Roinn Cumarsáide, Gníomhaithe ar son na hAeráide & Comhshaoil
Department of Communications, Climate Action & Environment

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Research Programme
- Short Calls, Final Report -

Lead Applicant Name	Siddhi Joshi
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Host Organisation name	National University of Ireland Galway (NUIG)
Project Title	Modelling maerl habitat dynamics in response to increased storminess
Contract Number	2017-sc-043

Date: 15th November 2018

This report covers the period November 1st 2017 to October 31st 2018

2. (a) Project information:

<u>Final project report (*max **2500**words, excluding figures and headings*)</u>:

- *<u>Progress</u>* of objectives and scientific/engineering targets beyond the state of the art & *<u>methods</u>* used

Rhodolith (maerl) beds are unique, free-living, non-geniculate coralline red algae forming biodiverse habitats and dense biogenic debris beaches. This multi-disciplinary study investigates the response of offshore maerl beds and maerl debris beaches to Atlantic storminess. Specifically, the morphosedimentary evolution of maerl beaches over timescales of seconds (swash dynamics) to months (seasonal response) was measured using a suite of integrated, multi-disciplinary field and laboratory methods based on hydrodynamic modelling, bathymetric and topographic mapping, and groundwater fluxes. The experiments utilise experimental results from previous research (Joshi et al. 2014, 2017a, 2017b, Farrell and Sherman 2015) to develop and validate process-response models for maerl.

Figure 1. A. Biogenic gravel composed entirely of dead maerl (debris) at Trá an Doilin (Carraroe) beach, County Galway. B. Individual clasts of maerl debris on beach (photo length: 0.05m). C. Living maerl beds in approximately 5m bathymetry (photo length: c.0.60m). D & E. Concentric patterns at Trá an Doilin suggests maerl has a higher mobility than quartz sediments.

Firstly, the INFOMAR LiDAR Bathymetry was obtained for Greatmans Bay from the Geological Survey Ireland (Figure 2) and the maerl distribution was compiled from data from the National Parks and Wildlife Service.

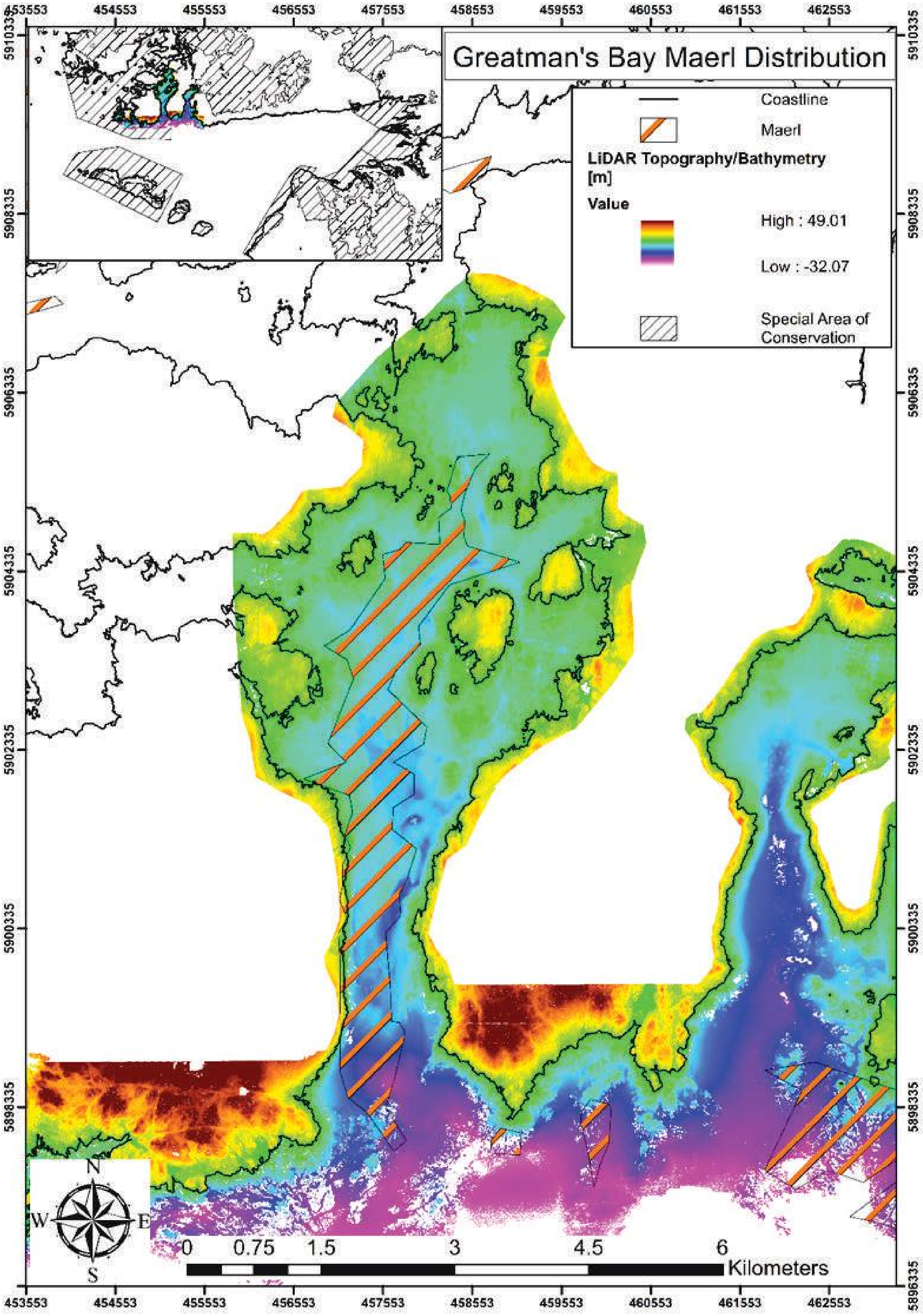

Figure 2: INFOMAR LiDAR Data of Greatman's Bay, with maerl bed distribution, as mapped by National Parks and Wildlife Service.

Tidal data was examined and the measured water levels from Rossaveel tide gauge are presented here (Figure 3).

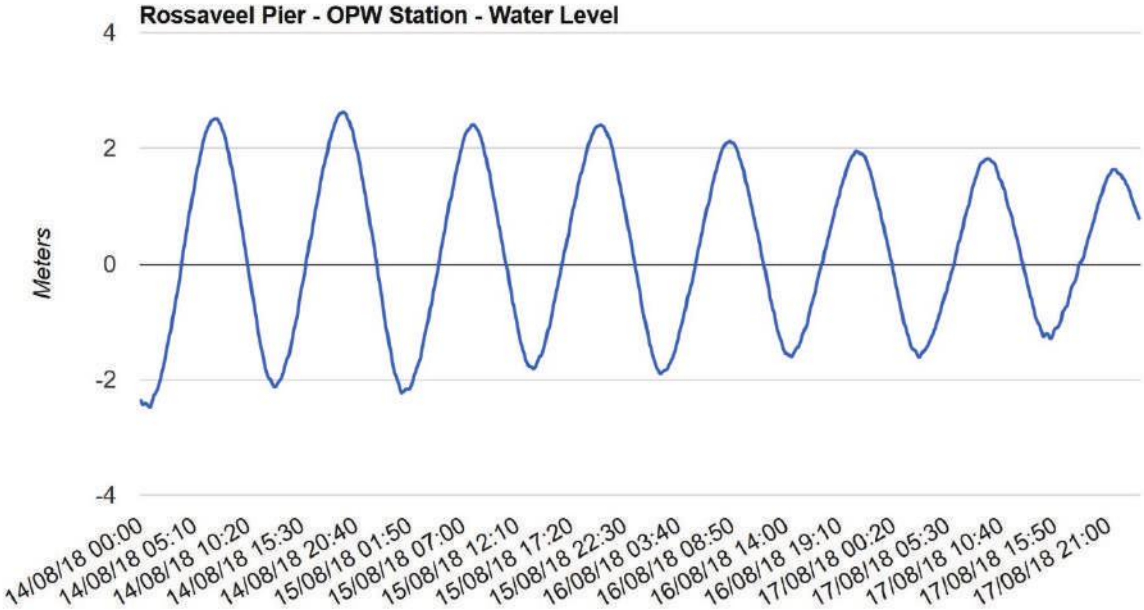

Figure 3: The measured tidal data for duration of the fieldwork days.

The Senix ultrasonic distance sensor was the primary tool utilised for monitoring the intrawave sediment transport on the maerl beach. The first stage involved calibration of the distance sensors (Figure 4). This was carried out in the laboratory and gave a very high R^2 value as expected. The biggest challenge was to construct an instrument suitable to withstand the high shear stresses of the swash zone and the 4.5m mean spring tidal range (Admiralty, 2015). The designing of a new prototype frame constructed with Conlok pieces was carried out in the lab. It was important for the mobilisation of the frame to be possible during low tide and the field set up to be as efficient as possible. The final frame (Figure 5) was constructed in the field and spanned 7 m (in length) x 1 m (in width) x 2 m (in depth). Figure 6 shows the frame during the flooding tide and Figure 7 shows a close up of the frame (sensors).

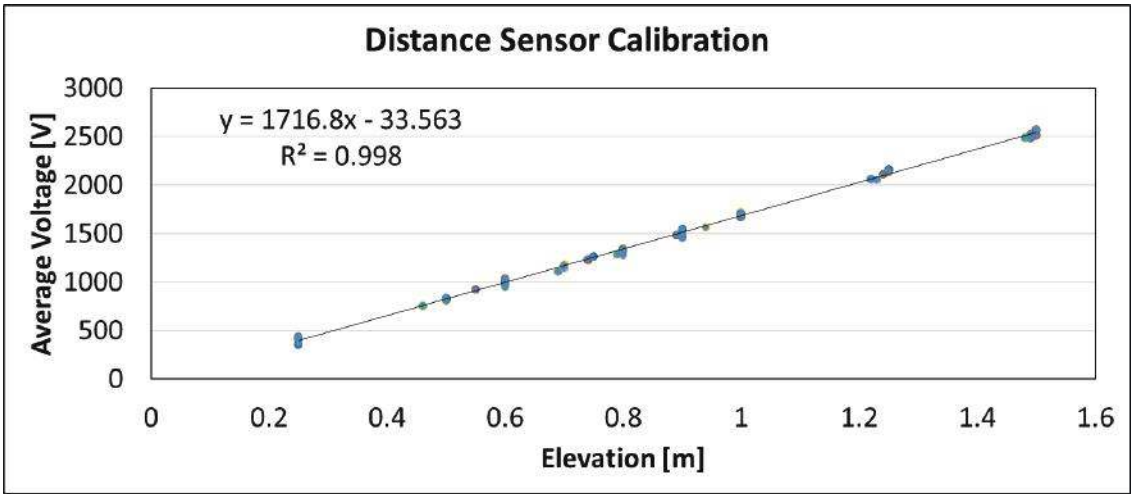

Figure 4: The calibration line of the ultrasonic distance sensors was utilised to convert measured voltages into elevations.

Figure 5: The frame with seven ultrasonic distance sensors mounted to monitor the morphodynamic response with the incoming and outgoing tide and the intrawave sediment transport.

Figure 6: The frame needed to be strong enough to withstand the flooding (and ebbing) tide.

Figure 7: Close up of the frame with sensors mounted.

The UAV drone footage of the maerl beach was successfully obtained (Figure 8), as well as a GoPro underwater video camera mounted at the side of the frame (Figure 9 and Figure 10).

Figure 8: Footage of the constructed frame at Carraroe maerl beach as obtained by the drone.


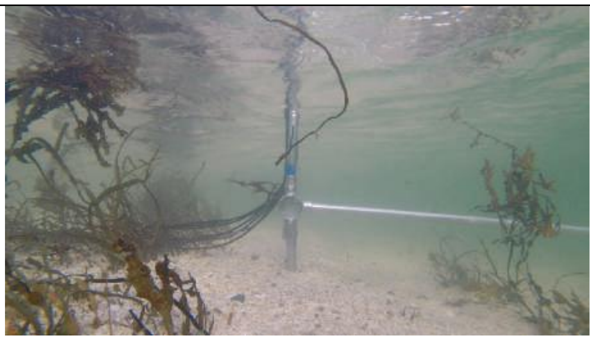

Figure 9 (left): The GoPro video mounted at the side of the frame was able to capture the intrawave sediment transport to additionally be a visual check for the distance sensor data. Figure 10 (right): Example of immersed GoPro footage.

Figure 11: Drone footage obtained using the DGI Pro taking transects of the maerl beach.

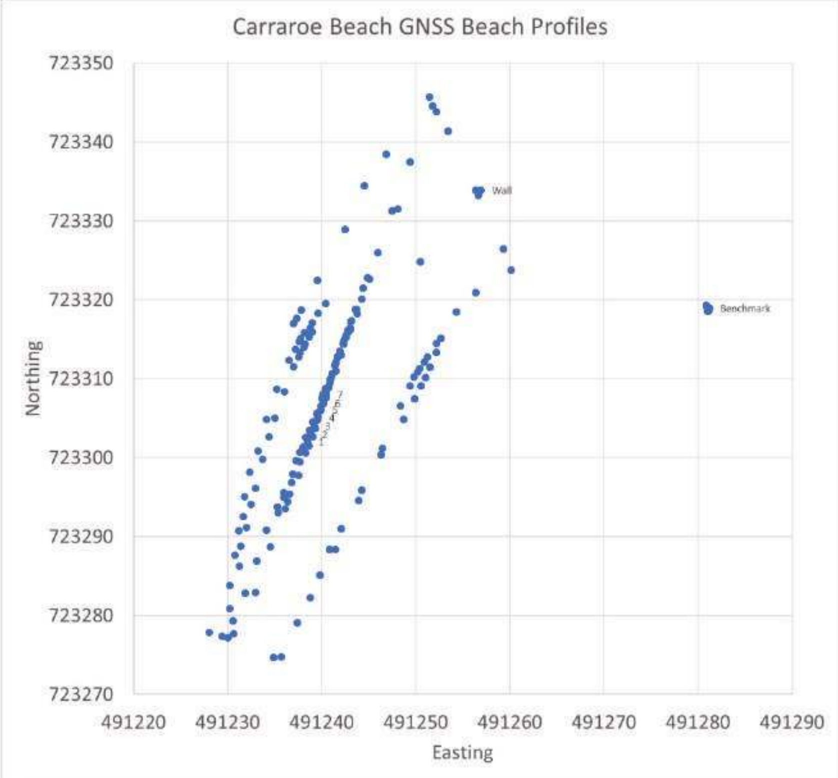

Figure 12: Location map of the points used to construct a beach profile of Carraroe beach.

A Nortek AWAC was deployed using a small boat for the duration of the week to measure the offshore waves (Figure 13). Winds from Mace Head Atmospheric station are being utilised to drive the wave model, to simulate a hindcast model during the field work week (Figure 14).

Figure 13: The RIB use utilised to deploy the AWAC at a depth of 7m in the centre of Greatman's Bay, with acknowledgements to Clynton Gregory of Earth and Ocean Science, NUI Galway.

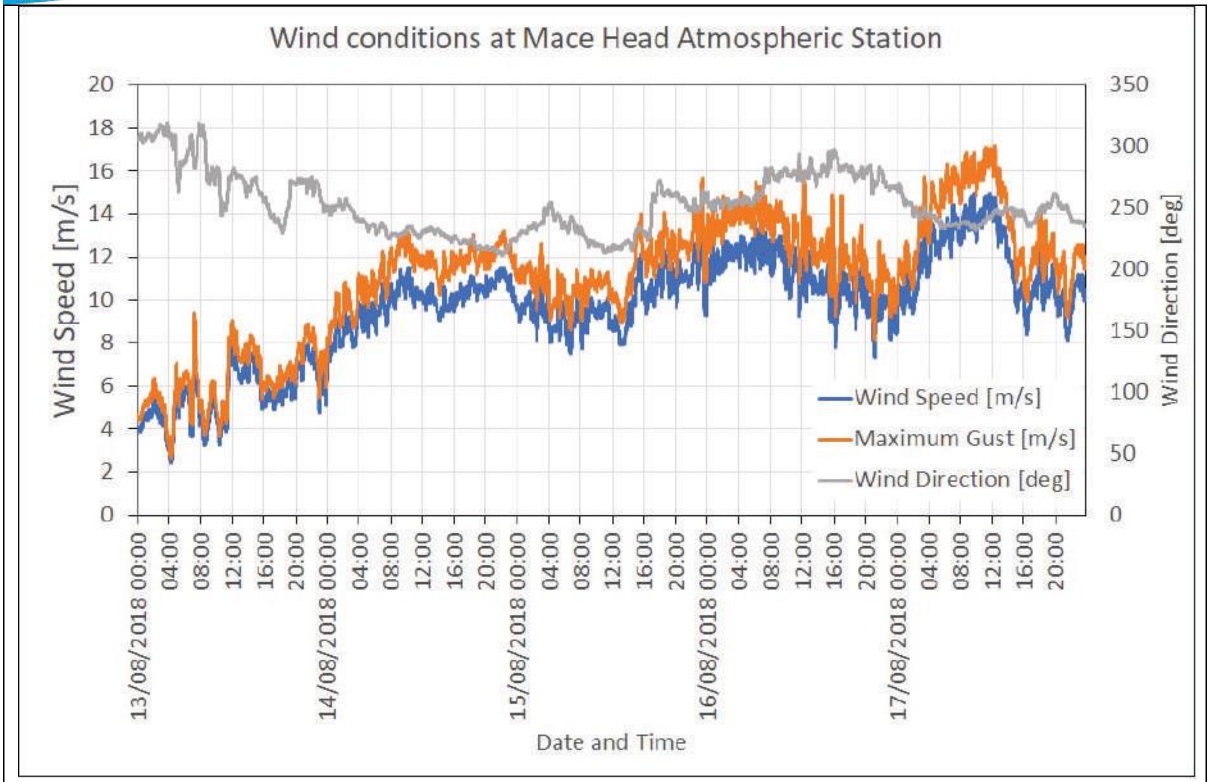

Figure 14: Wind conditions at Mace Head Atmospheric Research Station during the field week.

The AWAC data is presently being utilised to drive the XBeach model and utilise results from field work to develop a coupled- hydrodynamic-wave- sediment transport model and subsequently a morphodynamic model. Following a training course on WaveWatch III wave model in Brest in France, the following coupled modelling methodology is considered to be most appropriate to model the storm surge and the morphodynamics response of the maerl beach (Figure 15).

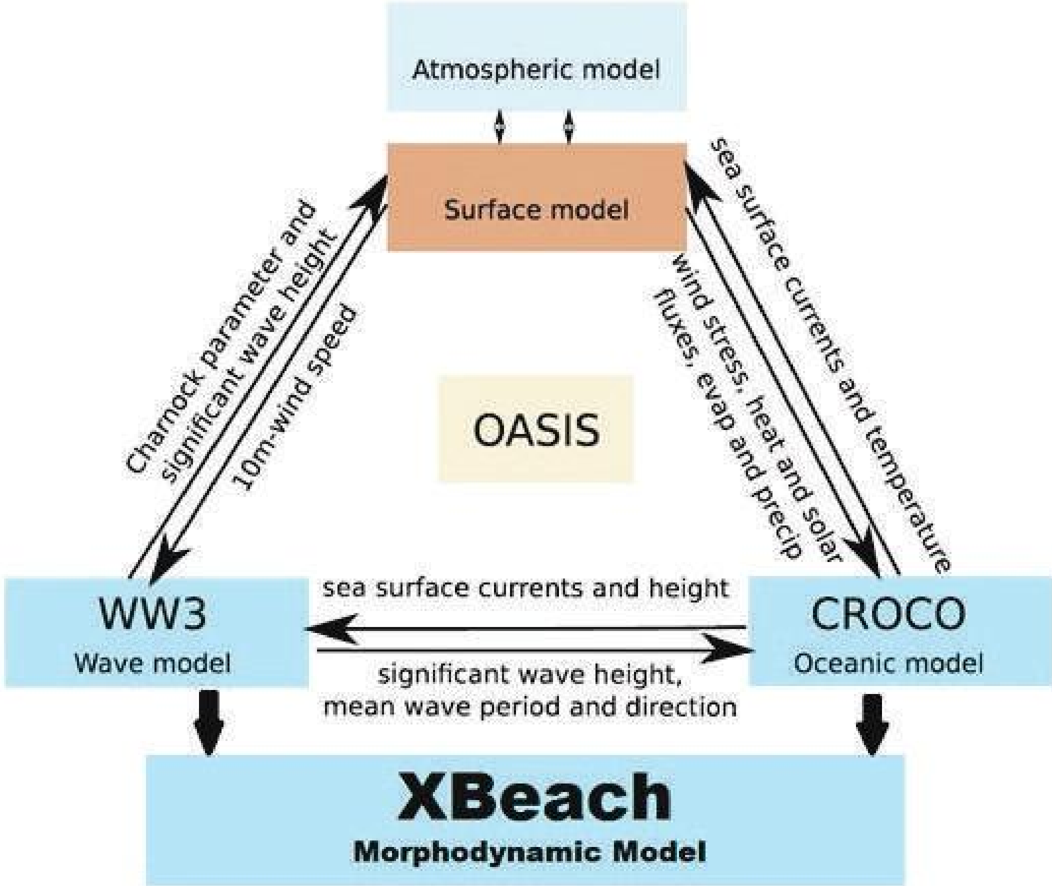

Figure 15: The resources of the Irish Centre for High End Computing are being utilised to run the coupled model methodology on the Kay super computer.

As wave induced currents are an important component to model the combined wave-current induced sediment transport, the modelling methodology has been modified to include these new coupled models. The Coastal and Regional Ocean Community (CROCO) regional hydrodynamic model, was coupled to the WaveWatch3 modelling software to model the regional wave climate. The OASIS Coupling software is utilised for the coupling and the sediment transport model of CROCO is also utilised. The hydrodynamic conditions generated by this model then feeds into the XBeach model. An Unstructured Computational Mesh was generated in several iterations to ensure a balance between resolution and computational efficiency (Figure 16).

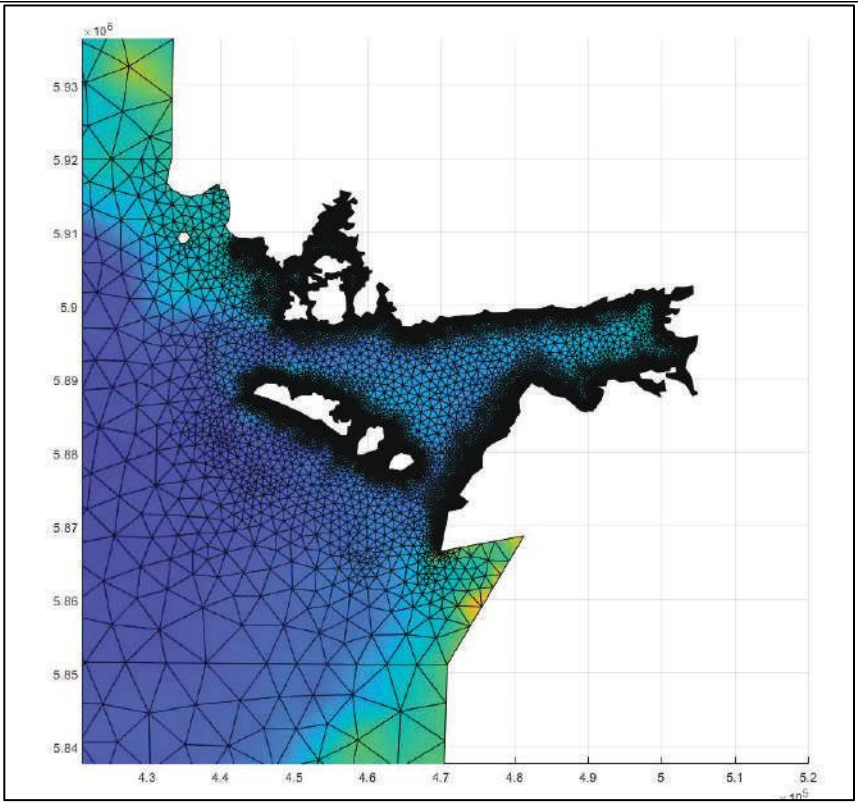

Figure 16: The unstructured computational mesh, with high resolution nests adjacent to the coast.

One dimensional and two dimensional morphodynamics models are being developed in XBeach-G and XBeach (2D). To date, the simulated wave conditions have been successfully applied with other physical parameters at the site. The Intergovernmental Panel on Climate Change (IPCC) wave climate scenarios are presently being selected in order to model the impact of increased storminess on maerl environments. XBeach morphodynamic model one dimensional model are being run (Figure 17) and an example of XBeach Morphodynamic Model Two Dimensional Results (Figure 18) are discussed in the modelling amended final report.

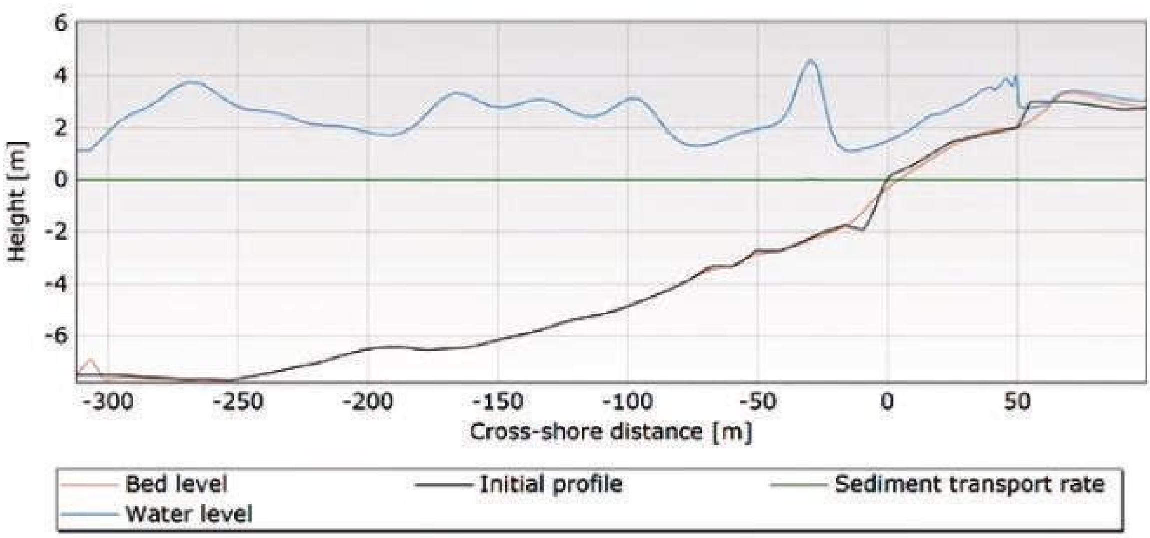

Figure 17: A one dimensional XBeach model (see: https://vimeo.com/264141336/c7bea7a5c9)

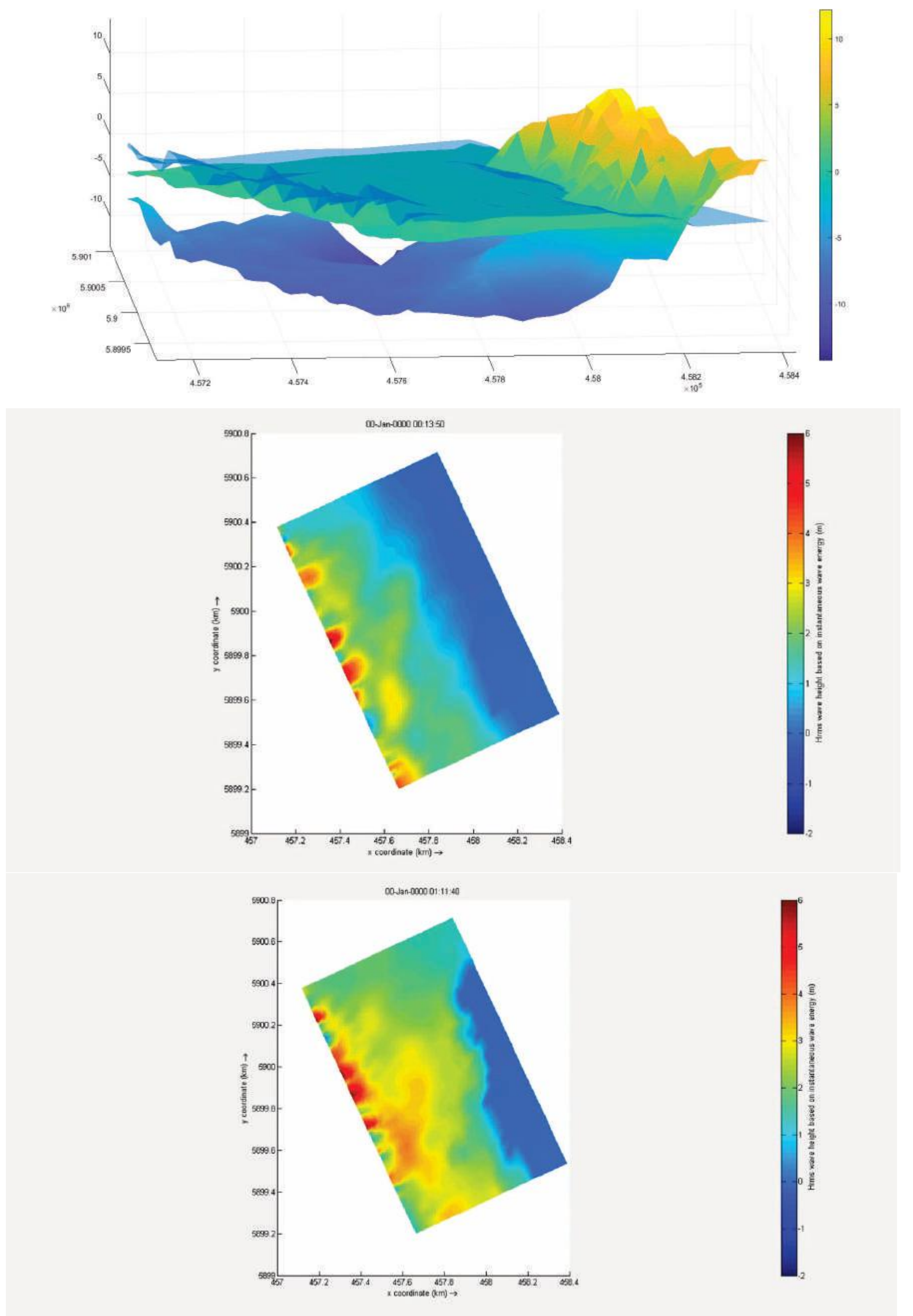

Figure 18: Two dimensional X-Beach model of Carraroe (see https://vimeo.com/265401892/59cfd73ee7)

This model is presently being extended into a coupled storm surge model, with the inclusion of an atmospheric model, hydrodynamic model and wave model (in future amendment to report), utilising the facilities of the Irish Centre for High End Computing (ICHEC). Please see the upcoming amended final report for the following results:

- Modelling: CROCO Hydrodynamic Model
- Modelling: WaveWatchIII Model
- Modelling: CROCO Sediment Transport Model
- Modelling: Atmospheric model
- Modelling: Mobility Indices
- Final Distance sensor results
- DTM of Carraroe Beach utilising drone footage and GNSS

Implementation **(please include any issues with timelines, milestones, management etc. or deviations from the original implementation plan)**

All components of this project have been successfully implemented however with some delays of several months due to factors outside our control. Due to exceptionally severe winter storms, fieldwork took place in August 2018 rather than during winter and captured a summer storm event. This decision allowed us to design and test the new frame for morphodynamics fieldwork during summer storm conditions. The field design proved to be very successful and the prototype frame can be used in future summer conditions for beach morphodynamics work. Delays in the Irish Centre for High End Computing of over 3 months have resulted in the modelling component being delayed and hence majority of the modelling results will be included in the amended final report. (Their supercomputer was being upgraded from Fionn to Kay over the summer).

The International Rhodolith Workshop occurs every three years and is a highlight amongst rhodolith or maerl related researchers. This meeting in Roscoff marine station was world leading in the field of coralline algal research. The main learning objectives were to gain feedback about our coupled hydrodynamic-wave-sediment transport modelling results in Galway Bay and morphodynamic modelling of the maerl beach in Carraroe. Numerous international scientists – botanist, ecologists and multidisciplinary coastal scientists were present including Jacques Grall of IUEM, Daniella Basso, Italy and Sophie Martin of Roscoff Marine Labs. I made my presentation in the Geology strand on Wednesday and this presentation was unique in the field of sediment dynamics of maerl and received many positive comments from researchers.

The conference was an ideal learning opportunity at this stage and presenting something for the third time (2012, 2015, 2018) I was able to demonstrate a commitment towards rhodolith research and this was very beneficial for my professional development and personal confidence in terms of presenting at international conferences. Numerous networking opportunities were available including with Francis Bunker of Pembrokeshire and Jason Hall-Spencer of University of Plymouth, who expressed an interest in the maerl documentary. Diana Steller of Moss Landings, in her presentation identified significant research gaps in research on the Geomorphology of Maerl/Rhodolith beds and I completed and submitted a chapter on this exact topic for a book on Seafloor Geomorphology as Benthic Habitat. A supervision opportunity was also a possibility, with Memorial University in Canada. Practically, the highlight was the boat trip in the Bay of Brest, where we had the opportunity to examine the condition and carry out in-situ sampling of the live maerl beds as well as heavily fished maerl beds. A short blog post about this trip was made on the Seabed Habitats Blog.

The benefits of presenting this work to the wider marine research community is that the knowledge gap in understanding these coastal ecosystems is gradually being filled. Additionally, Ireland demonstrated a commitment to protecting this unique marine habitat in the shallow seas.

- **Outputs** **(please provide a short description *and* complete the table below)**

The outputs from this project include numerous national and international (both poster and oral) presentations as discussed in the list below, a book chapter on the geomorphology of maerl being submitted to the "Seafloor Geomorphology as Benthic Habitat" Elsevier Insights book (Second Edition) and in future as a logical progression to this work, peer-reviewed papers.

A key output is that we submitted the book chapter on Maerl in Galway Bay to the Seafloor Geomorphology as Benthic Habitat book (Elsevier Insights) and in my scientific opinion, Irish maerl beds are very high in naturalness, with numerous rare species of maerl occurring together in inner Galway Bay, but the condition of these beds shows a declining trend. This is primarily due to increased storminess and coastal erosion of the maerl sub-aqueous dune systems, but also due to increased anthropogenic impacts over maerl beds. This conference has enabled me to better identify additional factors to consider with quantifying the disturbance of this benthic habitat.

The Rhodolith conference also introduced the Rhodolith Ecosystem Ecology and COnservation Network (REECON)- a new network of rhodolith related scientists and conservationists. Overall, this network aims better coordinate international research efforts in rhodolith-related science. This network is currently in its early stages and there is the opportunity to take further leadership roles in future. I had the opportunity to volunteer for open positions and roles.

Overall, this international conference was a tremendous opportunity to present our work on maerl geomorphology and morphodynamics to a multidisciplinary audience of world leading scientists. My presentation made a significant impact and had numerous questions and encouraging comments afterwards. A copy of the presentation, with the GSI and MI Travel and Networking Grant acknowledgements slide was provided in the Second Interim Report. In terms of networking, this conference was highly significant in fostering future collaborations with international scientists, both in the British Isles, France, Italy, United States and Canada. The scientific gaps internationally in understanding the geomorphology and the oceanographic drivers governing maerl distribution are now being addressed through a book chapter (Supplementary Materials). The REECON Network is a newly established international networking initiative with aims to bridge the knowledge gaps in rhodolith research and there is the opportunity to take further leadership roles in future as a result of attending this conference.

Task No.	Deliverable description	Planned delivery (as per proposal)	Date of delivery
1	Permissions to work in SAC (NPWS, Galway CC) Field design and instrument testing One Dimensional Modelling Results Month 1-2	December end	July End
2	Instrument deployment (long term): Nortec AWAC, Groundwater, Monitoring camera. Field observations (1-2 weeks onsite): high frequency instrumentation and mapping Month 3	January end	August end
3	Time series analyses (morphodynamics) Two Dimensional Modelling Results Month 5	March end	September end
4	GIS mapping and spatial analyses Additional Fieldwork Results (to be confirmed) Month 7	To be confirmed	Not applicable
5	Validation of Models and Measurements Complete Month 8	June end	October end
6	Conference presentation in France Month 8	(June 25th- 29th 2018)	(June 25th- 29th 2018)
7	Peer-Reviewed publication in international journal Month 11	September end	September end
8	End of Project Report Month 12	October end	Due date
9	Scientific Blogging on Seabed Habitats Blog	All stages	All stages

Publications to date:

Book Chapter: Joshi S. and Farrell E (Submitted) Physical Oceanographic Drivers of Geomorphology of Rhodolith/Maerl Beds in Galway Bay, Ireland, In: Harris P.T. and Baker E., Seafloor Geomorphology as Benthic Habitat- 2nd Edition, Elsevier Insights.

RTE Brainstorm: Life's a (maerl) beach.

Poster: Joshi S and Farrell E. Modelling Maerl Habitat Dynamics in Response to Increased Storminess (2), Geoscience 2018, Dublin Castle, November 2018

Poster: Joshi S and Farrell E. Modelling Maerl Habitat Dynamics in Response to Increased Storminess (2), INFOMAR Seminar, Kinsale, November 2018

Invited Presentation: Joshi S and Farrell E. Sediment Mobility Modelling and Habitat Dynamics of Maerl in Galway Bay, DHI Symposium Day Ireland, Engineers Ireland, Dublin, September 2018

Presentation: Joshi S and Farrell E. Modelling Maerl Habitat Dynamics in Response to Increased Storminess, VI International Rhodolith Workshop, Roscoff Marine Station, France, June 2018

Poster: Joshi S and Farrell E. Modelling Maerl Habitat Dynamics in Response to Increased Storminess (1), Irish Geological Research Meeting (IGRM), February 2018, University College Cork, Cork

Poster: Joshi S and Farrell E. Modelling Maerl Habitat Dynamics in Response to Increased Storminess (1), Ryan Institute Research Day, NUIG, Galway, February 2018

Poster: Joshi S and Farrell E. Modelling Maerl Habitat Dynamics in Response to Increased Storminess (1), Geoscience Early Career Conference, January 2018, NUI Galway

Poster: Joshi S and Farrell E. Modelling Maerl Habitat Dynamics in Response to Increased Storminess (1), Irish Geomorphology Meeting 2017, Geological Survey Ireland, Dublin

4. Data/outputs submitted with final report *(please list the documents, presentations, datasets etc. submitted with this report)*

a. Fieldwork: GPS Beach Profiles
b. Fieldwork: AWAC offshore wave data
c. Fieldwork: Distance sensors Data
d. Fieldwork: UAV DTM of Maerl Beach
e. Fieldwork: GoPro Video
f. Fieldwork: Generic Photos
g. Modelling: Input Data
h. Modelling: CROCO Hydrodynamic Model Results
i. Modelling: WaveWatch3 Model Results
j. Modelling: CROCO Sediment Transport Model Results
k. Modelling: XBeach Morphodynamic Model One Dimensional Results
l. Modelling: XBeach Morphodynamic Model Two Dimensional Results
m. Modelling: Validation Data
n. Modelling: (in future amendment to report) Atmospheric model Results
o. Modelling: (in future amendment to report) Mobility Indices Results

SUPPLEMENTARY MATERIAL

(This section will be included in your published report unless otherwise instructed. If you have a published report, publication, etc. you may include it here).

Book Chapter on maerl geomorphology (Not for inclusion on website)