Radiometric dating of seagrass sediments using short-lived isotopes

MASTS Small Grants June 2013 round – Final Report

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Background and overview

Although seagrass meadows occupy less than 0.2% of the world's oceans, they are responsible for more than 10% of carbon buried annually in the oceans (Fourqurean et al., 2012). Understanding the environmental, ecological and biological controls of seagrass carbon stocks is crucial not only for accurately estimating global carbon budgets, but also efficiently mitigating greenhouse gas emissions (Macreadie et al., 2014). Very little work has been conducted on seagrass carbon in Scotland, with major knowledge gaps about the total carbon pool, the carbon density and the residence times of carbon in these systems. This grant supported preliminary work testing the applicability of isotopic dating techniques to seagrass sediments from the Tay estuary, in the hope of using derived dates to determine accumulation rates and residence times of sequestered carbon.

Radioisotopes dating

Coastal ecosystems receive both direct atmospheric radionuclide deposition and river-derived inputs from catchment soil erosion. Thus, chronology for recent rates of sedimentation can be obtained through the use of a combined radionuclide approach. Whilst unsupported ^{210}Pb provides an excess-decay method of dating for the last ~100 years, down-core trends of ^{137}Cs and ^{241}Am activity provide further chronological markers. More specifically, ^{137}Cs enables some fixing of age with depth to be determined from the onset of ^{137}C's atmospheric deposition, when weapons testing first occurred in 1954. The maximum ^{137}Cs activity occurs at peak fallout from weapons testing in 1963, and a more recent peak in ^{137}Cs in 1986 may show atmospheric fallout from the Chernobyl nuclear accident.

Sediment samples from seagrass and unvegetated plots from the Tay estuary were analysed for ^{210}Pb, ^{226}Ra, ^{137}Cs and ^{241}Am by direct gamma assay using an EG&G Ortec LO-AX n-type High-Purity germanium gamma photon detector. ^{137}Cs and ^{241}Am were measured by their emissions at 661 keV and 59 keV, respectively. ^{210}Pb was determined via its gamma emissions at 46 keV, ^{226}Ra by the 295 keV and 352 keV g-rays emitted by ^{214}Pb, and by the by the 661 keV g-rays emitted by ^{214}Bi, following three weeks-storage in sealed containers to allow radioactive equilibration. Excess unsupported ^{210}Pb activity was determined by subtracting the ^{226}Ra from the total ^{210}Pb activity.

Stable isotope analysis

Following the radionuclides dating analysis, the same subset of samples were used for the determination of stable isotopic ratios of ^{12}C/^{13}C (δ^{13}C) (via mass-spectrometry) in order to determine the contribution of seagrasses to the organic carbon pool.

Results

Table 1: ^{210}Pb, ^{137}Cs and ^{241}Am inventories (Bq kg^{-1}) for seagrass and control sediments from the Tay estuary, along with stable isotope results.

	Total ^{210}Pb 46keV (Bq kg^{-1})	Excess ^{210}Pb	^{226}Ra supported			Weapons testing		δ^{13}C ‰
			295keV ^{214}Pb	352keV ^{214}Pb	609keV ^{214}Bi	661keV ^{137}Cs	59keV ^{241}Am	
Seagrass								
0-2cm	32±4	17.3	14±4	15±3	15±4	4.9±1.2	1.9±0.5	-22.8
7-8cm	28±3	13.3	18±3	12±2	14±3	7.5±0.9	0.9±0.3	-24.4
12-15cm	28±4	6.7	25±5	19±3	20±4	4.3±1	0	-24.2
16-18cm	23±3	0	15±5	27±3	27±4	BDL	BDL	-
18-20cm	20±2	NA	14±5	29±3	28±4	BDL	BDL	-
20-22cm	20±3	NA	14±5	28±3	29±4	BDL	BDL	-
22-24cm	21±3	NA	13±5	23±3	27±4	BDL	BDL	-
24-26cm	15±3	NA	9±5	23±3	26±5	BDL	BDL	-
27cm	22±4	NA	24±4	19±3	24±4	BDL	BDL	-25.5
40cm	20±4	NA	18±5	17±3	20±4	BDL	BDL	-
Control								
0-2cm	22±5	9.7	11±4	12±3	14±4	BDL	BDL	-22.6
7-8cm	25±3	9	16±3	16±2	16±3	BDL	BDL	-24
12-15cm	19±3	6.7	12±3	11±2	14±3	BDL	BDL	-24.7
27cm	14±3	2	10±4	13±2	13±4	BDL	BDL	-23
40cm	15±3	NA	19±4	24±3	23±4	BDL	BDL	-21.7

Interpretation and discussion

The relative contribution of the carbon sources accumulated in seagrass sediments vary widely. Globally ~ 50% of the carbon in seagrass sediments is of seagrass origin, whereas the rest is a combination of allochthonous (both of terrestrial and aquatic origin) and other autochthonous material (algal or epiphytes-derived carbon) that accumulates in seagrass meadows.

If seagrasses are important carbon sources to their underlying soils, then we would predict that the δ^{13}C of the sediment would reflect the presence of seagrasses inhabiting the area. Our results showed that the δ^{13}C signatures of sediments were indistinguishable between seagrass and unvegetated plots. We interpret this as a homogenisation of sediment organic matter within the Tay estuary, which might have been caused by the repeated resuspension and transport of sediment. Also, the higher (yet not significant) δ^{13}C values of the organic matter of seagrass plots at 27cm compared to surficial samples is indicative of the persistence of seagrass-derived carbon relative to other sources following diagenesis.

Even though our results indicate that in seagrass plots there is excess ^{210}Pb up to 18cm, and ^{137}Cs and ^{241}Am detected concentrations up to 8cm, as opposed to control plots, where a different pattern was observed, no dating model could be fitted. These are therefore inconclusive and it is not possible to determine rates of tidal sedimentation in Tay estuary using radionuclides. Hence at this site, a combination of rapid sediment dynamics and very low levels of radionuclides mean that the methods tested here are not appropriate.

Further research

Having developed relevant expertise in using these methods, and eliminating this east coast site from ones that may be appropriate, we will continue this work at the Solway, where there are higher levels of radionuclides (specifically from Sellafield) and we believe there are more stable sediments.

References

Fourqurean, JW, et al. (2012) Seagrass ecosystems as a globally significant carbon stock. *Nature Geosciences 5:* 505-509.

Macreadie Pi et al. (2014) Quantifying and modelling the carbon sequestration capacity of seagrass meadow: A critical assessment. *Marine Pollution Bulletin 83:* 430-439.