

## Supplementary Materials for

### U.S. Pacific coastal wetland resilience and vulnerability to sea-level rise

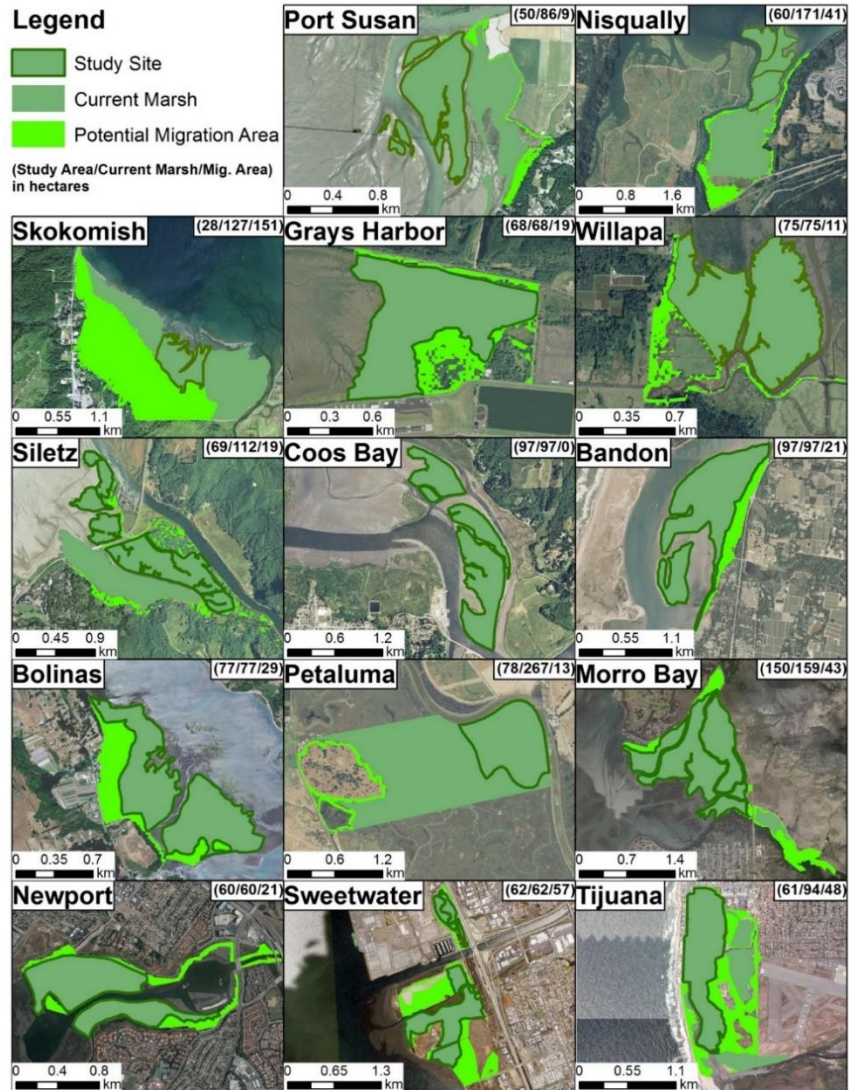
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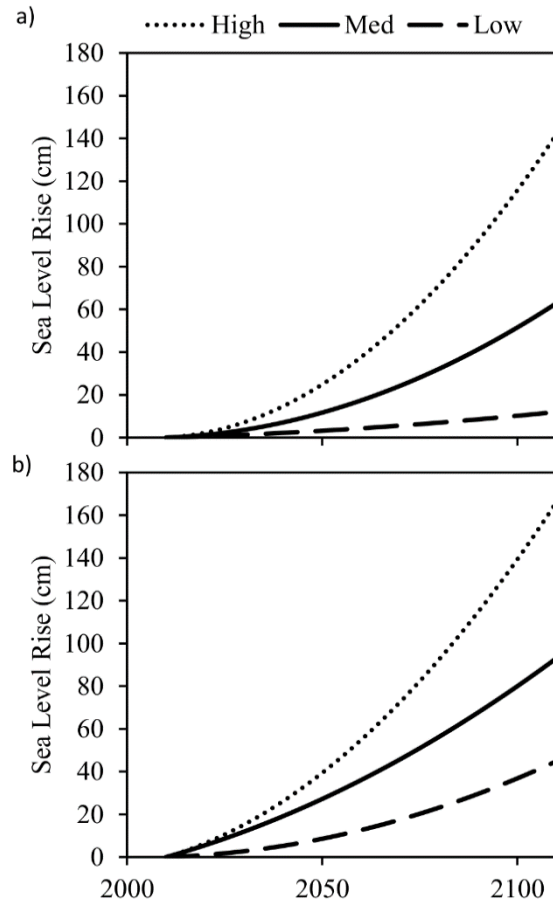
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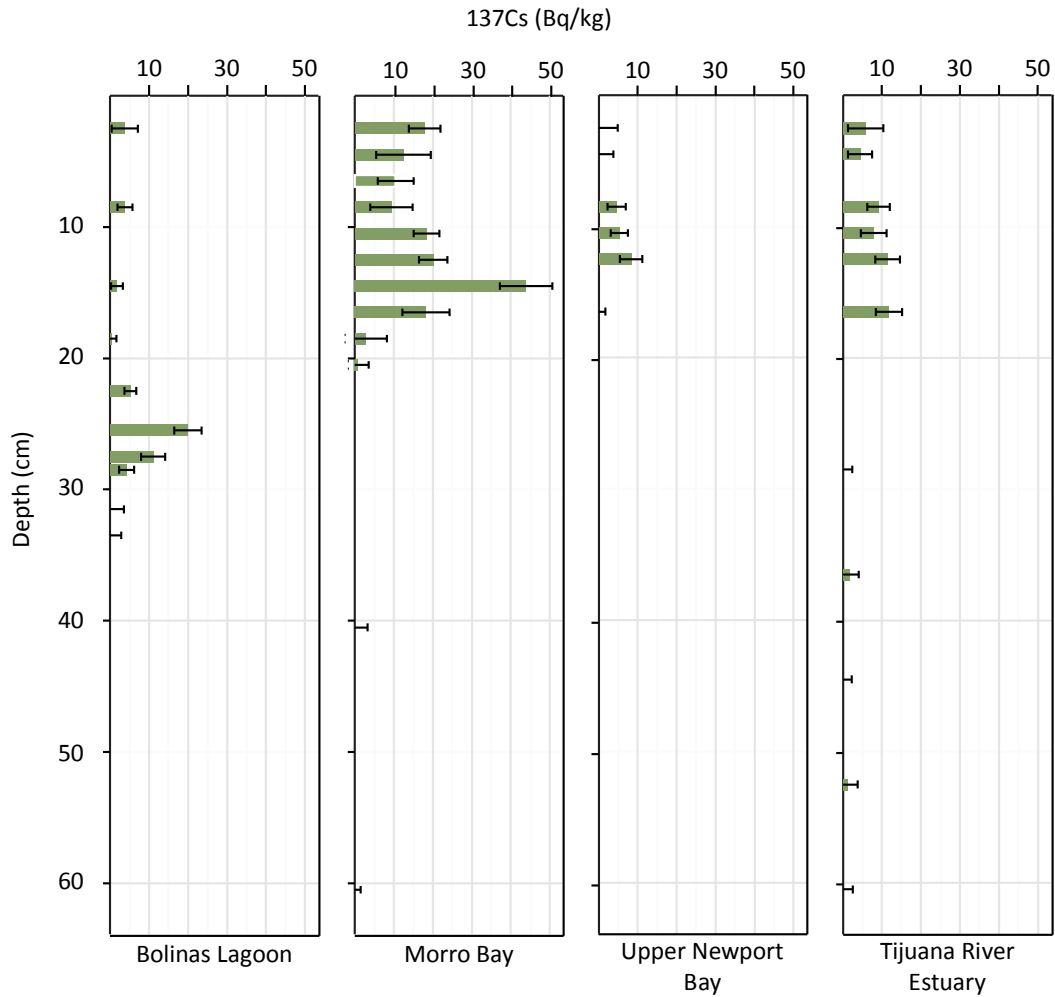
**Supplemental Figures & Tables:**



**fig. S1. Available transgression or migration space under high SLR scenarios for the study sites.** Study area and current marsh are compared to the relative area of migration space available in parenthesis (Study Area/Current Marsh/Mig. Area) in hectares. Most study sites in the Pacific Northwest are constrained by steep topography which consists of temperate forests, while most study sites in California are constrained by human development.



**fig. S2. Projections of future sea level used in the WARMER modeling for high, moderate, and low SLR scenarios, from the National Research Council, *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future* (6). Sea-level rise curves for sites in the Pacific Northwest (a) and California (b).**



**fig. S3.** <sup>137</sup>Cs activity (in becquerel per kilogram) shown by depth with mean ± SE for sediment cores taken from sites in Southern California. Maximums of <sup>137</sup>Cs activity were used as a marker for the year 1963 to calculate vertical accretion rates.

**table S1. Core elevation (in centimeters; relative to MSL) and accretion rate (in millimeters per year) for soil cores used in WARMER modeling.**

<b>Site</b>	<b>Core Elevation (cm, MSL)</b>	<b>Accretion Rate (mm yr<sup>-1</sup>)</b>	<b>Source</b>
<b>Port Susan</b>	111	7.2	Buffington 2017
<b>Port Susan</b>	145	5.2	Buffington 2017
<b>Nisqually</b>	121	3.6	Buffington 2017
<b>Nisqually</b>	150	3.4	Buffington 2017
<b>Nisqually</b>	182	2.8	Buffington 2017
<b>Skokomish</b>	79	2.8	Buffington 2017
<b>Skokomish</b>	145	1.6	Buffington 2017
<b>Grays Harbor</b>	49	8.2	Buffington 2017
<b>Grays Harbor</b>	143	8.0	Buffington 2017
<b>Grays Harbor</b>	116	7.4	Buffington 2017
<b>Willapa</b>	126	6.4	Buffington 2017
<b>Willapa</b>	198	6.0	Buffington 2017
<b>Siletz</b>	107	4.4	Buffington 2017
<b>Siletz</b>	124	3.6	Buffington 2017
<b>Siletz</b>	136	2.0	Buffington 2017
<b>Coos Bay</b>	116	3.2	Buffington 2017
<b>Coos Bay</b>	84	3.2	Buffington 2017
<b>Coos Bay</b>	134	3.4	Buffington 2017
<b>Bandon</b>	46	2	Buffington 2017
<b>Bandon</b>	105	2.4	Buffington 2017
<b>Bandon</b>	106	2.4	Buffington 2017

<b>Bolinas</b>	61	4.1	Bryne et al. 2006
<b>Bolinas</b>	80	4.9	This study
<b>Petaluma</b>	79	2	Callaway et al. 2012
<b>Petaluma</b>	75	2	Callaway et al. 2012
<b>Petaluma</b>	89	3.4	Callaway et al. 2012
<b>Morro Bay</b>	52	2.9	This study
<b>Newport</b>	75	2.6	This study
<b>Sweetwater</b>	70	1.3	Thorne et al. 2016
<b>Sweetwater</b>	85	1.7	Thorne et al. 2016
<b>Tijuana</b>	59	3.3	This study
<b>Tijuana</b>	61	8.3	Weis et al. 2001
<b>Tijuana</b>	68	9.4	Weis et al. 2001
<b>Tijuana</b>	57	10.6	Weis et al. 2001
<b>Tijuana</b>	59	7.1	Weis et al. 2001
<b>Tijuana</b>	63	9.4	Weis et al. 2001

**table S2. Sample size, mean elevation, and elevation range of real-time kinematic GPS (in meters; NAVD88) points collected at all study sites.**

<b>Site</b>	<b>Area (ha)</b>	<b>Elevation data points (n)</b>	<b>Mean elevation (m)</b>	<b>Maximum elevation (m)</b>	<b>Minimum elevation (m)</b>	<b>Elevation range (m)</b>
Port Susan	51.5	897	2.23	3.46	1.28	2.18
Nisqually	59.9	1072	2.77	3.16	2.26	0.9
Skokomish	28.8	605	2.66	4.08	1.48	2.6
Grays Harbor	67.8	1192	2.42	2.58	1.45	1.13
Willapa	74.8	1230	2.42	3.23	1.72	1.51
Siletz	69.2	1196	2.3.5	2.75	1.74	1.01
Coos Bay	97.2	1605	2.04	2.58	1.45	1.13
Bandon	96.7	1710	2.03	3.01	1.38	1.63
Bolinas	83.7	1622	1.62	2.63	1.2	1.43
Petaluma	80.6	655	1.82	2.28	0.87	1.41
Morro Bay	150.3	2575	1.63	2.82	1.03	1.79
Newport	59.8	1037	1.55	2.81	0.81	2
Sweetwater	128	1201	1.63	2.74	0.83	1.91
Tijuana	61.7	989	1.56	2.58	1.17	1.41

**table S3. Equilibrium elevations from WARMER.** Elevation ( $z^*$ ) at which WARMER predicts a stable marsh platform for each study site under the historic sea-level rise rate. Four sites, Skokomish, Petaluma, Newport, and Sweetwater, were not stable under rates of historic sea-level rise, indicating that the measured accretion rates at those sites are too low to maintain a marsh platform.

Site	Equilibrium ( $z^*$ )
Port Susan	1.04
Nisqually	1.57
Skokomish	-
Grays Harbor	1.39
Willapa Bay	1.11
Siletz	1.36
Coos Bay	2.11
Bandon	1.46
Bolinas	0.91
Petaluma	-
Morro Bay	1.45
Newport	-
Sweetwater	-
Tijuana	1.06



**table S4. Elevation range of low, middle, and high marsh zones at each site.** Zone boundaries were defined by degree of flooding by high tides and the lower extent of marsh vegetation at each site.

Study Site	Marsh zone	% high tides reaching zone	z* range	NAVD88 range (m)	MHHW range (m)	Sample size
Port Susan	High	0.16-25	1.255 to 1.026	3.061 to 2.746	0.351 to 0.036	22
	Middle	25-50	1.025 to 0.871	2.745 to 2.532	0.035 to -0.178	31
	Low	>50	0.870 to 0.139	2.531 to 1.525	-0.179 to -1.185	155
Nisqually	High	0.16-25	1.255 to 1.026	3.585 to 3.154	0.479 to 0.048	1
	Middle	25-50	1.025 to 0.871	3.153 to 2.864	0.047 to -0.242	82
	Low	>50	0.870 to 0.488	2.863 to 2.146	-0.243 to -0.960	162
Skokomish	High	0.16-25	1.255 to 1.026	3.158 to 2.803	0.395 to 0.040	30
	Middle	25-50	1.025 to 0.871	2.802 to 2.563	0.039 to -0.200	66
	Low	>50	0.870 to 0.163	2.562 to 1.467	-0.201 to -1.296	31
Grays Harbor	High	0.16-25	1.407 to 1.019	2.848 to 2.411	0.458 to 0.021	164
	Middle	25-50	1.018 to 0.800	2.410 to 2.165	0.020 to -0.225	47
	Low	>50	0.799 to 0.297	2.164 to 1.599	-0.226 to -0.791	51
Willapa Bay	High	0.16-25	1.407 to 1.019	2.839 to 2.265	0.602 to 0.028	138
	Middle	25-50	1.018 to 0.800	2.264 to 1.941	0.027 to -0.296	61
	Low	>50	0.799 to 0.359	1.940 to 1.289	-0.297 to -0.948	77

	High	0.16-25	1.400 to 1.019	2.787 to 2.337	0.472 to 0.022	72
Siletz	Middle	25-50	1.018 to 0.801	2.336 to 2.080	0.021 to -0.235	45
	Low	>50	0.800 to 0.587	2.079 to 1.827	-0.236 to -0.488	9
	High	0.16-25	1.400 to 1.019	2.821 to 2.349	0.495 to 0.023	13
Coos Bay	Middle	25-50	1.018 to 0.801	2.348 to 2.080	0.022 to -0.246	150
	Low	>50	0.800 to 0.364	2.079 to 1.539	-0.247 to -0.787	217
	High	0.16-25	1.379 to 1.016	1.877 to 1.643	0.244 to 0.010	55
Bolinas	Middle	25-50	1.016 to 0.748	1.643 to 1.471	0.010 to -0.162	139
	Low	>50	0.748 to 0.293	1.471 to 1.179	-0.162 to -0.454	93
	High	0.16-25	1.379 to 1.016	2.273 to 1.956	0.331 to 0.014	
Petaluma	Middle	25-50	1.016 to 0.748	1.956 to 1.722	0.014 to -0.220	
	Low	>50	0.748 to -0.135	1.722 to 0.951	-0.220 to -0.991	
	High	0.16-25	1.379 to 1.016	1.949 to 1.665	0.297 to 0.013	176
Morro Bay	Middle	25-50	1.016 to 0.748	1.665 to 1.454	0.013 to -0.198	307
	Low	>50	0.748 to 0.308	1.454 to 1.109	-0.198 to -0.543	97
	High	0.16-25	1.506 to 1.053	2.013 to 1.642	0.414 to 0.043	62
Newport	Middle	25-50	1.053 to 0.729	1.642 to 1.377	0.043 to -0.222	123
	Low	>50	0.729 to -0.164	1.377 to 0.646	-0.222 to -0.953	55
Sweetwater	High	0.16-25	1.506 to 1.053	2.048 to 1.663	0.430 to 0.045	41

	Middle	25-50	1.053 to 0.729	1.663 to 1.388	0.045 to -0.230	120
	Low	>50	0.729 to 0.027	1.388 to 0.791	-0.230 to -0.827	81
	High	0.16-25	1.506 to 1.053	2.112 to 1.708	0.451 to 0.047	67
Tijuana	Middle	25-50	1.053 to 0.729	1.708 to 1.420	0.047 to -0.241	195
	Low	>50	0.729 to 0.325	1.420 to 1.025	-0.241 to -0.534	26

**table S5. List of sediment cores taken from California, with locations, elevations, and estimated sediment accretion rate from  $^{137}\text{Cs}$  dating.**

Site	Core Name	Year Sampled	Latitude (dd)	Longitude (dd)	Accretion Rate (mm/yr)	±
<b>Bolinas</b>	BOL13-01	2013	37.919	-122.688	4.9	0.2
<b>Morro Bay</b>	MOB13-01	2013	35.341	-120.836	2.86	0.2
<b>Newport Bay</b>	UNB13-03	2013	33.651	-117.881	2.6	0.4
<b>Tijuana</b>	TJE12-07	2012	32.575	-117.128	3.27	1.2

**table S6. WARMER model parameters for Pacific Northwest study sites.**

<b>Model Parameter</b>	<b>Port Susan</b>	<b>Skokomish</b>	<b>Nisqually</b>	<b>Grays Harbor</b>	<b>Willapa</b>	<b>Siletz</b>	<b>Coos Bay</b>	<b>Bandon</b>
<b><sup>a</sup>Sediment accumulation rate (g/cm<sup>2</sup>/yr) at 0 MSL</b>	0.84	0.075	0.24	1.67	1.10	0.59	0.44	0.13
<b><sup>b</sup>Elevation of peak biomass (cm, MSL)</b>	152	164	175	159	163	133	101	123
<b><sup>c</sup>Minimum elevation of vegetation (cm, MSL)</b>	-9	25	105	11	40	7	34	12
<b><sup>a</sup>Max. aboveground organic accumulation (g/cm<sup>2</sup>/yr)</b>	0.0408	0.0097	0.012	0.0677	0.0252	0.0337	0.0051	0.0079
<b><sup>d</sup>Root-to-shoot ratio</b>	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95
<b><sup>a</sup>Porosity at the surface (percent)</b>	88	95	94	98	92	91	95	89
<b><sup>a</sup>Porosity at depth (percent)</b>	60	72	88	81	75	86	84	66
<b><sup>a</sup>Refractory carbon (percent)</b>	43.7	61	59.7	52.5	63.4	40.9	64.5	28.1
<b><sup>c</sup>Mean higher high water (cm, MSL)</b>	167	147	150	142	168	111	103	103
<b><sup>c</sup>Maximum astronomical tide (cm, MSL)</b>	253	236	286	200	232	180	224	183
<b><sup>e</sup>Historic sea-level rise (mm/yr)</b>	1.98	1.97	1.97	1.05	1.6	2.35	0.59	0.59

Data source: <sup>a</sup> soil cores; <sup>b</sup> NAIP imagery and interpolated DEMs; <sup>c</sup> vegetation surveys; <sup>d</sup> literature; <sup>e</sup> nearest NOAA tide station

**table S7. WARMER parameters for California study sites.**

Model parameter	Petaluma	Bolinas	Morro	Newport	Sweetwater	Tijuana
<sup>a</sup> Sediment accumulation rate [(g/cm <sup>2</sup> )/yr] at 0 MSL	0.10	1.05	0.15	0.25	0.18	0.19
<sup>b</sup> Elevation of peak biomass (cm, MSL)	73	91	93	92	82	73.
<sup>c</sup> Minimum elevation of vegetation (cm, MSL)	30	21	16	2	-2	11
<sup>a</sup> Maximum aboveground organic accumulation [(g/cm <sup>2</sup> )/yr]	0.0157	0.0783	0.0550	0.0338	0.007	0.0502
<sup>d</sup> Root-to-shoot ratio	0.458	0.458	0.458	0.458	0.458	0.458
<sup>a</sup> Porosity at the surface (percent)	83	79	90	87	86	87
<sup>a</sup> Porosity at depth (percent)	80	59	75	38	45	74
<sup>a</sup> Refractory carbon (percent)	14	26	16.7	8.9	27	7.00
<sup>c</sup> Mean higher high water (cm, MSL)	88	64	78	81	85	78
<sup>c</sup> Maximum astronomical tide (cm, MSL)	142	142	133	157	130	136.2
<sup>c</sup> Historical sea-level rise (mm/yr)	1.89	2.10	0.79	2.22	2.06	2.06

Data source: <sup>a</sup> soil cores; <sup>b</sup> NAIP imagery and interpolated DEMs; <sup>c</sup> vegetation surveys; <sup>d</sup> literature; <sup>e</sup> nearest NOAA tide station