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Root turnover and soil indicators capture belowground recovery following saltmarsh restoration

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Table S1: Average elevation of the plots at each site relative to Mean Higher High Water (MHHW).

Site Name	Distance from MHHW (m)
Grazed 1 (G1)	+0.0205
Grazed 2 (G2)	-0.2624
Grazed 3 (G3)	-0.22
Restored 1 (R1)	+0.0079
Restored 2 (R2)	+0.0621
Restored 3 (R3)	+0.0377
Restored 4 (R4)	-0.1119
Natural Reference 1 (NR1)	+0.0492
Natural Reference 2 (NR2)	+0.0135

Table S2: Pyrolysis products from pyrolysis gas chromatograph mass spectrometry (Py-GC-MS). The 109 products are listed by retention time (RT) in a two-column table and categorised by broad molecular groups. ANAPH = alkylnaphthalenes; CARB = carbohydrate products; LIG G = guaiacyl lignin; LEG H = p-hydroxyphenyl lignin; LIG S = syringyl lignin; MAH = monocyclic aromatic hydrocarbons; MCC a = methylene chain compounds: alkanes; MCC e = methylene chain compounds: alkenes; MCC FA = methylene chain compounds: fatty acids; MCC MK = methylene chain compounds: methylketones; NCOMP = nitrogen-containing compounds; PHEN = phenols; OTHER = other compounds.

RT (min)	m/z	Compound Identification	Group
1.394	60	acetic acid	CARB
1.413	74	3-hydroxypropanal	CARB
1.418	82	2-methylfuran	CARB
1.453	86	2,3-butanedione	CARB
1.563	102	2-hydroxybutanal-3-one	CARB
1.605	92	toluene	MAH
1.594	79	pyridine	NCOMP
1.595	67	pyrrole	NCOMP
1.708	82	2-cyclopenten-1-one	CARB
1.735	95	3/2-furaldehyde	CARB
1.835	59	acetamide	NCOMP
1.762	98	2,3-dihydro-5-methylfuran-2-one	CARB
1.822	91	C2-alkylbenzenes	MAH
1.901	95	2-acetylfuran	CARB
1.952	84	(5H)-furan-2-one	CARB
1.976	98	2,3-dihydro-5-methylfuran-2-one	CARB
2.061	110	5-methyl-2-furaldehyde	CARB
2.171	94	phenol	PHEN
2.217	114	4-hydroxy-5,6-dihydro-(2H)-pyran-2-one	CARB
2.339	112	2-hydroxy-3-methyl-2-cyclopenten-1-one	CARB
2.430	108	2/3-methylphenol	PHEN
2.519	107	4-methylphenol	PHEN
2.559	124	guaiacol	LIG G
2.699	126	3-hydroxy-2-methyl-4H-pyran-4-one	CARB
2.768	117	benzyl nitrile	NCOMP
2.818	107	C2-alkylphenol	PHEN
2.918	107	C2-alkylphenol	PHEN
3.010	123	4-methylguaiacol	LIG G
3.187	120	4-vinylphenol	LIG H
3.337	97	5-hydroxymethyl-2-furaldehyde	CARB
3.376	137	4-ethylguaiacol	LIG G
3.436	140	3-methoxycatechol	OTHER
3.543	150	4-vinylguaiacol	LIG G
4.731	194	4-(prop-1-enyl)syringol	LIG S
4.751	167	4-propylsyringol	LIG S
4.791	169	C4-alkylnaphthalene	ANAPH
4.840	60	levoglucosan	CARB
4.931	194	cis 4-(prop-2-enyl)syringol	LIG S
4.971	55	C17 alkene	MCC e
5.000	57	C17 alkane	MCC a
5.087	182	syringaldehyde	LIG S
5.089	177	C3H3-syringol	LIG S
5.120	194	trans 4-(prop-2-enyl)syringol	LIG S
5.269	186	diketodipyrrole	NCOMP
5.279	60	C14 fatty acid	MCC FA
5.309	181	4-acetylsyringol	LIG S
5.339	55	C18 alkene	MCC e
5.358	57	C18 alkane	MCC a
5.429	167	4-(propan-2-one)syringol	LIG S
5.607	181	4-(propan-3-one)syringol	LIG S
5.628	60	C15 fatty acid	MCC FA
5.688	55	C19 alkene	MCC e
5.708	57	C19 alkane	MCC a
5.807	74	C16 fatty acid methyl ester	MCC FA
5.973	60	C16 fatty acid	MCC FA
6.026	55	C20 alkene	MCC e
6.036	57	C20 alkane	MCC a
6.345	55	C21 alkene	MCC e
6.355	57	C21 alkane	MCC a
6.455	74	C18 fatty acid	MCC FA
6.536	67	C18:2 fatty acid	MCC FA
6.595	60	C18 FAME	MCC FA
6.644	55	C22 alkene	MCC e
6.664	57	C22 alkane	MCC a
6.674	67	C18:2 fatty acid	MCC FA
6.943	55	C23 alkene	MCC e

Supplementary Materials

RT (min)	m/z	Compound Identification	Group
3.655	118	C3-tetrahydronaphthalene (tentative)	ANAPH
3.695	154	syringol	LIG S
3.724	164	4-(prop-1-enyl)guaiacol	LIG G
3.754	137	4-propylguaiacol	LIG G
3.775	55	C14 alkene	MCC e
3.805	57	C14 alkane	MCC a
3.914	130	methylindole	NCOMP
3.944	164	cis 4-(prop-2-enyl)guaiacol	LIG G
3.973	156	C2-alkylnaphthalene	ANAPH
4.014	151	vanillin	LIG G
4.105	168	4-methylsyringol	LIG S
4.135	164	trans 4-(prop-2-enyl)guaiacol	LIG G
4.193	153	vanillic acid	LIG G
4.193	55	C15 alkene	MCC e
4.213	57	C15 alkane	MCC a
4.295	132	C4-tetrahydronaphthalene	ANAPH
4.303	147	C3H3-guaiacol	LIG G
4.372	151	4-acetylguaiacol	LIG G
4.427	167	4-ethylsyringol	LIG S
4.587	180	4-vinylsyringol	LIG S
4.611	57	C16 alkane	MCC a
4.621	155	C3-alkylnaphthalene	ANAPH

RT (min)	m/z	Compound Identification	Group
6.946	57	C23 alkane	MCC a
7.172	60	C20 fatty acid	MCC FA
7.233	55	C24 alkene	MCC e
7.229	57	C24 alkane	MCC a
7.501	55	C25 alkene	MCC e
7.501	57	C25 alkane	MCC a
7.591	74	C22 fatty acid methyl ester	MCC FA
7.721	60	C22 fatty acid	MCC FA
7.761	55	C26 alkene	MCC e
7.760	57	C26 alkane	MCC a
8.032	55	C27 alkene	MCC e
8.019	57	C27 alkane	MCC a
8.099	74	C24 fatty acid methyl ester	MCC FA
8.258	55	C28 alkene	MCC e
8.263	57	C28 alkane	MCC a
8.544	55	C29 alkene	MCC e
8.547	57	C29 alkane	MCC a
8.597	58	C27 methylketone	MCC MK
8.836	57	C30 alkane	MCC a
9.117	55	C31 alkene	MCC e
9.135	57	C31 alkane	MCC a

Table S3: Thermally-assisted hydrolysis and methylation products from gas chromatograph mass spectrometry (THM-GC-MS). The 105 products are listed by retention time (RT) in a two-column table and categorised by broad molecular groups. FAME = fatty acid methyl esters (unsubstituted); DAME = fatty diacids dimethyl esters; mid FAME = fatty acid methyl esters (mid-chain methoxy-substituted); oFAME = fatty acid methyl esters (terminal methoxy-substituted); ALCO = methoxyalkanes; CARB = carbohydrate products; MB H = methoxybenzenes (mostly p-hydroxyphenyl lignin); MG H = 1,2-dimethoxybenzenes (mostly guaiacyl lignin); MG S = 1,2,3-trimethoxybenzenes (mostly syringyl lignin); MG Cinn = methoxybenzenes: cinnamyl compounds; MB Phl = 1,3,5-trimethoxybenzenes: phloroglucinols; NCOMP = nitrogen-containing compounds; OTHER = other compounds.

RT (min)	m/z	Compound Identification	Group
3.657	122	4-methoxytoluene (P2)	MB H
4.252	105	benzoic acid methyl ester	OTHER
4.499	115	C4 diacid dimethyl ester (succinic acid dimethyl ester)	OTHER
4.644	138	1,2-dimethoxybenzene (G1)	MB G
4.717	134	4-methoxystyrene (P3)	MB H
4.797	123	1,3/4-dimethoxybenzene	OTHER
4.848	101	unidentified carbohydrate	CARB
5.015	101	unidentified carbohydrate	CARB
5.124	74	C9 fatty acid methyl ester	FAME
5.153	135	4-methoxybenzaldehyde (P4)	MB H
5.216	116	unidentified compound	OTHER
5.283	152	3,4-dimethoxytoluene (G2)	MB G
5.312	142	unidentified carbohydrate	CARB
5.599	129	methylated C6 saccharinic acid methyl ester	CARB
5.698	129	methylated C6 saccharinic acid methyl ester	CARB
5.748	74	C10 fatty acid methyl ester	FAME
5.758	168	1,2,3-trimethoxybenzene (S1)	MB S
5.967	135	4-methoxybenzoic acid methyl ester (P6)	MB H
6.080	98	unidentified N-compound	NCOMP
7.838	226	3,4,5-trimethoxybenzoic acid methyl ester (S6)	MB S
7.850	151	3-(3,4-dimethoxyphenyl)-propanoic acid methyl ester (G12)	MB G
7.999	169	C4-alkylnaphthalene	OTHER
8.039	240	unidentified compound	OTHER
8.059	256	iso/anteiso C15 fatty acid methyl ester	FAME
8.079	209	cis-1-(3,4,5-trimethoxyphenyl)-2-methoxyethylene (S7)	MB S
8.119	98	unidentified N-compound	NCOMP
8.159	209	trans-1-(3,4,5-trimethoxyphenyl)-2-methoxyethylene (S8)	MB S
8.157	181	threo/erythro 1-(3,4-Dimethoxyphenyl)-1,2,3-trimethoxypropane (G14)	MB G
8.208	223	cis-1-(3,4,5-trimethoxyphenyl)-1-methoxy-1-propene	MB S
8.208	181	threo/erythro 1-(3,4-Dimethoxyphenyl)-1,2,3-trimethoxypropane G15)	MB G
8.217	256	C15 fatty acid methyl ester	FAME
8.247	223	trans-1-(3,4,5-trimethoxyphenyl)-1-methoxy-1-propene (S11)	MB S
8.446	254	3-(3,4,5-trimethoxyphenyl)-propanoic acid methyl ester (S12)	MB S
8.544	238	cis-1-(3,4-Dimethoxyphenyl)-1,3-dimethoxyprop-1-ene (G16)	MB G
8.561	222	trans-3-(3,4-Dimethoxyphenyl)-3-propenoic acid methyl ester (G18)	MB Cinn
8.613	211	threo/erythro 1-(3,4,5-trimethoxyphenyl)-1,2,3-trimethoxypropane (S14)	MB S
8.633	74	C16 fatty acid methyl ester	FAME
8.664	211	threo/erythro 1-(3,4,5-trimethoxyphenyl)-1,2,3-trimethoxypropane (S15)	MB S

RT (min)	m/z	Compound Identification	Group
6.085	164	3,4-dimethoxystyrene (G3)	MB G
6.120	153	1,2,4-trimethoxybenzene	CARB
6.201	101	unidentified carbohydrate	CARB
6.261	88	trimethyllevoglucosan	CARB
6.303	182	3,4,5-trimethoxytoluene (S2)	MB S
6.323	168	1,3,5-trimethoxybenzene	MB Phl
6.391	116	unidentified compound	OTHER
6.591	101	unidentified carbohydrate	CARB
6.641	129	methylated C6 saccharinic acid methyl ester	CARB
6.683	115	methylated C5 metasaccharinic acid methyl ester	CARB
6.710	182	2,4,6-trimethoxytoluene	MB Phl
6.763	166	3,4-dimethoxybenzaldehyde (G4)	MB G
6.769	129	methylated C6 saccharinic acid methyl ester	CARB
6.779	178	1-(3,4-dimethoxyphenyl)-1-propene (G21)	MB G
6.839	74	C12 fatty acid methyl ester	FAME
6.849	195	unidentified compound	OTHER
6.859	194	3,4,5-trimethoxystyrene (S3)	MB S
7.017	101	unidentified carbohydrate	CARB
7.146	145	d-Gluconic acid, 2,3,4,6-tetra-O-methyl-, δ-lactone	CARB
7.176	180	3,4-dimethoxyacetophenone (G5)	MB G
7.175	171	Quinic acid, tetramethyl ether, methyl ester (tentative)	CARB
7.187	155	C3-alkylnaphthalene	OTHER
7.265	165	3,4-dimethoxybenzoic acid methyl ester (G6)	MB G
7.266	193	cis-3-methoxy-1-(3,4-dimethoxyphenyl)-1-propene (G9)	MB G
7.276	212	syringic acid methyl ester (S6 unmeth) (tentative)	MB S
7.346	181	3,4,5-trimethoxybenzaldehyde (S4)	MB S
7.414	210	3,4-dimethoxybenzeneacetic acid ME (G24)	MB G
7.424	194	2-(3,4-dimethoxyphenyl)-1-methoxyethylene (G7)	MB G
7.483	194	2-(3,4-dimethoxyphenyl)-1-methoxyethylene (G8)	MB G
7.503	208	cis-1-(3,4-dimethoxyphenyl)-1-methoxy-1-propene (G10)	MB G

RT (min)	m/z	Compound Identification	Group
9.089	252	trans-3-(3,4,5-timethoxyphenyl)-3-propenoic acid methyl ester (S18)	MB Cinn
9.324	55	C18:1 fatty acid methyl ester	FAME
9.404	74	C18 fatty acid methyl ester	FAME
9.476	67	C18:2 fatty acid methyl ester	FAME
9.506	55	C16 ω-methoxy fatty acid methyl ester	oFAME
9.635	67	C18:2 fatty acid methyl ester	FAME
9.734	55	C16 ω-hydroxy fatty acid methyl ester	oFAME
9.876	98	C16 diacid dimethyl ester	DAME
9.942	101	unidentified carbohydrate dimer (tentative)	CARB
9.972	83	unidentified aliphatic compound	MCC
10.062	304	unidentified compound	OTHER
10.101	326	C20 fatty acid methyl ester	FAME
10.121	67	C18:1 ω-methoxy fatty acid methyl ester	oFAME
10.239	101	unidentified carbohydrate dimer (tentative)	CARB
10.428	101	unidentified carbohydrate dimer (tentative)	CARB
10.457	55	C18:1 diacid dimethyl ester	DAME
10.537	98	C18 diacid dimethyl ester	DAME
10.746	74	C22 fatty acid methyl ester	FAME
10.775	67	unidentified aliphatic compound	MCC
10.871	55	C20 ω-methoxy fatty acid methyl ester	oFAME
10.914	201	9,10,ω-trimethoxy C18:0 fatty acid methyl ester	mid FAME
11.053	83	C24 methoxyalkane	ALCO
11.161	98	C20 diacid dimethyl ester	DAME
11.212	201	midchain methoxyfatty acid methyl ester	mid FAME
11.350	74	C24 fatty acid methyl ester	FAME
11.450	55	C22 ω-methoxy fatty acid methyl ester	oFAME
11.627	83	C26 methoxyalkane	ALCO
11.765	98	C22 diacid dimethyl ester	DAME
11.925	74	C26 fatty acid methyl ester	FAME
12.024	55	C24 ω-methoxy fatty acid methyl ester	oFAME

Supplementary Materials

RT (min)	m/z	Compound Identification	Group
7.632	208	trans-1-(3,4-dimethoxyphenyl)-1-methoxy-1-propene (G11)	MB G
7.687	195	3,4,5-trimethoxyacetophenone (S5)	MB S
7.731	161	trans-3-(4-methoxyphenyl)-3-propenoic acid methyl ester (P18)	MB Cinn
7.781	74	C14 fatty acid methyl ester	FAME
12.227	83	C28 methoxyalkane	ALCO
12.558	74	C28 fatty acid methyl ester	FAME
13.291	74	C30 fatty acid methyl ester	FAME

Table S4: Soil strength at two depths in grazed, restored and reference *Salicornia*-dominant saltmarsh ecosystems. Values represent means and standard error.

kPA	Grazed	Restored	Reference
10 cm depth	124.4 ± 8.0	53.5 ± 3.7	44.7 ± 5.9
20 cm depth	157.2 ± 8.4	73.7 ± 6.8	57.1 ± 5.8

Table S5: Decay rates of tea and *Salicornia quinqueflora* root litter. Decay rates are calculated using a single exponential decay equation using proportion mass (k), proportion carbon (k_C) or proportion nitrogen (k_N) remaining over time. Decay rate units are % d^{-1}. Values represent means and standard error.

Litter Type	Rehabilitation category	Decay rate, k	Carbon decay rate, k_C	Nitrogen decay rate, k_N
Salicornia roots	Grazed	0.635 ± 0.0705	0.556 ± 0.0538	0.379 ± 0.039
	Restored	0.591 ± 0.0477	0.501 ± 0.0119	0.429 ± 0.0195
	Reference	0.517 ± 0.0741	0.441 ± 0.0424	0.358 ± 0.0558
Green tea	Grazed	1.391 ± 0.269		
	Restored	1.418 ± 0.30		
	Reference	1.325 ± 0.153		
Rooibos tea	Grazed	0.181 ± 0.0203		
	Restored	0.166 ± 0.0056		
	Reference	0.163 ± 0.0183		

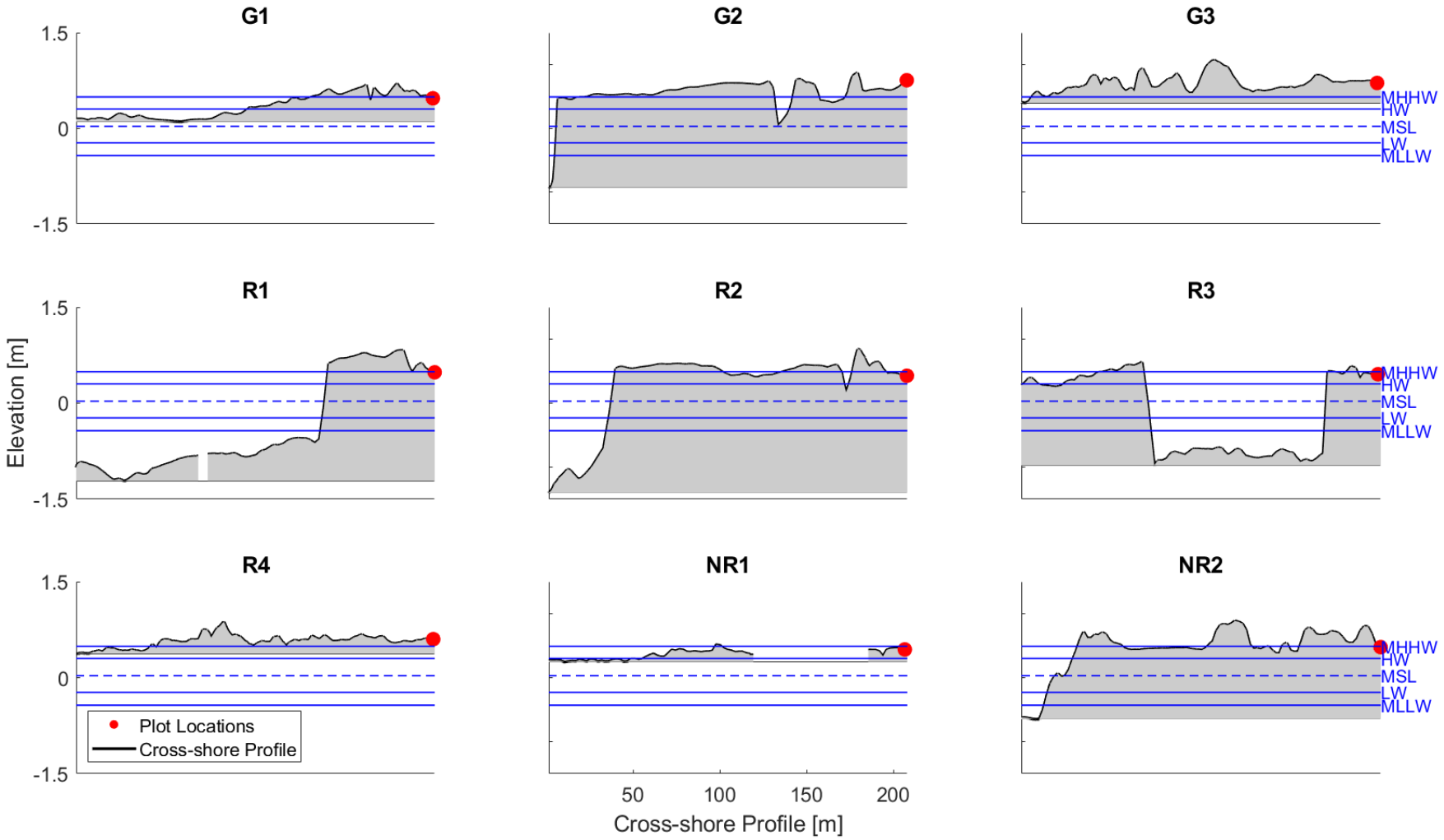

Figure S1: Cross-section of site elevation. G = Grazed site category, R = Restored site category, NR = Natural Reference site category, MHHW = Mean Higher High Water, HW = High Water, MSL = Mean Sea Level, LW = Low Water, and MLLW = Mean Lower Low Water.

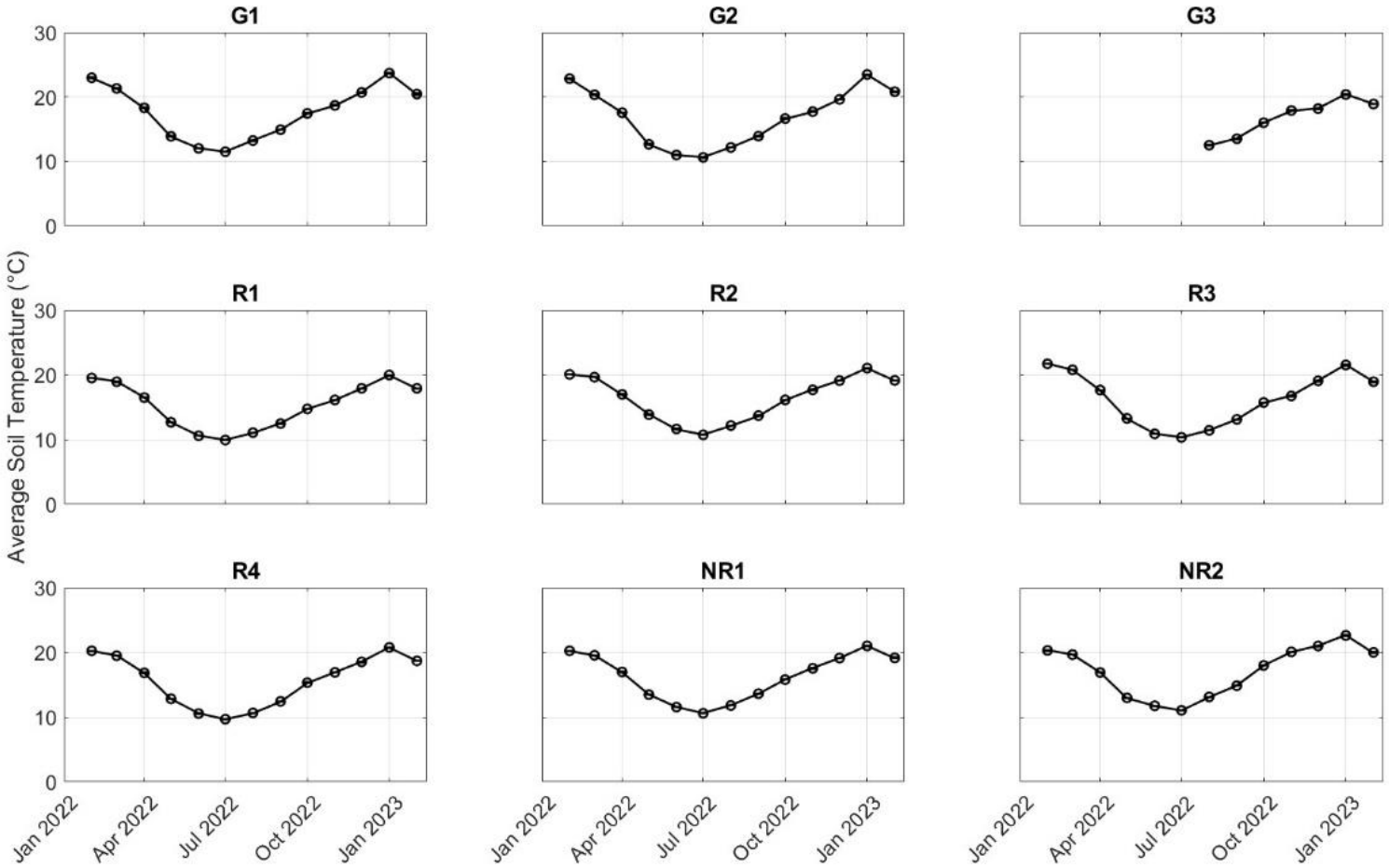

Figure S2: Monthly soil temperature time series for each site. Note that for site G3, there were logger fails resulting in lost temperature data for the first 6 months. G = Grazed, R = Restored and NR = Natural Reference. Points represent monthly means and standard deviation.

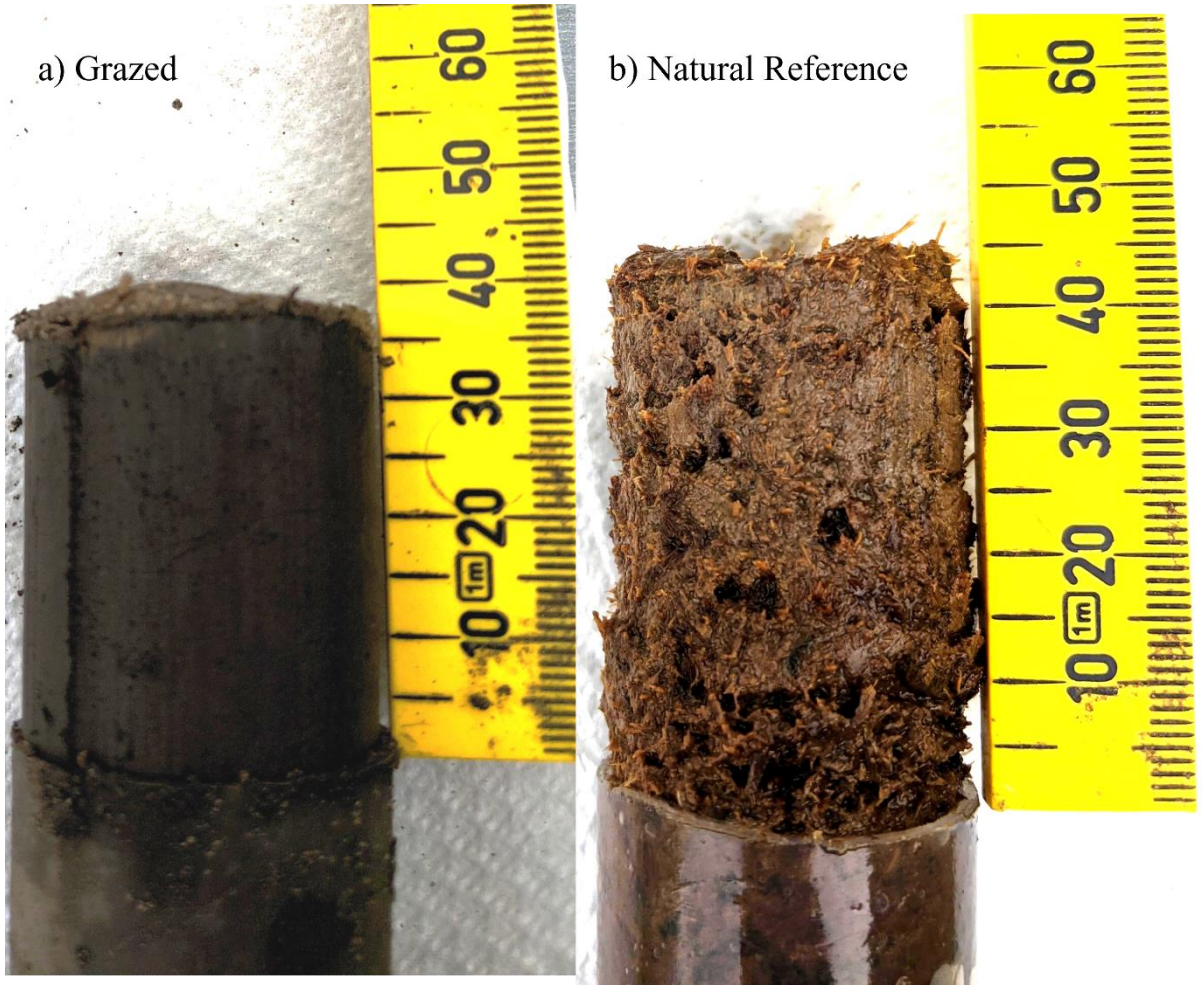

Figure S3: Soil cores demonstrating visible differences between Grazed and Restored belowground soil structure. (a) Shows the compaction and lack of roots at Grazed sites (b) shows peatier soil and presence of roots at Natural Reference sites.

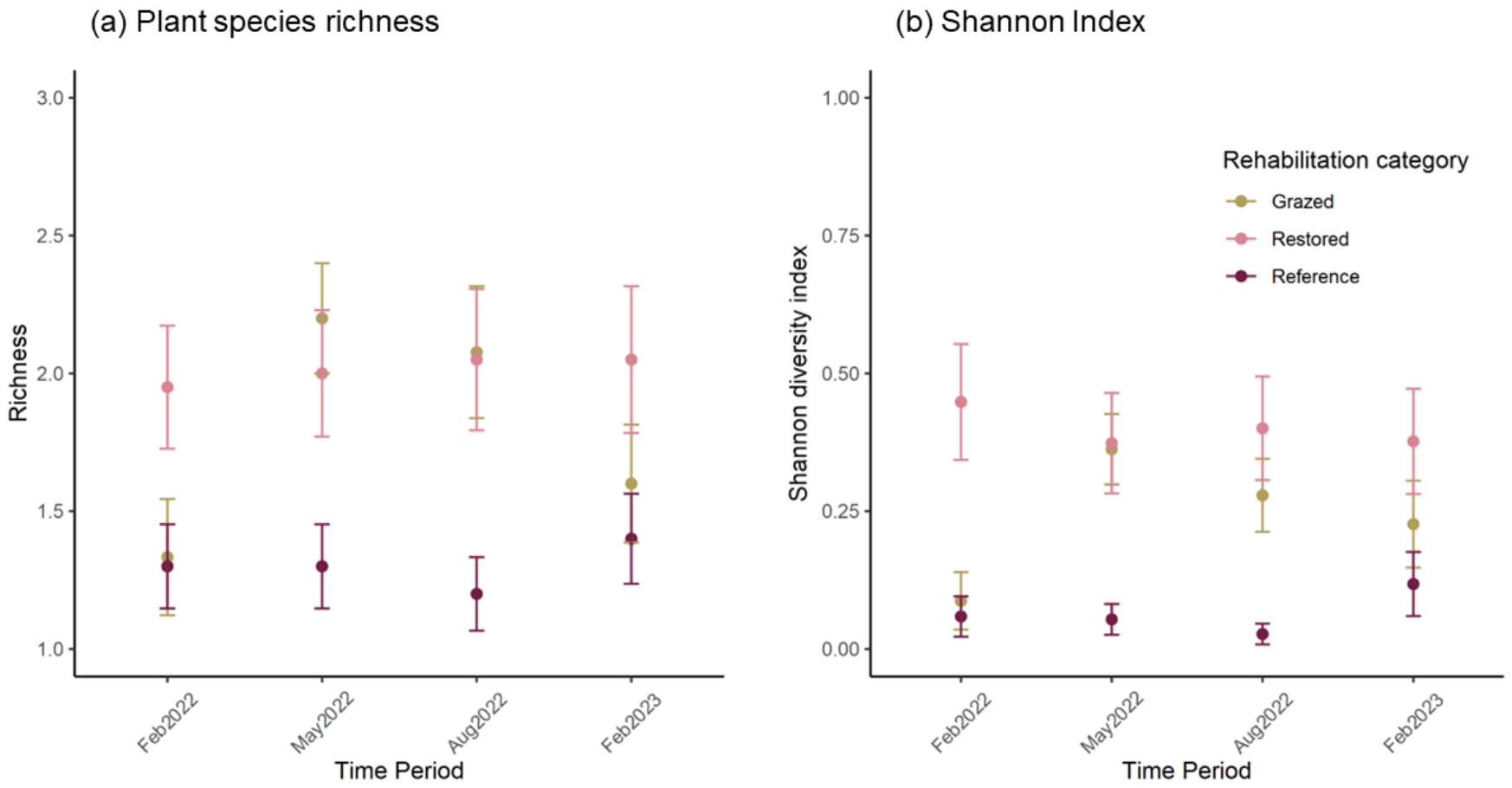

Figure S4: Vegetation alpha diversity metrics of saltmarsh plots at Grazed, Restored and Natural Reference sites. (a) Species richness. (b) Shannon Index. Vegetation surveys were taken of the experimental plots at initial, 3 month, 6 month and 12 month sampling periods. Values represent mean and standard error.

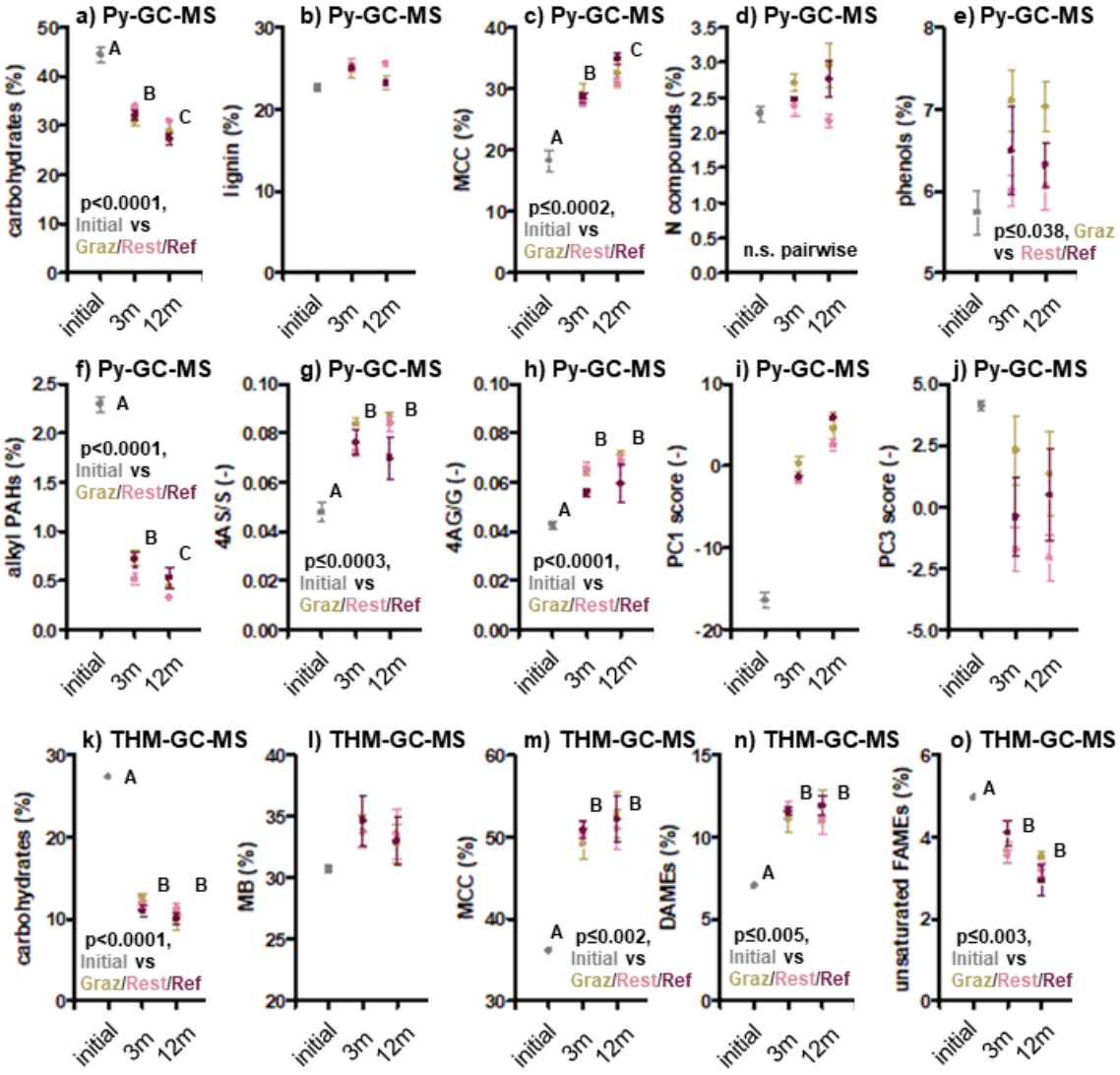

Figure S5: Molecular shifts of *Salicornia* roots with decay using Py-GC-MS and THM-GC-MS. (a-h) Molecular groups derived from pyrolysis gas chromatography mass spectrometry (Py-GC-MS). (i-j) Principal components 1 and 3 scores from Py-GC-MS molecular groups. (k-o) Molecular groups derived from thermally assisted hydrolysis and methylation gas chromatography mass spectrometry (THM-GC-MS). Decaying root materials were analysed for two sites in each rehabilitation category at initial, 3-month and 12-month time points. Capital letters indicate post hoc differences for significant shifts in a compound over time. Significant differences in rehabilitation categories are indicated as text in each panel. MCC = methylene chain compounds; PAH = polycyclic aromatic hydrocarbons; 4AS/S = syringyl-type lignin product; 4AG/G = guaiacyl- type lignin product; MB = methoxybenzenes; DAMEs = diacid methyl esters; FAMEs = fatty acid methyl esters. Values represent means and standard error.