MASTS Marine Biogeochemistry Forum Small Grant Scheme

Funding Report – MBFSG55: Tracing the source: Terrestrial carbon in marine sediments off the east coast of Scotland

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Project overview

To accurately account for carbon within the marine environment, understanding the pathways of organic material from 'source to sea' provides essential information with regards where and how carbon is being transported, stored, and lost from the aquatic continuum. Shelf seas are hotspots for productivity and carbon storage, particularly within fjords and inshore waters (Smith et al., 2015; Bianchi et al., 2020; Smeaton et al., 2021). Within Scotland, the west coast is characterised by fjordic environments, which have been well studied for their carbon capture services (Smeaton et al., 2016; Smeaton and Austin, 2017, 2019). Consequently, the west coast fjordic sediments have been described as providing a 'second chance' and being 'subsidised' by the loss of carbon from the terrestrial environment. Less is known about the fate of organic carbon on the east coast of Scotland however, which is characterised by broad, shallow estuaries. Estuarine environments can be sources of CO_2 emissions due to nutrient enrichment from fluvial sources, in addition to having slower lateral transport rates with continuous resuspension and deposition cycles (Bauer et al., 2013; Regnier et al., 2013). It is thus important to understand the role that these systems play within Scotland's wider marine carbon budget and to understand the differences between environments in carbon processing and/or storage on the two opposing coasts.

To better understand the spatial distribution of the quantity, quality, and source of organic carbon within the inner Moray Firth, grab samples were analysed using elemental and stable isotope analysis. The initial data analysis from a relatively small number of samples highlighted an intriguing trend in the isotope composition of the organic material present in the surface sediments of the Moray Firth. A gradual 'source-to-sea' shift in the C/N ratios and $\delta^{13}C$ values of sediments moving away from the estuary was observed. These subtle differences implied gradual changes in the relative importance of the source material from a terrestrial to marine signal yet there were limited data to support this finding. We also saw little variation in the 'quality' of the organic matter using thermogravimetric analysis – specifically, there appeared to be no change in the vulnerability of the material (as indicated by the Rp index based on the proportion of refractory material present (Kristensen, 1990)) irrespective of the location of the sediment sample. Observations suggest that the inner Firths act as sediment traps for fluvial, silty sediments (Reid and McManus, 1987). Despite, the rivers of the inner Firths draining peat-rich land, we suggest that prolonged transit times may be causing degradation of the organic carbon within the estuarine system before it reaches the coastal waters of the Inner Moray Firth (McManus and Duck, 1996).

Summary of the work funded by the grant

This grant directly contributed £500 towards the consumable and analytical costs for quantification and stable isotope analysis of organic carbon (OC), and thermogravimetric analysis of organic matter (OM) from a further set of surface sediment samples collected within the inner Moray Firth. In-kind contributions were made from the School of Geography and Sustainable Development physical laboratory and the St Andrews Isotope Geochemistry (StAIG) laboratory (Table 1).

Table 1: Summary of costs for elemental analysis, stable isotope, and thermogravimetric analysis of organic matter in surface shelf sediments.

Method	Attributed Cost (MASTS)	In-kind Contribution (USTAND)
Elemental analysis	£80	£120
Stable isotope analysis	£400	£200
Thermogravimetric analysis	£20	£20
Total	**£500**	**£340**

Results

Organic carbon varied spatially and was positively correlated with the % mud within the sediment. A stronger terrestrial signal was seen within these inner Moray Firth sediments relative to sediments collected at a greater distance from the coast, as hypothesised. Interestingly, a strong transition was observed at approximately 30 km distance from the coastline, after which point the sedimentary organic matter was composed almost solely of marine-sources (enriched in $\delta^{13}C$). There was a stronger terrestrial signal within the 30 km zone, highlighting that the Dornoch, Cromarty and Beauly Firths appear to be supplying terrestrially sourced OC into the inner Moray Firth where it is deposited into the seabed sediments (Figure 1).

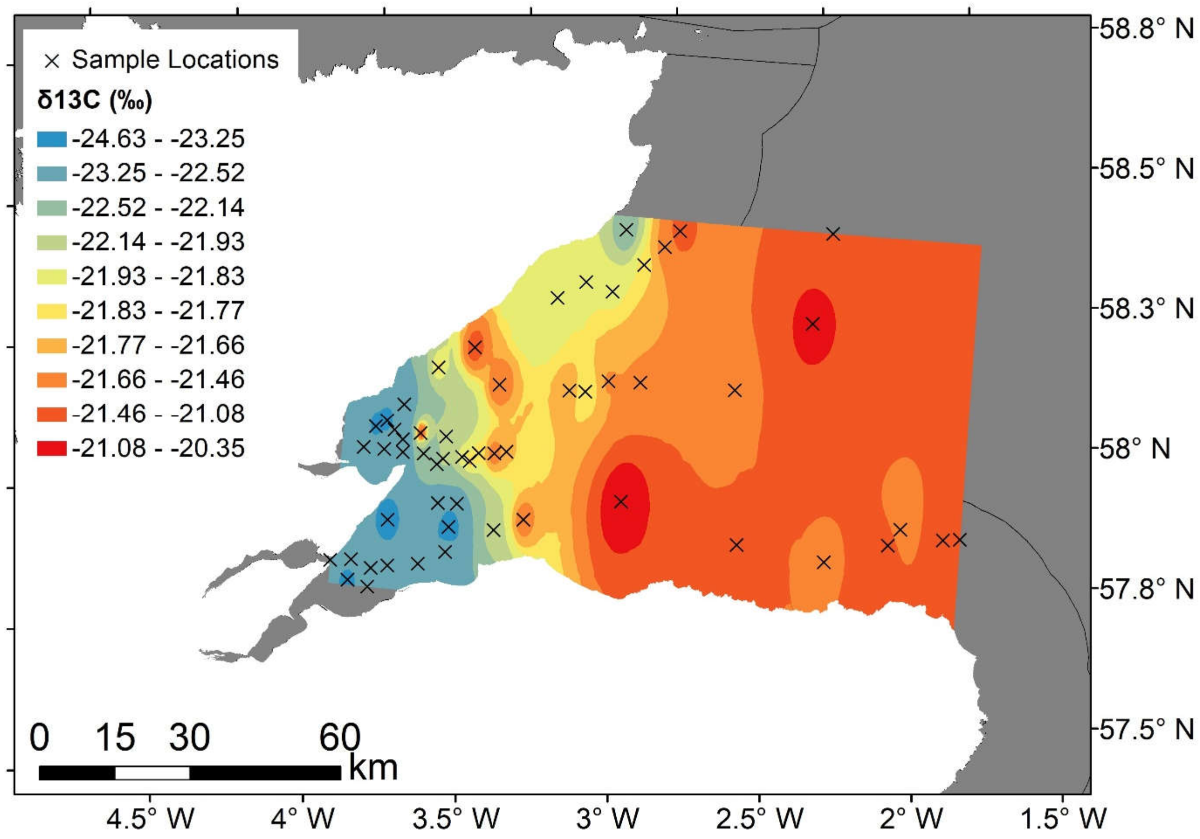

Figure 1: Spatial distribution of $\delta^{13}C$ within surface sediments of the Moray Firth. There is a source to sea trend showing a decreasing terrestrial signal with distance from the coast.

The quality of the OM did not vary spatially or with sediment type; the OM from all sediment samples was highly refractory suggesting that it was significantly degraded during transit through the estuarine systems, and subsequently within the water column further from the coast. This could increase the burial potential of OC within the inner Moray Firth sediments and suggests this coastal zone may become an increasingly important burial site of OM if climate change exacerbates coastal erosion and causes increased rainfall as predicted.

<u>Benefit to the MASTS community</u>

The research contributes information to support Scotland's national commitment to the sustainable use of the marine environment and net zero emissions, through a better understanding of the role of marine sediments in carbon storage. The information about the source, quantity, and quality of OC may allow extrapolation of the potential risks posed by anthropogenic activities The refractory nature of the OC within the Moray Firth suggests that it could be less vulnerable to remineralisation following disturbance from activities such as bottom-contacting fishing. This information could help to inform targeted spatial measures that serve to protect more vulnerable carbon stores on the seabed.

Expected outputs

The data produced will contribute directly to a chapter in my PhD thesis, "Characteristics of Sedimentary Organic Matter in Coastal Sediments of the Moray Firth: Sources and Reactivity". It is hoped that this research could eventually be published in a journal such as 'Estuarine, Coastal and Shelf Science'.

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