

Comparison of carbon stores by two morphologically different seagrasses*

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INTRODUCTION

The recent emphasis on global change has intensified research in the carbon sequestration potential of seagrass ecosystems (Nellemann *et al.* 2009). Most estimates on seagrass carbon storage are, however, derived from studies of a few species and habitats. Lavery *et al.* (2013) showed an 18-fold difference in carbon stores among Australian seagrasses highlighting the importance of inter-habitat variability in carbon stocks. One implication from this is that the factor of seagrass species may play a key role in the variation in carbon stores beneath those studied meadows. Different seagrass species have inherently dissimilar traits, well summarised by the seagrass functional-form model in Carruthers *et al.* (2007). This functional-form model differentiates seagrasses based on morphological plasticity, rhizome persistence and occurrences in varying depositional environments, among other traits. A further extension of this model is suggested such that the seagrass species may shift from low to high transitions of standing crop biomass between extreme ends of the model. Of interest, the two seagrass genera *Halophila* and *Posidonia* are placed at opposite ends of the functional-form model. *Halophila* has a small biomass with less persistent rhizomes while *Posidonia* has the opposite traits. We hypothesise that meadows of smaller, ephemeral seagrasses with low standing crop will have less accumulated carbon compared to the larger and more persisting forms with higher productivity and biomass. Estuarine seagrass habitats dominated by *Halophila ovalis* and *Posidonia australis* were studied to compare the total carbon stocks and origin of the preserved carbon.

METHODS

Four seagrass meadows were studied: *P. australis* from Oyster Harbour (OH: 34°58'58.3"S, 117°58'29.9"E) and Waychinicup Inlet Estuary (WI: 34°53'35.9"S, 118°19'57.7"E), and *H. ovalis* from Swan River Estuary (SR: 32°00'46.1"S, 115°47'43.5"E) and Harvey Estuary (HE: 32°38'00.3"S, 115°38'51.7"E). To allow viable comparisons

not confounded by habitat types potentially influencing the depositional environment of allochthonous carbon, this study compared estuarine meadows of both species. Both tidal and swell exchanges dominate WI while OH, SR and HE are wave dominated. Three sediment cores were each collected from the four sites in 2012 by either manually hammering core barrels or by vibracoring (Vibecore-D, SDI) into the sediments. These cores were sliced, dried and weighed for dry bulk-density analysis. Alternate slices of ground and acidified (1 M HCl) subsamples were encapsulated and analysed for total organic carbon (OC) and stable carbon isotope composition values ($\delta^{13}\text{C}$) at the UC Davis Stable Isotope Facility (continuous flow isotope ratio mass spectrometer analyser, Sercon). For testing differences in sedimentary OC content among different seagrass species and sites, a two-way nested ANOVA (SPSS 19) was applied (species as fixed factor, site nested within species) and post-hoc (Tukey) tests were further applied to assess differences among sites within the same species.

RESULTS

The sampling resulted in different lengths for all cores. After corrections for sediment compression during coring (Glew *et al.* 2001), core lengths ranged from 170 cm to 250 cm. To allow comparisons, OC characteristics in all sediment cores were standardised for the top 170 cm-thick deposits. In the *Posidonia* cores, localised agglutination of plant detrital matter was observed. This coarse *Posidonia* detritus was more abundant in OH cores. The top 10 cm of *Halophila* cores contained low amounts of coarse plant detrital matter becoming less evident until the 25 cm depth and was absent below this level. Mean OC content was higher in *P. australis* sites (mean \pm SE; 2.03 \pm 0.19% at OH and 1.12 \pm 0.08% at WI) compared to *H. ovalis* sites (0.34 \pm 0.15% at HE and 0.16 \pm 0.03% at SR). The mean OC content in 170 cm-thick deposits was 6-fold higher in *P. australis* sites (1.58 \pm 0.21%) compared to *H. ovalis* sites (0.25 \pm 0.07%; $p < 0.05$). The OC content was significantly higher in *P. australis* OH cores compared to those in WI ($p < 0.01$), while the OC content among *H. ovalis* sites was similar ($p > 0.05$). $\delta^{13}\text{C}$ values of sedimentary organic matter in *Posidonia* meadows at OH were more positive (-9.89‰ to -14.0‰) than in WI (-13.0‰ to -19.5‰). The $\delta^{13}\text{C}$ signatures in both *Halophila* sites followed similar trends in all cores (ranging from -16.0‰ to -21.5‰).

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DISCUSSION

Comparison of carbon stocks between species

The OC stocks in 170 cm-thick deposits beneath *P. australis* meadows were 6-fold higher than in *H. ovalis* sites. The difference in OC accumulation between the two different seagrass species can be partially explained by the higher biomass and productivity of *P. australis* meadows (1300–2100 g DW m⁻² and 0.23 g DW m⁻² d⁻¹, respectively) compared to the *H. ovalis* meadows (76 g DW m⁻² and 0.01 g DW m⁻² d⁻¹: Duarte & Chiscano 1999). In addition, *Posidonia* species invests larger amounts of carbon into below-ground organs (1220 g DW m⁻²) compared to small seagrasses such as *Halophila* (21 g DW m⁻²), which invests more energy in rapid clonal propagation resulting in high turnover rates. The below-ground organs of seagrasses are more recalcitrant than above-ground organs, and therefore are more likely to end buried *in situ* as detrital matter, particularly for *P. australis* rhizomes which can grow 20–50 cm beneath the sediment surface. Only in the event of major scouring would these below-ground tissues be uprooted and exported. Furthermore, the dense and relatively high canopy of *P. australis* stabilises the sediment, enhancing sediment deposition and reducing re-suspension, and increasing the likelihood of OC stocks being preserved. This contrasts with *H. ovalis* meadows with a sparse and low canopy. Below-ground living organs are ephemeral growing at 5–10 cm below the sediment surface. Any detrital matter produced by *H. ovalis* is thus more likely to be scoured and allochthonously transported rather than remain buried *in situ*.

Source of carbon

The $\delta^{13}\text{C}$ values of sedimentary organic matter in *P. australis* sites (mean = -13.82‰ for both sites) are indicative of a strong influence of *P. australis*-derived input. The reported $\delta^{13}\text{C}$ values of *P. australis* organs range from -9.9‰ to -11.9‰ (Hemminga & Mateo 1996), consistent with those observed in the deposits. In contrast, $\delta^{13}\text{C}$ values at *H. ovalis* sites (mean = -19.16‰) are indicative of low amounts of seagrass detritus contributing to the sedimentary organic pool. The reported $\delta^{13}\text{C}$ values of *H. ovalis* organs range from -6.4‰ to -15.5‰ (Hemminga & Mateo 1996), much more enriched than those we observed in the sediments. The $\delta^{13}\text{C}$ values of allochthonous sources of organic matter (i.e. seston, algae and terrestrial organic matter) are more negative than seagrass isotopic signatures, in the range of -13‰ to -29‰ (Smit *et al.* 2005; Loneragan *et al.* 1997) and may account for the relatively depleted values in the *H. ovalis* sediments. Previous studies have commented on the ability of the *Halophila* canopy to effectively trap allochthonous carbon (Fonseca 1989) and our findings are consistent with an earlier study which found that *H. ovalis* had the second highest OC accumulation after *P. australis* meadows, possibly due to the nature of the depositional environment and canopy-trapping of allochthonous carbon (Lavery *et al.* 2013).

Within-species variation

Both *H. ovalis* sites showed similar vertical profiles in the mass and $\delta^{13}\text{C}$ values of buried OC. In contrast, while we expected the two *P. australis* sites to show similar vertical

OC content trends and $\delta^{13}\text{C}$ values through the cores, OH meadows contained double OC stocks of mainly seagrass-derived OC compared to WI. Subsequent radiocarbon dating of the cores from WI (unpubl. data; accelerator mass spectrometry, Australian Nuclear Science and Technology Organisation) showed that at similar stratigraphic levels, the organic matter age varied by ~1000 calibrated years before present. A plausible explanation for this variation in the chronostratigraphy among cores is a scouring event leading to major sediment reworking at WI resulting in a loss of buried OC through erosion. Sediment scouring may also occur in estuaries with higher degree of tidal and swell influence, or during extreme events, and thus could affect the sedimentary OC and $\delta^{13}\text{C}$ characteristics.

CONCLUSIONS

The comparison of OC stocks and $\delta^{13}\text{C}$ signatures of sedimentary organic matter in the two morphologically different seagrass species demonstrated significant variations in both the carbon accumulation potential as well as the origin of buried carbon among the seagrasses. Meadows of the larger *P. australis* accrue 6-fold more OC than those of the smaller *H. ovalis* species. Seagrass-derived organic matter forms the bulk of those higher stores while allochthonous organic matter is the major contributor in the *Halophila* sites. However, within sites of the same species, further variations in carbon characteristics may be exhibited due to natural ecological processes. The results of this study clearly confirm that both species and habitat may contribute to variation in the OC stored in seagrass meadows and that more comprehensive scrutiny of the factors accounting for those variations are required to improve global estimates of Blue Carbon storage in seagrass meadows.

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