Shoreline Wave Energy Measurement

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Wave action measurements of the intertidal zone to enable long-term environmental monitoring and predictions of ecological impact due to wave energy converter (WEC) arrays.

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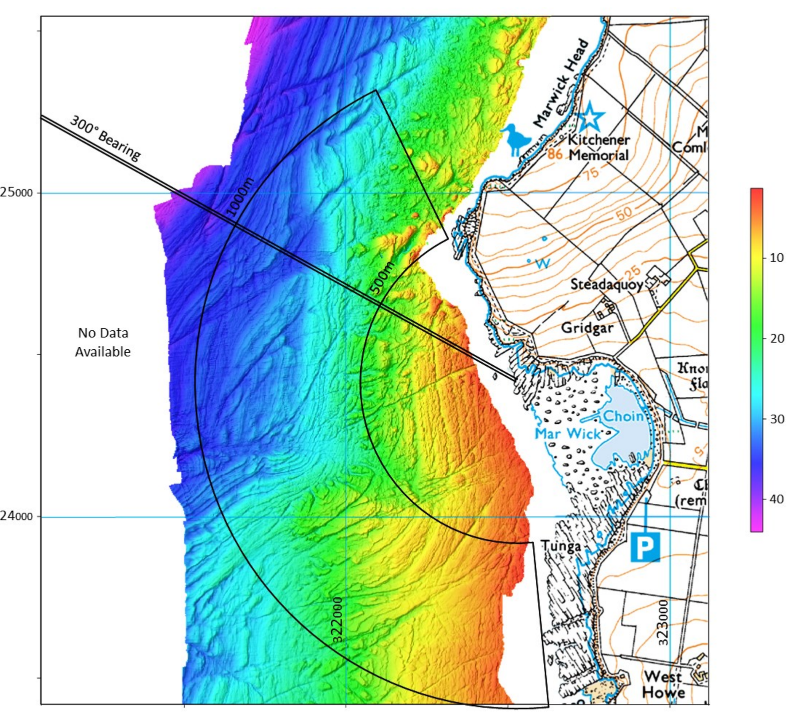
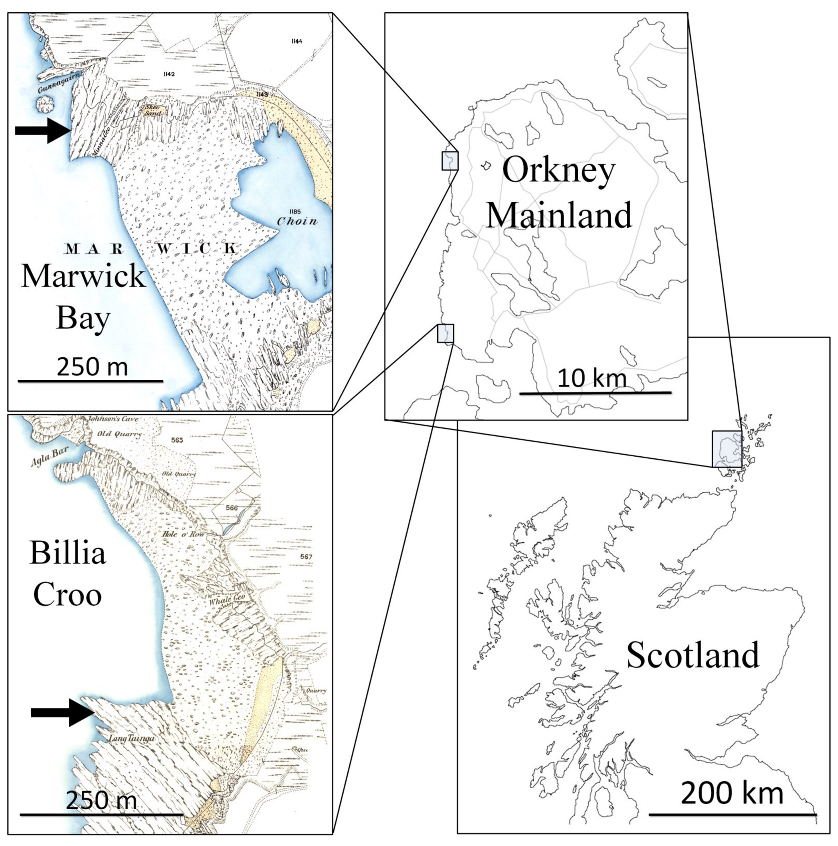
Quantifying energy dissipation is essential to accurately predict intertidal species survival within WEC modified wave regimes. This research has now enabled cost effective long-term monitoring on these high energy shorelines adjacent to wave energy development areas.

Modification of shoreline energy dissipation, by future WEC arrays, will be determined not just by their distance from the shore but by their operational activity and aggregated effects from concurrent developments such as those proposed off the West coast of Orkney [2] using 'Pelamis' and 'Oyster' technologies. The operational regimes of such developments are expected to generate energy on a continuous basis therefore, with the exception of some intermittency, WEC arrays would lead to a chronic reduction of shoreline wave action. But due to buoyant WEC arrays having minimal effect on extreme wave events, an increase in the seasonal (summer-winter) difference in wave energy levels will be introduced. Due to these poorly understood downstream effects there is an important need to provide quantitative data of shoreline wave action to enable the assessment of possible impact to species, some of which may be protected by legislation [3].

Many international ecological studies have been constrained by the difficulties and costs involved with long term monitoring and site replication in extreme marine rocky-shore environments.

This inherent problem restricts attempts at comparisons between widely separated sites [1] particularly for sites at alternative latitudes (temperature gradients) that feature different dominant species. For the first time sites can now be directly compared with ease in regard to shoreline wave action, widely recognised as one of the primary factors in determining floral and faunal abundance on rocky shores.





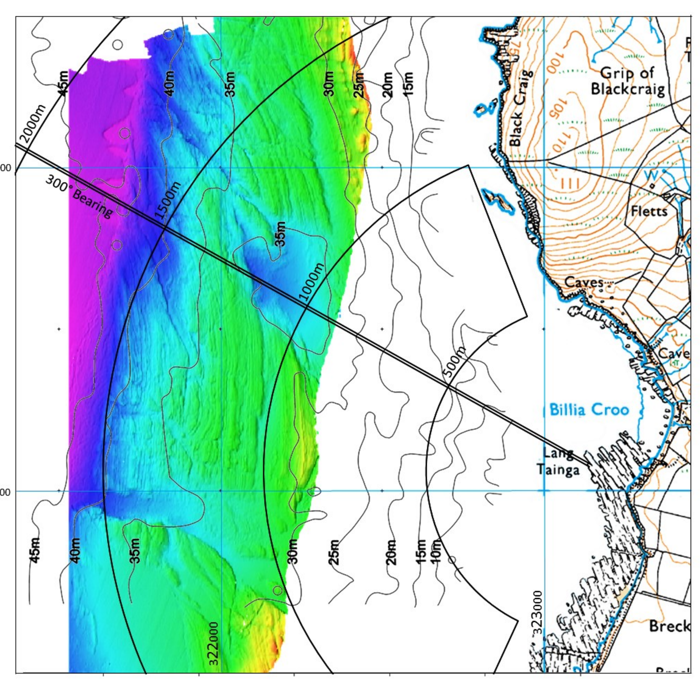


Figure 1. Site locations, Marwick Bay and Billia Croo, Orkney, 14 km separation distance. Showing bathymetry offshore from the two survey sites Marwick Bay (top-left) & Billia Croo (bottom-left). Note: Colour gradient depths differ between plots.

The 'Terobuoy' device developed and tested is a cost effective instrument able to simultaneously provide a quantitative measurement of wave action together with its directional components [4]. This is achieved by accurately measuring material wear of a sacrificial polymer block before and after installation. The interaction of the float with the hydrodynamic regime, within the surf zone and submerged with the tidal cycle, leads to a controlled loss of mass from the block; and is directly related to the forces exerted on the float over a definitive time scale. The direction of the wave field impacting the shore was established by examining the material loss along the curved block with the maximum wear occurring at the direction of maximum float oscillation in the water column. Being extremely robust it is able to survive in the harsh high-energy rocky shore environment where entrained sediment and flotsam can damage more sensitive equipment.

Figure 2. Replicate Terobuoy units (A & B) at Billia Croo showing Aquamarine Oyster in background

Two sites are compared in this research, Billia Croo (BC) and Marwick Bay (MB), on the West coast of Orkney Mainland with a separation distance of 14 km (Fig. 1), both sites using dual replicate units for the first year and individual units thereafter. The algae, barnacle and limpet matrix biotopes that are evident at both sites differ by the species that they comprise. The BC biotope is classed in EUNIS (ver.2007) as A1.1132 [*Semibalanus balanoides*], [*Fucus vesiculosus*] and red seaweeds on exposed to moderately exposed eulittoral rock and MB as A1.1222, [*Corallina officianalis*], [*Himanthalia elongata*] and [*Patella ulyssiponensis*] on very exposed lower eulittoral rock. Having different exposure levels these biotopes are grouped into the same broad categorisation of high energy.

The results from the 2 year monitoring programme show that shoreline wave action is closely related to offshore significant wave height and period, reflecting greater values of wave action experienced during the winter months (Fig. 3). Replicate units located at BC experienced a relatively consistent level of wave action throughout the study; also both sites experienced similar levels during the summer months. The results validate the exposure description of the given biotopes and go further to provide seasonality data with measurements at MB significantly higher during winter months, often exceeding double the wave action level than at BC. Even so, the biotopes are both classified as equivalent in EUNIS [5] which uses the 'exposure scale' developed for the Joint Nature Conservation Committee [6]. Furthermore the MB site should, in theory, be more sheltered than BC as it features a surface piercing reef at low tide 70m directly offshore of the test site (Fig. 5) but this location has been found to have the higher level of wave action typically occurring when average 2 week H_s, was greater than approximately 1.5 to 2 m.

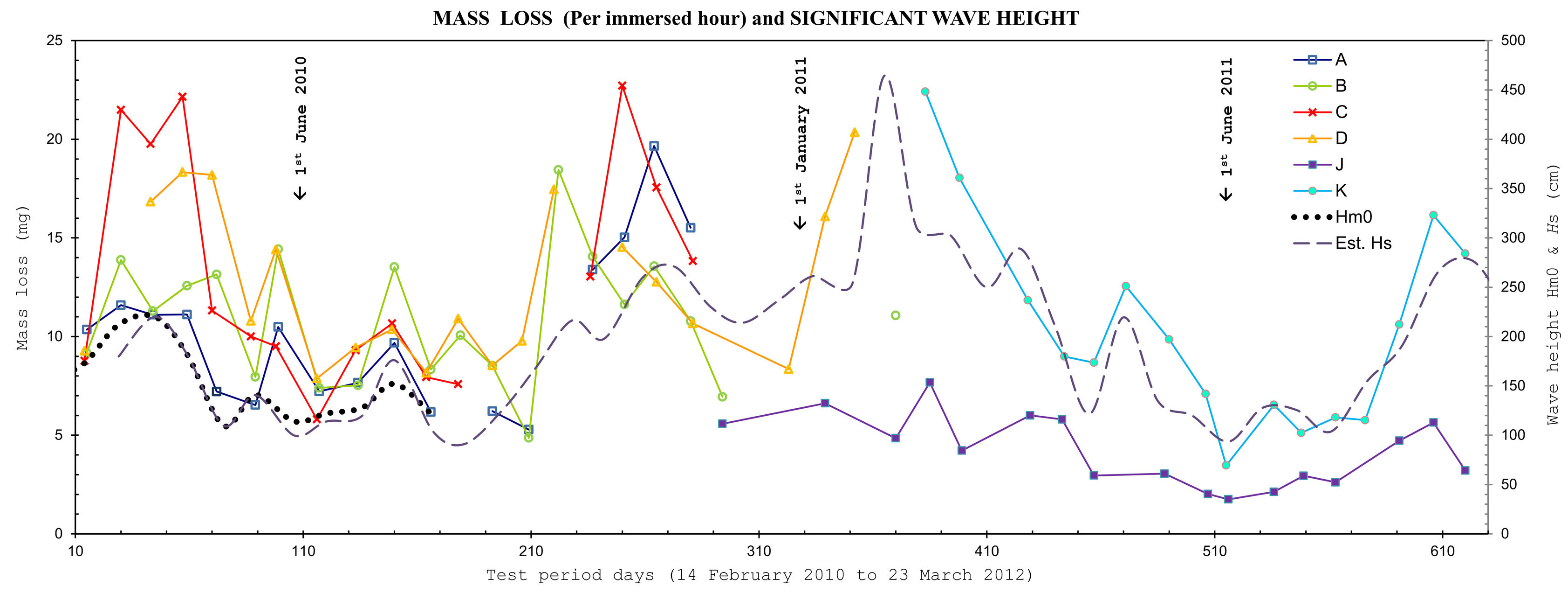


Figure 3. Terobuoy results in block mass loss averaged per immersed hour (milligrammes) at Billia Croo (A-Green/B-Blue/J-Purple) and Marwick Bay (C-Red/D-Orange/K-light blue). Compared with measured concurrent two week average significant wave height *Hm0* (dotted line) together with estimated local offshore 2-week significant wave height H_s (dashed line) calculated with 9 months direct comparison of EMEC and K7 MET buoy data (2007-2008).

Seasonal patterns in the wave action level (Fig. 4) can be seen to show higher wave action levels during equinoctial months although, high mean significant wave height does not necessarily result in higher levels of wave action. The grouping in early November 2010 occurs over sustained south-westerly wind perpendicular to the shore.

Average annual wave energy direction from wave-buoy data (300° bearing) corresponds with data from one Terobuoy unit at BC whilst the other is within 10° of the buoy data. Wave direction has also been investigated in relation to the close-shore bathymetry (fig. 6) with results showing, that at BC, wave action may be enhanced by deep water features close to the shore when in line with swell wave direction and that the steeper gradient evident at the MB site may explain the higher measurement of wave action even though 'protected' by an offshore reef.

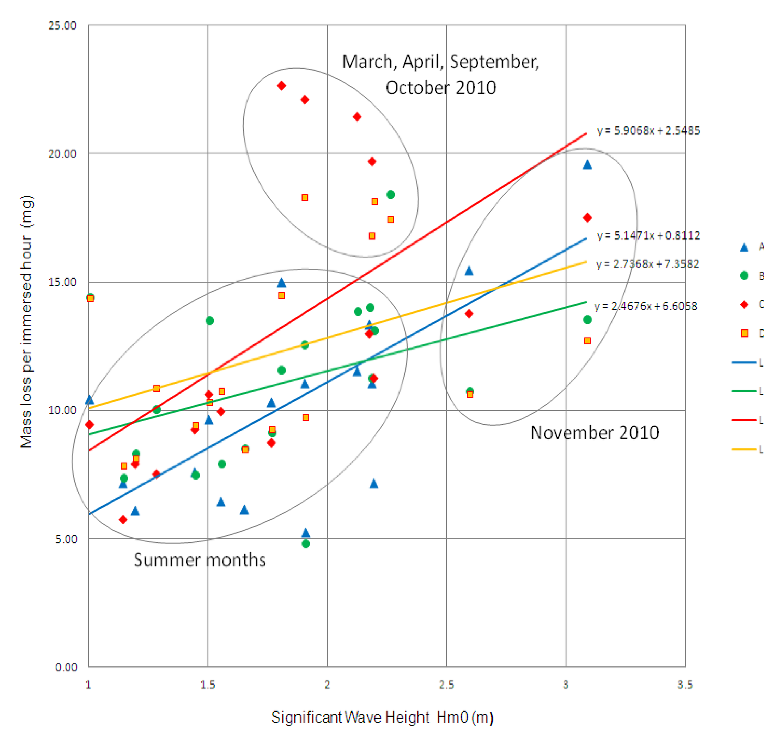


Figure 4. Wave action (mass loss per immersed hour) against significant wave height for units A, B, C & D with linear trend lines.

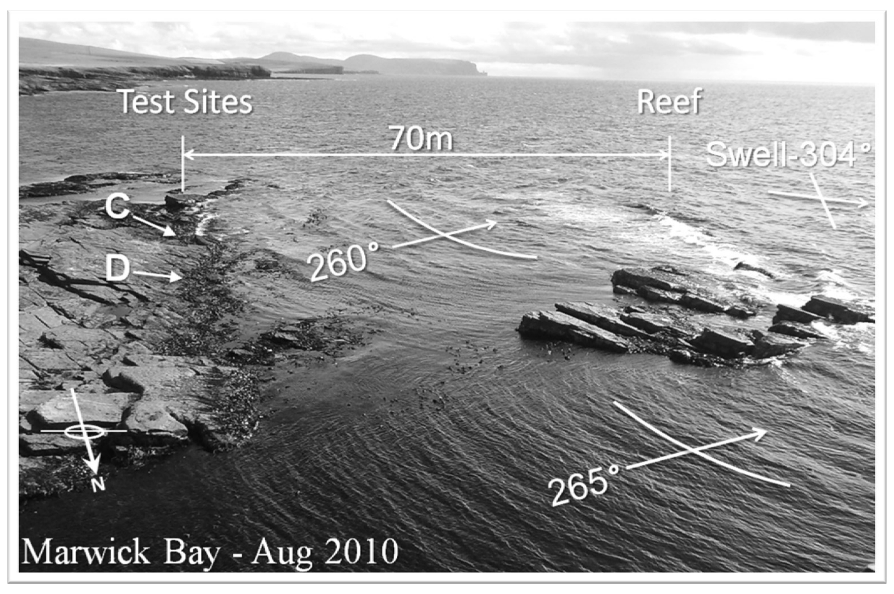


Figure 5. Overview of the Marwick Bay during a calm period, looking south, showing the proximity of the offshore reef and location of units C &D.

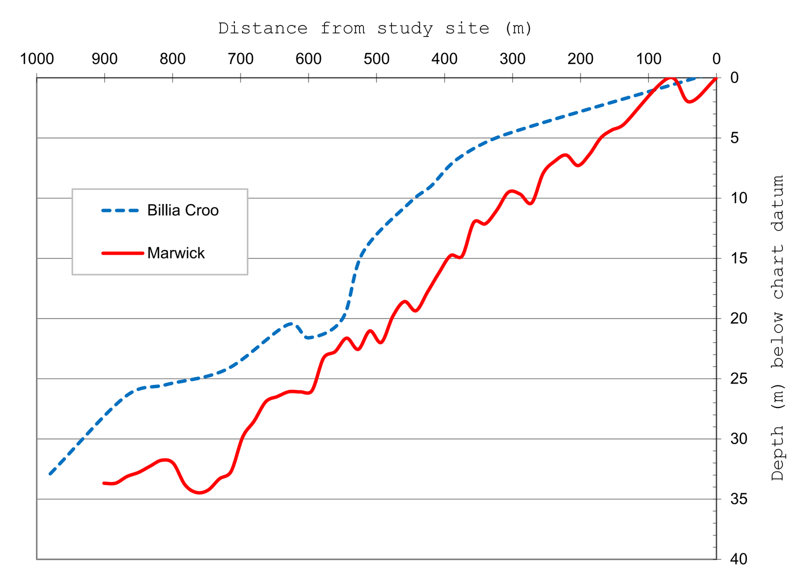


Figure 6. Bathymetry of the seabed at a bearing of 300° from the two study sites as indicated in figure 1.

Conclusions

Measurements of long-term wave action using the Terobuoy provide good correlation to both significant wave height and direction from concurrent wave buoy data [7] with greater levels experienced during the winter months. Although both study sites are classed as 'very exposed' there is a greater attenuation of wave energy reaching the shore at BC, due to increased energy dissipation over a shallower bathymetric gradient, if the offshore wave climate is assumed to be similar at both locations. There is a significant difference in seasonal energy level between biotopes currently classed as equivalent with the higher energy biotope is in a location that may initially be assumed to be in a more sheltered position. The results of directionality measurements show that near-shore bathymetry has a significant influence on the direction of waves impinging upon the shoreline especially due to reef-like structures at shallow depths. Wave action levels are affected by changes in the direction of swell waves dependent upon their aspect to the shoreline.

The Terobuoy device can not only enable specific biotopes to be studied in relation to an objective measurement of wave action, over biologically meaningful timescales, it could also be used for economical evaluations of near-shore wave energy levels and inform coastal zone management of eroding shorelines. Further research needs to be carried out with this device positioned within all relevant stable biotopes, which occur on rocky shores, within the medium to high energy levels listed in the EUNIS classification. The direct comparison of energy levels between them will enable accurate assessments of biotic change that may occur if wave action is reduced by future developments with WEC arrays in particular.

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