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SUPPLEMENTARY INFORMATION
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A marine heatwave drives massive losses from the world's largest seagrass carbon stocks

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Supplementary Discussion

Dry bulk density (DBD) of seagrass sediments sampled in Shark Bay had a wide range, from 0.06 to 1.86 g cm^{-3}, with median and mean values (0.96 g cm^{-3} and 0.94 ± 0.01 g cm^{-3}, respectively) similar to those found in carbonate systems and in seagrass sediments worldwide (1.03 ± 0.02 g cm^{-3})[1]. Spatially, DBD increased westwards towards Peron Peninsula (Supplementary, Fig. S1), opposite to C content, with which it was negatively correlated (ρ = -0.69; $P \leq 0.001$) (Supplementary, Table S1). Grain size was dominated by medium sands (30% on average), followed by fine and coarse sands (21% and 20%, respectively on average). Mean particle diameter (d50) increased with depth (ρ = 0.25; $P \leq 0.001$), though spatially it did not show a significant correlation with longitude, similarly than exposure (measured as sand:mud ratio) (ρ = -0.48; P =0.08 and ρ = -0.36; P =0.2, respectively). DBD was strongly negatively correlated with C, and positively correlated with sediment depth, particle size (d50) and sand:mud ratio. On the contrary, the correlation between particle size and C was weak (ρ = -0.13; $P \leq 0.05$) and between exposure and C was not significant ($P > 0.05$) (Supplementary, Table S1), suggesting that the seagrass-derived C plays a large role in sediment C storage than does the accumulation of fine, organic-rich allochthonous particles[2].

C burial rates are driven by sedimentation and by the C content available for storage. The high sediment C stocks in the Wooramel Bank and Faure Sill (average top meter: 245 ± 33 Mg C ha^{-1}; average last 4,000 cal yr BP: 514 ± 45 Mg C ha^{-1}) were supported by a 1.6-fold and 2-fold faster accretion of sediments (2.8 - 1.1 mm yr^{-1} compared to the 1.7 - 0.5 mm yr^{-1} measured in meadows at Peron Peninsula), in the short- and long-terms, respectively, and by a 2.7-fold higher concentration of C relative to the other sites surveyed (Table 1)[3]. The rapid sediment accumulation rates would have contributed to higher accumulation and preservation of C after burial[4] due to the prevention of oxygen exchange and limitation of redox potentials, which reduce remineralization[5]. This, together with the recalcitrant nature of seagrass-derived C[6] available for storage led to the formation of these organic-rich sediment deposits within South Wooramel and Faure Sill seagrass banks.

Supplementary Figures

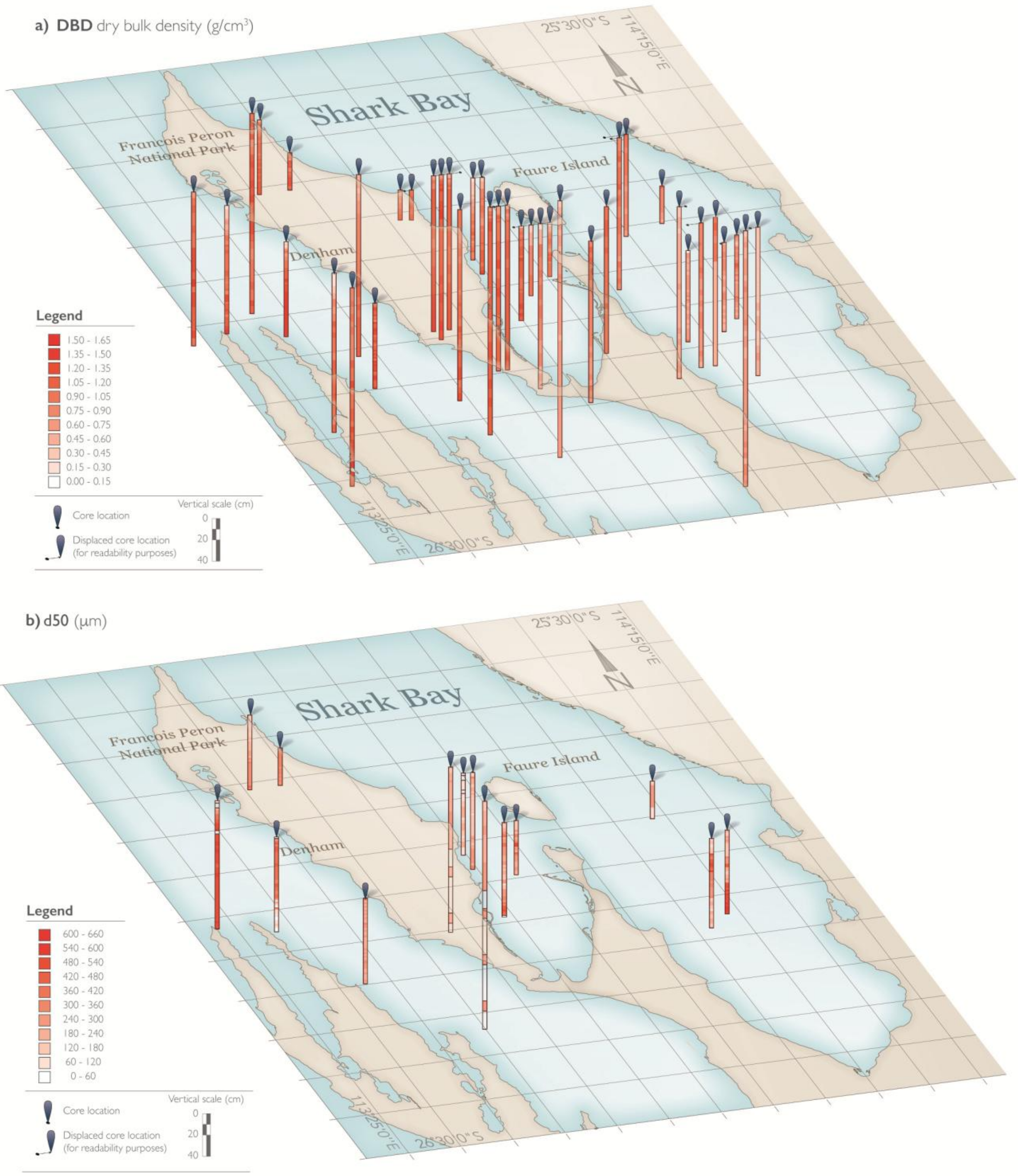

Figure S1. Spatial distribution of sediment properties. (a) Dry bulk density (DBD) and (b) d50 (median diameter of particles) measured in seagrass sediments of Shark Bay.

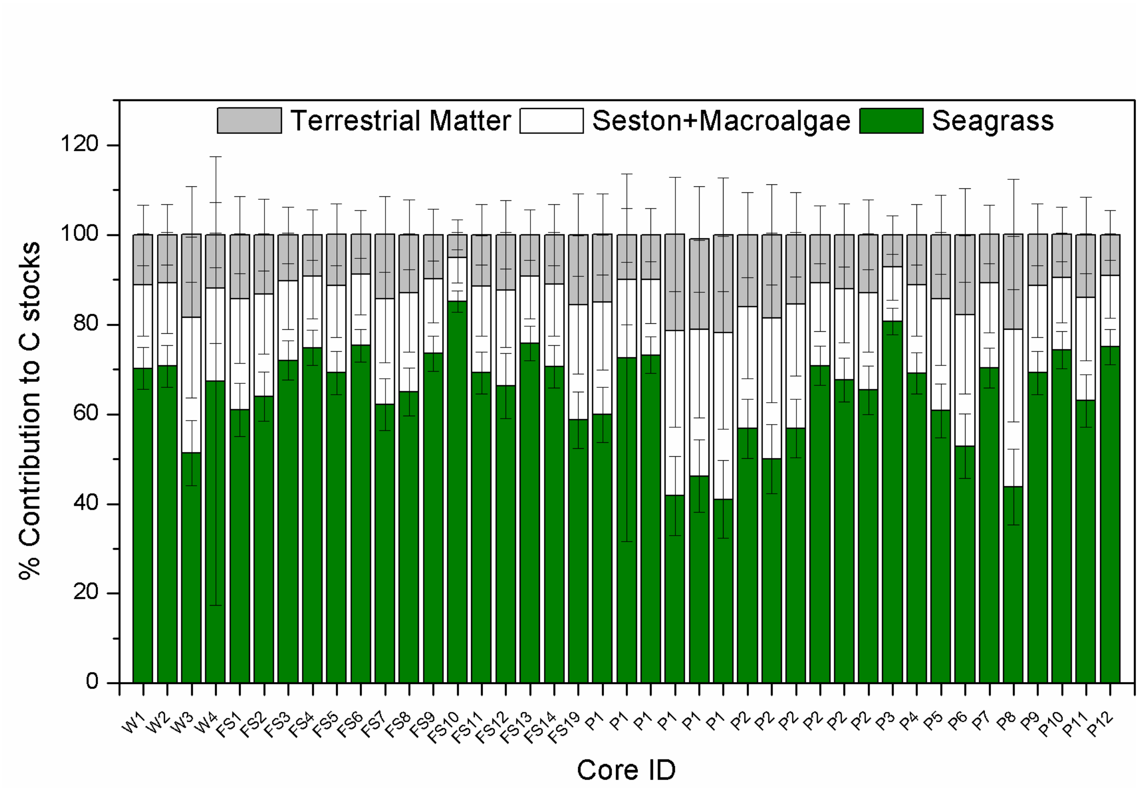

Figure S2. Percentage contribution of seagrass, seston and macroalgae and terrestrial matter to the sediment organic carbon (C) pools in Shark Bay.

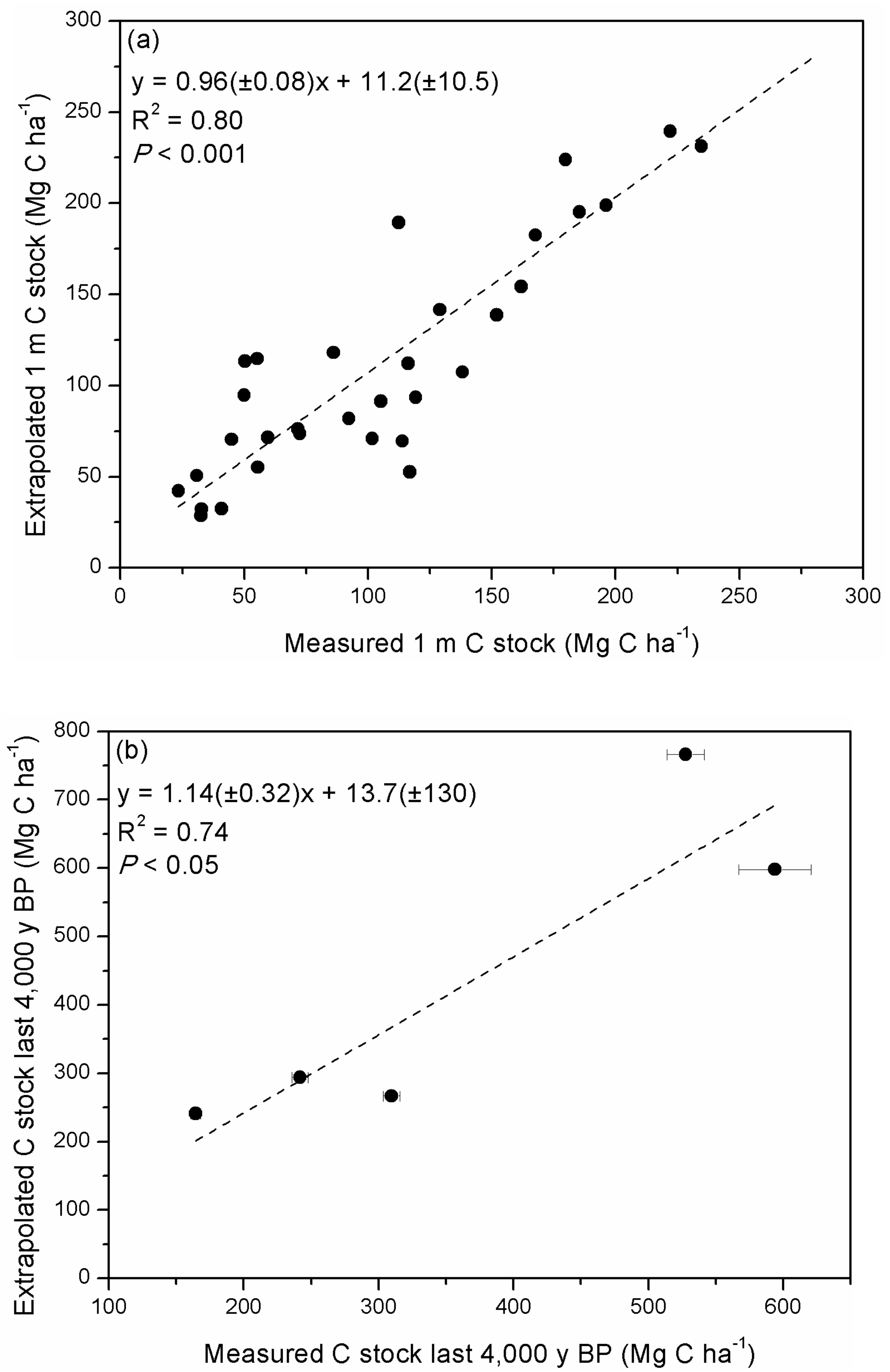

Figure S3. Relationship between extrapolated and measured organic carbon (C) stocks. (a) From 25 cm to 100 cm in sediment cores ≥ 1 m depth; (b) Accumulated over the last 2,000 to 4,000 yr in cores dating ≥ 4,000 cal yr BP.

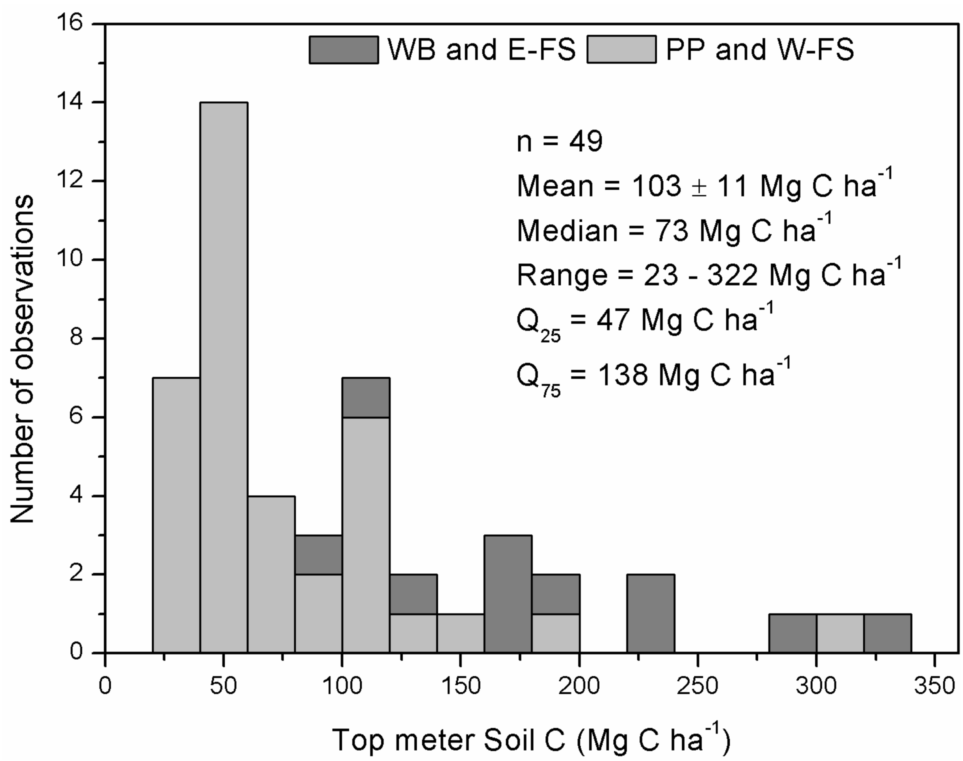

Figure S4. Frequency distribution of published and calculated observations of top meter sediment organic carbon (C) stocks in seagrass sediments in Shark Bay. Different shading is given to highlight spatial patterns. Light grey indicates observations from Peron Peninsula and West Faure Sill. Dark grey, Wooramel Bank and East Faure Sill.

Supplementary Tables

Table S1. Spearman correlation coefficients between sediment organic carbon (C) concentration (%) and physicochemical and biological variables determined in seagrass cores of Shark Bay. ***$P \leq 0.001$, **$P \leq 0.01$, *$P \leq 0.05$, NS, $P \geq 0.05$; significant correlations ($P \leq 0.05$) in bold (ρ value).

	n	Depth	DBD	%C	$\delta^{13}C$	d50	% Mud	%Sand	Sand:Mud
Depth	1102		***	***	***	***	NS	NS	NS
DBD	1102	**0.32**		***	***	***	***	***	***
%C	1102	**-0.24**	**-0.69**		***	*	NS	NS	NS
$\delta^{13}C$	854	**-0.26**	**-0.25**	**0.34**		***	***	***	***
d50	369	**0.25**	**0.29**	**-0.13**	**-0.20**		***	***	***
% Mud	369	-0.06	**-0.31**	0.03	**0.31**	**-0.72**			***
%Sand	369	0.06	**0.31**	-0.04	**-0.31**	**0.72**			***
Sand:Mud	369	0.06	**0.29**	-0.02	**-0.31**	**0.71**	**-0.98**	**0.98**	

Table S2. Sediment δ13C descriptive statistics estimated for the entire length (no older than 4,000 cal yr BP) of the seagrass sediment cores and putative sources of organic carbon (C) in Shark Bay. Same labels are used for cores with same coordinates sampled ~10 m apart from one another.

Core ID	Sections	$\delta^{13}C$(‰)				
	n	Mean	SD	Minimum	Median	Maximum
W1	21	-12.9	0.4	-13.8	-12.9	-12.2
W2	23	-12.8	0.6	-13.6	-12.9	-11.3
W3	38	-15.1	2.0	-19.9	-14.8	-11.5
W4	7	-13.2	0.3	-13.8	-13.1	-12.9
FS1	31	-13.9	1.3	-15.7	-14.5	-11.6
FS2	25	-13.6	1.5	-15.6	-13.7	-10.3
FS3	25	-12.7	1.1	-15.5	-12.6	-9.6
FS4	24	-12.3	1.4	-13.9	-13.0	-9.9
FS5	25	-13.0	1.0	-14.5	-13.2	-10.9
FS6	24	-12.3	1.1	-14.3	-12.3	-10.3
FS7	34	-13.8	1.0	-15.2	-14.0	-10.9
FS8	37	-13.5	0.8	-16.3	-13.3	-12.4
FS9	41	-12.4	1.4	-18.9	-12.3	-9.9
FS10	10	-11.1	0.9	-12.5	-11.3	-9.0
FS11	21	-12.9	2.1	-21.1	-12.8	-9.3
FS12	24	-13.3	1.0	-14.5	-13.5	-9.6
FS13	37	-12.2	0.8	-13.6	-12.4	-8.9
FS14	32	-12.8	1.0	-15.6	-12.8	-11.2
FS19	29	-14.2	1.0	-15.8	-14.3	-12.1
P1	5	-14.1	0.2	-14.4	-14.1	-13.9
P1	4	-12.6	0.9	-13.3	-12.9	-11.3
P1	5	-12.5	0.8	-13.6	-12.2	-11.8
P1	5	-16.2	1.2	-18.0	-16.3	-15.1
P1	5	-15.7	1.6	-17.8	-16.0	-13.7
P1	5	-16.3	1.2	-17.5	-16.3	-14.3
P2	5	-14.4	0.8	-15.7	-14.0	-13.9
P2	5	-15.2	1.7	-18.0	-14.8	-13.5
P2	5	-14.4	0.8	-15.1	-14.5	-13.0
P2	5	-12.8	1.2	-14.1	-12.5	-11.7
P2	5	-13.2	0.5	-13.8	-13.0	-12.7
P2	5	-13.4	1.0	-14.5	-14.0	-12.2
P3	24	-11.7	0.7	-12.7	-11.9	-10.0
P4	27	-13.0	1.1	-14.3	-13.4	-9.7
P5	34	-14.0	1.3	-15.8	-14.4	-9.9
P6	30	-14.9	2.2	-18.5	-15.3	-9.3
P7	31	-12.9	1.7	-15.8	-13.1	-10.0
P8	17	-16.0	2.5	-21.3	-16.0	-12.4

Table S2 continued						
P9	28	-13.0	1.1	-14.4	-13.5	-10.8
P10	22	-12.4	3.6	-21.1	-11.1	-8.9
P11	23	-13.7	1.1	-16.1	-13.8	-12.0
P12	50	-12.3	1.8	-16.6	-12.0	-8.9
Seagrass mean*		-9.41	±	1.32	Burkholder et al. 2011[7]	
Macroalgae mean		-18.12	±	3.93	Burkholder et al. 2011[7]	
Seston		-19.3	±	2.05	Cawley et al. 2012[8]	
Wooramel river DOM		-25.08			Cawley et al. 2012[8]	

* Mean of all seagrass organs from tropical and temperate species in the Bay.

Table S3. Top meter sediment organic carbon (C) stocks, location and main features of sampled seagrass meadows. Number of deep-cores, water column depth and sediment depth after compression corrections. Same labels are used for cores with same coordinates sampled ~10 m apart from one another.

Core ID	Latitude	Longitude	Site	Water depth (m)	Seagrass Species	Core length (cm)	Top meter C stock (Mg C ha^{-1})
W1	-25.9526	114.1838	Wooramel Bank	3.0	*Amphibolis* spp	232	111
W2	-25.9230	114.1458	Wooramel Bank	1.5	*Amphibolis* spp	205	124
W3	-25.9626	114.1561	Wooramel Bank	1.5	*Amphibolis* spp	199	220
W4	-25.8500	114.1020	Wooramel Bank	3.2	*Amphibolis* spp	206	322
W5	-25.7413	114.0746	Wooramel Bank	1.0	*Halodule uninervis, Amphibolis antarctica*	103	169
W6	-25.7448	114.0797	Wooramel Bank	0.9	*Halodule uninervis, Amphibolis antarctica*	55	185
W7	-25.9565	114.1741	Wooramel Bank	4.3	*Halodule uninervis, Amphibolis antarctica*	138	162
W8	-25.8940	114.1140	Wooramel Bank	3.0	*Halodule uninervis*	100	235
FS1	-25.8476	113.8352	Faure Sill	1.5	*Posidonia australis*	323	50
FS2	-25.8474	113.8356	Faure Sill	1.5	*Posidonia australis*	311	49
FS3	-25.8426	113.8359	Faure Sill	1.5	*Posidonia australis*	275	32
FS4	-25.7719	113.8227	Faure Sill	0.5	*Posidonia australis*	249	72
FS5	-25.7723	113.8236	Faure Sill	0.5	*Posidonia australis*	269	54
FS6	-25.7726	113.8250	Faure Sill	0.5	*Posidonia australis*	256	113
FS7	-25.9747	114.1240	Faure Sill	2.5	*Posidonia sinuosa*	202	91
FS8	-25.9789	114.0684	Faure Sill	2.5	*Amphibolis* spp	207	111
FS9	-25.8894	113.8410	Faure Sill	3.0	*Posidonia australis, Amphibolis antarctica*	263	101
FS10	-25.8893	113.8412	Faure Sill	3.0	*Posidonia australis, Amphibolis antarctica*	75	81
FS11	-25.8894	113.8409	Faure Sill	4.0	*Posidonia australis, Amphibolis antarctica*	83	313
FS12	-25.8900	113.8407	Faure Sill	4.0	*Amphibolis antarctica*	230	39
FS13	-25.7870	113.8516	Faure Sill	2.0	*Posidonia australis*	261	104
FS14	-25.7870	113.8518	Faure Sill	2.0	*Posidonia australis*	146	118

Table S3 continued

FS15	-25.9306	114.0961	Faure Sill	1.7	*Amphibolis antarctica*	99	180
FS16	-25.8746	113.9992	Faure Sill	0.7	*Amphibolis antarctica*	99	86
FS17	-25.9378	113.9364	Faure Sill	2.0	*Amphibolis antarctica*	109	281
FS18	-25.8513	113.9380	Faure Sill	2.0	*Halodule uninervis, Amphibolis antarctica*	139	168
FS19	-25.8449	113.7821	Faure Sill	2.0	*Amphibolis antarctica*	274	31
P1	-25.7942	113.7224	Peron Peninsula	0.5	*Posidonia australis*	27	45
P1	-25.7942	113.7224	Peron Peninsula	0.5	*Posidonia australis*	27	62
P1	-25.7942	113.7224	Peron Peninsula	0.5	*Amphibolis antarctica*	27	30
P1	-25.7942	113.7224	Peron Peninsula	0.5	*Amphibolis antarctica*	27	26
P1	-25.7942	113.7224	Peron Peninsula	0.5	*Posidonia australis*	27	51
P1	-25.7942	113.7224	Peron Peninsula	0.5	*Amphibolis antarctica*	27	29
P2	-25.7927	113.7189	Peron Peninsula	1.0	*Amphibolis antarctica*	27	42
P2	-25.7927	113.7189	Peron Peninsula	1.0	*Amphibolis antarctica*	27	47
P2	-25.7927	113.7189	Peron Peninsula	1.0	*Amphibolis antarctica*	27	42
P2	-25.7927	113.7189	Peron Peninsula	1.0	*Posidonia australis*	27	57
P2	-25.7927	113.7189	Peron Peninsula	1.0	*Posidonia australis*	27	63
P2	-25.7927	113.7189	Peron Peninsula	1.0	*Posidonia australis*	27	58
P3	-25.9358	113.5277	Peron Peninsula	1.5	*Posidonia australis*	246	70
P4	-25.9668	113.5387	Peron Peninsula	2.0	*Amphibolis antarctica*	251	54
P5	-26.0021	113.5546	Peron Peninsula	3.0	*Amphibolis antarctica*	248	150
P6	-25.6071	113.5883	Peron Peninsula	1.5	*Amphibolis antarctica, Posidonia* spp	289	30
P7	-25.6209	113.5897	Peron Peninsula	1.5	*Amphibolis antarctica, Posidonia* spp	273	137
P8	-25.6914	113.5986	Peron Peninsula	2.5	*Amphibolis antarctica*	99	59
P9	-25.7524	113.6733	Peron Peninsula	2.0	*Amphibolis antarctica, Posidonia* spp	259	44
P10	-25.8635	113.4928	Peron Peninsula	1.5	*Posidonia sinuosa*	275	110
P11	-25.7419	113.4157	Peron Peninsula	2.0	*Amphibolis antarctica*	214	23
P12	-25.7779	113.4483	Peron Peninsula	1.5	*Posidonia australis*	280	194

Table S4. Estimates of seagrass sediment thicknesses accumulated over the last 4,000 cal yr BP based on radiocarbon results. The total thickness of sediments surveyed and the age of the bottom sections are indicated, together with the % of sampled sediment thickness encompassing the last 4,000 yr.

Core ID	Total thickness surveyed (cm)	Age of bottom section (cal yr BP)	Estimated sediment thickness (4,000 cal yr BP)	% of sampled sediment thickness encompassing 4,000 cal yr BP
W3	199	3404 ± 444	234 ± 18	85
W4	206	1911 ± 587	431 ± 84	48
FS7	202	1367 ± 54	591 ± 11	34
FS9	263	3563 ± 123	295 ± 9	89
FS13	261	3757 ± 96	278 ± 5	94
FS14	146	1117 ± 61	523 ± 16	28
P5	248	5816 ± 159	171 ± 1	145
P7	273	4125 ± 86	265 ± 1	103
P8	99	2538 ± 68	156 ± 1	63
P10	275	6989 ± 227	157 ± 5	175
P12	280	3777 ± 170	296 ± 10	94

Supplementary References

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