Roinn Cumarsáide, Fuinnimh & Acmhainní Nádúrtha
Department of Communications, Energy & Natural Resources

Geoscience Research GSI Suirbhéireacht Gheolaíochta Éireann Geological Survey of Ireland

Geological Survey of Ireland Research Programme
- Short Call 2015, Final Report -

Name of Lead Investigator	Mary. C. Bourke
Email	Bourkem4@tcd.ie

Organisation name	Trinity College, the University of Dublin		
Organisation type:	☒HEI	☐Public Sector (other)	☒Private Sector
Department/section	Geography		

Project Title	Investigation of Ireland's Shore Platforms: Location, type and coastal protection.
Contract No.	2015-sc-064

INFOMAR Integrated Mapping for the Sustainable Development of Ireland's Marine Resource

Tellus Understanding Underground

Marine Institute Foras na Mara

2. Project information:

Title of project	Investigation of Ireland's Shore Platforms: Location, type and coastal protection.
Did you make any formal amendment to the project workplan / budget?	☒ yes ☐ no If yes, please specify: Extra funds moved to salary line.

Project Report (*max 1500 words, excluding figures and headings*):

(i) Objectives and scientific/engineering targets beyond the state of the art

Objective 1: Map the location of coastal rock platforms in the Republic of Ireland.

The primary goal of this task is to produce a map of hard rock shore platforms across the coastline of the Republic of Ireland. *This objective was fully met*.

Data sets used: The following data sources were used to undertake the mapping: data from Environmental Systems Research Institute (ESRI), the Ordnance Survey Ireland (OSI), the Office of Public Works (OPW) helicopter viewer (available online), and Google Earth DigitalGlobe.

Two data confidence assessments were made about data quality which influenced the mapping results:

<u>1. Development of attribute tables based on the data quality:</u> *Confidence levels:* Confidence levels were assigned by mappers using only image data where: 1 – Confident that there is a shore platform; 2 – unsure that there is a shore platform and; 3 – very unsure/undecided as to whether there is a shore platform.

2. Assessment of platform surface area: Each of the image data sets were acquired under different tidal regimes. Therefore the physical extent or width of the platform varied at a site between different data sets. We therefore mapped exposed bedrock under ESRI World Imagery and used the other available data sets to validate those interpretations. This means that the platform map delivers a conservative estimate of the surface area of platforms and is unsuitable to derive statistics on the relative size of platforms at different locations (Fig. 1).

Figure 1: Example of shore platform mapped in western Co. Clare.

Validation: Blind validation was conducted by two members of the team for 30% of the mapped coastal platforms. A 10 km grid was overlaid on the planform map. 30% of the mapped area was randomly selected to be validated. The team were asked to identify platforms in ARC GIS using the same image data base, and assign them a confidence level.

Field validation: Field visits to platforms were undertaken to confirm their identity in the data base. Figure 2 shows the locations of platforms that were visited in the field. The field data indicate that the inventory was >90% correct. We therefore refocused our efforts on mapping and validation activities rather than visiting the eastern seaboard platforms.

Figure 2: location of field validated sites.

Results: The new map of coastal platforms is presented in Figure 3. it shows an extensive distribution of platforms along Ireland's coastline. This map is a significant improvement on the previously known distribution of an important coastal landform, showing that shore platforms are much more extensive features than previously assumed. The new map of Ireland's shore platforms will be a legacy database which can be used for future research and for assisting coastal managers in assessing how coastal platforms may buffer valuable assets from climate change risks. Whilst our aim was to map the location of present day platforms, some of the platforms may be fossil features from a previous interglacial high stand. Further research and mapping is required to accurately separate palaeo features from active platforms. In addition, we propose to build on the data provided here to examine the role of geology and Quaternary sediments in platform distribution, and to explain variations in platform morphologies observed (see Figure 4). Shore platforms provide important supporting ecosystem services to key intertidal species, and may buffer coastal communities from intense storms. They are significant geomorphological components of Ireland's coastal systems, where little is understood about their rates of evolution, erosion and sediment production to beaches. Our work has provided a new, important dataset which can be used to more effectively research and manage these important landforms.

Objective 2: Develop a classification of shore platform types in Ireland

Figure 3: Map showing the location of coastal platforms (black lines) for the Republic of Ireland.

We have completed a provisional taxonomy of Ireland's coastal platforms. Our approach is useful and provides a basis upon which future data collection and interpretation can consolidate the categories. Project objective: Collate platform types into a new classification system that is representative of Ireland's high energy meso and macro tidal ranges. This classification will also be of global significance as it will extend the narrow range of platform types currently described (e.g., Sunamura, 1992).

Shore platforms are erosional landforms located on rock shorelines (Dana, 1849; Kennedy, 2015). They occur where the underlying geological structure has been truncated by external erosive processes (Kennedy, 2015; Stephenson et al., 2013). The system behaviour of shore platforms is considered to be complex, as at any given location interactions between geological controls, geomorphic processes and climatological drivers are spatially and temporally variable (Naylor and Stephenson, 2010). It is reasonable to expect therefore that the surface expression of these interactions lead to a myriad of morphometries. Our preliminary data (below) has demonstrated that platform roughness can lead to significant attenuation of wave energy across and along a platform. It is therefore prudent to consider surface morphometry of platforms as a controlling parameter on heterogeneous distribution of wave energy, and that the wave buffering capacity of shore platforms may thus be spatially variable. Here we provide a provisional classification of platforms along the Irish seaboard. Image data for this task were collected during the field validation of the platform map.

Previous platform classifications:

The classification of shore platforms in terms of morphology has been to subdivide shore platforms into two broad types, those which slope seaward as a uniform ramp and those with a distinctive seaward edge characterised by a cliff (Kennedy, 2015; Stephenson and Naylor, 2011). This form of classification was developed by Sunamura (1992) whom termed these as end-members in the form of 'Type-A' and 'Type-B', respectively.

Our proposed classification for Ireland:

Our classification builds on the pioneering work on Ireland's coastal platforms by McKenna et al. (1992). He characterised the Northern Irish platforms by the high relative relief and general ruggedness. We concur with his assertion that the term 'platform is a misnomer'. He describes chaotic erosional landforms composed of a highly irregular rock surfaces. He noted that the horizontal scale of these irregularities was typically 10-20 m where joints are frequently eroded into deep clefts separated by pavements. This pattern of erosion focussed at joints and/or bed layer boundaries has been observed in South Wales, (Naylor et al., 2012; Naylor and Stephenson, 2010). South coast of England, (Dornbusch and Robinson, 2011) and in Scandinavia (Cruslock et al., 2010). Surface morphologies include stacks, ramparts, scarps and gullies. He also noted that some platforms dipped landward as well as seaward.

The geology of rock coasts are understood to strongly influence the morphology of the shoreline, its mode of evolution (Trenhaile, 1987; Trenhaile and Lakhan, 2011) and the scale of erosion (Naylor et al., 2012; Stephenson and Naylor, 2011).

Our provisional proposition is to isolate the broad characteristics we noted in the field. Examples of typical features are shown in Figure 4.

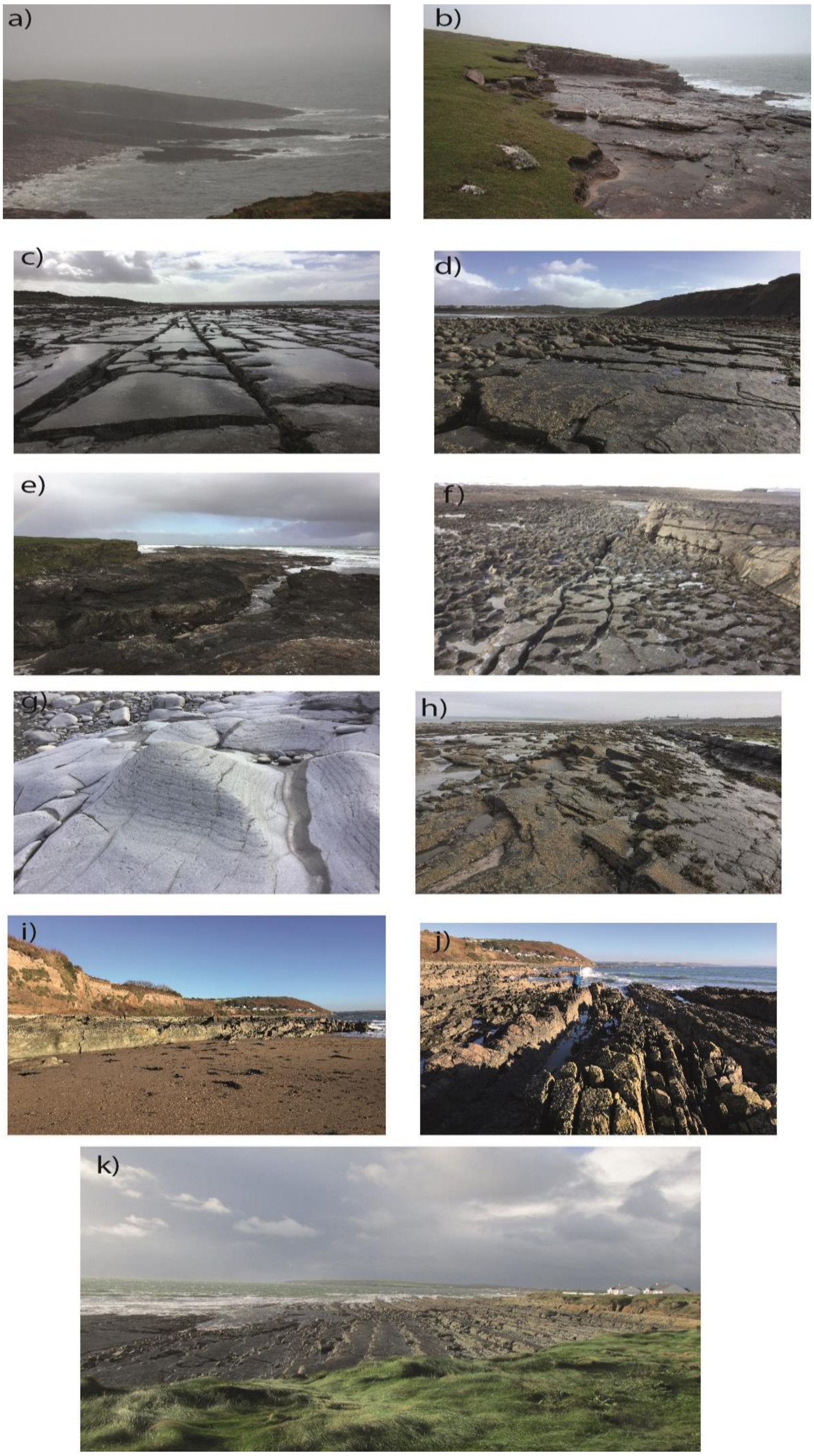


Figure 4: Examples of different platform types along Ireland's coastline. a and b are seaward dipping; h is backward dipping; c shows pavements; d: is stepped with boulder deposits in lower topography pools; e shows large channel; f shows microtopography from bioerosion; g is an example of a pyramid mound; i) shows large step; j) shows washboard with near-vertical dip and k is example of stepped platform.

Ireland's platforms have been modified (eroded and buried) by glacial deposits and the coastline experiences differential rates of isostasy. As such we have not differentiated between active and fossil platforms. In addition, higher-elevation platforms are activated during more extreme events and are therefore viewed as part of the platform landform continuum.

We have devised a typology which classifies platform characteristics at two scales. One, the platform-scale, is the scale of the entire landform feature which is analogous to existing platform classifications in terms of spatial extent. Two, we assess morphological variability and classify this at the within-platform scale, thus extending the existing shore platform classification globally to include important geomorphological features that occur at the sub- platform scale. These features are spatially variable between platforms of the same 'platform-scale' classification category and create local scale (mm to m^1 scale) variations in morphology.

<u>Platform-scale</u>

1: Shore attached (A) and unattached (U).

> These platforms may be a considerable distance from the shore and have water between their location and the shoreline during low tide.

2: Rock cliff backed (C) and no rock cliff (~~C~~)

> There are sites where no rock cliff is present (preserved) we propose that the current definition of shore platform should be extended to these features as they are providing the same geomorphic and ecosystem service as shore platforms which are cliff-backed.

3: Dip (d): forward dipping (d_{+}) or backward dipping ((d_{-}), vertical ($d^{|}$) (340-20 degrees), sideways dip (d_s) (complex dip (e.g., steepens in intertidal) d_c)

4: 3-D: caves, blowholes. $3D_{c,\,b}$

<u>Platform surface features</u>:

Two key feature types are identified along with three variations in surface morphology:

5: Step (S_s): (micro (mm-cm), meso (cm-m), macro: m-decametre (cliff)). Configuration varies between mainly planar with small or large steps to mainly stepped with small planar surfaces between the steps. Found mainly on finely laminated to massively bedded sedimentary rocks such sandstones, siltstones, chalk and limestone.

6: Washboard (S_w). They tend to form in in sedimentary rocks where weaknesses along bedding planes and the strike and dip to coastline are important. Depending on how massive the facies are, the topographic highs can be planar or crenulated. Relief is on the order of 1m < 10 cm. (micro (mm-cm), meso (cm-m), macro: m-decametre (cliff)

<u>Surface morphology</u>:

7: Pits, pans, pools (micro, meso, macro (surface area) [open, closed]

8: Channels (micro, meso, macro)

9: Islands/pavements/pyramids/mounds/pinnacles.

Surface deposits (SD)

Colluvial (c)

Boulder berm (bb)

Beach (B) (gravel/sand) (g/s)

Boulders (isolated – distributed)

Platform-Scale	**Primary Surface features**	**Secondary surface features**	**Index**	**Figure**
Shore-attached			A	
Shore-unattached			U	
Cliff-backed			C	
No Cliff			~~C~~	
Dip forward			Df	
Dip backward			Db	
Dip vertical			Dv	
Steps			S	
Washboard			W	
	Basins		B	
	Channels		Ch	
	Islands	pavements	I_{pa}	
		pyramids	I_{py}	
		mounds	I_{m}	
		Pinnacles/pedestals	I_{pi}	
	3D Caves			
	3D Blowholes			
	Deposits (*d*)		*d*	
		Colluvial (boulder, gravel, sand, mud)	d_c (b, g, s, m)	
		Berm (boulder, gravel, sand, mud)	d_b d_c (b, g, s, m)	
		Beach (Boulder, gravel, sand, mud)	D_{be} d_c (b, g, s, m)	
		Isolated (boulder, gravel, sand, mud, anthropogenic)	D_{bi} d_c (b, g, s, m)	

Objective 3: Measure wave energy along a platform using pressure transducers.

New emerging evidence suggests that coastal rock platforms may provide an additional, important role in attenuating wave energy and protecting the coastal cliffs and assets from direct wave impact. This wave attenuation capacity may slow rates of landward coastal retreat.

We have conducted a pilot study to investigate the role that variable platform morphology has on attenuation of wave energy. Our study aimed to evaluate the potential for platforms to buffer coasts from storm wave hazards. In particular we were interested in the effect of platform roughness on wave attenuation.

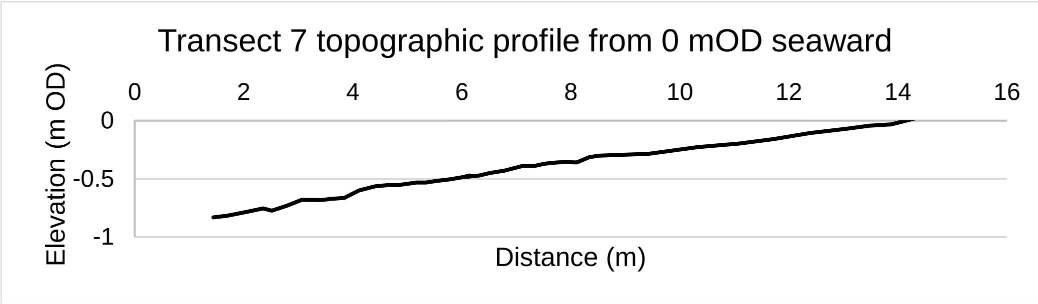
For our pilot study we conducted two field trials on the Baltard Shore Platform (Irish Grid Ref 91583.434E 166693.191N), one in summer and another in winter, as outlined in our project proposal.

Figure 6. Topographic transects (yellow dashed lines) and the locations of pressure transducers (red dots) deployed at Ballard Bay Platform for August (T07_PT01 and T08_PT01) and November (T08_PT01, T08_PT03). Instruments deployed at other locations on this figure failed to return data.

Trial 1 was undertaken in August 2016. We deployed two pressure transducers (PT) (RBR solo wave)) at MSL (0 m Malin Head) during a spring tide. The PTs were placed into two drilled holes (site T08_PT01 and Site T07_PT01) and the sensors were flush with the platform surface (after Stephenson et al., submitted) (see Figure 6 for location). We programmed the sensors to sample every 30 minutes, over a period of 48 hours (4 tides). The nearest tide gauge in Galway, recorded water levels rising by approximately 3.5 m. High resolution topographic profiles were measured using differential GPS through the PT sites. A plot of these data is shown in figure 7

Both sites have a similar slope (difference = 1^0). Qualitatively site 08 appeared to have a higher roughness value. This observation was validated by calculating the RMS value for a 15 m length seaward to the PT deployment site. Site T08_PT01 (0.6) has a higher value than site T07_PT01 (0.5).

Trial 2 was undertaken in November 2016 in order to capture higher energy conditions. The PTs were placed into two drilled holes (site T08 at sites PT01 and PT03 at 3.2 m above MSL) (Figure 6). We programmed the sensors to sample every 30 minutes, over a period of 96 hours (8 tides). Roughness values for the shore platform seaward of site 03 is 1.1.



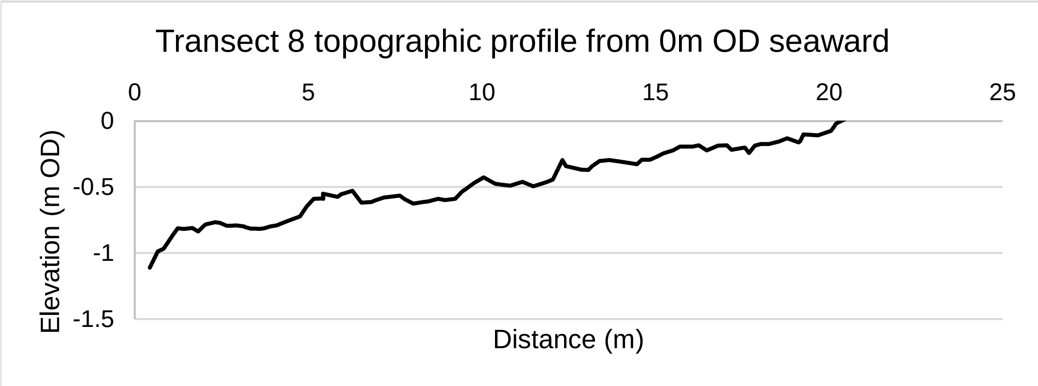


Figure 7. (Top) Topographic profile for transect 7 (T07) from PT deployment location at 0 m OD. (Bottom)Topographic profile for transect 8 (T08) from PT deployment location at 0 m OD.

Results: The data for Trial 1 show that there is a difference in the peak wave energy values at the two sites. Site T08_PT01 had a lower peak (1095 j/m^2) value than site T07_PT01 (1393 j/m^2) (Fig. 8). For smaller tidal ranges there does not appear to be a significant difference in the response of sites with site T08_PT01 showing slightly higher values than site T07_PT01. These data show that even small differences in roughness can significantly attenuate wave energy.

The data for Trial 2 show a distinctive lowering of wave energy between the two sites along T08. The platform roughness value is significantly higher (geologically controlled) and it is expected that this higher value effectively reduced wave energy by the time it reached site T08_PT3 (Fig. 9).

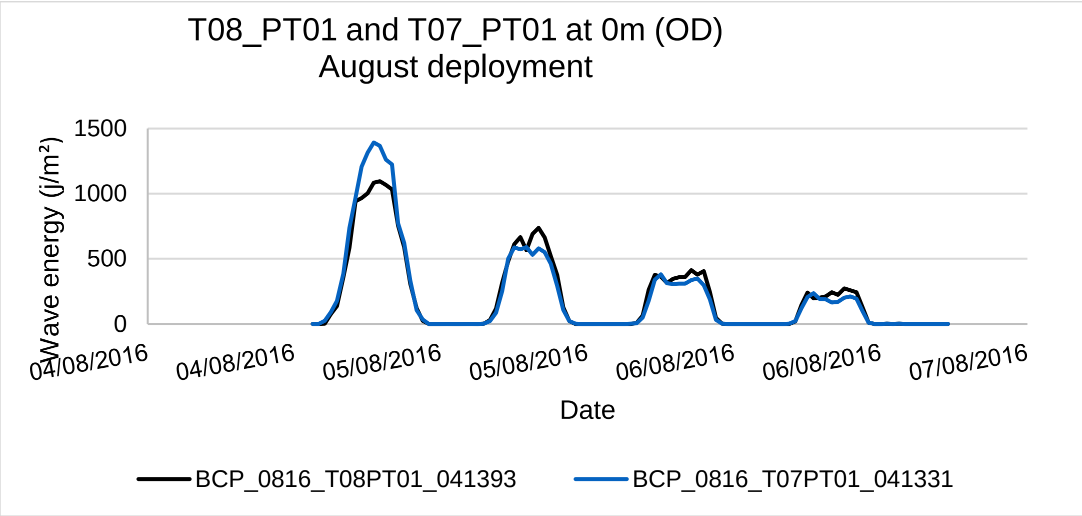


Fig. 8 Results for PT deployment in Trial 1 at Site 07 and 08.

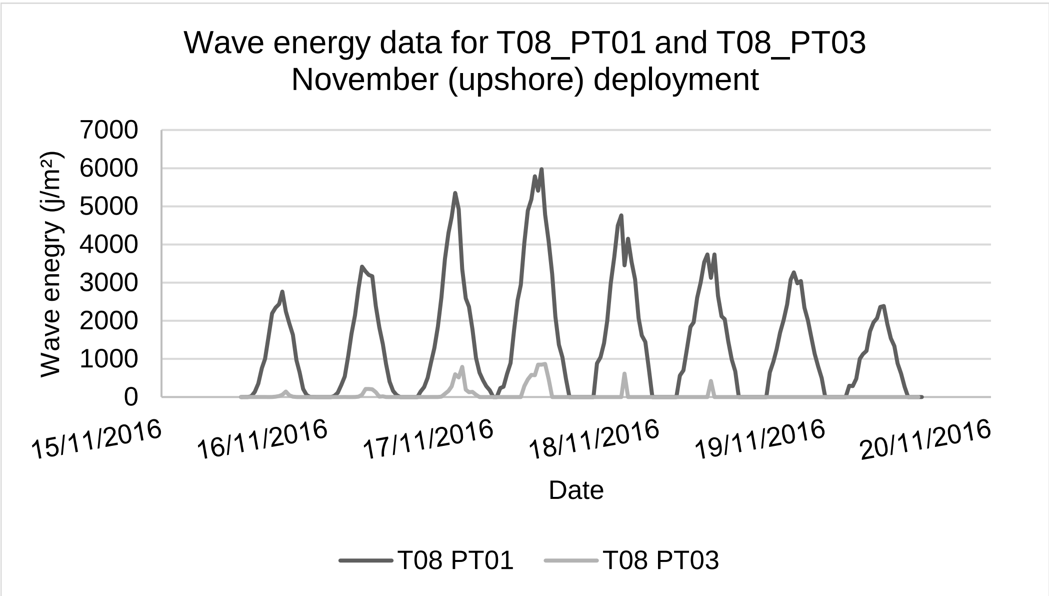


Figure 9: Wave energy data showing significant attenuation on T08 as the wave moved across the platform. Data reported for position at PT01 and position at PT03.

Discussion: The higher roughness at site T08_PT01 was geologically controlled by the presence of mounds. However we have observed significant differences in roughness elsewhere on the platform due to bioerosion. We suggest that further work should focus on the effect of different species, differential erosion processes and their resulting influence on landform development and hence surface roughness. The effects of climate change (e.g., change in storm frequency and intensity, sea water temperature and salinity) are expected to change the colonisation patterns of shore platforms, as well as impact shore platform erosion rates and processes. This in turn may affect the subsequent landform characteristics and thus roughness of platforms.

The significant reduction of wave energy along (e.g. the difference between T08 and T07 summer deployment) and as a wave moves up a platform (e.g., the difference between PT01 and PT03 along T08) illustrates the importance of the role of geological controls on surface morphology and the effects of these on wave energy dissipation. These data reinforce the importance of a new platform classification at geomorphologically and oceanographically relevant spatial scales.

References

Cruslock, E.M., Naylor, L.A., Foote, Y.L., Swantesson, J.O.H., 2010. Geomorphologic equifinality: A comparison between shore platforms in Höga Kusten and Fårö, Sweden and the Vale of Glamorgan, South Wales, UK. Geomorphology, 114(1–2), 78-88.

Dornbusch, U., Robinson, D., 2011. Removal and step backwearing as erosional processes on rock shore platforms: a preliminary case study of the chalk platforms of south east England. Earth Surface Processes and Landforms, 36(5), 661-671.

Kennedy, D.M., 2015. Where is the seaward edge? A review and definition of shore platform morphology. Earth-Science Reviews, 147(0), 99-108.

McKenna, J., Carter, R.W.G., Bartlett, D., 1992. Coast Erosion in Northeast Ireland:-Part II Cliffs and Shore Platforms. Irish Geography, 25(2), 111-128.

Naylor, L.A., Coombes, M.A., Viles, H.A., 2012. Reconceptualising the role of organisms in the erosion of rock coasts: A new model. Geomorphology, 157–158(0), 17-30.

Naylor, L.A., Spencer, T., Lane, S.N., Darby, S.E., Magilligan, F.J., Macklin, M.G., Möller, I., 2016. Stormy geomorphology: geomorphic contributions in an age of climate extremes. Earth Surface Processes and Landforms, n/a-n/a.

Naylor, L.A., Stephenson, W.J., 2010. On the role of discontinuities in mediating shore platform erosion. Geomorphology, 114(1–2), 89-100.

Naylor, L.A., Stephenson, W.J., Trenhaile, A.S., 2010. Rock coast geomorphology: Recent advances and future research directions. Geomorphology, 114(1–2), 3-11.

Stephenson, W.J., Dickson, M.E., Trenhaile, A.S., 2013. Rock Coasts, Treatise on Geomorphology.

Stephenson, W.J., Naylor, L.A., 2011. Geological controls on boulder production in a rock coast setting: Insights from South Wales, UK. Marine Geology, 283(1–4), 12-24.

Stephenson, W.J., Naylor, L.A., Smith, H.A., Chen, B., Brayne, R.P., submitted. Wave attenuation across a macro tidal platform in South Wales, UK. Earth Surface Processes and Landforms.

Sunamura, T., 1992. Geomorphology of rocky coasts, 3. John Wiley & Son Ltd.

Trenhaile, A.S., 1987. The geomorphology of rock coasts. Oxford University Press, USA.

Trenhaile, A.S., Lakhan, V.C., 2011. Transverse micro-erosion meter measurements; determining minimum sample size. Geomorphology, 134(3–4), 431-439.

Wang, S., McGrath, R., Hanafin, J., Lynch, P., Semmler, T., Nolan, P., 2008. The impact of climate change on storm surges over Irish waters. Ocean Modelling, 25(1–2), 83-94.

(ii) Implementation (including reference to timelines, milestones, management)

There were some challenges in implementing the plan. The most significant was that we underestimated the time required to map and validate the platforms. We had to redeploy funds to address shortfall in that budget line. Our hired researcher (Rory Flood) took a teaching position in the UK after 5 months. We were able to rapidly hire a replacement (Ciaran Nash) however this led to some unanticipated short delays in progress.

(iii) Outputs (please use bullet points)

- Map of shore platform distribution for the Republic of Ireland coastline in GIS format is completed. The shape files will be made publically available following publication.
- An improved classification of Ireland's shore platforms is underway. This will submitted for peer review: 'Towards a unified global classification of shore platform types'. *Earth surface Processes and Landforms* (IF = 3.505) (Q1 Journal).
- The quantification of wave energy attenuation across a shore platform in two seasons and relationship to platform roughness was completed. These data demonstrate the need for further work in this area to measure the effects of different platform morphologies on wave attenuation capacity to inform coastal risk and management decisions in Ireland.

Impact/value of the project (M*ax 500 words*):

The proposed research is a fundamental step towards a more complete understanding of the response of Ireland's coastline to future climate change.

In light of recent climate change predictions for increases in the intensity of extreme storms an increase in coastal storm surges and therefore wave height and intensity (e.g., Wang et al., 2008), there is an urgent need to understand the role of shore platforms in natural coastal protection (Naylor et al., 2010). If shore platforms help to reduce rates of coastal retreat through attenuation of wave energy, as our data would suggest, then our new map of their distribution represents a significant contribution towards understanding of the response of Ireland's coast to the impacts of future climate change, specifically sea level rise and increased storminess. As such, our contribution to identifying where these features are located and illustrating how wave energy is attenuated or exacerbated across platforms with different morphologies is a significant contribution and will have important implications for predicting rates of coastal erosion in the future. This work thus demonstrates the crucial role geomorphological science can play in aiding society understand and better manage the landscape risks associated with climate change (Naylor et al., 2016).

The proposed new classification platforms will make a contribution of international significance. It will contribute to the tool kits available for understanding platform geomorphology and contribute to a more comprehensive, quantitative and unified global classification of platform morphologies found in meso and macro tidal environments. This classification, once published in the academic literature, will be a large improvement in the simple, qualitative classification frameworks that currently exist. This classification will be useful for field scientists, as well as landform evolution and climate change impact modelers. We expect citations of our work to be high (in the context of rock coast geomorphology paper citations), sustained over time and thus help highlight Ireland's globally cutting edge research capacity.

The mapping outputs and GIS data layers will be made freely available after publishing, which will increase the long-term use of these mapping data by practitioners for strategic planning purposes. We will disseminate this to practitioners via the Geological Survey and through our contacts in relevant government departments.

The pilot analysis of shore platform wave attenuation across platform types provides the first Irish dataset of wave attenuation across shore platforms. This will be used to guide future research and management efforts to develop a risk register for rock coast erosion under a changing climate.

The academic and user impact of the results of this project is expected to be long term and stimulate further research on these neglected coastal landforms in the future.

Appendix 1 – Publications & Presentations:

Bourke, M.C., Flood, R., Goffo, F., Migge, K., Cullen, N., Nash, C.**,** Naylor, L., (2016). “They’re not all flat y’know”: Mapping Ireland’s coastal platforms. Irish Geomophology Group, Cork.

Bourke, M.C., Flood, R., Goffo, F., Cullen, N., Naylor, L., Nash, C.**,** (2016). A new map of Ireland’s coastal platforms. *Integrated Mapping for the Sustainable Development of Ireland’s Marine Resource*, Galway