An Investigation into the History and Morphology of the Outer Hebridean Machair Grassland Environment

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Introduction:

The Outer Hebrides are one of only two locations globally where machair, a form of calcareous grassland, can be found (Doody, 2012). The Holocene Marine Transgression (HMT) saw a large relative rise in sea level, which, combined with the powerful Atlantic coastal processes, led to the major incursion of sand and glacial outwash in c 7600 BP, creating the low-lying, sediment rich machair landscapes (Ritchie et al., 2001).

The Udal Peninsula on the Outer Hebridean island of North Uist, is a site with a rich archaeological palimpsest providing an unbroken timeline of occupation from the Neolithic Age to the Medieval period.

Concerningly, my previous research indicates that land-coverage changes due to 20th Century agriculturalization and pastoralism, coupled with rising sea levels and increasing storm activity (Hansom and Angus, 2005), have resulted in average coastal erosion rates of up to 2.7 m/y, with 950,000m² of land lost since 1881.

Furthermore, lithostratigraphic evidence suggests that a large marine influx in the 1880s occurred, destructively inundating the peninsula. These initial findings highlight the erosional threats to this archaeological heritage, and the need to find cost-effective ways to preserve both the archaeology and the livelihoods of the peninsula's inhabitants.

This research aims to build on these previous findings to better understand the erosional processes and the role of the vegetation in affecting the coast's susceptibility to erosion, which in turn will be used to inform mitigative land management strategies. This years research will investigate:

- **Part A.** Does the biostratigraphy of the fossil sediments support the Marine Influx Hypothesis (MIH)?
- **Part B.** Does the sediment stratigraphy support the MIH and provide an indicator of which processes drive coastal change?
- **Part C.** To what extent do the structures of the root systems of different coastal vegetation types affect the susceptibility to coastal erosion?

Field Locations:

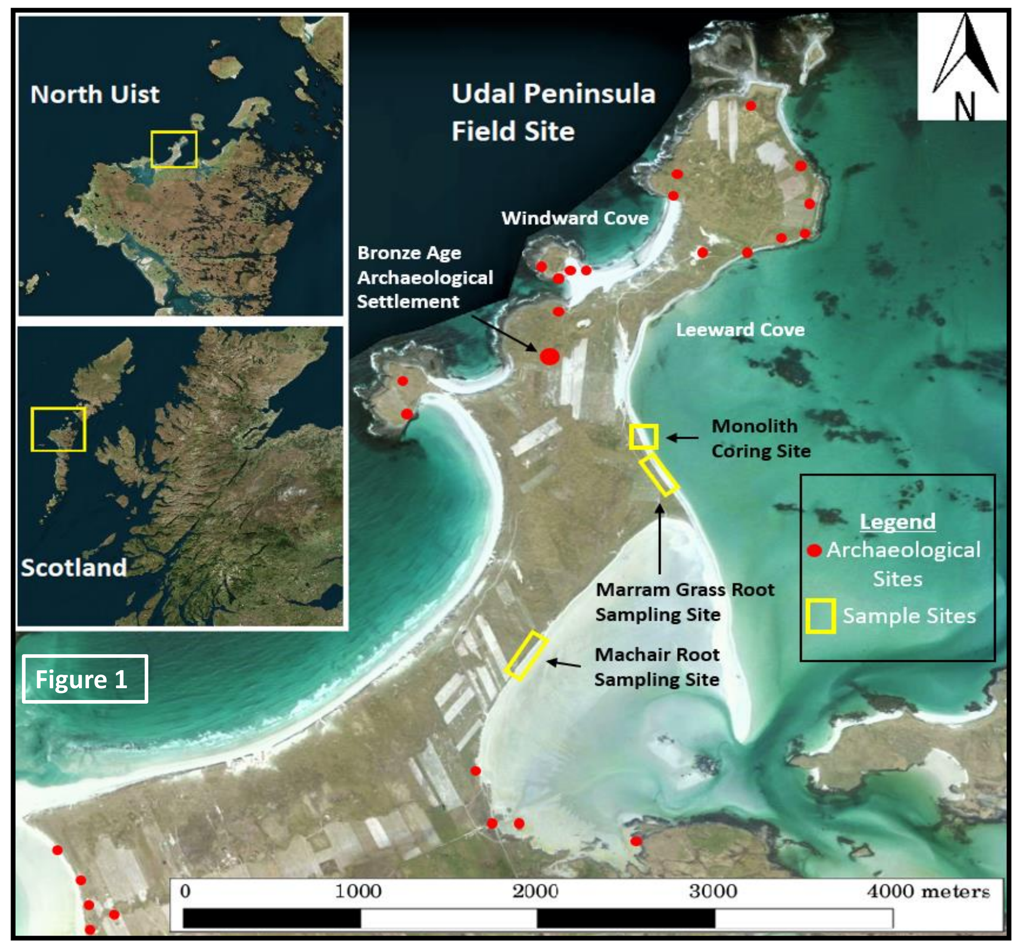


Figure 1

Methods:

- **Part A:** Subsampled between 68-84cm in the monolith core, segregating the 63-550μm fraction by wet sieving.
- Microscopically analysed the 63-500μm fraction for foraminifera.
- **Part B:** Subsampled from the monolith core at 4cm intervals and chemically prepared the samples for analysis.
- Measured particle size using the Coulter laser diffraction granulometer. Analysed the data using the Gradistat software and plotted the results in Microsoft Excel.
- **Part C:** Used Vernier calipers to measure all root diameters within three 30cm² areas at regular depths for both the machair and marram grass land coverages.
- Calculated the root area ratio and plotted the data in Excel.

Part A: Biostratigraphic Evidence of a Marine Influx

- The presence of foraminifera (calcareous micro-organisms) in terrestrial sediment sequences can indicate a marine influx as they live in planktic or benthic habitats.

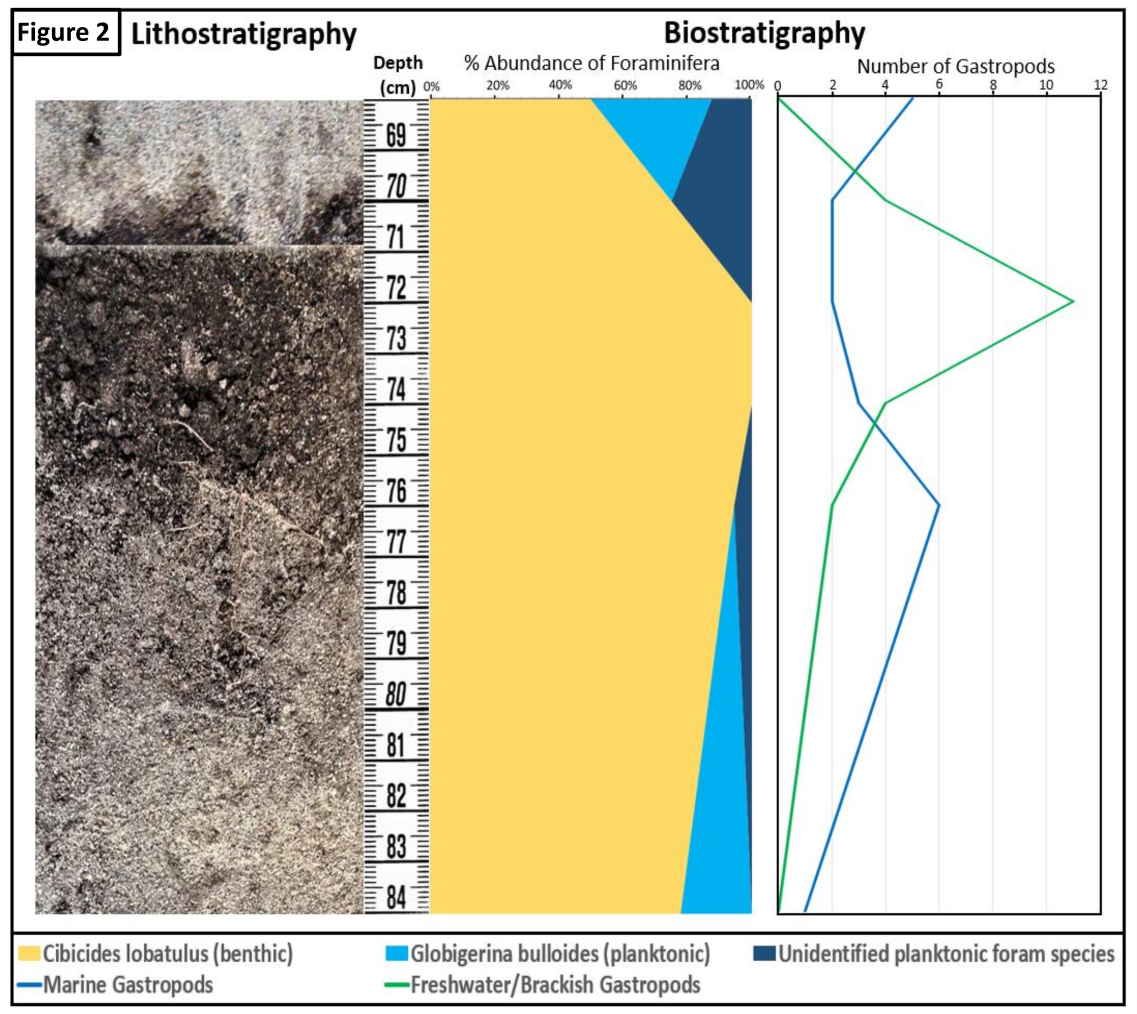
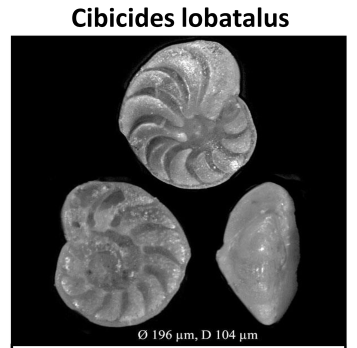


Figure 2 illustrates that the percentage abundance of planktonic foraminifera and number of marine gastropods are highest immediately above the humus layer.

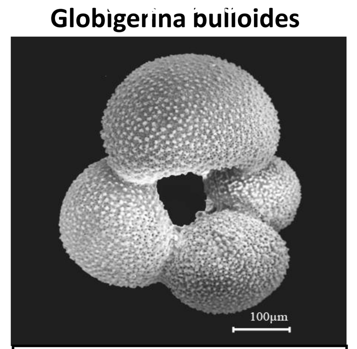
Freshwater gastropods are found primarily within the layer between 70-76cm. The abundance of *Cibicides lobatulus* within this layer appears high due to the absence of other forams, however only 20 were found between 70-76cm, suggesting they are aeolian

Cibicides lobatulus



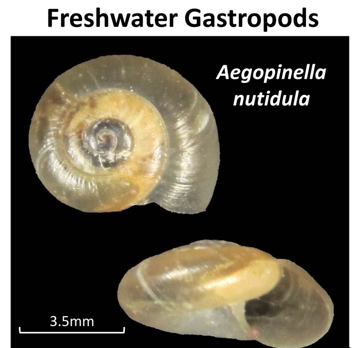
Habitat: Hebridean marine slope in the coarse substrate.

Globigerina bulloides



Habitat: The photic zone of pelagic environments.

Freshwater Gastropods

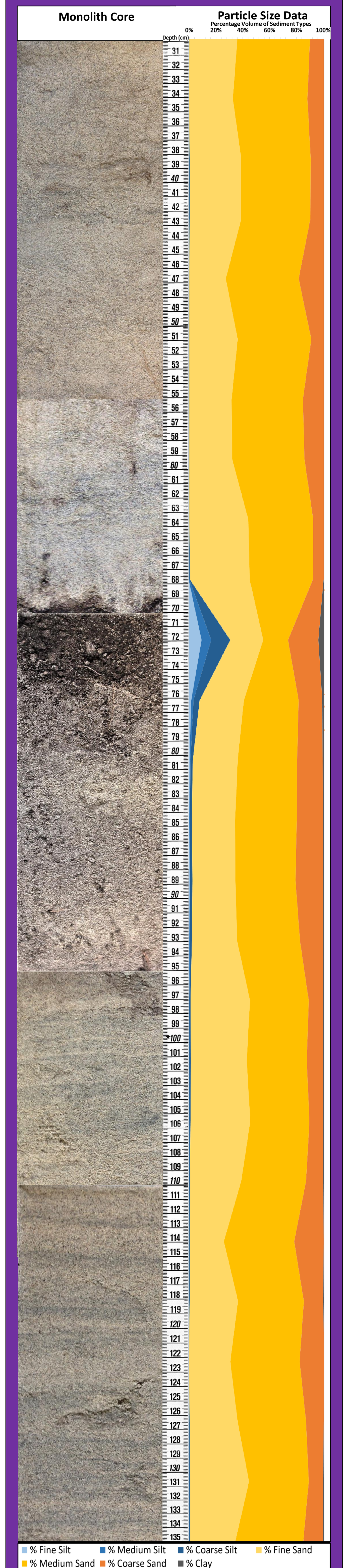


Habitat: Humid conditions such as marshes and springs.

- The numerous freshwater gastropods in the humus layer strongly suggest that it is a paleo-marsh.
- The presence of planktonic foraminifera above the humus contact suggests a high-energy depositional environment.
- The monolith core's biostratigraphy is therefore found to strongly corroborate the MIH proposed in Poster 1.

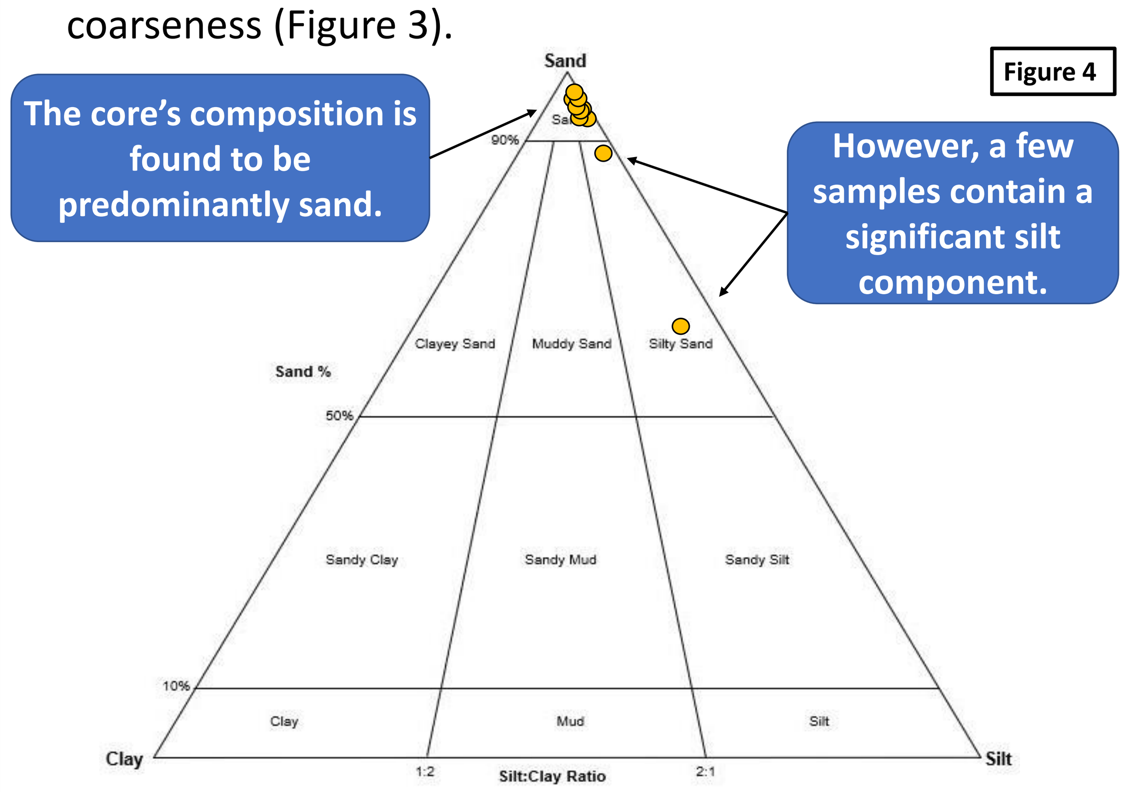
Udal Monolith

Figure 3



Part B: Lithostratigraphic Evidence of a Marine Influx and Erosional Processes.

- Particle size analysis of the sediment in the monolith core revealed the presence of clay, silt and sand of varying coarseness (Figure 3).



The core's composition is found to be predominantly sand.

However, a few samples contain a significant silt component.

The predominant composition of the samples illustrated in Figure 4, can be explained by the distribution of offshore sediment types detailed in Figure 5.

The large storm event of November 1881 that is hypothesised to have resulted in the marine influx, would likely have deposited only the offshore sandy sediment to the east of the study site onto the marsh.

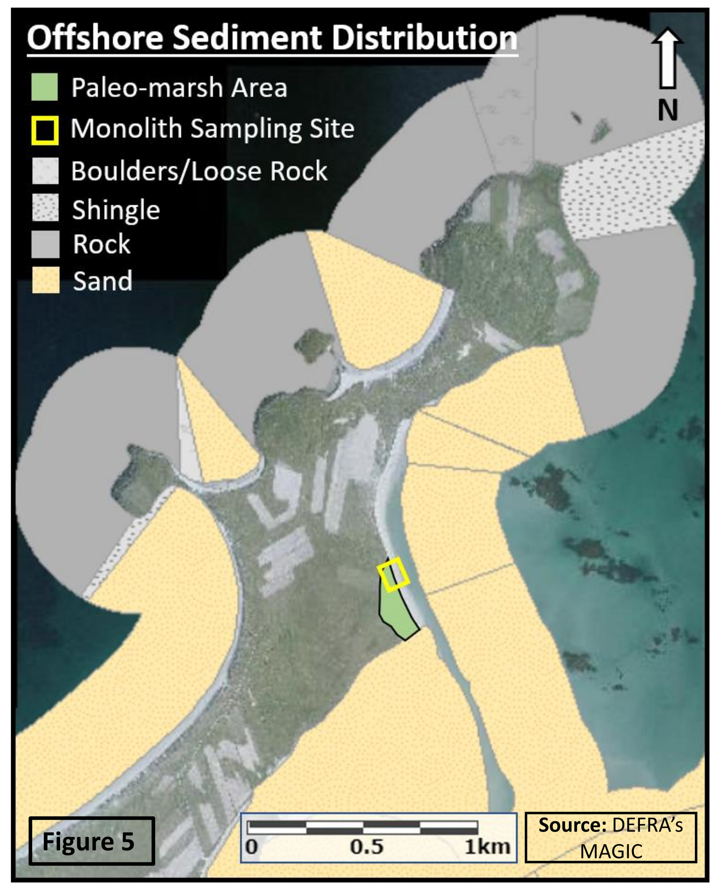
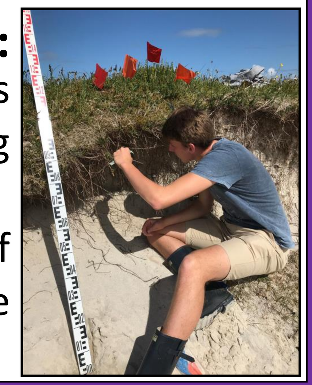


Figure 5

This offshore sediment distribution explains the core's homogeneity of sediment and the paucity of shingle or marine clays.

- The 30.9% increase in silt and 4.4% increase in clay content at 72cm illustrated in Figure 3, correlates with the humus unit from 70-76cm, denoting their terrestrial origin.
- The particle size data above the lithostratigraphic contact at 70cm is comparable to the rest of the core, showing no notable increase in granule size or the presence of marine clays which are typically associated with a marine influx.
- Furthermore, the fine laminated strata evident between 95-135cm in the core, likely indicating the occurrence of storm events (Dawson et al. 2004), are found to be imperceptible to the PSA procedure.
- These findings suggest that the PSA data doesn't support the MIH and cannot elucidate the events and processes driving the coast's morphology. However, further analysis at a higher resolution is needed to confirm this conclusion.

Part C: Effects of Vegetation on Erosion:



- My previous research on the peninsula's erosion rates suggests that the overlying vegetation plays a determinative role.
- Measuring the biomechanical attributes of the vegetation's root systems will elucidate their role in the erosional system.

- As detailed by Nyambane and Mwea (2011), the root area ratio at each depth class, defined as the ratio of the roots' total cross-sectional area to the 30cm² sample area, serves as a function of the plant's ground stabilising influence.

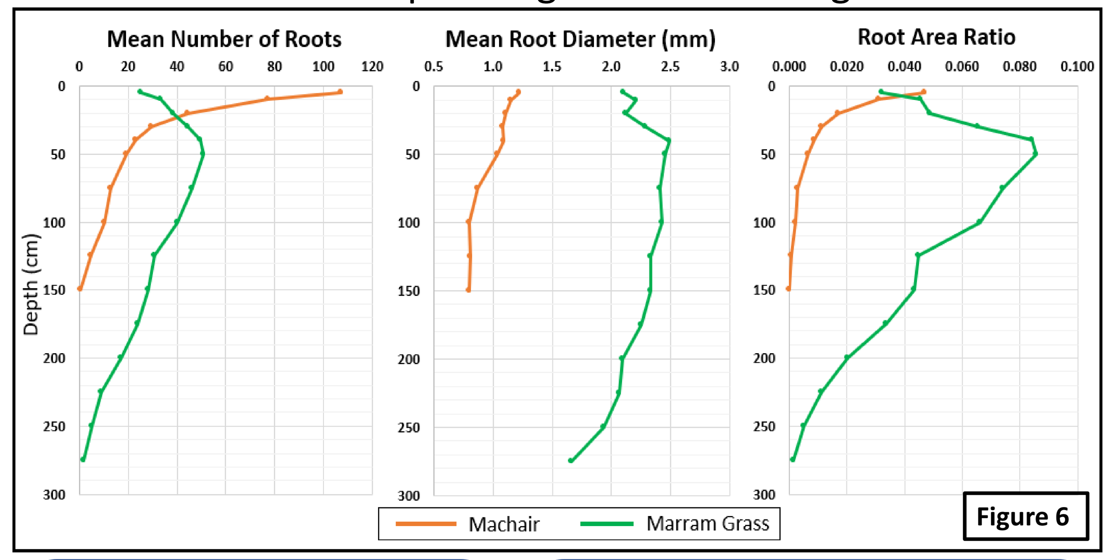


Figure 6

Figure 6 shows a sharp decline in machair root numbers with depth, while the majority of marram roots are found at 50cm where they typically bifurcate.

The large diameters and numbers of marram roots at depth result in overall higher RAR values, however the dense root matrices of machair at the surface can be seen in the higher RAR value between 0-5cm.

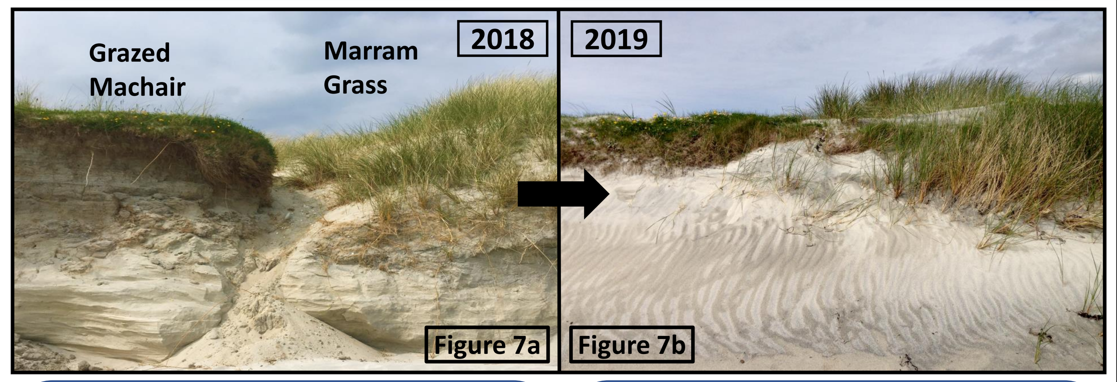


Figure 7a Figure 7b

The RAR values for these land coverages support the observed erosional differences, with machair prone to undercutting and marram grass to trampling.

However, Figure 7b shows that aeolian sediment transport is also key in determining the rate of coastal retreat: rapidly covering the exposed profiles.

Summary:

- **A:** The biostratigraphic sequence in the monolith core corroborates the MIH, providing clear evidence of a paleo-marsh being inundated with marine sediment.
- This highlights the peninsula's vulnerability to marine inundations, a growing threat due to Climate Change.
- **B:** The homogeneity of the sediment stratigraphy doesn't support the MIH, except for the sharp contact at 70cm.
- However, the fine laminations in the core indicate a highly volatile erosional and depositional environment.
- **C:** The different root properties of machair and marram grasses explain the two visible erosional tendencies, confirming their high impact on erosional susceptibility.

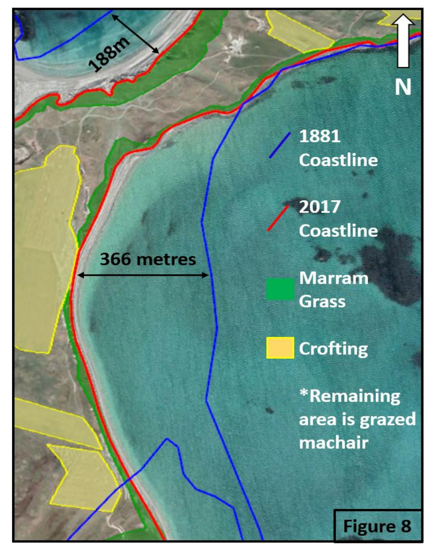


Figure 8

➢ Based off this data and last year's spatial erosion analysis (Figure 8), this research proposes the following land management changes to mitigate erosion:
➢ Plant a buffer of marram grass around the coastline.
➢ Protect machair growth by trackways and plant winter cover crops on crofting fields to reduce aeolian erosion.

References:

- Dawson et al. (2004). Late Holocene coastal sand movements in the Outer Hebrides, N.W. Scotland. Marine Geology, 210(1-4), pp.281-306.
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- Nyambane, O. and Mwea, S. (2011). Root tensile strength and contribution to soil shear strength. Journal of CERP, 8(1).