Evaluation of the Performance of Breakwater Designs at a Coastal Marsh Shoreline Using a Smartphone-Based Wave Intensity Sensor (WILSON)

Taken By: Morton, 2024

Coastal Estuaries are Disappearing

>80,000 acres of coastal marsh are lost each year in the US alone.

Barnegat Bay watershed has an estimated loss of **~80 per year.**

Source: NOAA et al., 2008, Krause, 2023

Solution: Breakwaters and Shoreline Armoring

- Bulkheads and Seawalls
  - Protect Coastal Communities
  - Destroy Marshes

Bayside Bulkhead Construction – First Coastal. (2016, January 1). First Coastal. Retrieved January 25, 2025, from https://firstcoastal.com/bayside-bulkhead-construction/

- Breakwaters
  - Offshore Structures
  - Wave Attenuation and Shoreline Accretion

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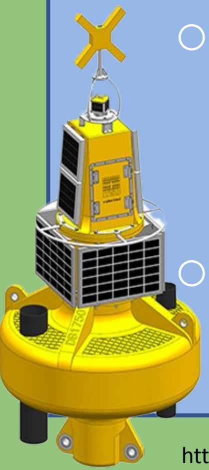
- “Living Shorelines”
  - Wave attenuation
  - Accomodating to Marine Life

NOAA Fisheries. (2022, July 20). *Living Shorelines Provide Nature-Based Approach to Coastal Protection*. Retrieved January 25, 2025, from https://www.fisheries.noaa.gov/story-map/living-shorelines-provide-nature-based-approach-coastal-protection

Limitation: Inaccessible Measurement Tools

$$$

- Wave Measurement Devices
  - Cost upwards of thousands of dollars (Miros, 2019)
  - Proprietary software



https://nautikaris.com/product/motus-wave-buoys/

- Existing Cost-Effective Alternatives
  - Lack of validated and available methods and accessible analysis

Problems, Objectives, and Hypothesis

Problem:

$$$

P1: Tools used to measure wave action are prohibitively expensive.

P2: Lack of investigation of boat wakes.

P3: Breakwaters or natural shorelines are hardly ever tested in the field.

Goals:

G1: Create WILSON, verify accuracy.

G2: Use WILSON to model boat wakes with an iPhone's accelerometer.

G3: Observe various types of breakwaters using the WILSON.

Hypothesis:

H1: WILSON will accurately measure wave heights.

H2: WILSON will measure boat wakes.

H3: Observe breakwater efficiency and significance between structures ($p<0.01$).

Phase 1 Methodology: Device Calibration

Creation of the WILSON device

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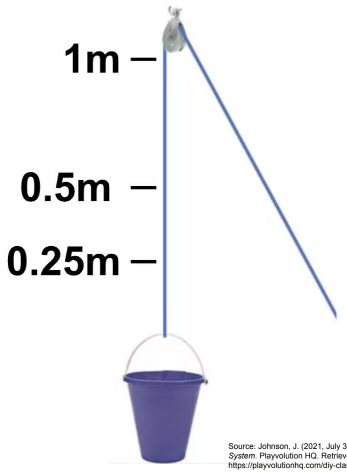
Design and Construction

Calibration of the device



Source: Johnson, J. (2021, July 3). *DIY | Easy Classroom Pulley System*. Playvolution HQ. Retrieved January 26, 2025, from https://playvolutionhq.com/diy-classroom-pulley-system/

Pulley System: Synthetic waves

Benchmarking to Professional Device

Source: RBRsolo³ | Single Channel Logger - RBR. (n.d.). RBR Global. Retrieved September 5, 2024, from https://rbr-global.com/products/compact-loggers/rbrsolo/

Compare conventionally used device to WILSON in the field with Root Mean Square Error test

Phase 2 Methodology: Field Testing

Verify that WILSON could generate wave heights from boat wakes


Source Morton, 2023


Source Morton, 2023


Source Morton, 2023

Speed Boat Wake

Jet Ski Wake

Fishing Boat Wake

Phase 3 Methodology: Breakwater Research



Breakwater 1:

Interlocking concrete blocks

- One solid structure
- Oyster Seed
- Above the surface

Source: Media Archive, 2020

Breakwater 2:

Triangular concrete structures

- Puzzle-Piece like configuration
- Above the Surface

Source: Media Archive, 2020

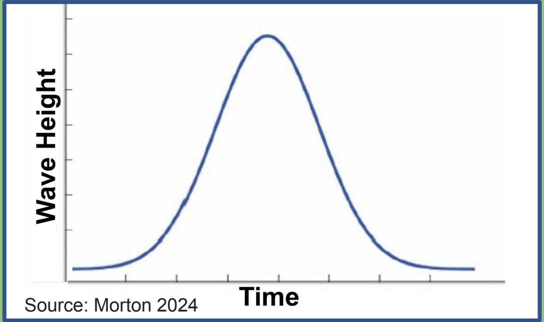
Breakwater 3:

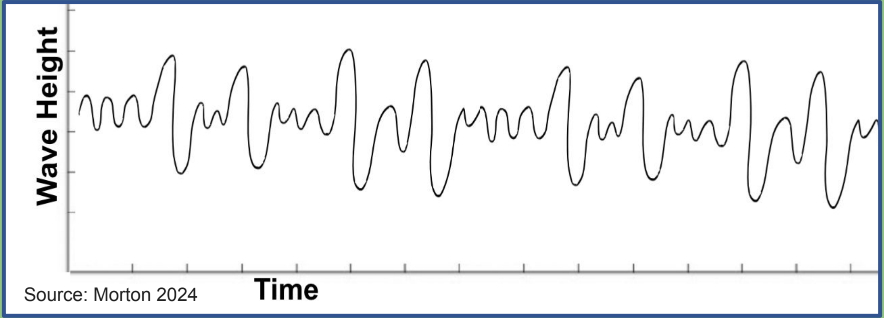
Sand-filled geosynthetic tubes

- Sat below the surface
- Allowed waves to passover

Source: Media Archive, 2020

Phase 3 Methodology: Analytical Approaches





- Isolated Wave Events
  - Boat Wakes
  - Large Waves
  - Small intervals of data
  - Observing attenuation of harmful boat wakes

- 1-Hour Intervals
  - Ambient (wind) waves
  - Smaller waves
  - Larger intervals of data
  - Observing attenuation from wind waves

Fast Fourier Transformation (FFT) + Data Filtering In MatLab

Problem: Noise Accumulation → Inflated Wave Height Values

Frequency Analysis: FFT → Identify Noise

Data Filtering: Remove Noise

Phase 1 Results: Device Calibration

Synthetic Waves: 4 Replicates

Actual Heave (m)	Avg. Measured Heave (m)	Error (%)
1.00	0.9885	1.1548
0.50	0.5472	9.4363
0.25	0.2611	4.7921

Synthetic waves were measured within 10% accuracy.

Comparison to Professional Device:

RMSE value = 0.0236
(-0.01 to 0.5m)

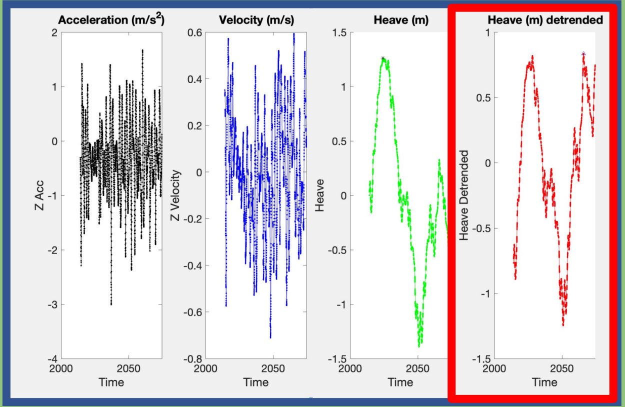
Device was found comparable to professionally used device with Root Mean Square Error Test (RMSE) to compare ranges.

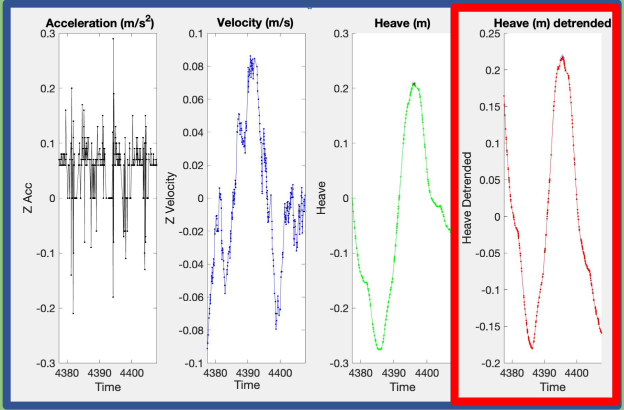
Phase 2 Results: Field Testing

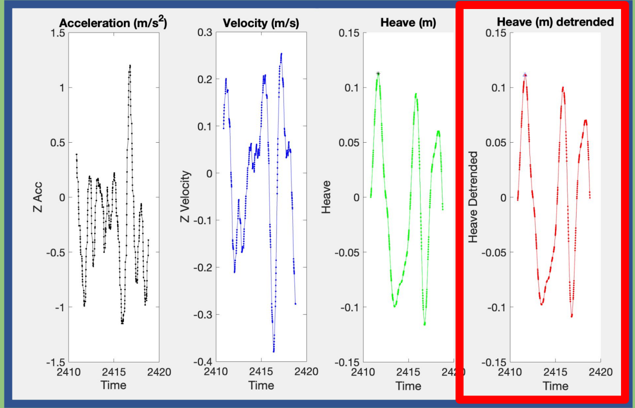
Fishing Boat: 0.8 m

Jet Ski: 0.22 m

Speed Boat: 0.11 m

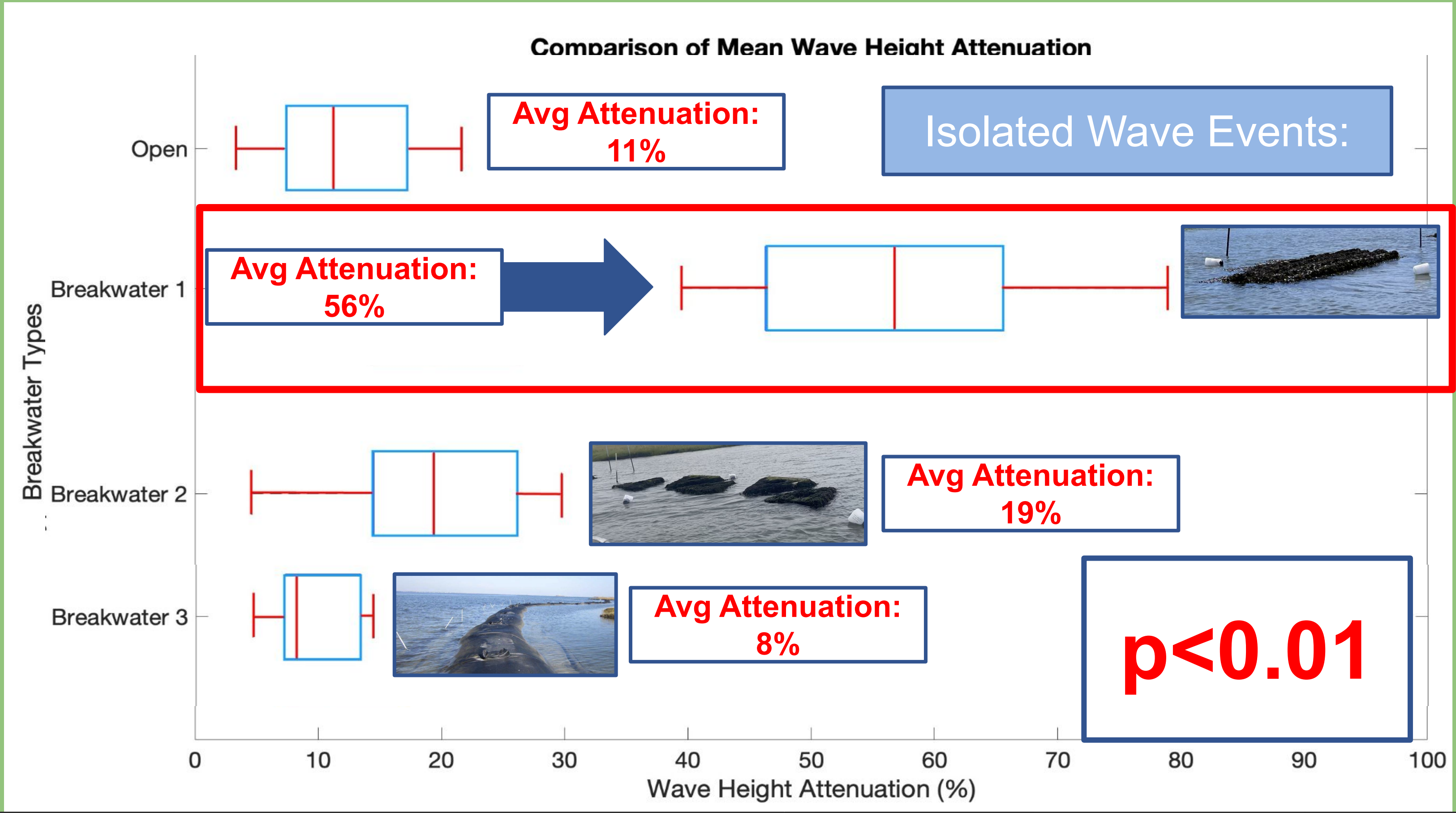




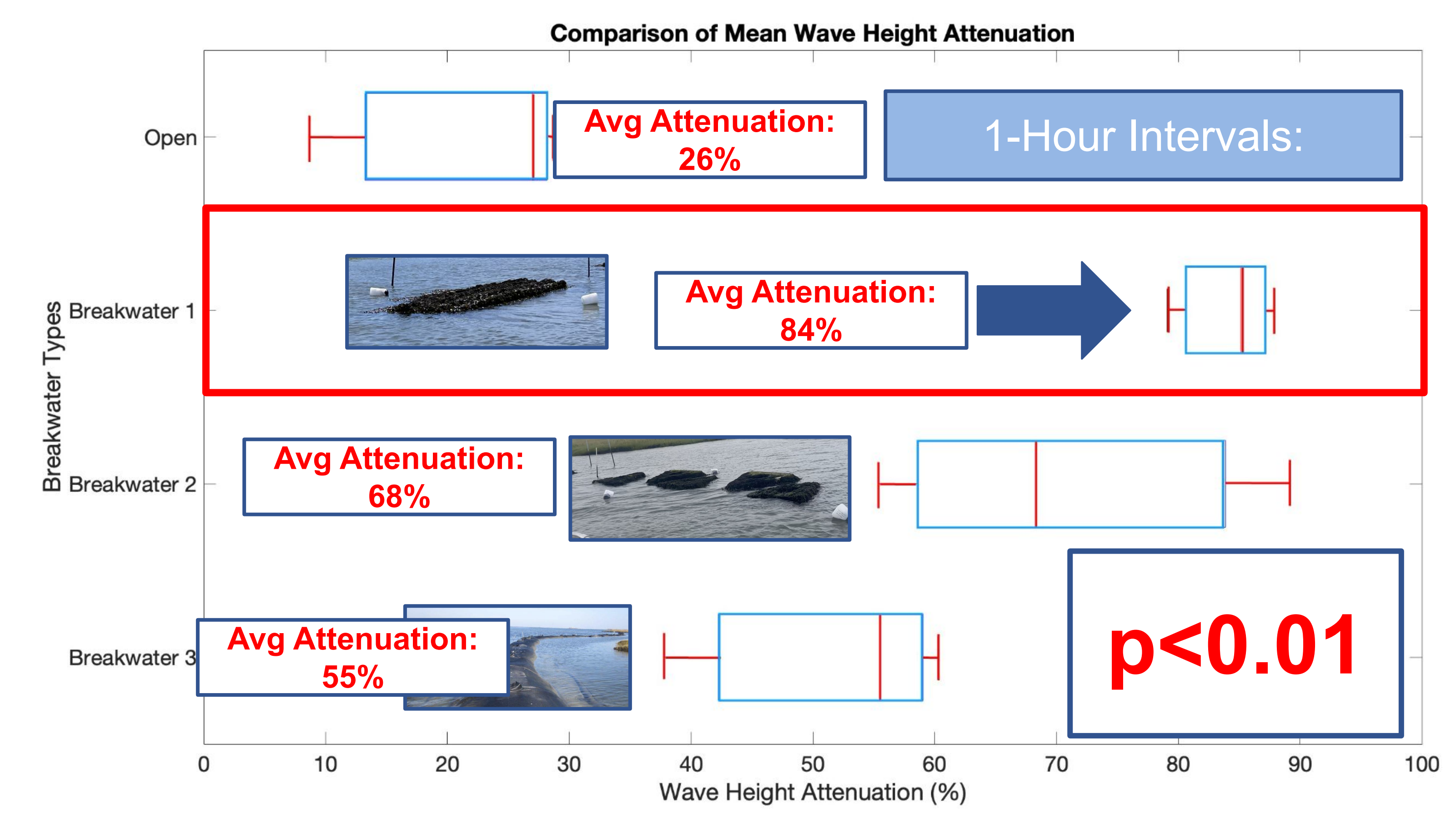


Range of boat wake heights from field testing

Phase 3 Results: Breakwater Research



Phase 3 Results: Breakwater Research



Discussion

Phase 1: **Device Calibration**

H1 ✓

- Designed and verified WILSON
- Compared WILSON to professionally used wave measurement tool

Phase 2: **Field Testing**

H2 ✓

- Deployed WILSON in the field to measure boat wakes
- Various vessels

Phase 3: **Breakwater Research**

H3 ✓

- Observed breakwaters wave attenuation capabilities
- Statistical comparison

Limitations

Human Factors

Location + Breakwater Installation

Battery Life

Data Analysis

Applications:

Affordable Kinematics Measurement Tools → Increased accessibility for physics-based research

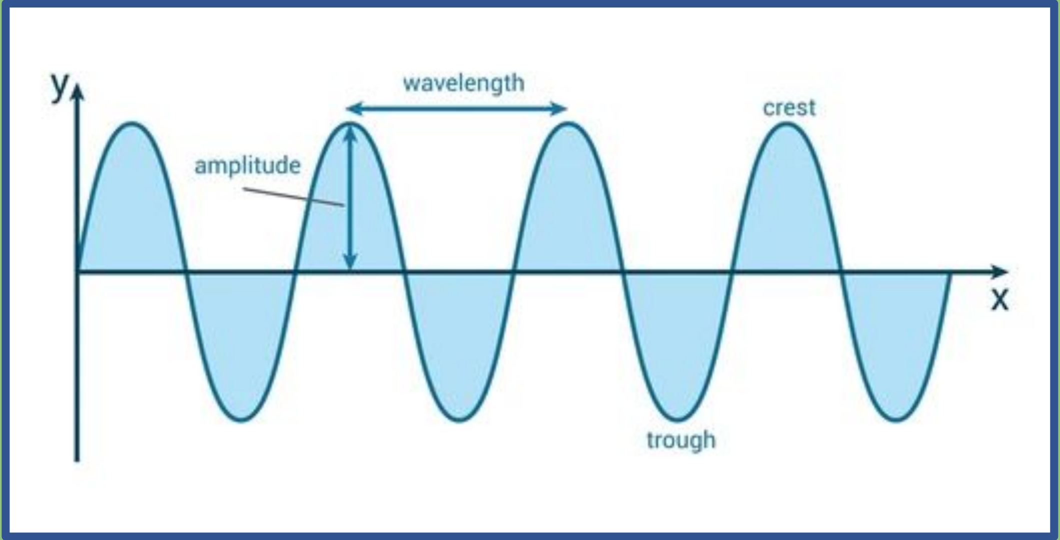
Smartphone Application in Marine Science/Engineering → Larger understanding of waterways, erosion, and recreational boating

Future Research:

Breakwater Research

Machine Learning Tool

Wave Modeling - Multiple Axis of Measurement



https://www.shutterstock.com/image-vector/label-parts-transverse-wave-crest-trough-2151810649

Conclusion:

- **Created and verified cost-effective wave action device**

Taken by: Morton, 2023

- **Measured boat wake wave heights**

Taken by: Morton, 2024

- **Showed significance between structures in wave attenuation ($p<0.01$)**

Taken by: Morton, 2024

H1 ✓ H2 ✓ H3 ✓

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