Schuh, E., Grilli, A.R., Grilli, S.T., Crowley, D., Stempel, P., 2023. Assessing the morphodynamic response of a New England barrier system to an artificial reef. *Coastal Engineering*, *184*, p. 104355.

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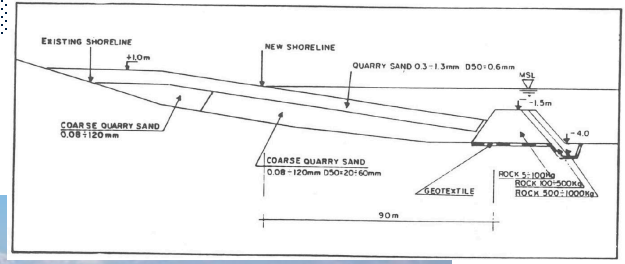


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**Perched beach:** 3 km submerged detached reef with -1.5 m on depth of 4 m with 1.3 Mm$^3$ sand nourishment from land quarry; no groins, $H_s$=4.m (1 year), Tide 0.4 m

"Required only occasional minor maintenance" [Franco, 2/26/2025]

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**Perched beach** : partly submerged groynes and parallel submerged barrier along 20 km shore with 4 $Mm^3$ sand nourishment from offshore, barrier crest at -1.0 m $H_s$ = 3.5 m (1 year), Tide 1 m

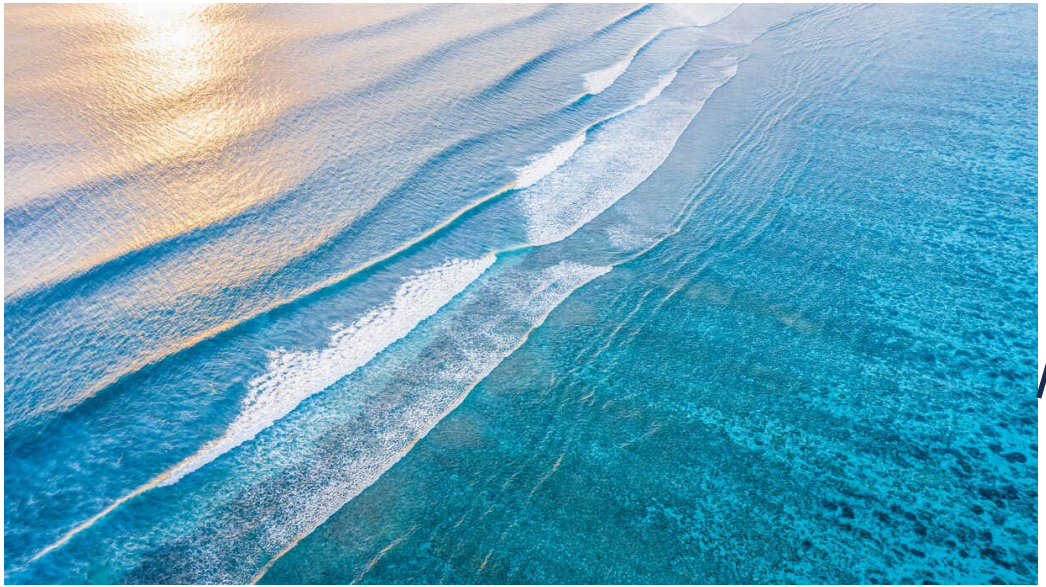
"Losses < 10%!" [Franco 2/26/2025]

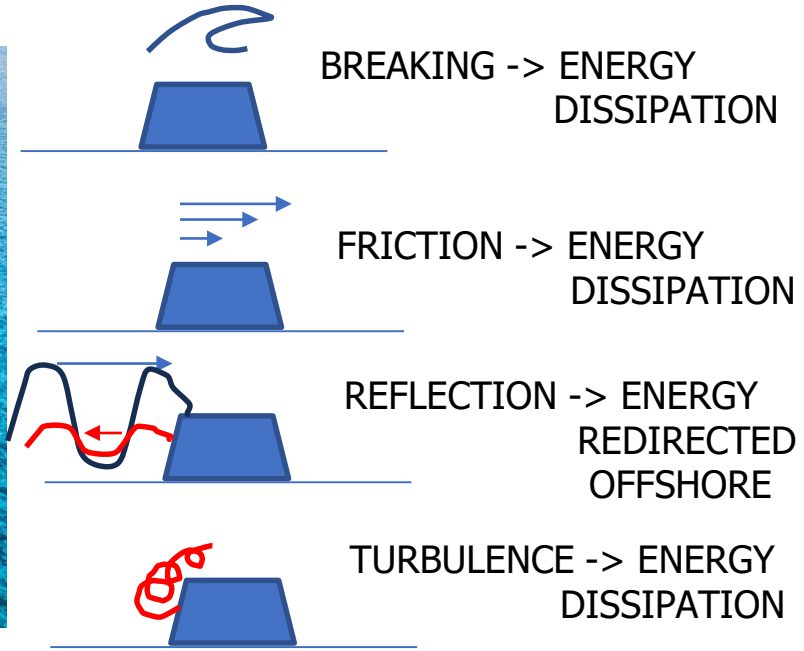
# VALUING REEFS IN COASTAL RISK REDUCTION

- BENEFIT PROVIDED BY REEFS IN THE US (PER YEAR) : 1.8 B$
- HAWAII & FLORIDA: 10 M$/KM

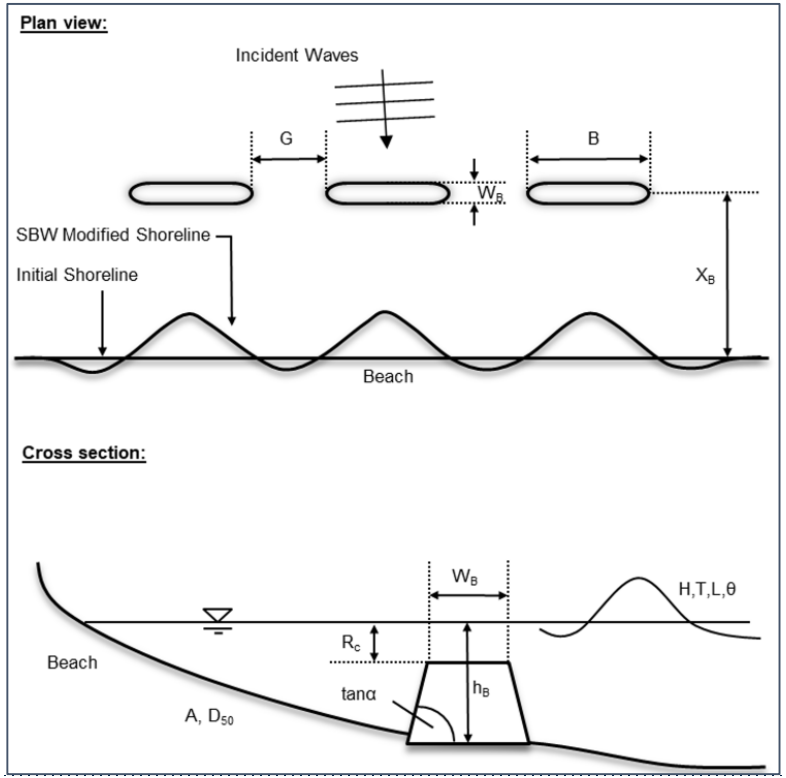
[Reguero, Beck, et al., 2021. The value of US coral reefs for flood risk reduction. *Nature Sustainability.*]

# HOW IS A REEF PROTECTING THE SHORELINE?





# ARTIFICIAL REEFS (AR) – HOW DO THEY WORK?




An AR

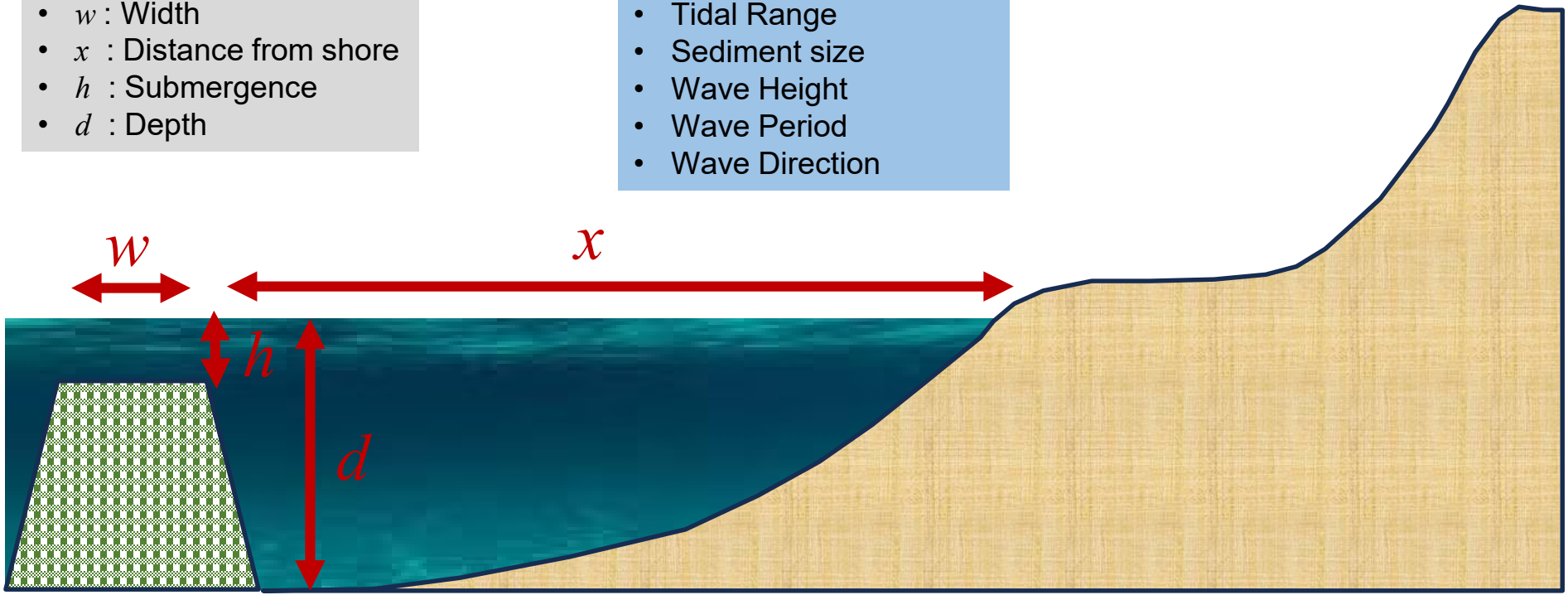
*'Entails using a little finesse to control rather than resist wave activity"*

Ahrens and Cox (1990)

# UNCERTAINTIES AND SITE-SPECIFIC PARAMETERS

- $w$ : Width
- $x$ : Distance from shore
- $h$ : Submergence
- $d$ : Depth

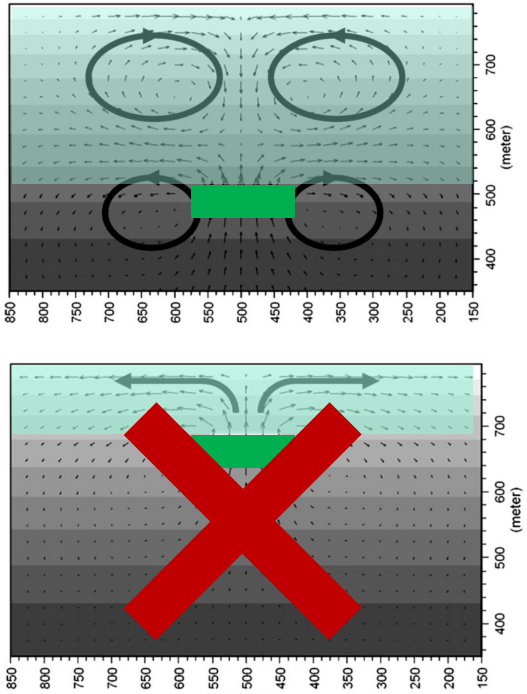
- Tidal Range
- Sediment size
- Wave Height
- Wave Period
- Wave Direction



# CURRENT NATURE-BASED SOLUTION PROJECTS AT URI

- NOAA: *Modeling, visualizing, and communicating nor'easter and hurricane threats with s*
  *support coastal management within New England*" (2021-2025)
  TEAM: Ginis, Grilli. A., Grilli S., Walsh, Stemple*, Rubinoff , Damon, Duhaime [URI, *Pen
  and National Park partners [Babson, Lafrance, Smith] + students
- NOAA: "*Quantification and optimization of nature-based solutions for mitigating coastal*
  *vulnerability and risk*" (2023-2025)
  TEAM: Ginis, Grilli A., Grilli S., Walsh, Stemple*, Rubinoff , Damon, Duhaime [URI, *Pen S
  students
- SEAGRANT: "*Combining monitoring and numerical simulations of NNB solutions to coastal*
  *erosion: Block Island, a numerical test site*" (2024-2026)
  TEAM : Grilli A., Grilli S., Oakley, Damon, Baxter, Spaulding [URI, Eastern
  Connecticut State University]

# FINESSE ?




PROTECT SHORELINE FROM WAVE ACTION

Energy transmitted 10-20% incident energy

PREVENT EROSIVE CURRENTS ALONG SHORELINE

# MORPHOLOGICAL RESPONSE OF THE RI SHORELINE TO AN ARTIFICIAL REEF

Coastal Engineering 184 (2023) 104355

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Assessing the morphodynamic response of a New England beach-barrier system to an artificial reef

Elin Schuh [a], Annette R. Grilli [a,*], Felix Groetsch [a], Stephan T. Grilli [a], Deborah Crowley [b], Isaac Ginis [b], Peter Stempel [c]

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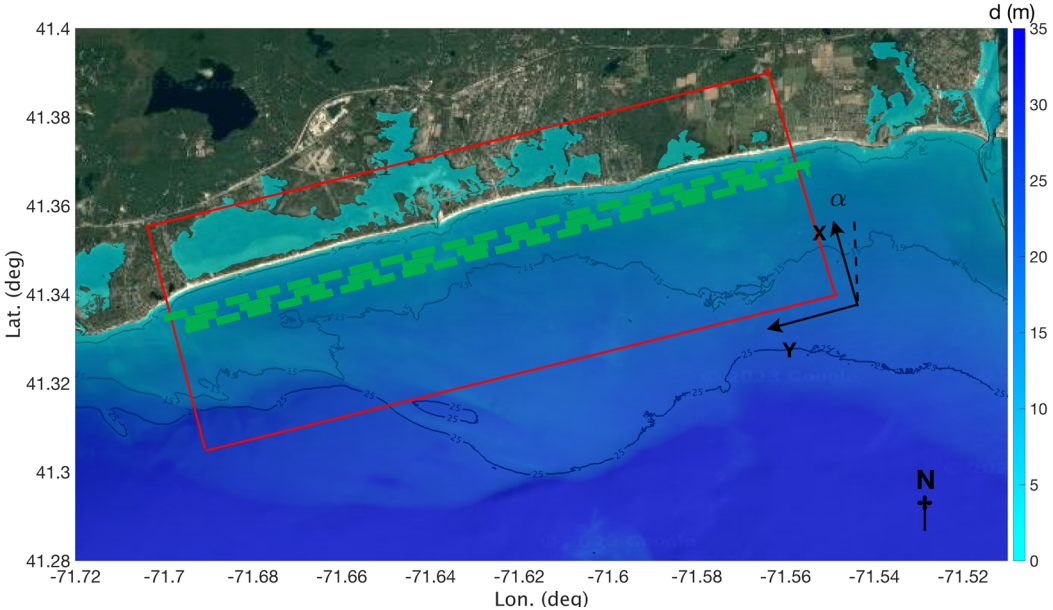
[Schuh et al, 2023]

- Designed 9 *reef concepts* based on Ranasinghe's methodology [Ranasinghe, 2010
- *Concept*: "optimal design based on local wave climate"
- Numerical simulations along *RI's South Shore*

# COMPUTATIONAL DOMAIN AND REEF CONCEPTS




- DISTANCE TO SHORELINE:
  $x$ = 300 to 500 m

- SPACING BETWEEN SEGMENTS:
  $G$ = 40 to 80 m

- SEGMENT LENGTH:
  $B$ = 100 m

"*Modeling, Visualizing, and Communicating Nor'easter and Hurricane Threats with Sea-level Rise to Support Coastal Management within New England*"
Team: Ginis, Grilli & Grilli, Crowley, Walsh, Stempel, Rubinoff, Duhaime, Damon, Babson,Lafrance

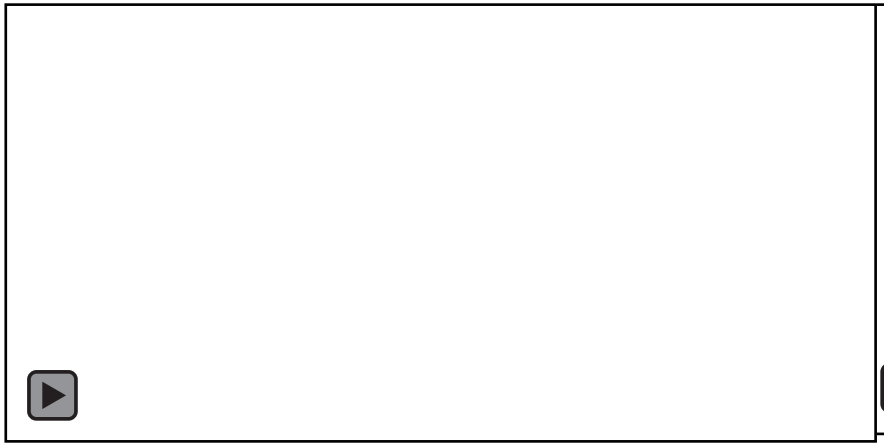
# SIMULATED CURRENTS - SANDY-like STORM

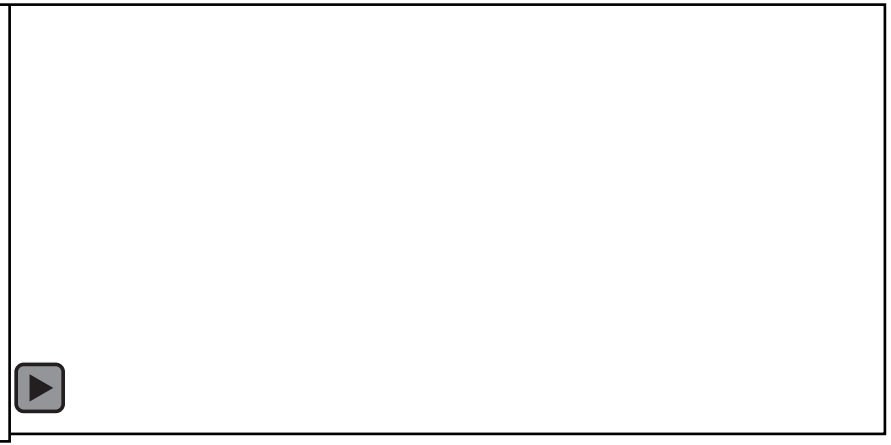
NO REEF

REEF

SANDY NO SLR

# MORPHOLOGICAL CHANGES – SANDY-like STORM





# KEY IMPACTS ON THE SHORELINE

## STORM EVENTS

- All reef concepts show a *reduced beach erosion*
- Reef concepts *sited further away* from shore are *more efficient* in controlling beach erosion

## CALM WEATHER

- *Gaps* between reef segments control erosion/accretion
- *Small gap* concepts enhance sand deposition along the shoreline
- *Large gap* concepts [80 m] might enhance local erosion

# MORPHOLOGICAL RESPONSE TO EXTREME EVENT

- EXAMPLE:
  Charlestown Breachway/
  Beach access road,

  12/23/22 Nor'easter

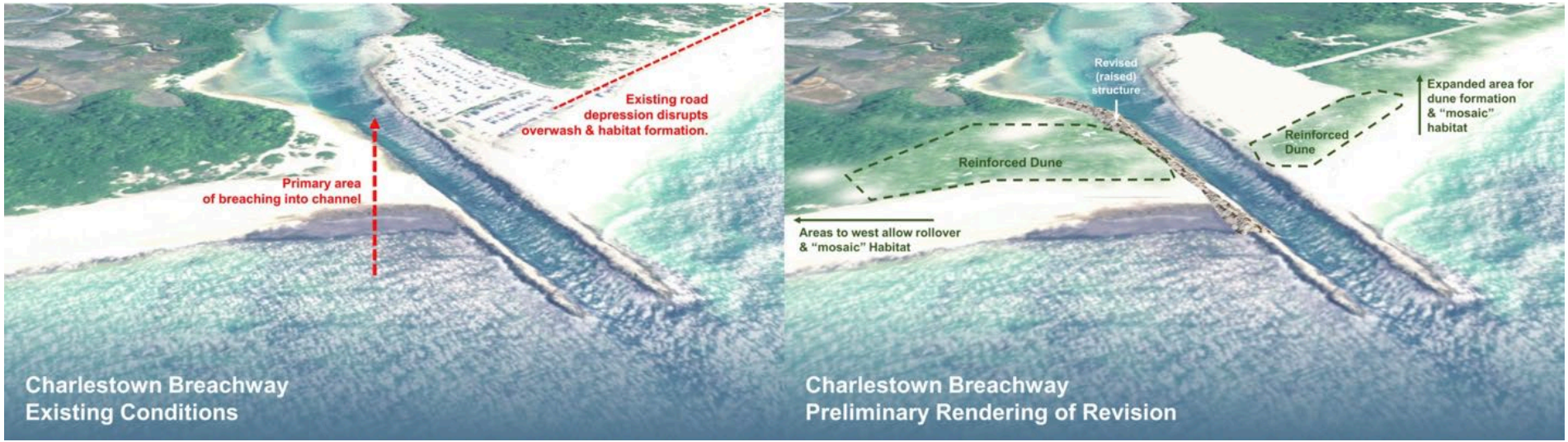
# MORPHOLOGICAL RESPONSE TO EXTREME EVENT

12/23/22 Nor'Easter [Pictures, JP WALSH]

# MORPHOLOGICAL RESPONSE TO EXTREME EVENT

## STUDY OF THE CHARLESTOWN BREACHWAY AREA TO IMPROVE ITS RESILIENC

"Quantification and optimization-Based Nature solutions for mitigating coastal vulnerability and risk"





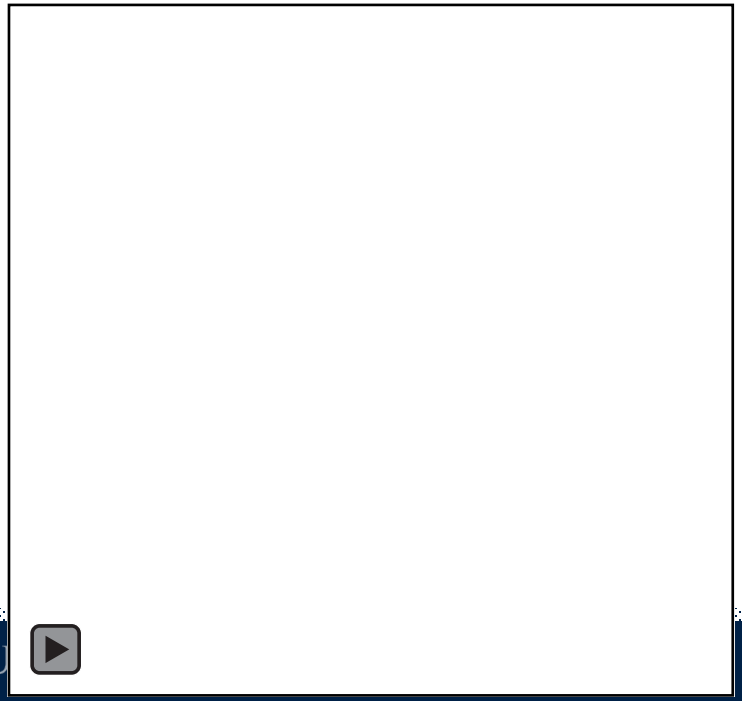

[Visualization, P Stempel]

# MORPHOLOGICAL RESPONSE TO EXTREME EVENT

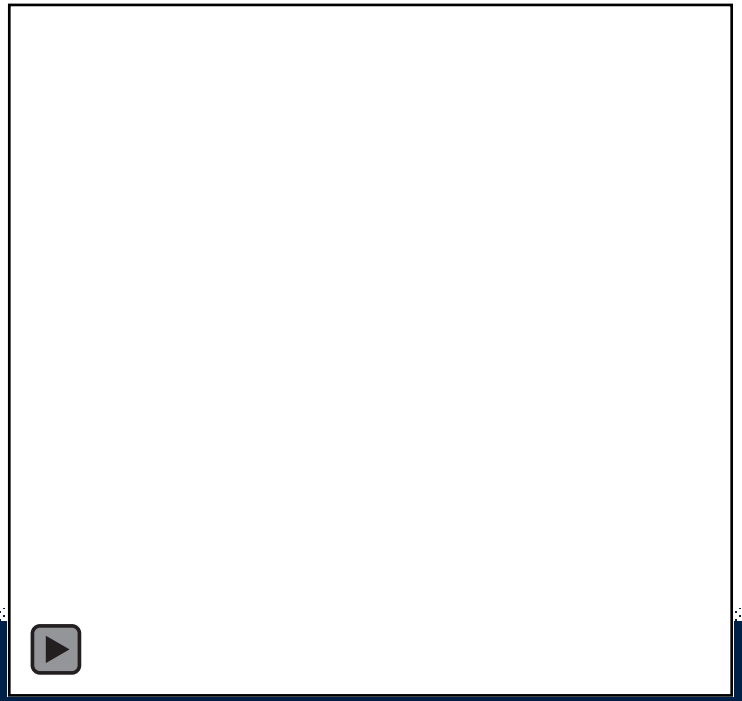
## STUDY OF THE CHARLESTOWN BREACHWAY AREA TO IMPROVE ITS RESILIENC

"Morphodynamic modeling of beach renourishment like Sandy for 40h"

NO RENOURISHMENT



WITH RENOURISHMENT



# ICCE 2024 ROME September 8-13
# REEF with. NATURE-BASED FEATURES

**Reefense X**

## Reefense X-REEFS: hybrid biological and engineered reef structures for Nature-based Coastal Defense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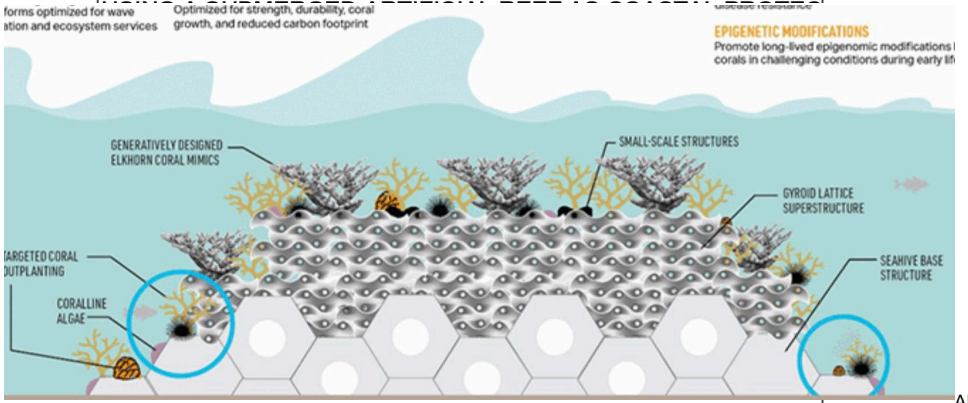


SSIPATION OF THE REEF ENHANCING BREAKWATER:
A PHYSICAL MODEL STUDY


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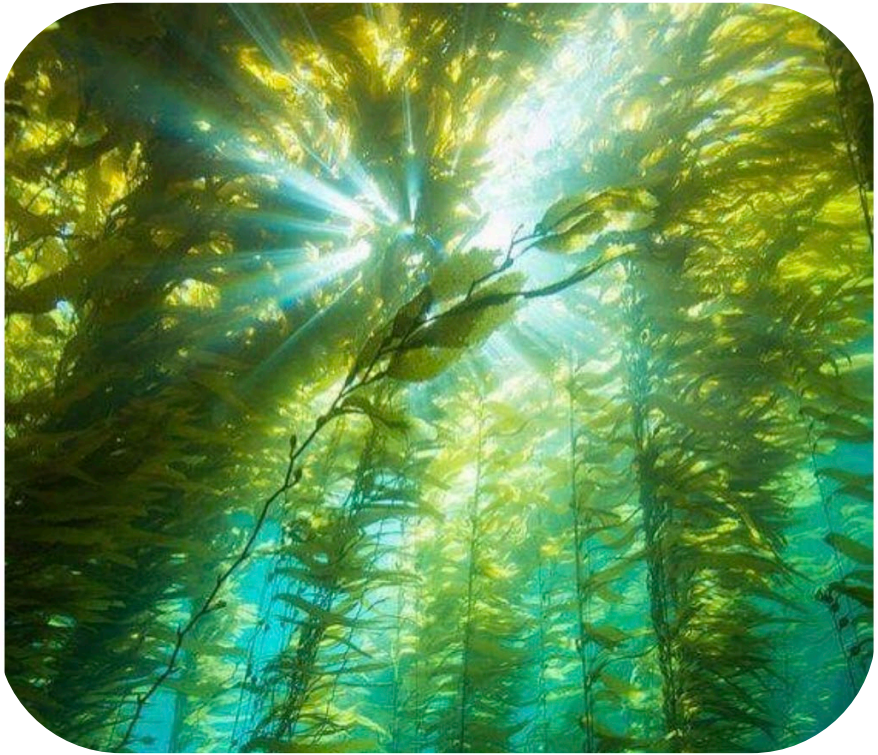


# ICCE 2024

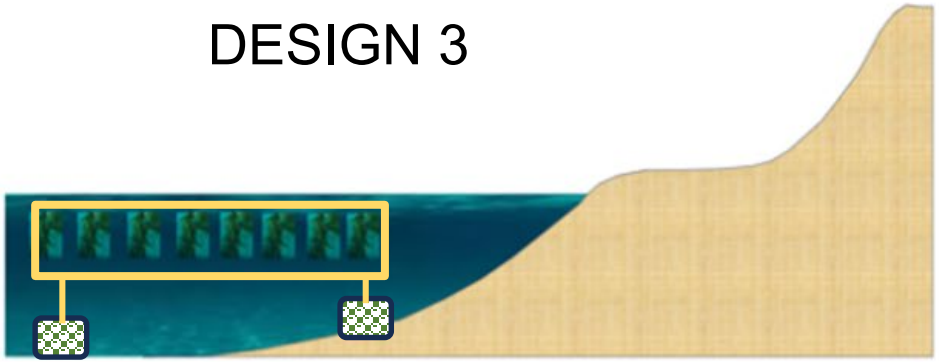
EXPERIMENTAL STUDY OF WAVE OVERTOPPING ON BREAKWATERS CO-LOCATED WITH SEAWEED AQUACULTURE SYSTEMS (kelp)

Filipe Miranda, Hydraulics, Water Resources and Environmental Division, Department of Civil Engineering, Faculty of Engineering of the University of Porto,

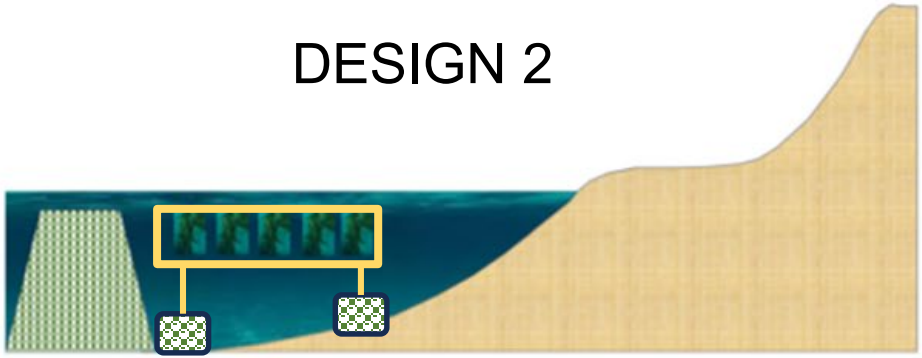
# ARTIFIAL REEFS and HYBRID REEFS

DESIGN 1

DESIGN 3



DESIGN 2



DESIGN 4

*USGS - shallow fringing coral reef flat Tumon Bay, Guam.*

Thank you

Contact:
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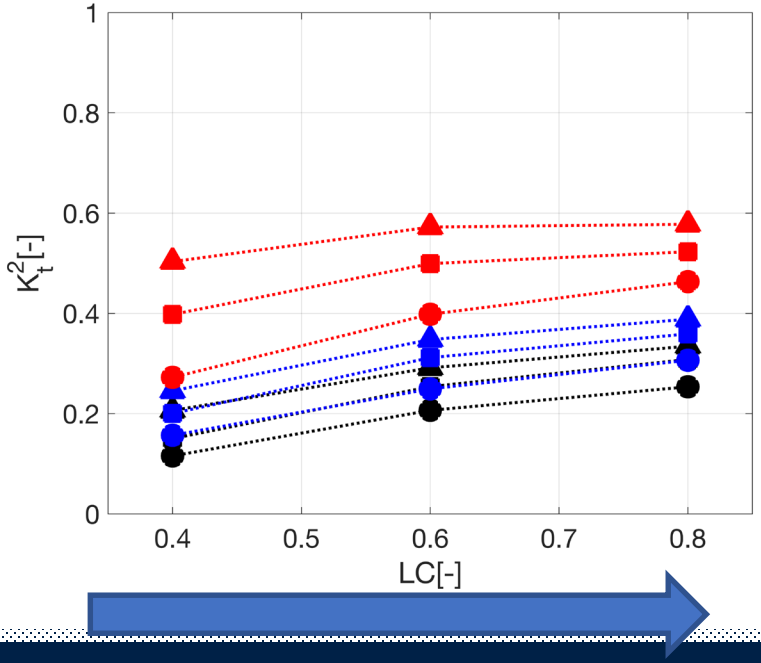
# TRANSMISSION COEFFICIENT



$$K_t = \sqrt{\frac{E_t}{E_i}}$$




Average Wave Climate

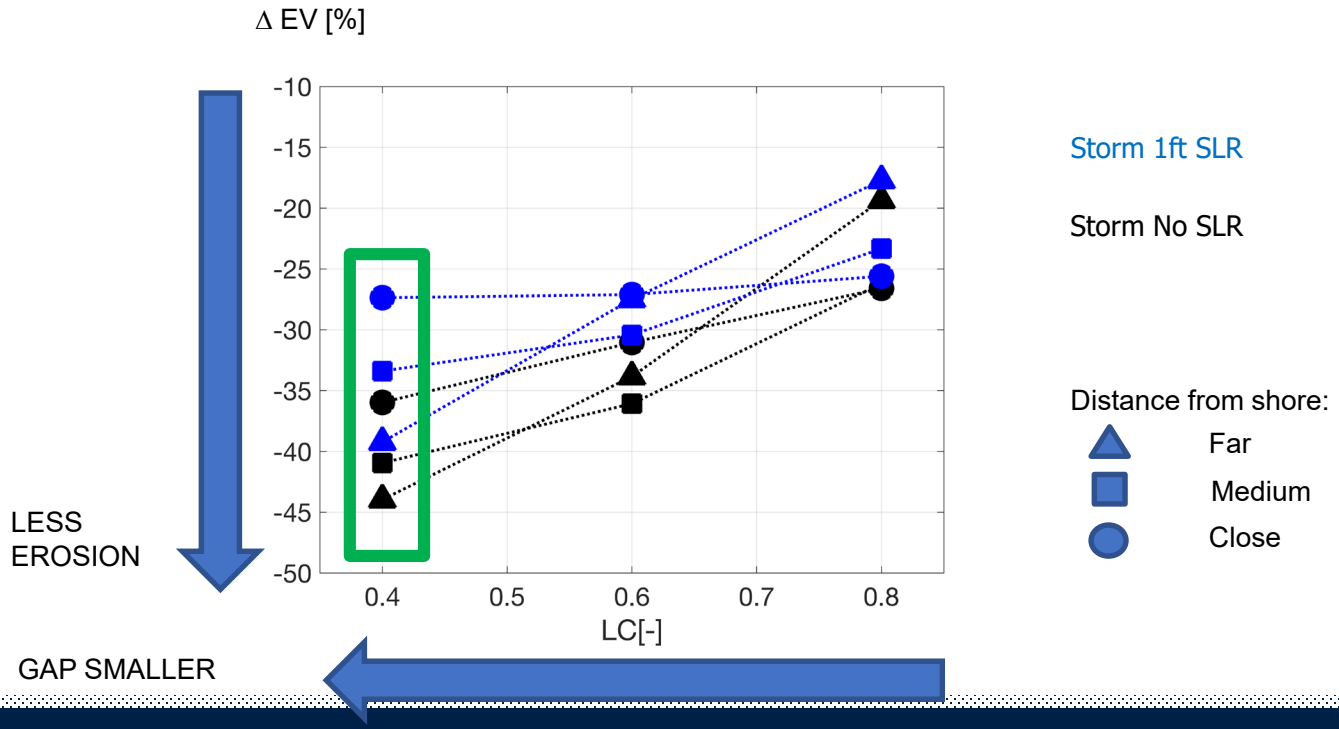
Storm 1ft SLR

Storm No SLR

Distance from shore:

- Far
- Medium
- Close

# STORM WAVE CLIMATE
# SUBAERIAL EROSION REDUCTION


Storm 1ft SLR

Storm No SLR

Distance from shore:

Far

Medium

Close

# AVERAGE WAVE CLIMATE
# MODE OF SHORELINE RESPONSE