1 **Can mud (silt and clay) concentration be used to predict soil organic carbon**

2 **content within seagrass ecosystems?**

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26   **ABSTRACT**

27   The emerging field of blue carbon science is seeking cost-effective ways to estimate the organic

28   carbon content of soils that are bound by coastal vegetated ecosystems. Organic carbon (C_{org})

29   content in terrestrial soils and marine sediments has been correlated with mud content (i.e. silt

30   and clay), however, empirical tests of this theory are lacking for coastal vegetated ecosystems.

31   Here, we compiled data (n = 1345) on the relationship between C_{org} and mud (i.e. silt and clay,

32   particle sizes <63 μm) contents in seagrass ecosystems (79 cores) and adjacent bare sediments

33   (21 cores) to address whether mud can be used to predict soil C_{org} content. We also combined

34   these data with the $\delta^{13}C$ signatures of the soil C_{org} to understand the sources of C_{org} stores. The

35   results showed that mud is positively correlated with soil C_{org} content only when the contribution

36   of seagrass-derived C_{org} to the sedimentary C_{org} pool is relatively low, such as in small and fast-

37   growing meadows of the genera *Zostera*, *Halodule* and *Halophila*, and in bare sediments

38   adjacent to seagrass ecosystems. In large and long-living seagrass meadows of the genera

39   *Posidonia* and *Amphibolis* there was a lack of, or poor relationship between mud and soil C_{org}

40   content, related to a higher contribution of seagrass-derived C_{org} to the sedimentary C_{org} pool in

41   these meadows. The relative high soil C_{org} contents with relatively low mud contents (i.e. mud-

42   C_{org} saturation) together with significant allochthonous inputs of terrestrial organic matter could

43   overall disrupt the correlation expected between soil C_{org} and mud contents. This study shows

44   that mud (i.e. silt and clay content) is not a universal proxy for blue carbon content in seagrass

45   ecosystems, and therefore should not be applied generally across all seagrass habitats. Mud

46   content can only be used as a proxy to estimate soil C_{org} content for scaling up purposes when

47   opportunistic and/or low biomass seagrass species (i.e. *Zostera*, *Halodule* and *Halophila*) are

48   present (explaining 34 to 91% of variability), and in bare sediments (explaining 78% of the

49   variability).

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1. INTRODUCTION

The sedimentary organic carbon (C_{org}) stores of seagrass meadows – often referred to as 'blue carbon' – can vary among seagrass species and habitats, with reports of up to 18-fold differences (Lavery et al. 2013). Ambiguity remains in the relative importance of the depositional environment and species characteristics contributing to this variability. Seagrasses occur in a variety of coastal habitats, ranging from highly depositional environments to highly exposed and erosional habitats (Carruthers et al. 2007). Since seagrass species differ in their biomass and canopy structure, and occur in a variety of habitat types, this raises the question of whether mud content can be used to predict C_{org} content within coastal sediments, or whether the species composition will significantly influence the soil C_{org} stores independently of the geomorphological nature of the habitat.

Geomorphological settings (i.e. topography and hydrology), soil characteristics (e.g. mineralogy and texture) and biological features (e.g. primary production and remineralization rates) control soil C_{org} storage in terrestrial ecosystems (Amundson, 2001, De Deyn et al. 2008; Jonsson and Wardle, 2009) and in mangrove and tidal salt marshes (Donato et al. 2011; Adame et al. 2013; Ouyang and Lee, 2014). While it is clear that habitat interactions have a large influence on stores of soil C_{org}, our understanding of the factors regulating this influence in seagrass meadows is limited (Nellemann et al. 2009; Duarte et al. 2010; Serrano et al. 2014).

The accumulation of C_{org} in seagrass meadows results from several processes: accretion (autochthonous plant and epiphyte production, and trapping of allochthonous C_{org}; Kennedy et al. 2010), erosion (e.g. export; Romero and Pergent, 1992; Hyndes et al. 2014) and decomposition (Mateo et al. 1997). Previous studies demonstrate that both autochthonous (e.g. plant detritus and epiphytes) and allochthonous (e.g. macroalgae, seston and terrestrial matter) sources contribute

75   to the C_{org} pool in seagrass soils (Kennedy et al. 2010; Watanabe and Kuwae, 2015). Plant net

76   primary productivity is a key factor controlling the amount of C_{org} potentially available for

77   sequestration in seagrass ecosystems (Serrano et al. 2014), but the depositional environment is an

78   important factor controlling C_{org} storage in coastal habitats (De Falco et al. 2004; Lavery et al.

79   2013).

80   Previous studies have shown a large variation in C_{org} stores among morphologically different

81   seagrass species (Lavery et al. 2013; Rozaimi et al. 2013). Also, that C_{org} accumulates more in

82   estuaries compared to coastal ocean environments (estimated at 81 Tg C_{org} y^{-1} and 45 Tg C_{org} y^{-1},

83   respectively; Nellemann et al. 2009). This is due largely to estuaries being highly depositional

84   environments, receiving fine-grained particles from terrestrial and coastal ecosystems which

85   enhance C_{org} accumulation (i.e. silt and clay sediments retain more C_{org} compared to sands; Keil

86   and Hedges, 1993; Burdige 2007) and preservation (i.e. reducing redox potentials and

87   remineralization rates; Hedges and Keil, 1995; Dauwe et al. 2001; Burdige, 2007; Pedersen et al.

88   2011). The inputs of seagrass-derived C_{org} in the sedimentary pool could break the linear

89   relationship among mud (i.e. silt and clay particles) and C_{org} contents typically found in

90   terrestrial (Nichols, 1984; McGrath and Zhang, 2003) and marine sedimentary environments

91   (Bergamaschi et al. 1997; De Falco et al. 2004). However, the amount of C_{org} that can be

92   associated with silt and clay particles is limited (Hassink, 1997), which could lead to a poor

93   relationship between mud and soil C_{org} contents. Also, other factors found to play a key role in

94   controlling soil C_{org} accumulation in terrestrial and coastal ecosystems, such as chemical

95   stabilization of organic matter (Percival et al. 1999; Burdige, 2007), carbon in microbial biomass

96   (Sparling, 1992; Danovaro et al. 1995), and soil temperature (Pedersen et al. 2011), could also

97   influence C_{org} storage in seagrass meadows.

98   A positive relationship between mud (i.e. silt and clay) and C_{org} contents would allow mud

99   to be used as a proxy for C_{org} content, thereby enabling robust scaling up exercises at a low cost

100   as part of blue carbon stock assessments. Furthermore, since most countries have conducted

101   geological surveys within the coastal zone to determine sediment grain-size, a strong, positive

102   relationship between mud and C_{org} contents would allow the development of geomorphology

103   models to predict blue carbon content within seagrass meadows, dramatically improving global

104   estimates of blue carbon storage. The purpose of this study was therefore to test for relationships

105   between C_{org} and mud contents within seagrass ecosystems and adjacent bare sediments.

106

107   **2. MATERIAL AND METHODS**

108   Data was compiled from a number of published and unpublished studies from Australia and

109   Spain, in seagrass meadows across diverse habitats (Table 1). The study sites encompass

110   monospecific and/or mixed meadows from a variety of temperate and tropical seagrass species of

111   the genera *Posidonia*, *Amphibolis*, *Zostera*, *Halophila* and *Halodule*, and adjacent bare

112   sediments, while including a variety of depositional environments (from estuarine to exposed

113   coastal areas encompassing different water depths, from intertidal to the deep limit of seagrass

114   distribution; Table 1). Data from 100 cores (79 from seagrass meadows and 21 from bare

115   sediments) on sediment grain size, organic carbon (C_{org}) content and stable carbon isotope

116   signatures of the C_{org} ($\delta^{13}C$) was explored in this study (N = 1345).

117   Sediment cores were sampled by means of percusion and rotation, or vibrocoring (ranging

118   from 10 to 475 cm long). The core barrels consisted of PVC or aluminium pipes (50 to 90 mm

119   inside diamater) with sharpenned ends to cut fibrous material and minimize core shortening

120 (compression) during coring (Serrano et al. 2012, 2014). All cores were sealed at both ends,

121 transported vertically to the laboratory and stored at 5°C before processing.

122 The cores were sliced at regular intervals, each slice/sample was weighed before and after

123 oven drying to constant weight at 70°C (DW), and subsequently sub-divided for analysis. The

124 C_{org} elemental and isotopic composition of the organic matter was measured in milled

125 subsamples from several slices along the cores. The sediment core sub-samples were acidified

126 with 1 M HCl, centrifuged (3500 RPM; 5 minutes) and the supernatant with acid residues was

127 removed using a pipette, then washed in deionized water, centrifuged again and the supernatant

128 removed. The residual samples were re-dried (70°C) before carbon elemental and isotopic

129 analyses. The samples were encapsulated and the organic carbon elemental and isotopic

130 composition was analyzed using an elemental analyzer interfaced with an isotope ratio mass

131 spectrometer. Percentage C_{org} was calculated for the bulk (pre-acidified) samples. Carbon isotope

132 ratios are expressed as δ values in parts per thousand (‰) relative to VPDB (Vienna Pee Dee

133 Belemnite). For sediment grain-size analysis, a Coulter LS230 laser-diffraction particle analyzer

134 was used following digestion of the samples with 10% hydrogen peroxide. The mud content in

135 the sediments (silt and clay, <63 μm) was determined, and expressed as a percentage of the bulk

136 sample.

137 Pearson correlation analysis was used to test for significant relationships among C_{org} and

138 mud contents, and C_{org} and $\delta^{13}C$ signatures. Correlations between the variables studied were

139 tested among seagrass species (9 categories) and bare sediments, seagrass genera (4 categories)

140 and habitat geomorphology (coastal and estuarine habitats).

141

142 **3. RESULTS**

143   The soil organic carbon (C_{org}) and mud contents varied within the seagrass meadows and

144   bare sediments studied in Australia and Spain. The soil C_{org} and mud contents were higher in

145   seagrass meadows (average ± SE, 1.5 ± 0.2% and 18 ± 2.4%, respectively) compared to bare

146   sediments (0.6 ± 0.1% and 10.8 ±1 .2%, respectively; Table 2). On average, seagrass meadows

147   of the genera *Amphibolis* and *Posidonia* contained higher soil C_{org} (1.6 ± 0.1%) and lower mud

148   (7.2 ± 0.4) than meadows of *Halophila*, *Halodule* and *Zostera* (1.2 ± 0.2% and 34.9 ± 5.4%,

149   respectively; Table 2). Overall, carbon isotopic ratios from sedimentary organic matter ($\delta^{13}C$)

150   were similar between seagrass soils and bare sediments (-17.6 ± 0.3‰ and -17.3 ± 0.2‰,

151   respectively). The C_{org} in soils from *Posidonia* and *Amphibolis* meadows were ^{13}C-enriched (-

152   15.5 ± 0.3‰) compared with seagrass soils from *Halophila*, *Halodule* and *Zostera* meadows (-

153   20.7 ± 0.4‰; Table 2). The C_{org} content in soils from estuarine and coastal habitats were similar,

154   while mud content in estuarine sediments was higher and $\delta^{13}C$ values depleted when compared

155   to coastal habitats (Table 2).

156   The relationships between the variables studied (i.e. %C_{org}, % mud, and $\delta^{13}C$ signatures of

157   sedimentary C_{org}) in all cores were explored in Figure 1 and 2, and Table 3. The C_{org} content

158   increased with increasing mud content in bare sediments (R^2 = 0.78) and at species level (9

159   species in total), except for *Amphibolis griffithii* (Table 3). Although most of the correlations at

160   species level were significant, they only explain 2 to 39% of the trends described, except for

161   *Halophila ovalis* (91%; Table 3). In particular, *Posidonia* meadows (*P. australis*, *P. sinuosa* and

162   *P. oceanica*) had the lower correlation values (R^2 ranged from 0.02 to 0.15). When combining

163   mud and C_{org} contents in seagrass meadows of the colonizing and opportunistic genera

164   *Halophila*, *Halodule* and *Zostera* (Kilminster et al. 2015), a relatively high correlation was found

165   (R^2 = 0.56; Figure 1), while soil C_{org} and mud contents in persistent genera were only slightly

166 positively correlated in combined *Amphibolis* spp and not correlated in *Posidonia* spp meadows

167 (Figure 1). The classification of habitats based on geomorphology (i.e. coastal and estuarine)

168 showed a lack of correlation between soil C_{org} and mud contents in coastal ecosystems, and a

169 poor but slightly significant correlation in estuarine ecosystems ($R^2 = 0.14$; Figure 2 and Table

170 3).

171 The relationships between soil %C_{org} and $\delta^{13}C$ signatures were poor for all individual

172 *Amphibolis* and *Posidonia* species studied (R^2 ranging from 0.09 to 0.3; Table 3), and for

173 combined *Amphibolis* spp (Figure 1), with an exponential tendency of C_{org}-rich soils being

174 enriched in ^{13}C (Figure 1). In contrast, %C_{org} and $\delta^{13}C$ signatures were not correlated in any of

175 the small and fast-growing *Halodule*, *Zostera*, *Halophila* meadows studied (Table 3), neither

176 individually nor when combined (Figure 1 and Table 3). A lack of correlation between soil %C_{org}

177 and $\delta^{13}C$ signatures was also found in bare sediments adjacent to seagrass meadows (Figure 2

178 and Table 3).

179

180 **4. DISCUSSION**

181 Overall mud content is a poor predictor of soil C_{org} in seagrass meadows and care should be

182 taken in its use as a cost-effective proxy or indicator of C_{org} for scaling-up purposes in the

183 emerging field of blue carbon science. Although we describe some promise for opportunistic and

184 early colonizing *Halophila*, *Halodule* and *Zostera* meadows (i.e. mud content explained 34 to

185 91% of variability in C_{org} content) and in bare sediments adjacent to seagrass meadows

186 (explaining 78% of the variability), mud is not a universal proxy for blue carbon content and

187 therefore should not be applied generally across all seagrass habitats. In particular, mud content

188 only explained 5 to 32% of soil C_{org} content in *Amphibolis* spp meadows and 2 to 15% of soil

189   C_{org} content in *Posidonia* spp meadows, and therefore, mud content is not a good proxy for blue

190   carbon content in these meadows.

191   A tenet of carbon cycling within the coastal ocean is that fine-grained sediments (i.e. mud)

192   have higher C_{org} contents. The positive relationship found between mud and C_{org} contents in

193   coastal bare sediments (explaining 78% of the variability) is in agreement with previous studies

194   (e.g. Bergamaschi et al. 1997; De Falco et al. 2004), and is related to their larger surface areas

195   compared to coarse-grained sediments, providing larger binding sites for C_{org} on the surface of

196   minerals and increasing the available space within the mineral matrix for C_{org} aggregates (Keil

197   and Hedges, 1993; Mayer, 1994a, 1994b; Galy et al. 2007; Burdige 2007). In addition, the

198   predominance of fine sediments reduces oxygen exchange and results in low sediment redox

199   potentials and remineralization rates, contributing to the preservation of sedimentary C_{org} after

200   burial (Hedges and Keil, 1995; Bergamaschi et al. 1997; Dauwe et al. 2001; Burdige 2007;

201   Pedersen et al. 2011). However, the maximum capacity of a given soil to preserve C_{org} by their

202   association with clay and silt particles is limited (i.e. mud-C_{org} saturation; Hassink, 1997), which

203   could explain the relative high C_{org} contents found in some bare sediment with relatively low

204   mud contents (Figure 1). Also, the results obtained showed that these samples were ^{13}C-depleted,

205   suggesting significant contributions of soil C_{org} from allochthonous sources (e.g. terrestrial

206   ecosystems; Kennedy et al. 2010). This could have disrupted the correlation found between soil

207   C_{org} and mud contents in the bare sediments studied.

208   Mud is not a universal proxy for soil C_{org} content in seagrass meadows, which could be

209   mainly explained by additional inputs of seagrass-derived C_{org} to the sedimentary C_{org} pool,

210   ending the linear relationship between mud and C_{org} contents found in the absence of vegetation.

211   The δ^{13}C values indicated that both seagrass-C_{org} and non-seagrass-derived C_{org} (i.e. epiphytes,

212   algae, seston or terrestrial matter) were buried in the soils of all studied meadows, but are

213   consistent with a model of increasing capture of seagrass-derived C_{org} at meadows formed by

214   persistent, high-biomass seagrasses (i.e. genera *Posidonia* and *Amphibolis*) relative to

215   opportunistic, low-biomass seagrasses (i.e. genera *Halophila*, *Halodule* and *Zostera*).

216   On one hand, the soil $\delta^{13}C$ signatures measured in these long-living and large seagrass

217   meadows (averaging -15 ± 0.2‰ in both cases) were closer to the $\delta^{13}C$ signatures of *Posidonia*

218   and *Amphibolis* tissues (ranging from -8 to -14‰; Hyndes and Lavery 2005; Hindell et al. 2004;

219   Cardona et al. 2007; Fourqurean et al. 2007; Collier et al. 2008; Kennedy et al. 2010; Hanson et

220   al. 2010; Serrano et al. 2015) than to $\delta^{13}C$ values of algae or terrestrial organic matter (ranging

221   from -18 to -32‰; e.g. Smit et al. 2006; Cardona et al. 2007; Kennedy et al. 2010; Hanson et al

222   2010; Deudero et al. 2011). The poor relationship between mud and soil C_{org} contents in

223   *Posidonia* and *Amphibolis* soils could be explained by their relatively low mud content and ^{13}C-

224   enriched soil C_{org}, indicating that the contribution of seagrass-derived C_{org} (i.e. root, rhizome and

225   sheath detritus) in their soils play a much larger role than the accumulation of fine, organic-rich

226   allochthonous particles.

227   On the other hand, the soil $\delta^{13}C$ signatures measured in *Halodule*, *Halophila* and *Zostera*

228   meadows (averaging -21 ± 0.4‰) were more similar to $\delta^{13}C$ values of algae or terrestrial organic

229   matter than to $\delta^{13}C$ values of their seagrass tissues (ranging from -10 and -14‰; e.g. Hemminga

230   and Mateo, 1996; Kennedy et al. 2010; Hanson et al. 2010). The positive relationship between

231   mud and soil C_{org} contents in *Halodule*, *Halophila* and *Zostera* soils could be explained their

232   relatively high mud content and ^{13}C-depleted C_{org}, indicating that allochthonous C_{org} inputs and

233   mud content play a major role in soil C_{org} accumulation in these opportunistic and early-

234   colonizing seagrasses. However, the relative high C_{org} contents found with relatively low mud

235   contents (i.e. mud-C_{org} saturation) disrupted the correlation found between soil C_{org} and mud

236   contents in these meadows (Figure 1).

237   The results obtained showed a tendency for high-biomass and persistent meadows (i.e.

238   *Posidonia* and *Amphibolis*) to accumulate higher C_{org} stores and seagrass-derived C_{org} compared

239   to ephemeral and low-biomass meadows (i.e. *Halophila*, *Halodule* and *Zostera*), suggesting that

240   factors (biotic and abiotic) affecting the production, form and preservation of C_{org} within habitats

241   exert a significant influence on soil C_{org} content (Lavery et al. 2013; Serrano et al. 2014, 2015).

242   The above- and belowground biomass in meadows of the genus *Posidonia* (averaging 535 and

243   910 g DW m^{-2}, respectively) is up to 2-fold higher than in *Amphibolis* meadows (averaging 641

244   and 457 g DW m^{-2}, respectively) and 4 to 18-fold higher than in small and opportunistic

245   seagrasses of the genera *Halophila*, *Halodule* and *Zostera* (125 and 49 g DW m^{-2}, on average;

246   respectively; Duarte and Chiscano, 1999; Paling and McComb 2000). Indeed, larger seagrasses

247   tend to have larger and more persistent rhizomes, constituted by more refractory forms of C_{org},

248   more prone to be preserved in soils than simpler, more labile forms of C_{org} such as seston and

249   algal detritus which are more suitable to experience remineralization during early diagenesis

250   (Henrichs 1992; Burdige, 2007).

251   Habitat conditions in seagrass meadows not only influence the amount of C_{org} accumulation

252   through detrital plant inputs, but the capacity of the plant canopies to retain particles (Gacia et al.

253   1999). The amount of fine suspended particles available for burial varies among sites, driven by

254   geomorphological features (e.g. run-off, hydrodynamic energy and water depth), while meadow

255   structure (i.e. density, cover and morphology of the canopy) constrains their capacity to

256   accumulate sediment particles (Hendriks et al. 2010; Peralta et al. 2008). Although the number of

257   cores and species studied in coastal and estuarine ecosystems was unbalanced (i.e. *Amphibolis*

258   and *Posidonia* dominate in coastal habitats and *Halophila*, *Halodule*, *Zostera* dominate in

259   estuarine habitats), the lack of, or poor correlations found within estuarine and coastal

260   ecosystems, precludes the general use of mud as a predictor of blue carbon content based on

261   habitat geomorphology (Figure 2). Seagrass meadows and bare sediments in environments

262   conducive for depositional processes (i.e. estuaries) accumulated up to 4-fold higher amounts of

263   mud compared to other coastal ecosystems, but the saturation of mud with C_{org} and the large

264   contribution of seagrass detritus into the sedimentary C_{org} pool (^{13}C-enriched soils) in some study

265   sites disrupted the positive relationship expected between mud and soil-C_{org} contents. In

266   estuarine ecosystems, soil C_{org} originated from both mud inputs linked to allochthonous-C_{org} via

267   deposition from upstream transport (e.g. Aller, 1998) and seagrass inputs. The insignificant

268   relationship between mud and soil C_{org} contents in coastal habitats could be explained by their

269   relatively low mud content and the accumulation of seagrass-derived C_{org}.

270   In sum, mud is not a universal proxy for blue carbon content in seagrass ecosystems and

271   should not be applied generally across all habitat and vegetation types. Overall, the positive

272   relationship between mud and C_{org} contents found in bare sediments and in opportunistic and/or

273   low biomass seagrass meadows (i.e. genera *Zostera*, *Halodule* and *Halophila*) allow mud to be

274   used as a proxy for C_{org} content in these ecosystems, thereby enabling robust scaling up exercises

275   (i.e. benefiting from existing geological surveys and models) at low cost as part of blue carbon

276   stock assessment programs. However, mud content is not a good predictor of C_{org} content in

277   highly productive meadows such as those constituted by *P. oceanica* in the Mediterranean Sea

278   and *P. australis, P. sinuosa* and *Amphibolis* spp in Australia. Other biological, chemical and

279   geological factors not explored in detail in this study may also play a key role in C_{org} storage, and

280   ultimately in the relationship between soil C_{org} and mud contents. For example, the effects of

habitat geomorphology (e.g. hydrodynamic energy, terrestrial mud and C_{org} inputs, export of seagrass biomass) and species identity (e.g. variation in terms of productivity, oxygen exposure and recalcitrance of C_{org} stores, and plant influence on sediment retention) within both coastal and estuarine environments, are among the factors identified in this study which might explain significant variation in the C_{org} stores of meadows in relatively similar exposure conditions. Other factors found to play a key role in controlling soil C_{org} accumulation in terrestrial ecosystems, such as chemical stabilization of organic matter (Percival et al. 1999; Galy et al. 2008) and microbial biomass carbon (Danovaro et al. 1994), could also influence C_{org} storage in seagrass ecosystems. Further studies are needed to identify the influences of these other factors on C_{org} storage in seagrass meadows, and in addition to the mud content, other characteristics should be taken into account when attempting to obtain robust estimates of C_{org} stores within coastal areas.

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Tables and Figures

Table 1. Data on soil organic carbon and mud contents, and stable carbon isotope from coastal soils were gathered from a variety of seagrass meadows (and also from adjacent bare sediments) and habitat types.

Species	Study site	Geomorphology	Number of cores	Number of samples	Core depth (cm)	Water depth (m)
Amphibolis (mixed spp)	Rottnest Island, WA, Australia	Coastal	2	68	0-120	2
	Shark Bay, WA, Australia	Coastal	1	38	0-170	2
Amphibolis antarctica	Shark Bay, WA, Australia	Coastal	2	63	0-200	2-3
Amphibolis grifficiae	Jurien Bay, WA, Australia	Coastal	2	41	0-70	4
Posidonia australis	Oyster Harbour, WA, Australia	Estuarine	3	31	0-120	2
	Waychinicup Inlet, WA, Australia	Estuarine	2	79	0-150	2
	Robbins Island, TAS, Australia	Coastal	6	138	0-180	3
Posidonia sinuosa	Frenchman's Bay, WA, Australia	Coastal	4	100	0-80	2-8
	Cockburn Sound, WA, Australia	Coastal	3	50	0-30	6
	Garden Island, WA, Australia	Coastal	5	147	0-120	2-8
Posidonia oceanica	Portlligat, Spain	Coastal	1	192	475	3
	Balearic Islands, Spain	Coastal	6	25	0-270	3
Halodule uninvervis	Carnarvon, WA, Australia	Estuarine	1	39	0-210	2
	Gladstone, QLD, Australia	Estuarine	6	6	0-10	intertidal
Halophila decipiens	Gladstone, QLD, Australia	Estuarine	2	2	0-10	intertidal
Halophila ovalis	Rottnest Island, WA, Australia	Coastal	1	17	0-30	3
	Swan River, WA, Australia	Estuarine	1	5	0-70	2
	Leschenault Inlet, WA, Australia	Estuarine	1	8	0-120	1
	Harvey Inlet, WA, Australia	Estuarine	1	5	0-20	2
	Gladstone, QLD, Australia	Estuarine	2	2	0-10	intertidal
Zostera muelleri	Fagans Bay, NSW, Australia	Estuarine	2	20	0-10	intertidal
	Gladstone, QLD, Australia	Estuarine	23	23	0-10	intertidal
	Tuggerah Lakes, NSW, Australia	Estuarine	2	64	0-400	3
Bare	Cockburn Sound, WA, Australia	Coastal	10	131	0-30	2-9
	Garden Island, WA, Australia	Coastal	1	16	0-30	4
	Oyster Harbour, WA, Australia	Estuarine	1	26	0-110	3
	Gladstone, QLD, Australia	Estuarine	9	9	0-10	intertidal

Table 2. Average ± SE organic carbon (C_{org}) content (in %), $\delta^{13}C$ signatures and mud content in all coastal habitat studied. a) Descriptive statistics based on species identify. b) Descriptive statistics based on habitat geomorphology (estuarine *vs* coastal environments). N, number of samples.

a)

Habitat (species)	Organic carbon (%)			$\delta^{13}C$ (‰)			Mud (%)		
	N	Mean	SE	N	Mean	SE	N	Mean	SE
Posidonia oceanica	217	3.91	0.35	217	-14.92	0.08	217	11.73	0.53
Posidonia australis	248	1.87	0.08	244	-15.79	0.24	248	11.79	0.68
Posidonia sinuosa	297	0.80	0.04	291	-14.08	0.16	297	2.59	0.18
Amphibolis (mixed spp)	106	1.41	0.11	106	-15.20	0.23	106	4.75	0.33
Amphibolis antarctica	63	0.99	0.06	62	-14.62	0.24	63	6.64	0.44
Amphibolis grifficiae	41	0.85	0.07	36	-15.83	0.56	41	5.44	0.29
Halodule uninervis	45	0.78	0.12	45	-19.86	0.53	45	17.68	3.04
Zostera muelleri	107	1.10	0.07	43	-20.02	0.30	107	31.68	2.59
Halophila decipiens	2	1.87	0.51	2	-25.60	0.31	2	65.99	9.62
Halophila ovalis	37	0.97	0.23	37	-17.22	0.44	37	24.09	6.23
Bare	182	0.59	0.08	182	-17.25	0.24	182	10.83	1.20
Grand Total	1345	1.56	0.07	1265	-16.18	0.10	1345	10.83	0.43

b)

Habitat (geomorphology)	Organic carbon (%)			$\delta^{13}C$ (‰)			Mud (%)		
	N	Mean	SE	N	Mean	SE	N	Mean	SE
Coastal	1026	1.59	0.09	1014	-15.70	0.10	1026	6.85	0.24
Estuarine	319	1.44	0.07	251	-18.10	0.24	319	23.62	1.41

Table 3. Pearson correlation analyses to test for significant relationships among soil C_{org} and mud contents, and soil C_{org} and $\delta^{13}C$ signatures; based on (a) species identity and (b) habitat geomorphology.

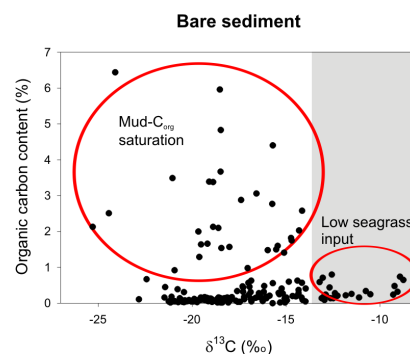
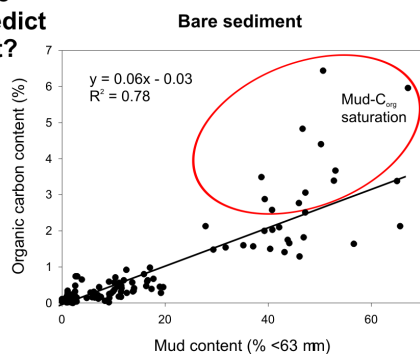
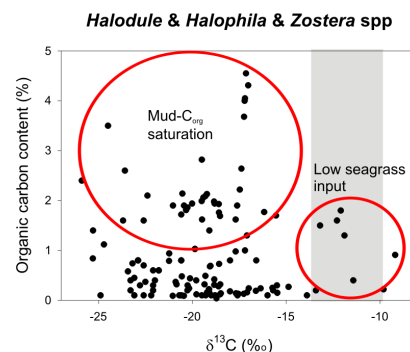
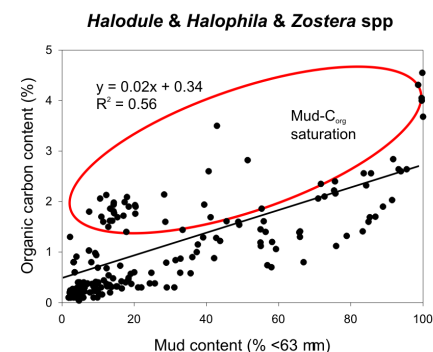
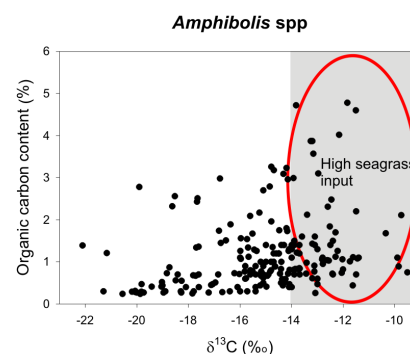
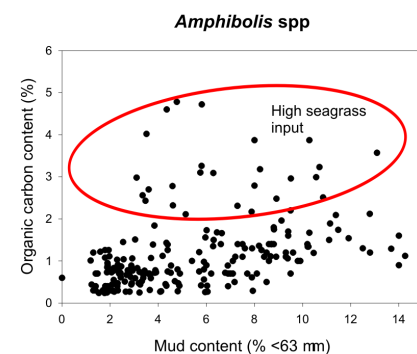
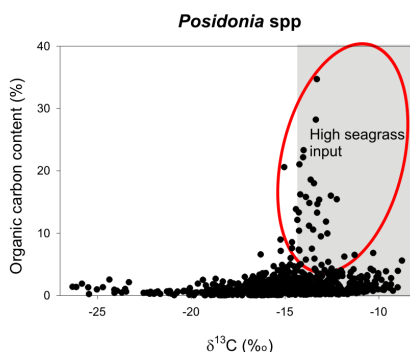
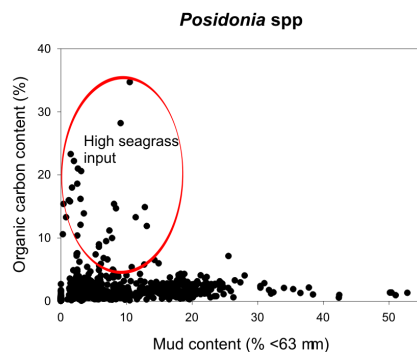
a)

Habitat (species)	Organic carbon (%) vs mud (%)			Organic carbon (%) vs $\delta^{13}C$ (‰)		
	Formula	R^2	P value	Formula	R^2	P value
Posidonia oceanica	$C_{org} = -0.26*mud + 6.95$	0.15	***	$C_{org} = 1.59*\delta^{13}C + 27.61$	0.13	***
Posidonia australis	$C_{org} = 0.02*mud + 1.69$	0.02	*	$C_{org} = 0.18*\delta^{13}C + 4.73$	0.30	***
Posidonia sinuosa	$C_{org} = 0.07*mud + 0.61$	0.09	***	$C_{org} = 0.12*\delta^{13}C + 2.44$	0.23	***
Amphibolis (mixed spp)	$C_{org} = 0.17*mud + 0.61$	0.26	***	$C_{org} = 0.14*\delta^{13}C + 3.53$	0.09	**
Amphibolis antarctica	$C_{org} = 0.08*mud + 0.47$	0.32	***	$C_{org} = 0.14*\delta^{13}C + 3.10$	0.29	***
Amphibolis griffithii	*na*	0.05	0.18	$C_{org} = 0.06*\delta^{13}C + 1.79$	0.21	**
Halodule uninervis	$C_{org} = 0.02*mud + 0.37$	0.34	***	*na*	0.00	0.89
Zostera muelleri	$C_{org} = 0.02*mud + 0.54$	0.39	***	*na*	0.08	0.07
Halophila ovalis	$C_{org} = 0.04*mud + 0.12$	0.91	***	*na*	0.00	0.89
Bare	$C_{org} = 0.06*mud - 0.03$	0.78	***	*na*	0.01	0.24

b)

Habitat (geomorphology)	Organic carbon (%) vs mud (%)			Organic carbon (%) vs $\delta^{13}C$ (‰)		
	Formula	R^2	P value	Formula	R^2	P value
Coastal	*na*	0.01	0.85	$C_{org} = 0.17*\delta^{13}C + 4.14$	0.03	***
Estuarine	$C_{org} = 0.02*mud + 1.01$	0.14	*	$C_{org} = 0.17*\delta^{13}C + 4.52$	0.22	**

Figure 1. Relationships among soil C_{org} and mud contents, and soil C_{org} and $\delta^{13}C$ signatures in the habitats studied: bare sediments, combined *Halodule*, *Halophila* and *Zostera* species, and combined *Amphibolis* and *Posidonia* species. Only correlations with $R^2 > 0.5$ are showed. The grey shaded areas showed the range of $\delta^{13}C$ signatures of plant detritus (based on literature values; see main text). The red circles indicate the samples showing mud-C_{org} saturation, while the red intermittent circles showed samples with high contribution of seagrass-derived C_{org}.

Can mud be used to predict C$_{org}$ content?

491   **Figure 2.** Relationships among soil C_{org} and mud contents, and soil C_{org} and $\delta^{13}C$ signatures in

492   the coastal and estuarine habitats studied. The grey shaded areas showed the range of $\delta^{13}C$

493   signatures of plant detritus (based on literature values; see main text). The red circles indicate

494   the samples showing mud-C_{org} saturation, while the red intermittent circles showed samples

495   with high contribution of seagrass-derived C_{org}.

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