REEFENSE: PERFORMANCE OF A MODULAR OYSTER REEF HABITAT FOR COASTAL PROTECTION APPLICATIONS

Ryan Lowe, The University of Western Australia, Ryan.Lowe@uwa.edu.au
Marco Ghisalberti, The University of Western Australia, Marco.Ghisalberti@uwa.edu.au
Justin Geldard, The University of Western Australia, Justin.Geldard@research.uwa.edu.au
Rebecca Morris, The University of Melbourne, Rebecca.Morris@unimelb.edu.au
Alex Goad, Reef Design Lab, alexgoad@alex-goad.com
Kelly Kibler, University of Central Florida, kelly.kibler@ucf.edu
David Bushek, Rutgers University, bushek@hsrl.rutgers.edu

INTRODUCTION
Hybrid artificial reef structures can be designed to promote the development of a self-sustaining habitat for reef organisms while simultaneously enhancing their effectiveness at coastal protection. Such hybrid structures also offer many additional ecosystem benefits over conventional engineering structures that are used to provide coastal protection (e.g., rubble-mound breakwaters). In this study we investigate the wave attenuation capacity of engineered oyster reef modules that have been designed through the Defense Advanced Research Projects Agency (DARPA) initiative Reefense: A Mosaic Oyster Habitat for Coastal Defense. The modules are designed with significant porosity (through misaligned holes), shelves to facilitate oyster recruitment, and an interlocking mechanism to maximize reef stability.

PROJECT BACKGROUND
The Reefense program within the DARPA Biological Technologies Office "seeks to develop self-healing, hybrid biological, and engineered reef-mimicking structures" to mitigate the coastal flooding, erosion, and storm damage that increasingly threaten civilian and US Department of Defense infrastructure and personnel". Reefense is framed by three technical areas (TAs): (TA1) structure, (TA2) ecosystem engineering, and (TA3) adaptive biology.

The present study focuses on research led by a multidisciplinary team within TA1 to create a Mosaic Oyster Habitat (MOH) for coastal defense that will achieve 70-90% wave attenuation while providing an optimal biological structure that will enhance oyster recruitment, oyster growth and resilience to predation and disease (in TA2 and TA3). This presentation will describe physical model testing of a novel porous modular reef structure to assess wave attenuation performance under a range of wave and water level conditions. In 2024, a 50-m-long full-scale reef will be constructed and deployed in Florida, USA, which was designed to attenuate wave energy under 20-yr storm wave conditions at the site.

EXPERIMENTAL TESTING
Reduced scale (1:2) physical model testing of numerous modular reef layouts was conducted in the 54-m long wave flume at the University of Western Australia's Coastal and Offshore Research Laboratory (CORLab). A piston type wave maker with active absorption was used to generate both regular and irregular wave conditions, with test conditions spanning a range of wave heights, periods and water depths. The number and spacing of rows as well as the height, surface roughness and porosity of modules varied across each layout tested to investigate how their arrangement can influence attenuation while also accounting for oyster colonization and growth (e.g., Figure 1). Wave heights, velocities and force time series were measured across each reef to quantify the attenuation of wave energy by dissipation (due to both wave breaking and drag forces) and reflection.

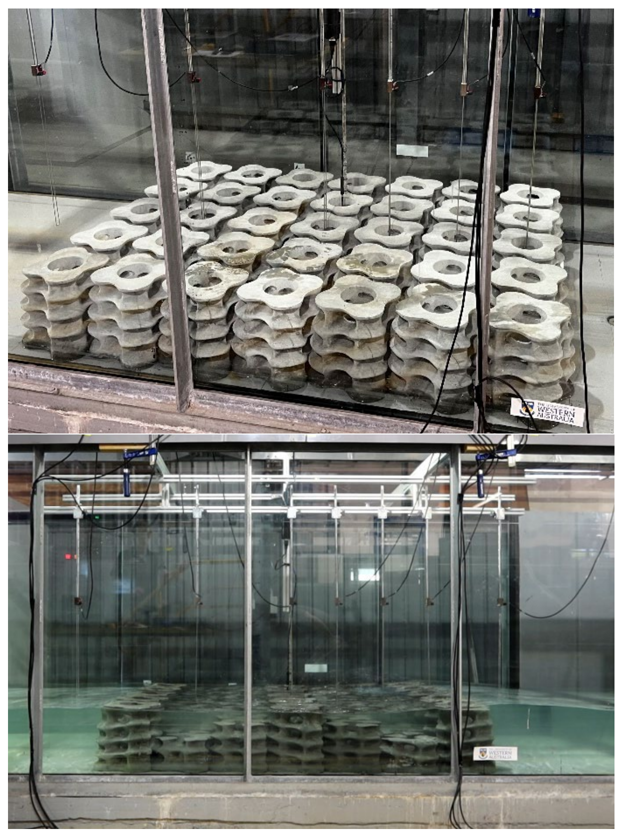

Figure 1 – Top: A reef consisting of full height reef modules in the wave flume. Bottom: A modified layout with varying module heights.

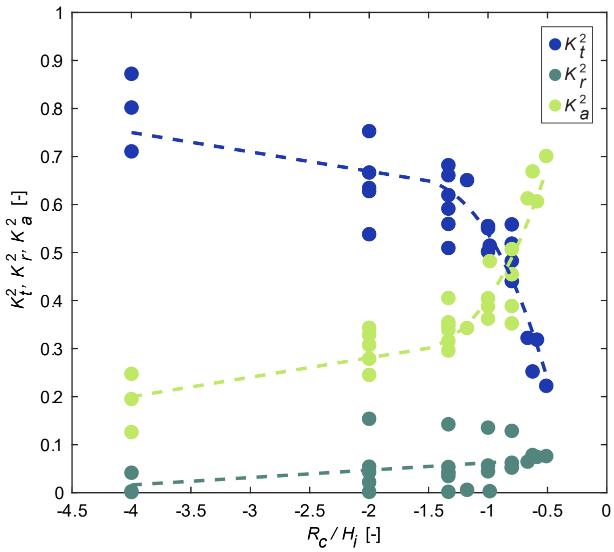

Figure 2 - The influence of relative freeboard on the fraction of wave energy attenuated over 5 rows of full height reef modules.

RESULTS

The transmission (K_t), reflection (K_r) and dissipation (K_a) coefficients were calculated for each case using the decomposed offshore incident (H_i) and reflected wave height (H_r) as well as the decomposed transmitted wave height (H_t) as:

$$K_t = H_t / H_i \tag{1}$$

$$K_r = H_r / H_i \tag{2}$$

$$K_a = \sqrt{1 - K_t^2 - K_r^2} \tag{3}$$

Wave transmission was strongly governed by the dimensionless relative freeboard, the mean water depth above the top of the reef (R_C) relative to the offshore incident wave height (Figure 2). The attenuation of wave energy was dominated by dissipative processes, due to both drag forces associated with porous modules and wave breaking, with wave reflection making a minor contribution. Increasing the number of rows in the reef leads to diminishing returns of wave attenuation and the contribution of wave breaking to attenuation was particularly sensitive to module height variations within the reef. Over a broad structural and hydrodynamic parameter space, predictive tools have been developed to quantify the wave attenuation (and the dominant attenuation mechanism) for a range of reef layouts. Such tools will enable the development of design guidelines for modular porous hybrid reef structures as a nature-based solution for coastal protection.