Appendixes

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Appendix A. Site Specific Details for Padilla Marsh, Padilla Bay, Skagit County, Washington

Photo: K. Turner, USGS

Summary:

- Study site size: 5.2 hectares
- *Location*: 48° 29' 36" N latitude, 122° 28' 56" W longitude.
- *Site management*: Padilla Bay National Estuarine Research Reserve (NOAA)
- *Site vegetation and elevation survey*: 31 August – 7 September 2012
- *Sample size*: 76 (elevation data points), 19 (vegetation quadrats)
- *Marsh elevation model*: Padilla was the highest study site in the Pacific Northwest region with 96% of the elevation data points above MHHW.
- *Plant community composition*: *Distichlis spicata* had the highest frequency of occurrence at the site. *Sarcocornia perennis* was also common.
- *Bathymetric surveys*: 50.6 ha of nearshore habitat were mapped adjacent to the study area.
- *Soil characteristics:* Sediment cores were not collected at Padilla marsh. WARMER parameters were based on core data obtained at Port Susan, WA (see Table B4).

- *Salinity monitoring*: April 2013 – May 2014. Weekly maximum salinity usually ranged between 25-30 during the study period. The maximum recorded salinity throughout the study period was 30 PSU.
- *Calculated tidal datums*: MHHW is at 2.37 m NAVD88; MHW is at 2.13 m NAVD88.
- *Sea-level rise marsh response modeling:* Under the low NRC SLR projection (12 cm), Padilla is projected to become gradually dominated by high (51%) and transitional (49%) marsh over the coming century. Under the NRC's mid SLR projection (63 cm), high marsh initially increases from 2010 to 2040, but then decreases after 2050. By 2110 most of the site is low marsh. Under the NRC's high SLR projection (142 cm), there is a relatively rapid change in habitat composition with the site losing high marsh by 2070, mid marsh by 2080, and low marsh by 2090.

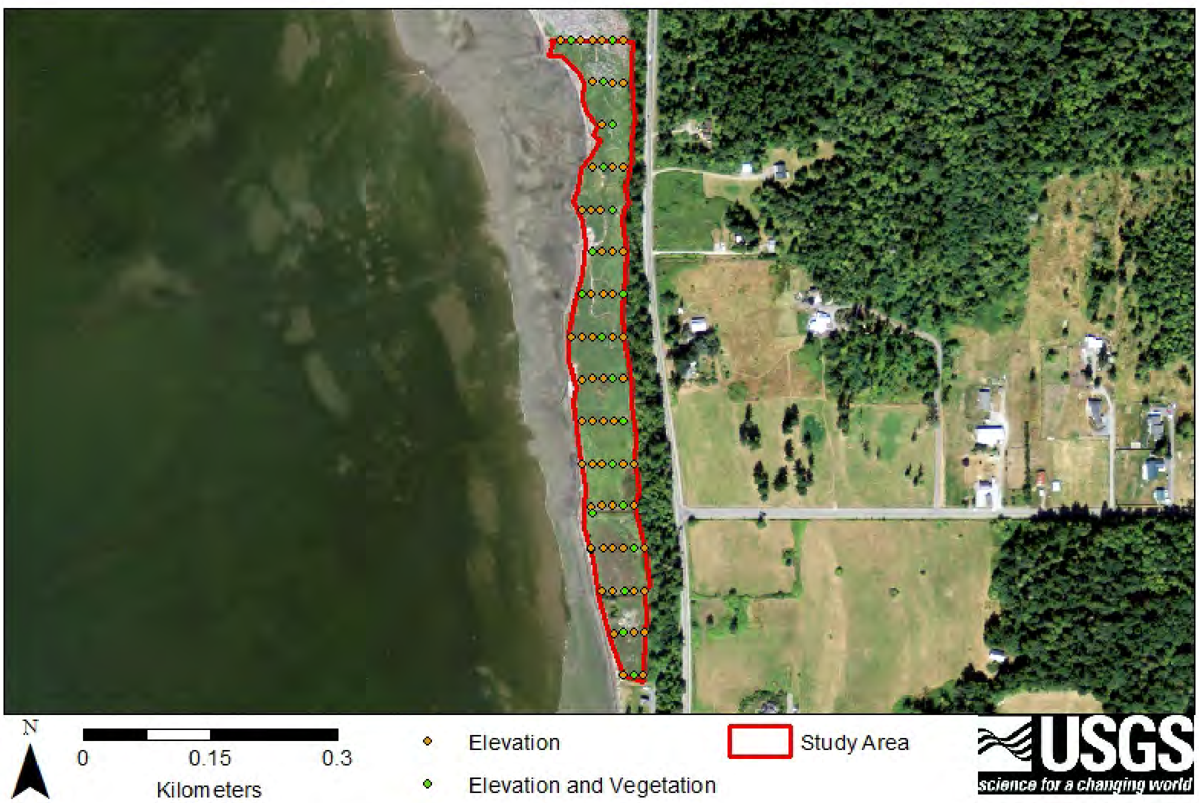

Figure A1. Distribution of elevation and vegetation survey points at Padilla.

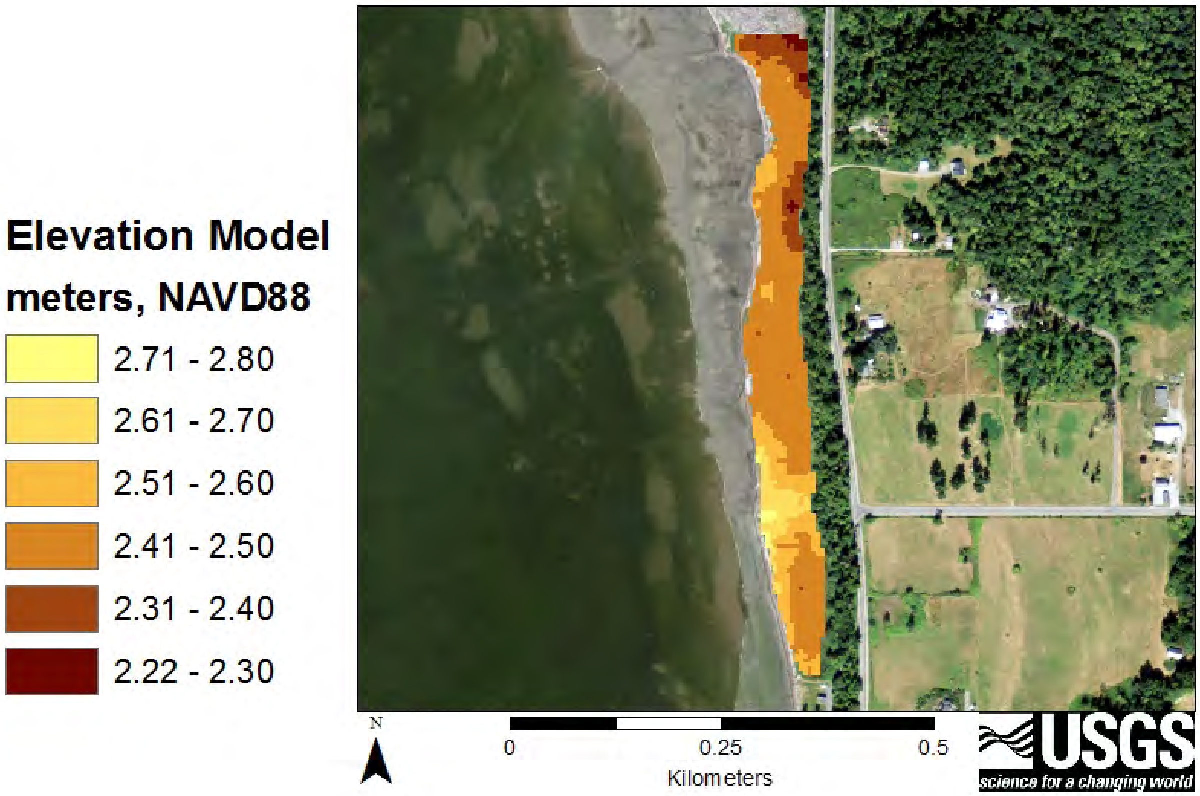

Figure A2. Elevation model (3 m resolution) developed from RTK GPS survey data.

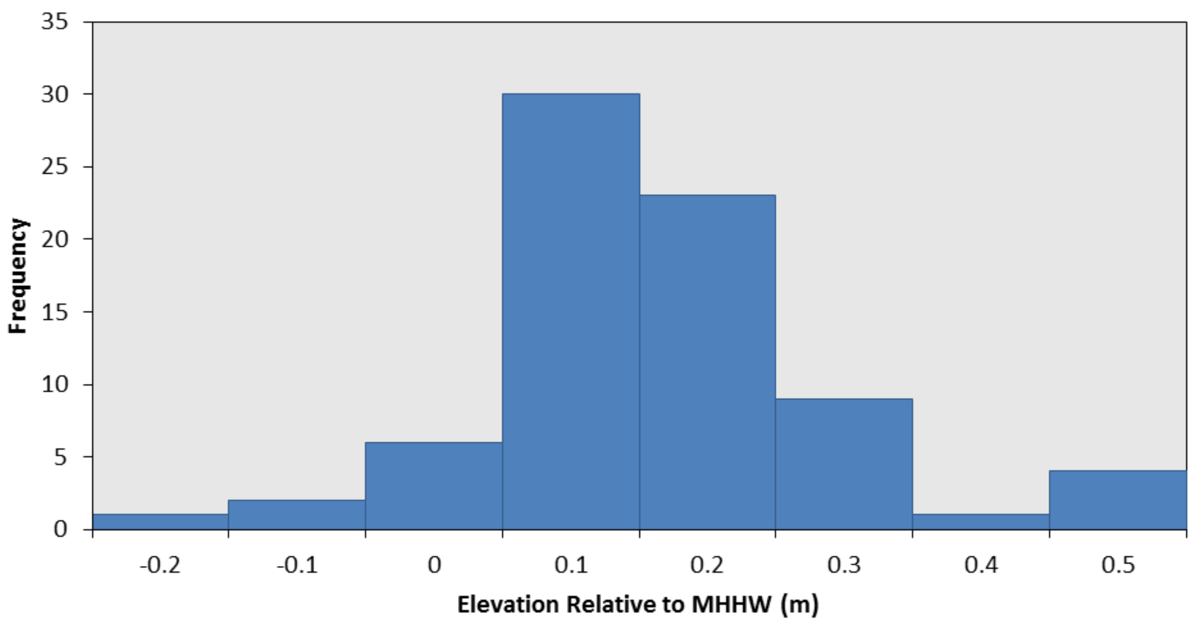

Figure A3. Frequency distribution of marsh surface elevation measurements relative to local mean higher high water (MHHW) at Padilla.

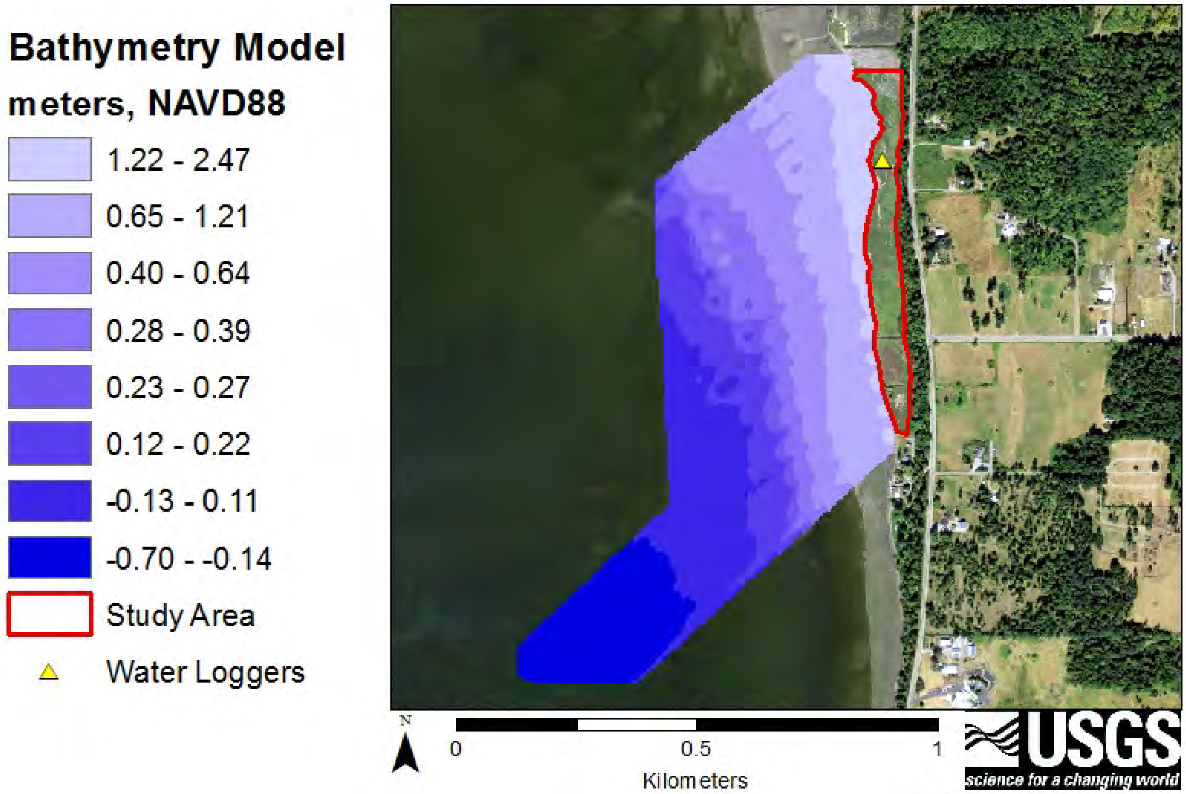

Figure A4. Near-shore bathymetry model at Padilla. Water level logger locations are shown within the marsh study site.

Table A1. Frequency of occurrence, percent cover and height of vascular plant species encountered in sample plots at Padilla. NA = not determined.

Species	Species characteristics	Freq (%)	Mean cover (%)	Mean height (cm)
Distichlis spicata	Native perennial grass	84.2	56.3	28
Sarcocornia perennis	Native perennial forb	47.4	23.2	16
Atriplex prostrata	Non-native annual forb	26.3	5.4	18
Typha latifolia	Native perennial forb	10.5	2.4	82
Hordeum brachyantherum	Native perennial grass	10.5	1.1	49
Undetermined species	NA	10.5	0.3	8
Deschampsia cespitosa	Native perennial grass	5.3	5.3	30
Symphyotrichum subspicatum	Native perennial forb	5.3	4.2	125
Leymus mollis	Native perennial grass	5.3	0.5	26
Agrostis stolonifera	Non-native perennial grass	5.3	0.3	28
Oenanthe sarmentosa	Native perennial forb	5.3	0.3	30
Rumex crispus	Non-native bi-perennial forb	5.3	0.3	28
Cirsium vulgare	Non-native biennial forb	5.3	0.1	53
Rubus armeniacus	Non-native shrub	5.3	0.1	43
Vicia gigantea	Native perennial legume	5.3	0.1	33

Table A2. Mean percent cover of dominant plant species by marsh zone at Padilla. Zones were defined by degree of flooding by high tides.

[DisSpi = *Distichlis spicata*; SarPer = *Sarcocornia perennis*; AtrPro = *Atriplex prostrata*; SymSub = *Symphyotrichum subspicatum*.]

Marsh zone	% high tides reaching zone	MHHW range (m)	Sample size	Mean cover of top four dominant plants (%)
Transition	0.14-3	0.518 to 0.258	1	*Insufficient sample size*
High	3-25	0.257 to 0.026	12	DisSpi (59), SarPer (30), AtrPro (7), SymSub (7)
Middle	25-50	0.025 to -0.130	4	DisSpi (43), SarPer (21), AtrPro (4)
Low	>50	-0.131 to -0.313	2	DisSpi (95)

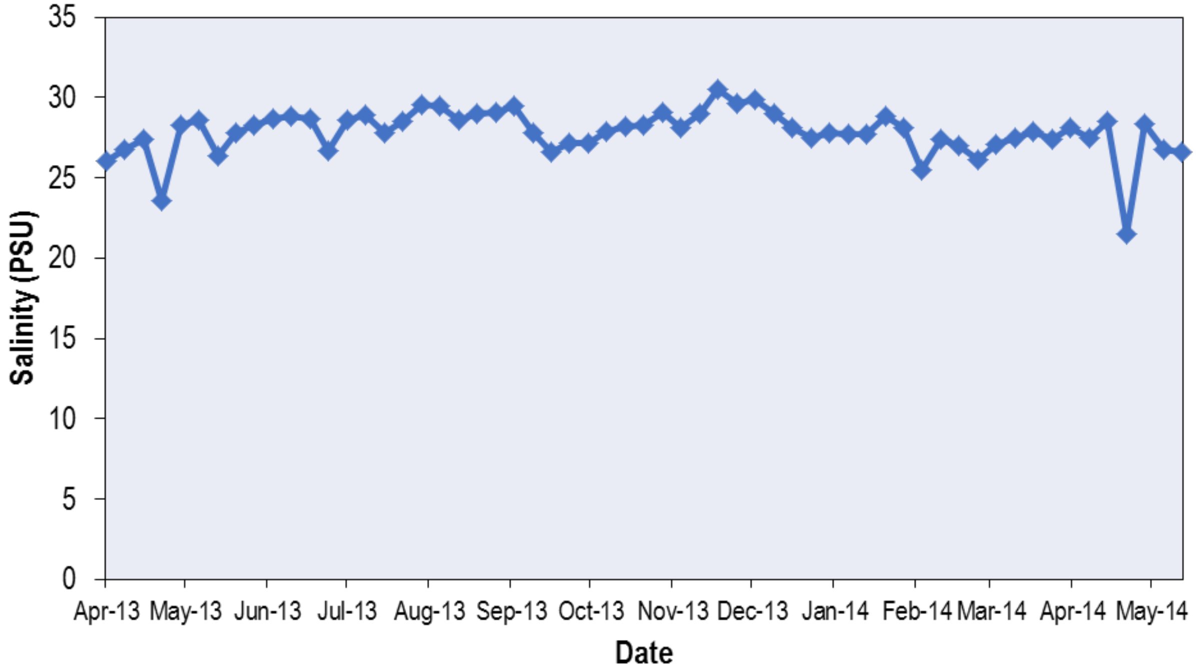

Figure A5. Average weekly maximum salinity from April 2013 – May 2014 at Padilla. Data are from the Bayview NERR water quality monitoring station (NOAA). Seawater is approximately 35 PSU.

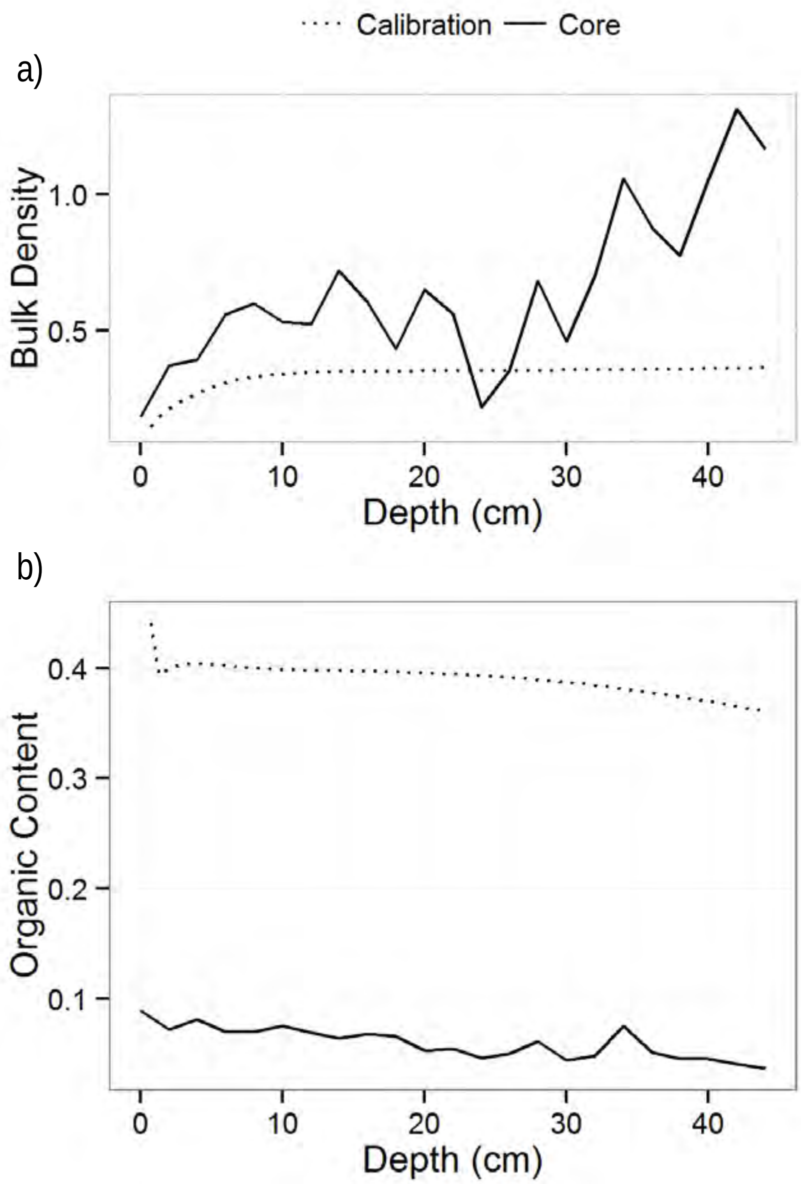

Figure A6. Deep core calibration of the WARMER model using depth profiles of (a) sediment bulk density (g cm^{-3}) and (b) sediment organic matter content (%).

Table A3. Model input parameters for Padilla. Sediment accumulation rate is reported at MSL. NDVI is the Normalized Difference Vegetation Index and NAIP is the National Agriculture Inventory Program.

Model parameter	Value	Source
Sediment accumulation rate (g cm^{-2} yr^{-1})	1.23	Core calibration
Elevation of peak biomass (cm, MSL)	149	NDVI from NAIP
Minimum elevation of vegetation (cm, MSL)	69	Field surveys
Max. aboveground organic accumulation (g cm^{-2} yr^{-1})	0.0472	Core calibration
Root-to-shoot ratio	1.95	C. Janousek, unpub data
Porosity surface (%)	88	Core
Porosity depth (%)	60	Core
Refractory carbon (%)	43.7	Core
Maximum astronomical tide (cm, MSL)	167	CERCC water logger
Historic sea-level rise (mm yr^{-1})	1.98	Port Townsend tide gauge (NOAA, 9444900)
Organic matter density (g cm^{-3})	1.14	DeLaune 1983
Mineral density (g cm^{-3})	2.61	DeLaune 1983

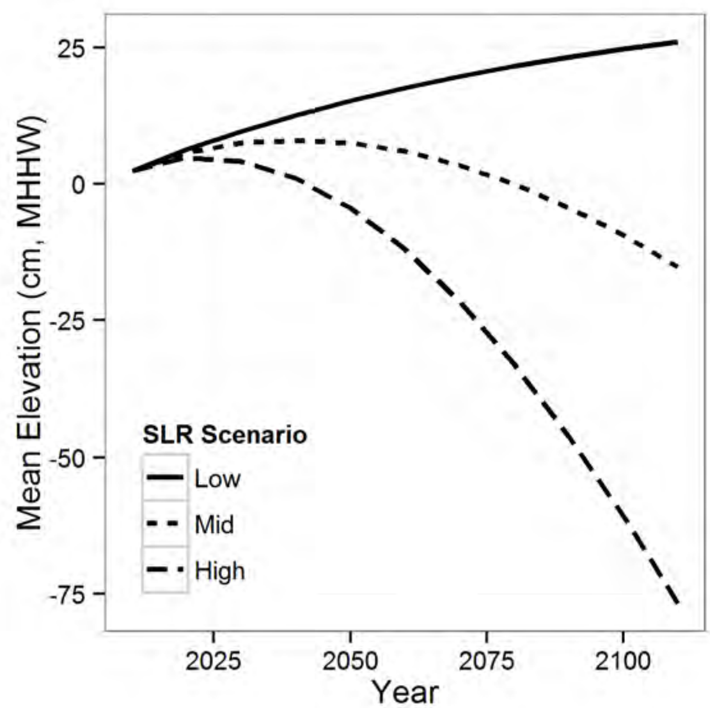

Figure A7. WARMER model projections for the change in average marsh elevation (relative to MHHW) at Padilla from 2010 to 2110 under low, mid, and high NRC sea-level rise (SLR) scenarios.

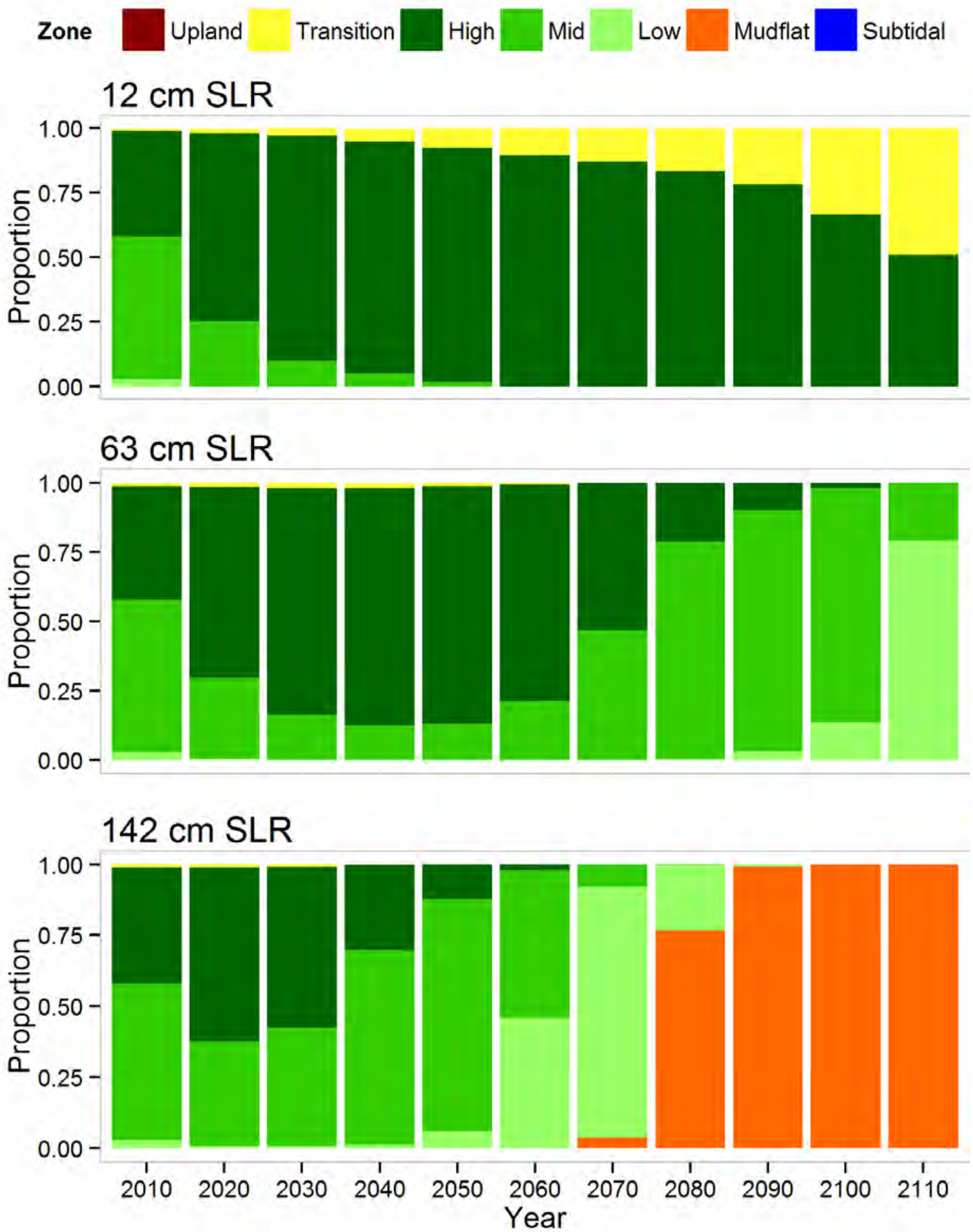

Figure A8. Model projections for change in the relative proportion of upland, transitional, high, mid and low marsh habitat, and mudflat under low (12 cm), mid (63 cm), and high (142 cm) NRC sea-level rise scenarios from 2010 to 2110.

Table A4. Model projections for change in the percentage of marsh elevation zones for three NRC sea-level rise scenarios between 2010, 2050, and 2110.

	Low SLR (12 cm)			Mid SLR (63 cm)			High SLR (142 cm)		
	2010	2050	2110	2010	2050	2110	2010	2050	2110
Upland	0	0	0	0	0	0	0	0	0
Transition	1	8	49	1	1	0	1	0	0
High	41	90	51	41	86	0	41	12	0
Mid	55	2	0	55	13	21	55	82	0
Low	3	0	0	3	0	79	3	6	0
Mudflat	0	0	0	0	0	0	0	0	100
Subtidal	0	0	0	0	0	0	0	0	0

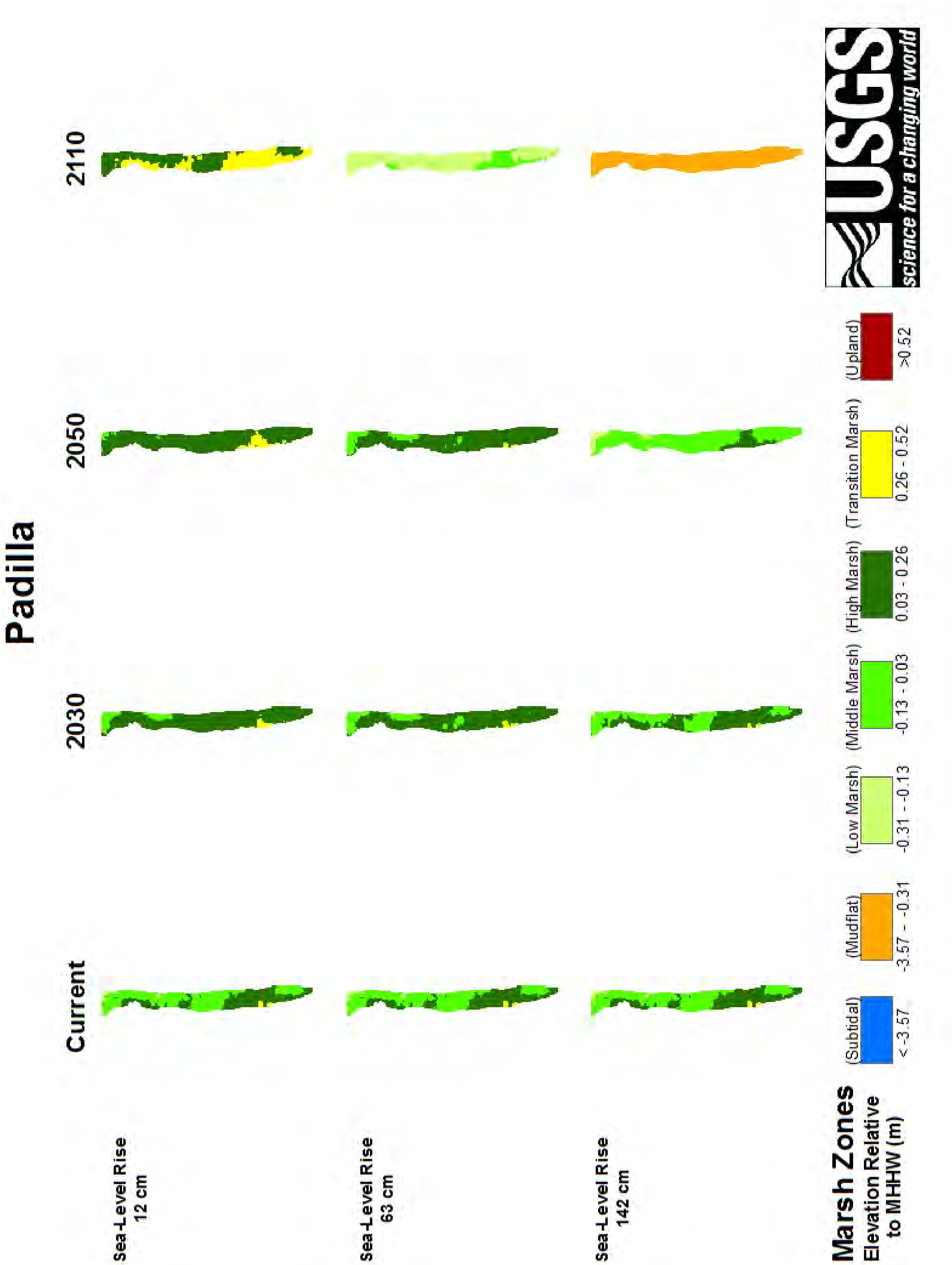

Figure A9. Projected habitat distribution at Padilla for 2030, 2050 and 2110 with the WARMER model under three NRC sea-level rise scenarios.

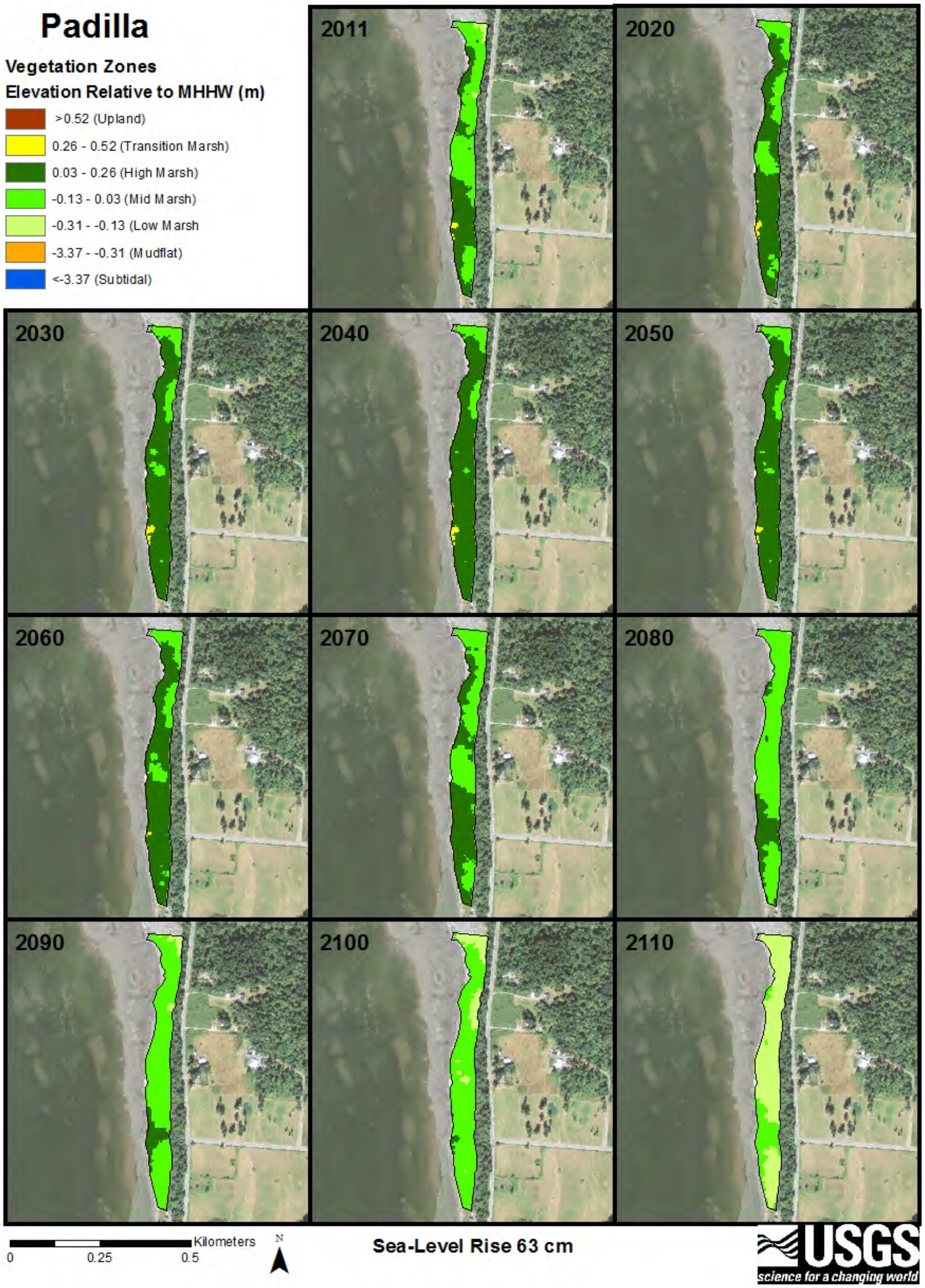

Figure A10. Projected changes in Padilla elevation zones under the mid NRC sea-level rise scenario (63 cm).

Appendix B. Site Specific Details for Port Susan, Port Susan Bay, Snohomish County, Washington

Photo: K. Turner, USGS

Summary:

- *Study site size*: 51.5 hectares
- *Location*: 48° 11' 35" N latitude, 122° 21' 55" W longitude.
- *Site management*: The Nature Conservancy
- *Site vegetation and elevation survey*: 1-9 October 2012
- *Sample size*: 897 (elevation data points), 210 (vegetation quadrats)
- *Marsh elevation model*: Most of the study site was below MHHW, with only 20% of elevation points occurring above MHHW.
- *Plant community composition*: *Schoenoplectus pungens* was the most frequently occurring species at the site. *Agrostis stolonifera* was also common.
- *Bathymetric surveys*: 319.1 ha of nearshore habitat were mapped adjacent to the study area.

- *Soil characteristics*: The accumulation rates used in WARMER for this site were: mineral accumulation rate = 2.04 g cm^{-2} yr^{-1}; organic matter accumulation rate = 0.037 g cm^{-2} yr^{-1}; net accretion = 2.077 cm yr^{-1}.
- *Water monitoring data collection*: water level (April 2011 – December 2014); conductivity (August 2013 – December 2013). Water level and conductivity monitoring is ongoing.
- *Salinity*: Maximum weekly salinities at the site ranged between polyhaline and mesohaline conditions during the study period.
- *Calculated tidal datums*: MHHW is at 2.71 m NAVD88; MHW is at 2.47 m NAVD88.
- *Marsh inundation pattern*: Maximum monthly inundation occurred during January 2014; minimum monthly inundation occurred during October 2013.
- *Sea-level rise marsh response modeling:* Presently, Port Susan is dominated by low marsh with very little area in higher elevation zones. Under the NRC's low sea-level rise scenario (12 cm), the site is projected to have modest areal gains in mid and high marsh. However, under mid sea-level rise (63 cm) the marsh continues to be dominated by low marsh while mid marsh is lost by 2100. Under high sea-level rise (142 cm) mudflat gradually replaces most low marsh habitat between 2060 and 2110.

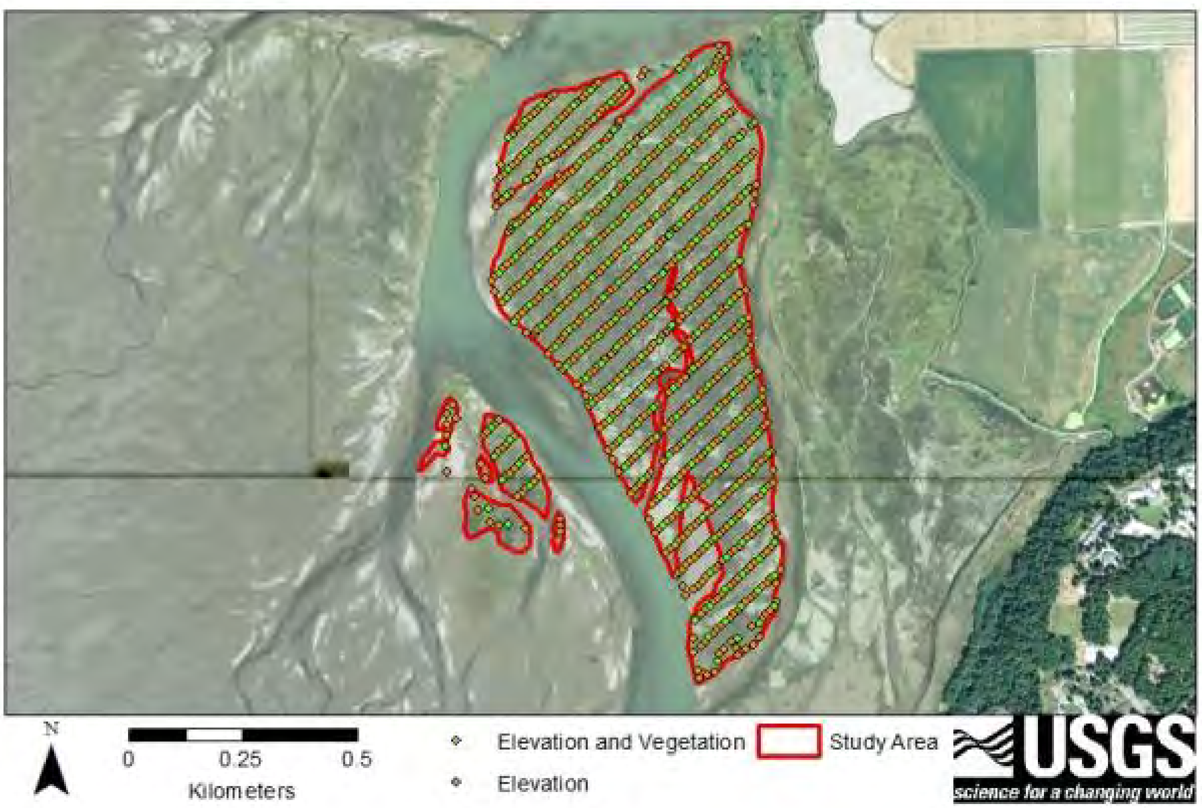

Figure B1. Distribution of elevation and vegetation survey points at Port Susan.

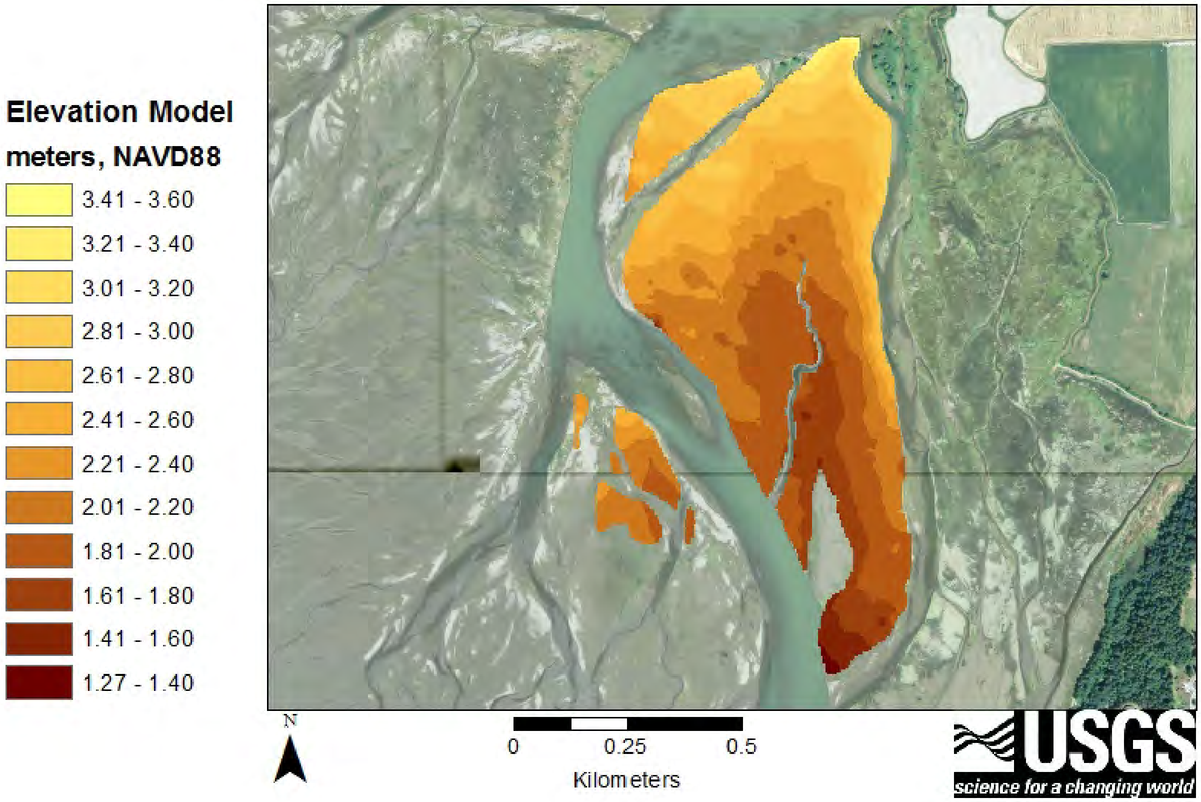

Figure B2. Elevation model (3 m resolution) developed from RTK GPS survey data.

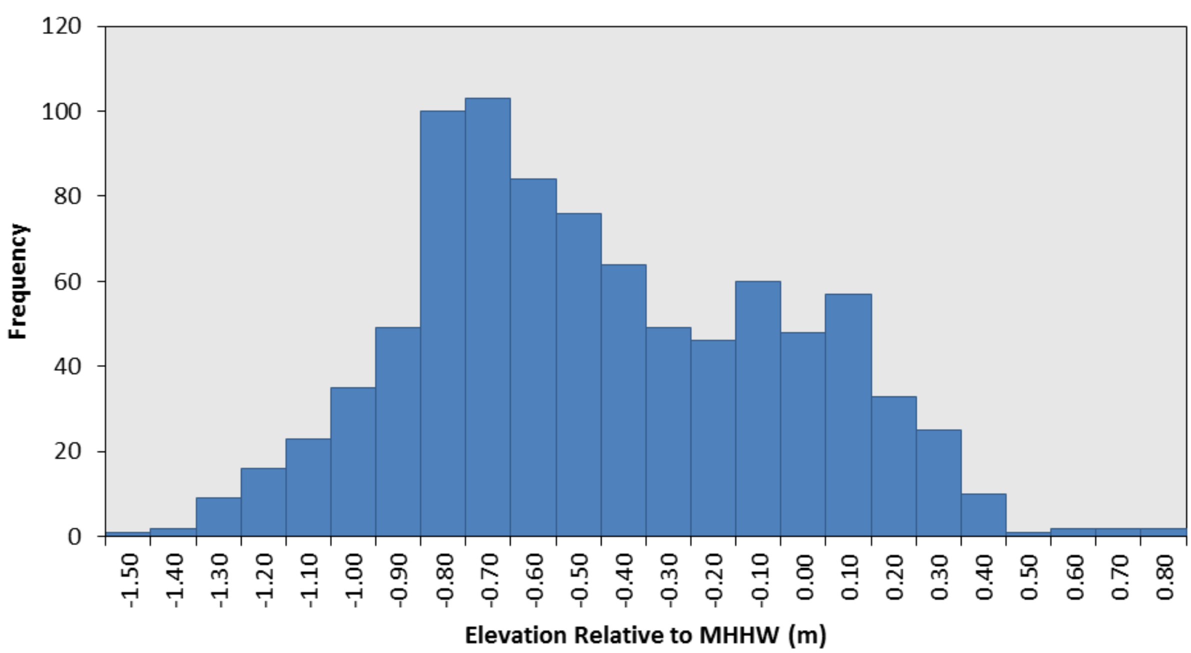

Figure B3. Frequency distribution of marsh surface elevation measurements relative to local mean higher high water (MHHW) at Port Susan.

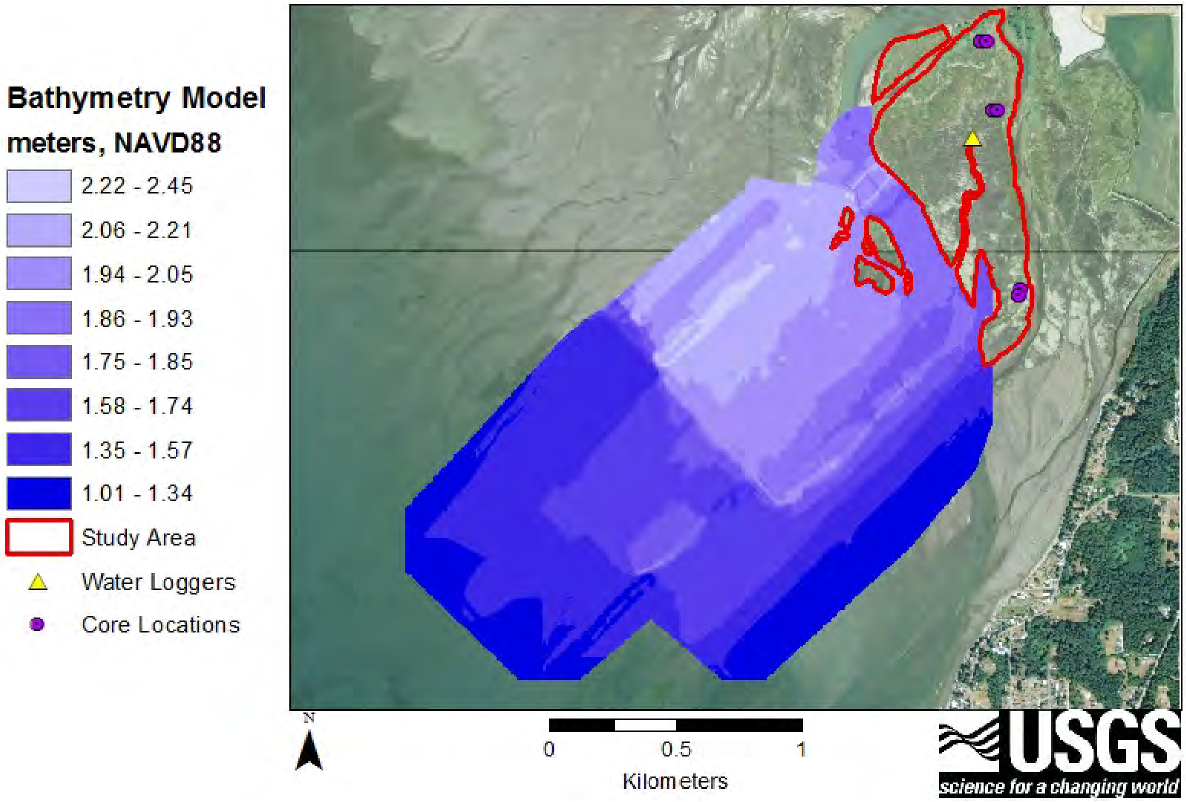

Figure B4. Near-shore bathymetry model for Port Susan. Water level logger and core locations are shown within the marsh study site.

Table B1. Frequency of occurrence, percent cover and height of vascular plant species encountered in sample plots at Port Susan. NA = not measured.

Species	Species characteristics	Freq (%)	Mean cover (%)	Mean height (cm)
Schoenoplectus pungens	Native perennial sedge	57.1	25.2	50
Agrostis stolonifera	Non-native perennial grass	47.6	18.7	31
Carex lyngbyei	Native perennial sedge	30.0	7.2	41
Potentilla anserina	Native ann-perennial forb	28.1	3.9	26
Juncus balticus	Native perennial rush	27.6	10.7	45
Triglochin maritima	Native perennial forb	24.8	1.5	39
Deschampsia cespitosa	Native perennial grass	12.4	5.3	85
Cotula coronopifolia	Non-native perennial forb	12.4	0.3	10
Bolboschoenus maritimus	Native perennial sedge	11.0	1.5	99
Lotus corniculatus	Non-native perennial legume	10.0	3.7	32
Symphyotrichum subspicatum	Native perennial forb	9.5	1.7	52
Lilaeopsis occidentalis	Native perennial forb	7.6	0.2	7
Juncus acuminatus	Native perennial rush	6.7	1.3	40
Schedonorus arundinaceus	Non-native perennial grass	5.2	1.0	42
Schenoplectus sp.	Sedge	5.2	0.8	111
Distichlis spicata	Native perennial grass	4.3	0.2	39
Eleocharis palustris	Native perennial sedge	3.8	1.1	18
Ranunculus cymbalaria	Native forb	2.4	0.1	9
Undetermined Poaceae	Grass	2.4	0.0	32
Phalaris arundinacea	Non-native perennial grass	1.9	0.5	73
Typha latifolia	Native perennial forb	1.9	0.3	143
Eleocharis parvula	Native perennial sedge	1.4	0.0	1
Cirsium arvense	Non-native perennial forb	1.4	0.1	101
Atriplex sp.	Forb	1.0	0.1	33
Rumex crispus	Non-native bi-perennial forb	1.0	0.0	88
Jaumea carnosa	Native perennial forb	1.0	0.0	1
Cuscuta pacifica	Native ann-perennial parasite	0.5	NA	NA
Elymus repens	Non-native perennial grass	0.5	0.1	20
Solanum dulcamara	Non-native perennial forb	0.5	0.0	23

Table B2. Mean percent cover of dominant plant species by marsh zone at Port Susan. Zones were defined by degree of flooding by high tides.

[AgrSto = *Agrostis stolonifera*; CarLyn = *Carex lyngbyei*; CirArv = *Cirsium arvense*; DesCes = *Deschampsia cespitosa*; LotCor = *Lotus corniculatus*; JunBal = *Juncus balticus*; PhaAru = *Phalaris arundinacea*; PotAns = *Potentilla anserina*; SchPun = *Schoenoplectus pungens*; NA = not sampled.]

Marsh zone	% high tides reaching zone	MHHW range (m)	Sample size	Mean cover of top four dominant plants (%)
Transition	0.14-3	0.707 to 0.352	2	LotCor (45), PhaAru (38), JunBal (25), CirArv (5)
High	3-25	0.351 to 0.036	22	JunBal (36), AgrSto (24), PotAns (20), LotCor (18)
Middle	25-50	0.035 to -0.178	31	JunBal (21), AgrSto (21), DesCes (20), PotAns (9)
Low	>50	-0.179 to -1.185	155	SchPun (34), AgrSto (18), CarLyn (8), JunBal (5)

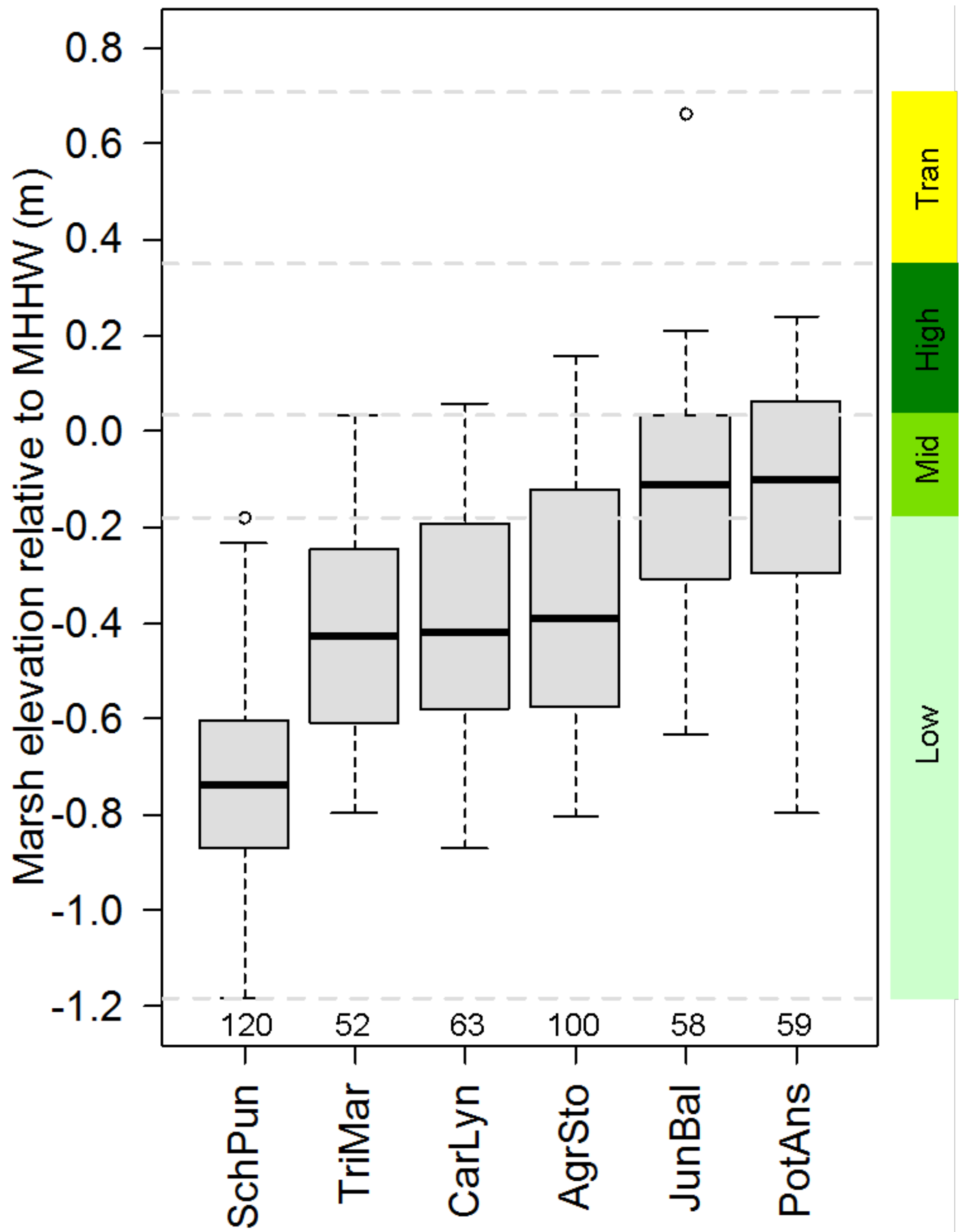

Figure B5. Elevation distribution of the six most common vascular plant species at Port Susan. The black horizontal bars show the median elevation at which the species occurs; shaded boxes indicate the interquartile range; upper and lower whiskers encompass points no greater than 1.5x the length of the shaded box; and open circles indicate outliers. The number of plots in which the species occurred is indicated above the species codes (out of a total of 210 plots). Marsh elevation zones (low, middle, high and transition) are illustrated at right. SchPun = *Schoenoplectus pungens*; TriMar = *Triglochin maritima*; CarLyn = *Carex lyngbyei*; AgrSto = *Agrostis stolonifera*, JunBal = *Juncus balticus*, PotAns = *Potentilla anserina*.

Table B3. Location of water level loggers and deep sediment cores (UTM coordinates).

	Northing (m)	Easting (m)
Water level logger	547226	5337780
Deep core locations	547424	5337179
	547312	5337890
	547266	5338163

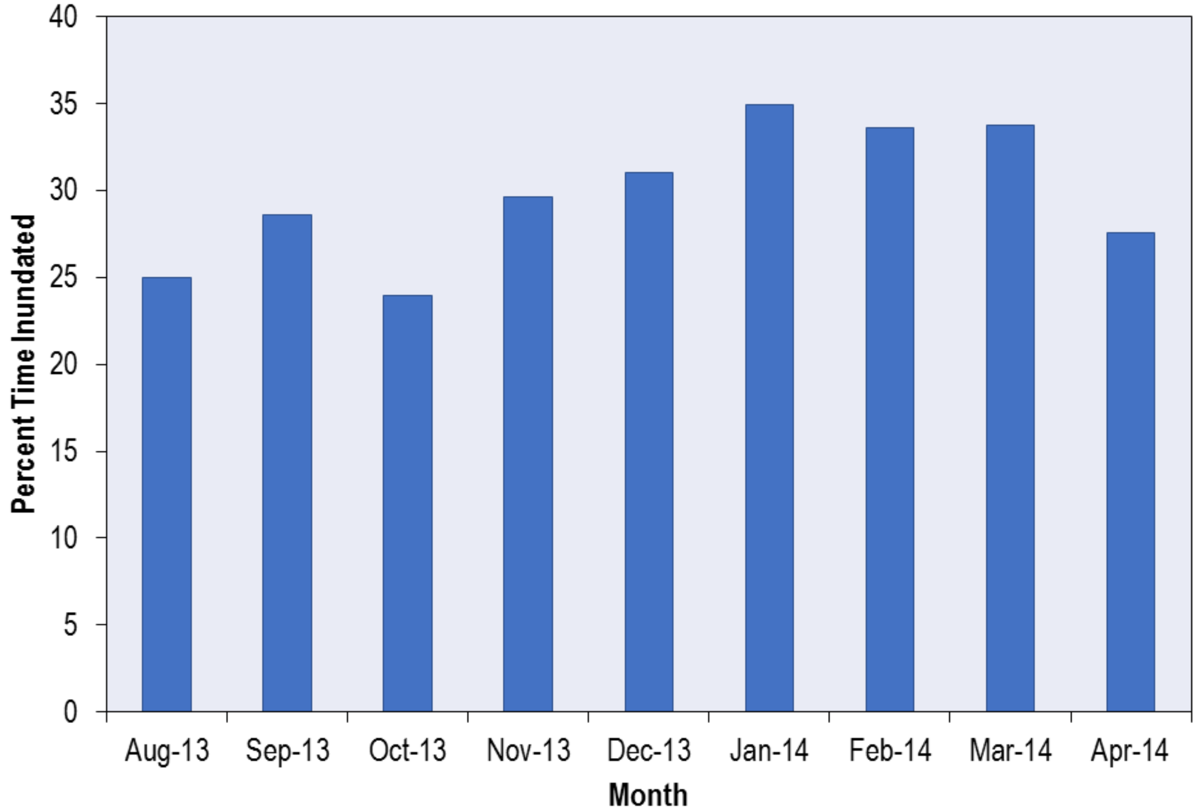

Figure B6. Average monthly inundation of the study site based on an average marsh elevation. Water levels were determined with a water level logger deployed at 1.18 m above NAVD88.

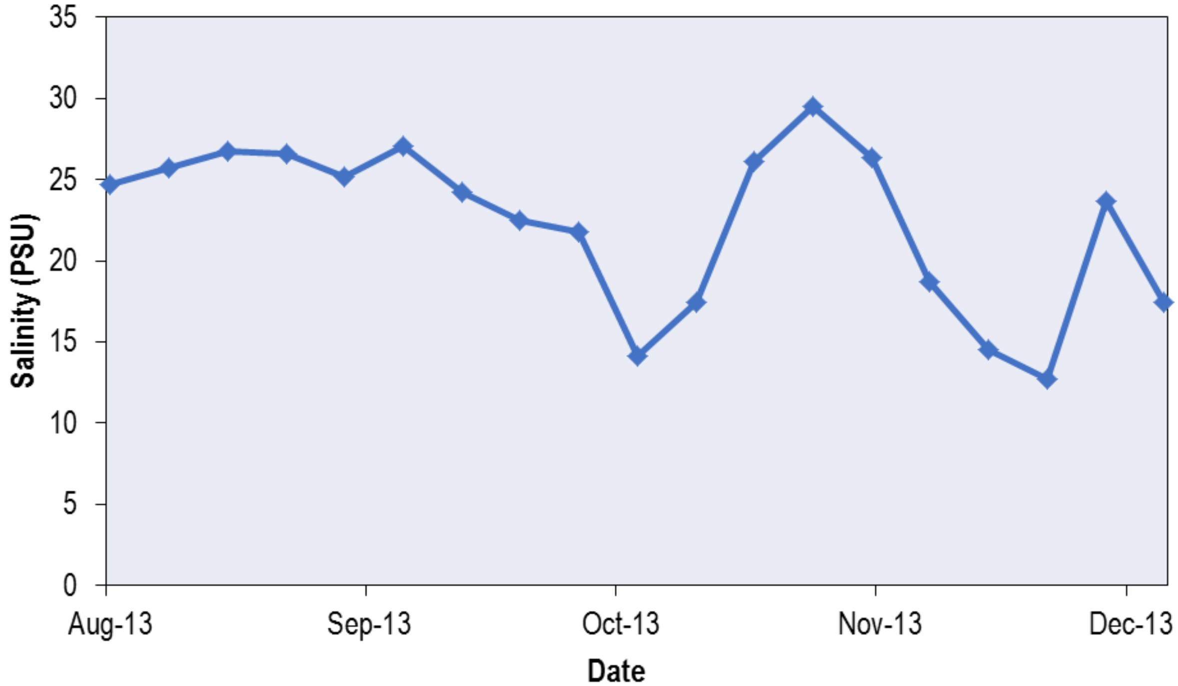

Figure B7. Average weekly maximum salinity, in practical salinity units (PSU) from August 2013 – December 2013 at Port Susan. Seawater is approximately 35 PSU.

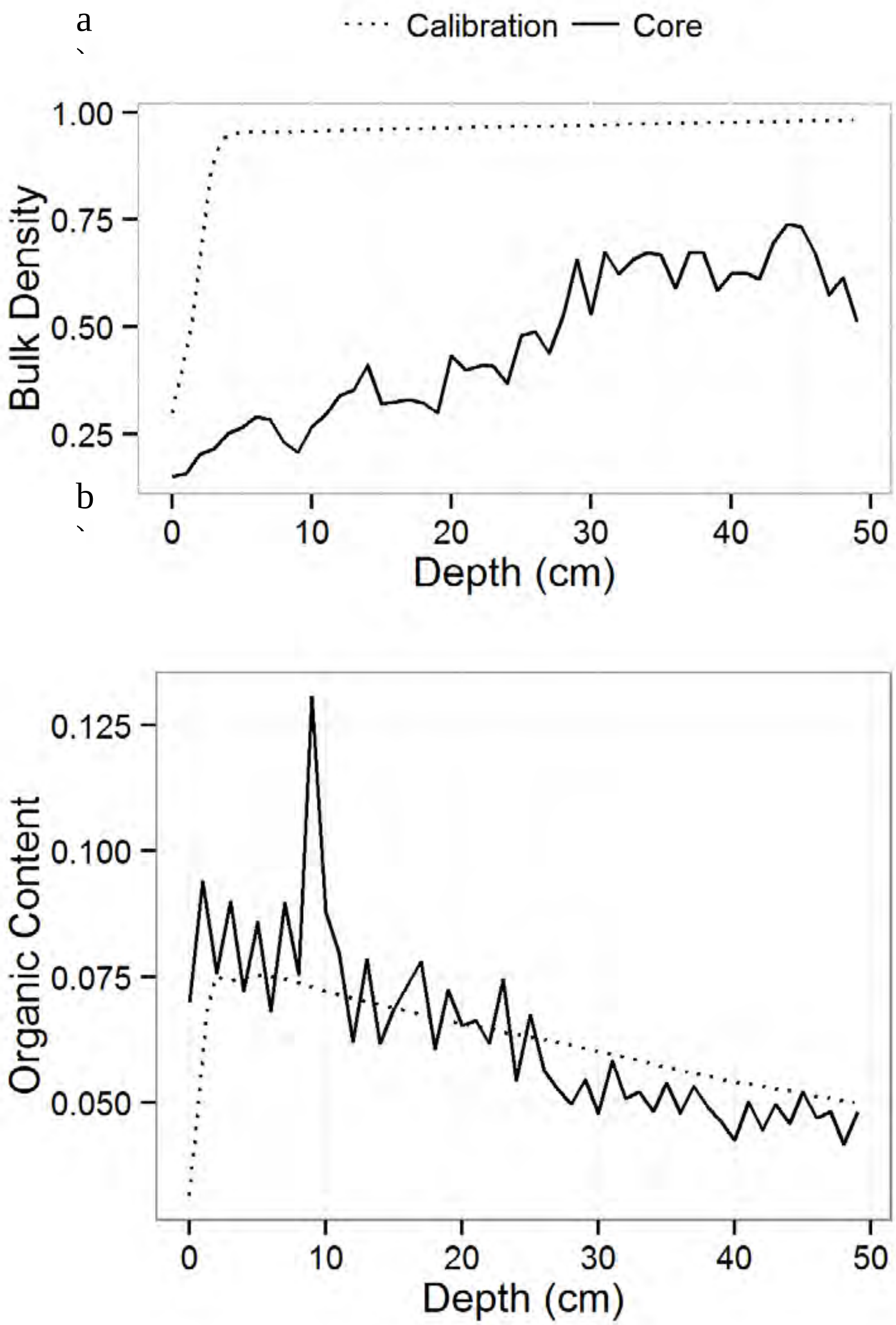

Figure B8. Deep core calibration of the WARMER model using depth profiles of (a) sediment bulk density (g cm^{-3}) and (b) sediment organic matter content (%).

Table B4. Model input parameters for Port Susan. Sediment accumulation rate is reported at the elevation of MSL. NDVI is the Normalized Difference Vegetation Index and NAIP is the National Agriculture Inventory Program.

Model parameter	Value	Source
Sediment accumulation rate (g cm-2 yr-1)	0.84	Core calibration
Elevation of peak biomass (cm, MSL)	152	NDVI from NAIP
Minimum elevation of vegetation (cm, MSL)	-9	Field surveys
Max. aboveground organic accumulation (g cm-2 yr-1)	0.0408	Core calibration
Root-to-shoot ratio	1.95	C. Janousek, unpub data
Porosity surface (%)	88	Core
Porosity depth (%)	60	Core
Refractory carbon (%)	43.7	Core
Maximum astronomical tide (cm, MSL)	253	CERCC water logger
Historic sea-level rise (mm yr-1)	1.98	Port Townsend tide gauge (NOAA, 9444900)
Organic matter density (g cm-3)	1.14	DeLaune 1983
Mineral density (g cm-3)	2.61	DeLaune 1983

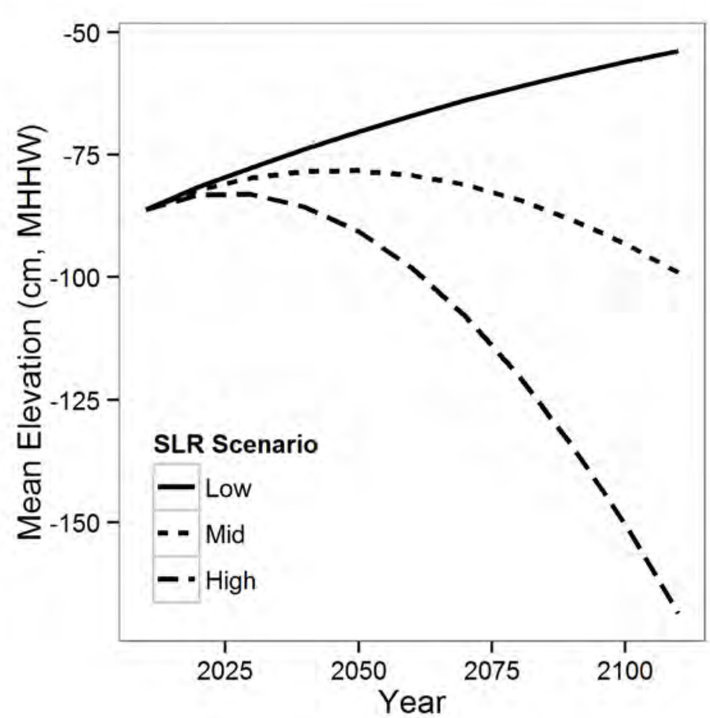

Figure B9. WARMER model projections for the change in average marsh elevation (relative to MHHW) at Port Susan from 2010 to 2110 under low, mid, and high NRC sea-level rise (SLR) scenarios.

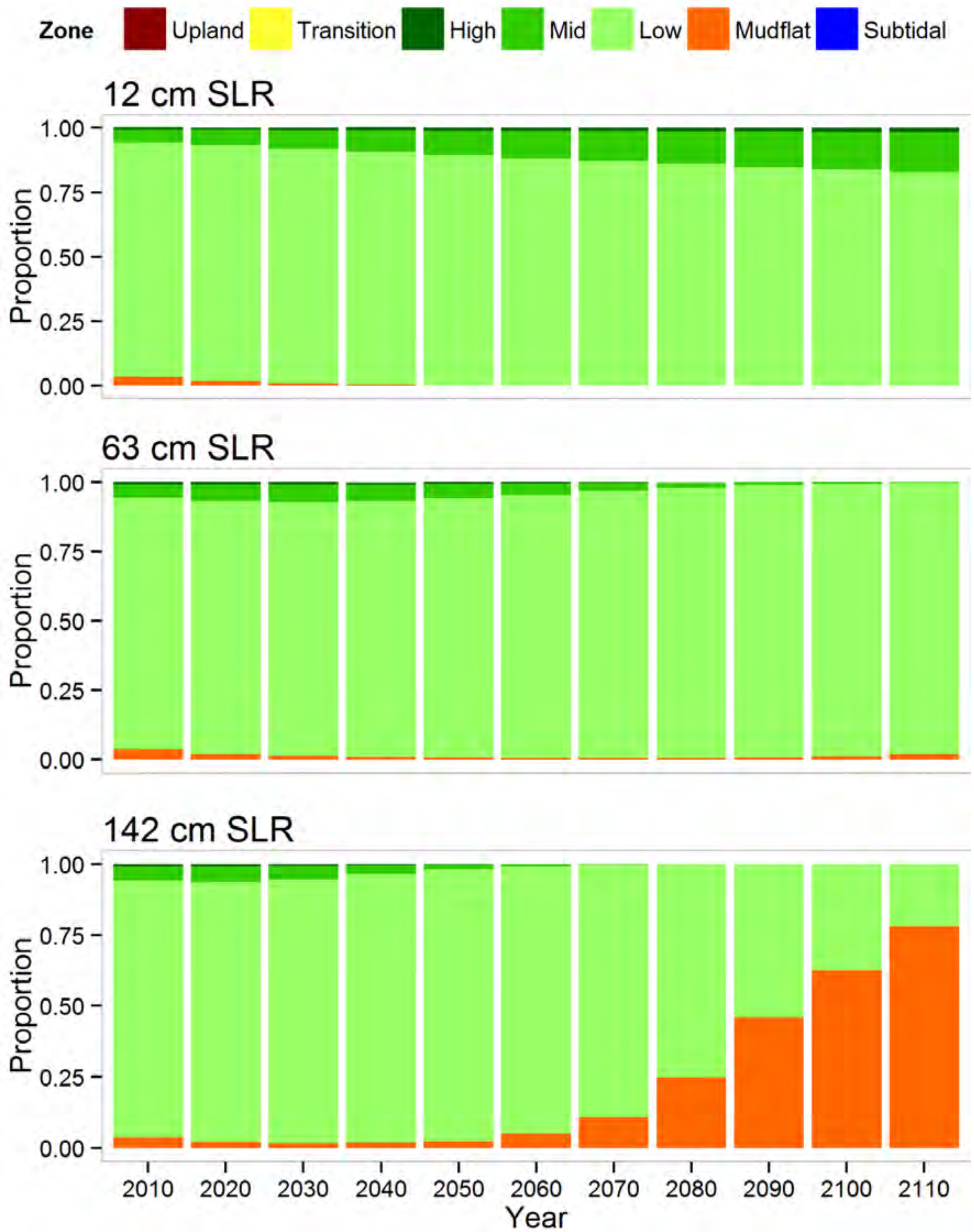

Figure B10. Model projections for change in the relative proportion of upland, transitional, high, mid and low marsh habitat, and mudflat under low (12 cm), mid (63 cm), and high (142 cm) NRC sea-level rise scenarios from 2010 to 2110.

Table B5. Percentage of habitat area modeled for three sea-level rise scenarios for 2010, 2050, and 2110.

	Low SLR (12 cm)			Mid SLR (63 cm)			High SLR (142 cm)		
	2010	2050	2110	2010	2050	2110	2010	2050	2110
Upland	0	0	0	0	0	0	0	0	0
Transition	0	0	0	0	0	0	0	0	0
High	1	1	2	1	1	0	1	0	0
Mid	5	10	15	5	5	0	5	2	0
Low	91	89	83	91	93	98	91	96	22
Mudflat	3	0	0	3	1	2	3	2	78
Subtidal	0	0	0	0	0	0	0	0	0

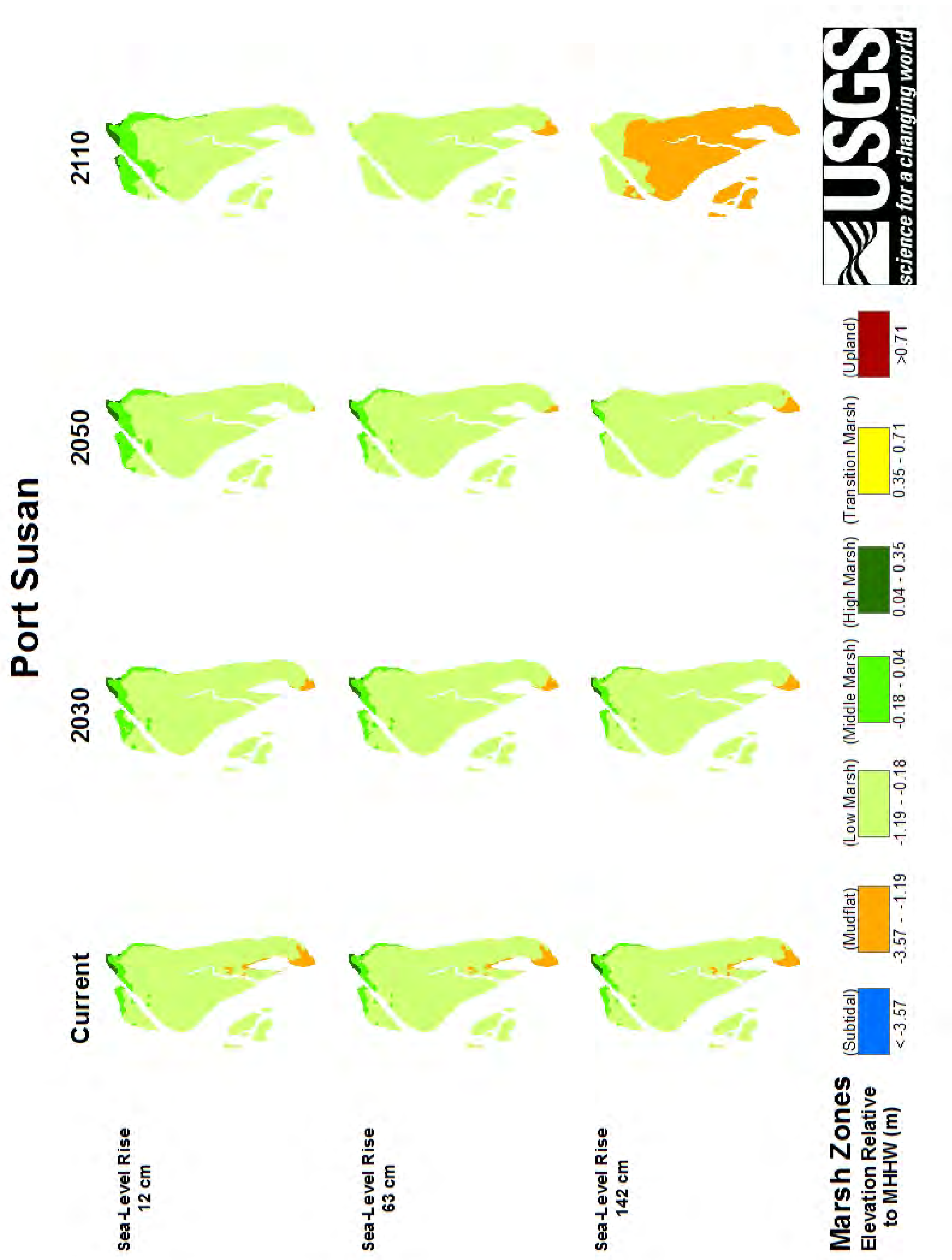

Figure B11. Projected habitat distribution at Port Susan for 2030, 2050 and 2110 with the WARMER model under three sea-level rise scenarios.

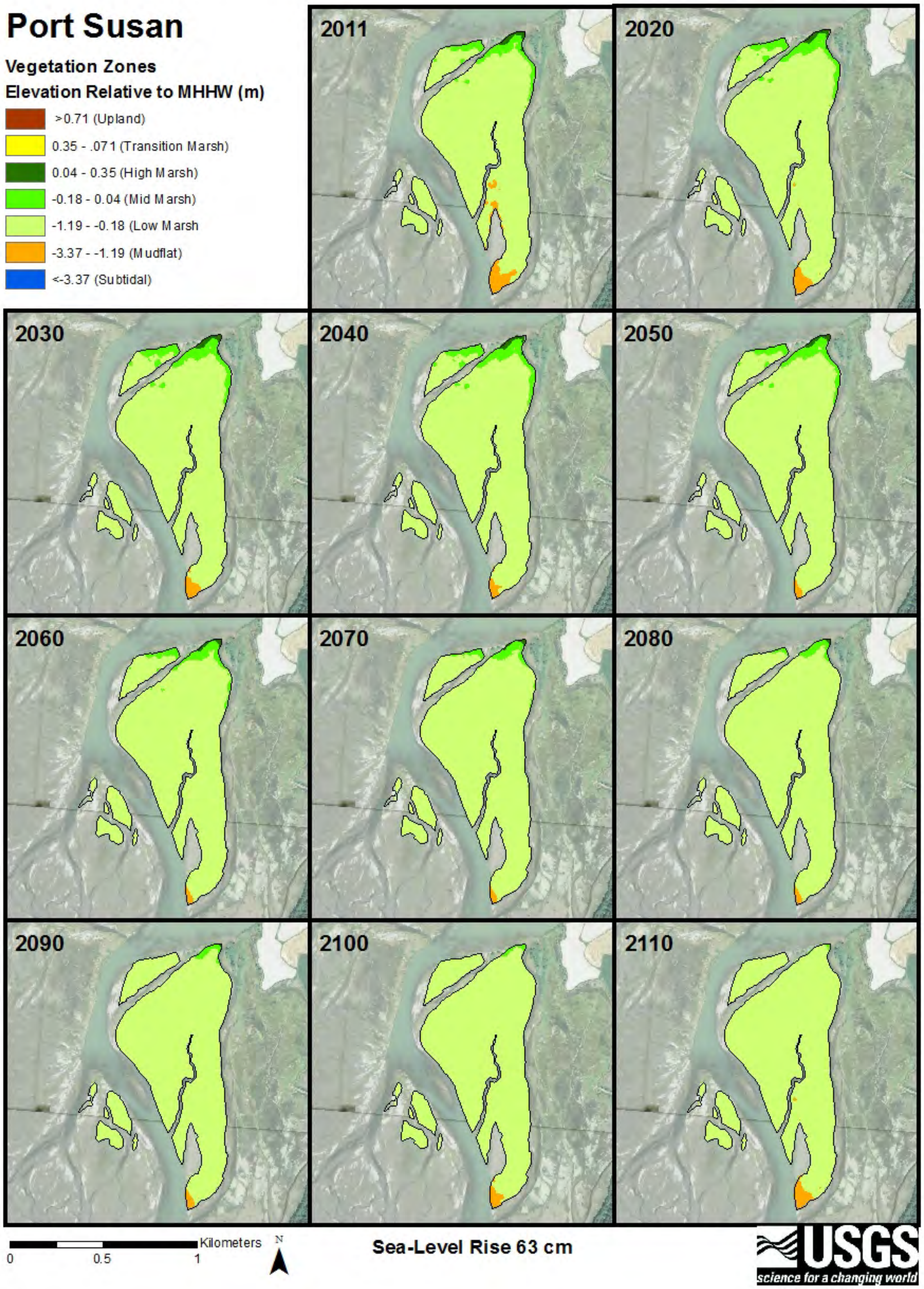

Figure B12. Projected changes in the distribution of Port Susan habitat zones under the NRC's mid (63 cm) sea-level rise scenario.

Appendix C. Site Specific Details for Skokomish marsh, Skokomish Estuary, Mason County, Washington

Photo: K Powelson, USGS

Summary:

- *Study site size*: 28.8 hectares
- *Location*: 47° 20' 30" N latitude, 123° 08' 24" W longitude.
- *Site management*: Skokomish Indian Tribe
- *Site vegetation and elevation survey*: 26-28 September 2012
- *Sample size*: 605 (elevation data points), 128 (vegetation quadrats)
- *Marsh elevation model*: Most of the study site was above MHHW, with 57% of elevation data points occurring above MHHW.
- *Plant community composition*: *Distichlis spicata* was the most frequently-occurring species. *Jaumea carnosa* and *Sarcocornia perennis* were also common.
- *Bathymetric surveys*: 59.3 ha of nearshore habitat were mapped adjacent to the study area.

- *Soil characteristics*: The accumulation rates used in WARMER for this site were: mineral accumulation rate = 0.067g cm^{-2} yr^{-1}; organic matter accumulation rate = 0.0092 g cm^{-2} yr^{-1}; net accretion = 0.076 $cm^{-2}yr^{-1}$.
- *Water level and salinity monitoring*: water level (October 2012 – April 2014); conductivity (August 2013 – May 2014). Water level and conductivity monitoring is ongoing.
- *Salinity*: The maximum recorded salinity throughout the study period was 34 PSU.
- *Marsh inundation pattern*: Maximum monthly inundation occurred during March 2014; minimum monthly inundation during October 2013
- *Calculated tidal datums*: MHHW is at 2.76 m NAVD88; MHW is at 2.48 m NAVD88.
- *Sea-level rise marsh response modeling*: Under the low NRC SLR projection (12 cm), the composition of marsh zones remains relatively unchanged over the coming century. Under the NRC's mid SLR projection (63 cm), there is a gradual loss of high marsh between 2020 and 2070, and total loss of mid marsh by 2110. Under the NRC's high SLR projection (142 cm), loss of middle and high marsh occurs more rapidly: by 2070, the site is projected to be comprised of low marsh and some mudflat. By 2110, the site is projected to be predominately mudflat, with a small percentage of low marsh remaining.

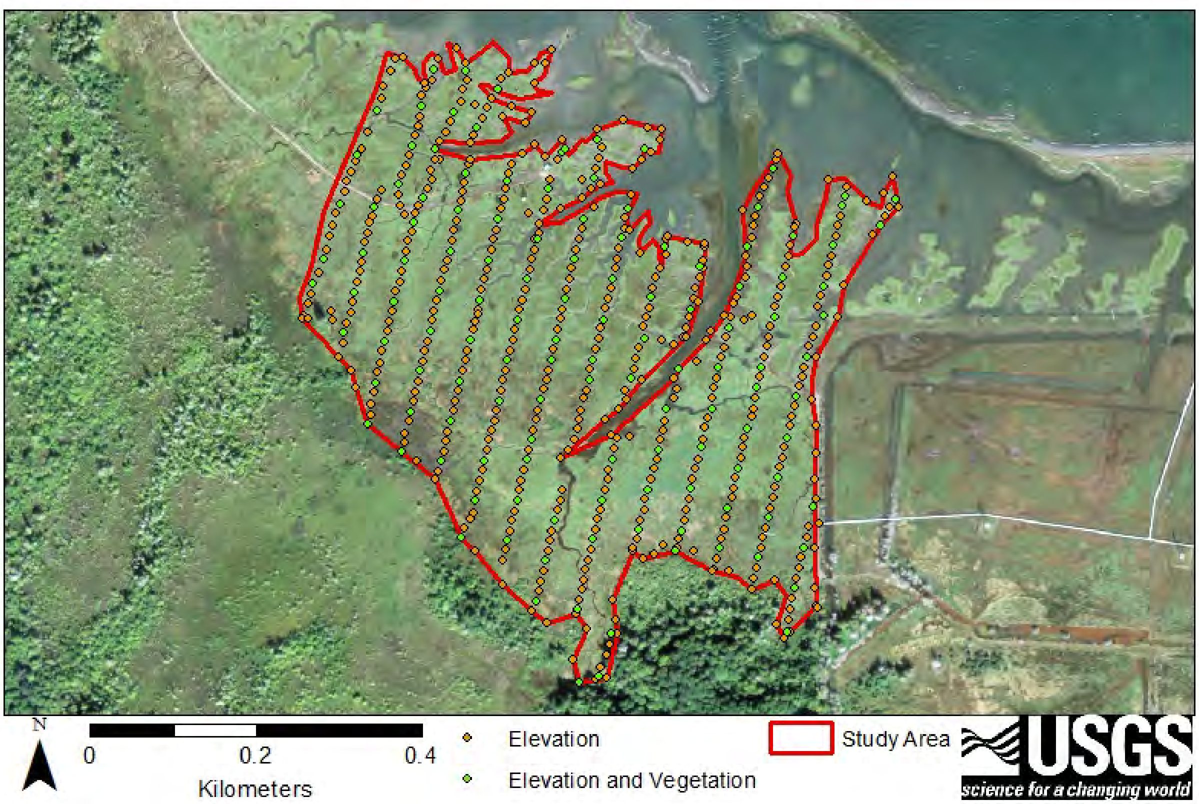

Figure C1. Distribution of elevation and vegetation survey points at Skokomish.

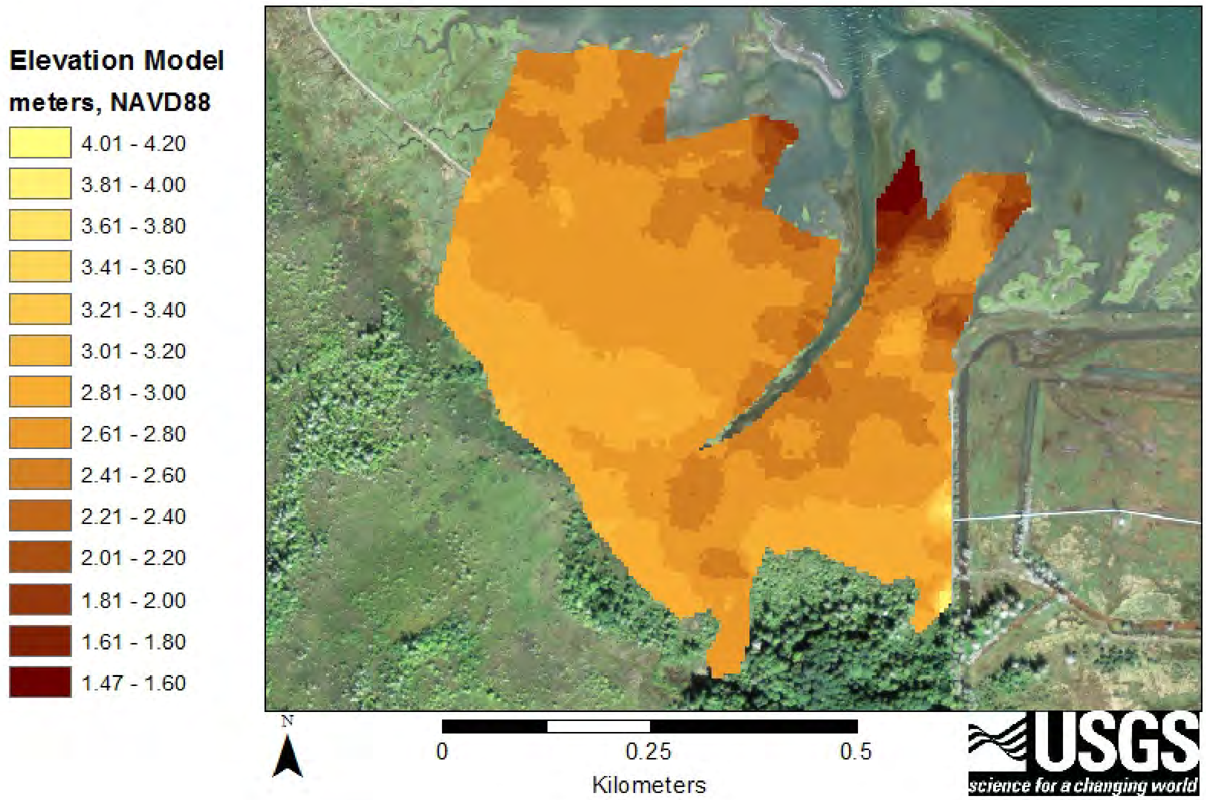

Figure C2. Elevation model (3 m resolution) developed from RTK GPS survey data.

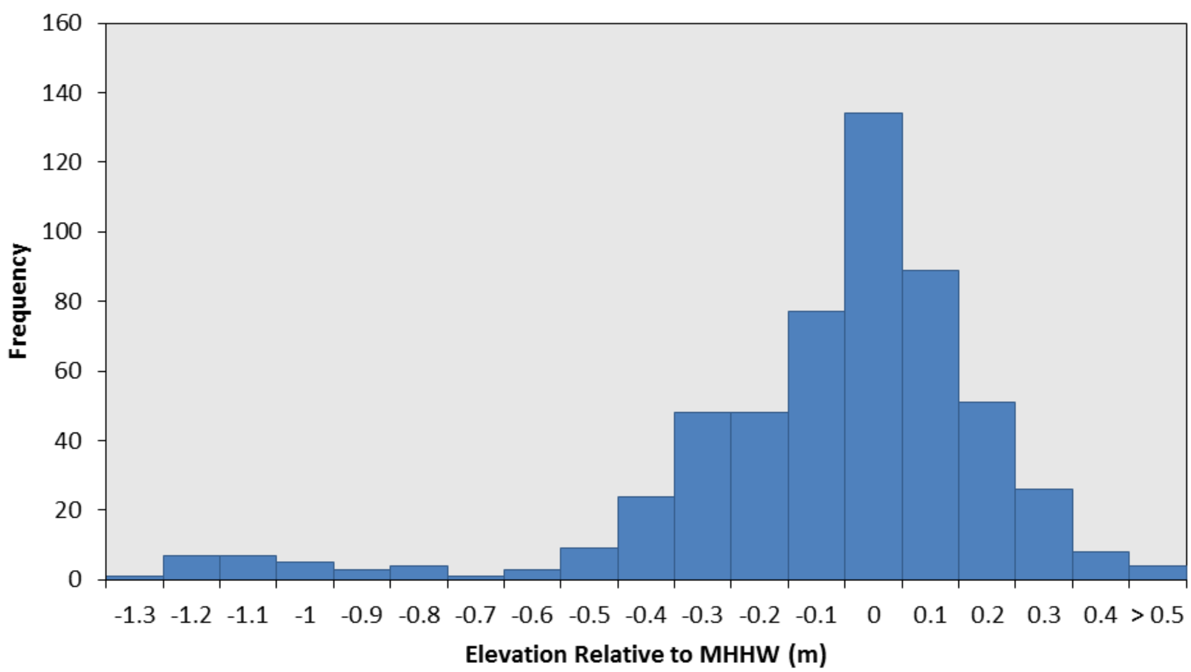

Figure C3. Frequency distribution of marsh surface elevation data points relative to local mean higher high water (MHHW) at Skokomish.

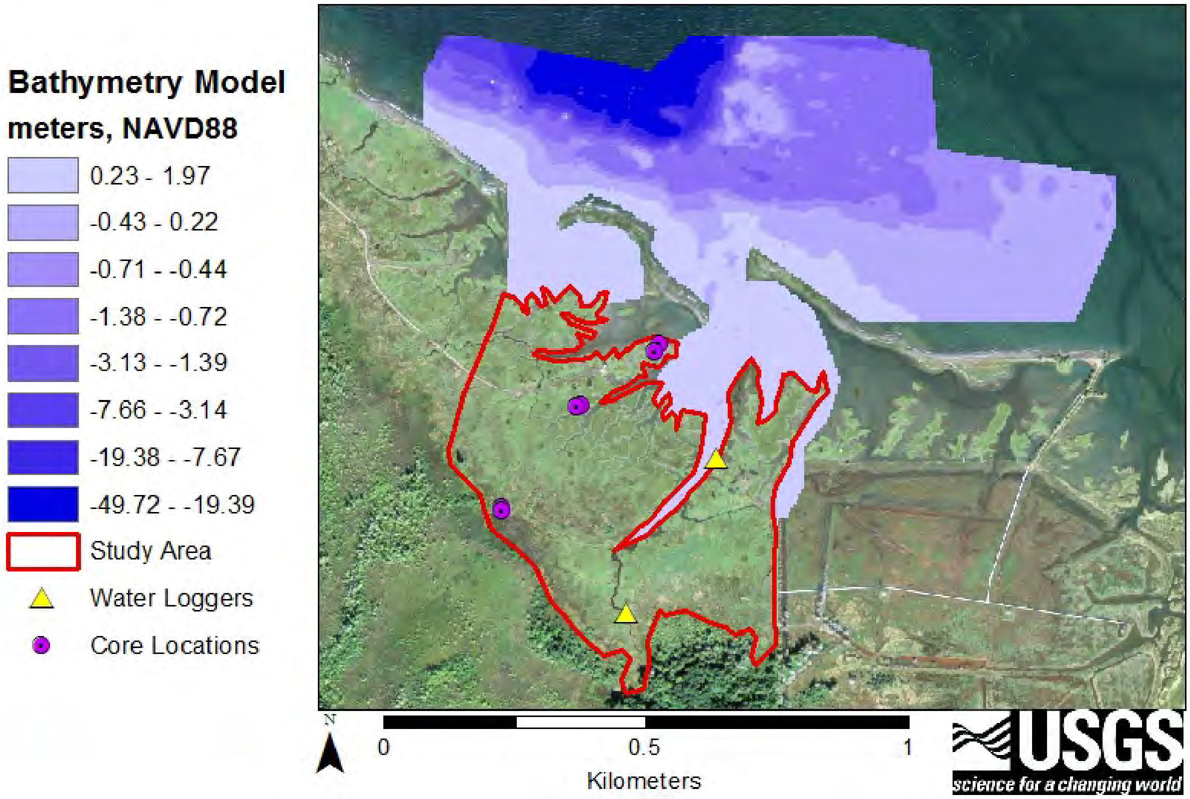

Figure C4. Near-shore bathymetry model for Skokomish. Water level logger and core locations are shown within the marsh study site.

Table C1. Frequency of occurrence, percent cover and height of vascular plant species encountered in sample plots at Skokomish. NA = not measured.

Species	Species characteristics	Freq (%)	Mean cover (%)	Mean height (cm)
Distichlis spicata	Native perennial grass	82.0	31.5	29
Jaumea carnosa	Native perennial forb	70.3	40.9	17
Sarcocornia perennis	Native perennial forb	62.5	19.3	20
Atriplex prostrata	Non-native annual forb	33.6	4.1	25
*Juncus spp.**	Rush	28.9	15.5	48
Plantago maritima	Native perennial forb	25.8	4.5	26
Grindelia integrifolia	Native perennial forb	23.4	2.3	30
Glaux maritima	Native perennial forb	21.1	0.5	18
Triglochin maritima	Native perennial forb	16.4	1.2	37
Potentilla anserina	Native ann-perennial forb	9.4	1.4	37
Agrostis stolonifera	Non-native perennial grass	7.8	1.5	57
Hordeum brachyantherum	Native perennial grass	7.8	0.4	50
Deschampsia cespitosa	Native perennial grass	3.9	1.0	88
Schoenoplectus tabernaemontani	Native perennial sedge	3.1	1.5	64
Symphyotrichum subspicatum	Native perennial forb	3.1	1.3	42
Carex lyngbyei	Native perennial sedge	3.1	0.9	64
Cuscuta pacifica	Native ann-perennial parasite	2.3	NA	NA
Hordeum jubatum	Native ann-perennial grass	2.3	0.1	30
Fabaceae species	Legume	0.8	0.7	41
Achillea millefolium	Native perennial forb	0.8	0.2	39
Elymus repens	Non-native perennial grass	0.8	0.1	69

* Includes *J. balticus* (native) and *J. gerardii* (non-native).

Table C2. Mean percent cover of dominant plant species by marsh zone at Skokomish. Zones were defined by degree of flooding by high tides.

[AtrPro = *Atriplex prostrata*; DisSpi = *Distichlis spicata*; JauCar = *Jaumea carnosa*; Juncus = *J. balticus* (native) and *J. gerardii* (non-native); SarPer = *Sarcocornia perennis*; TriMar = *Triglochin maritima*.]

Marsh zone	% high tides reaching zone	MHHW range (m)	Sample size	Mean cover of top four dominant plants (%)
Transition	0.14-3	0.796 to 0.396	1	*Insufficient sample size*
High	3-25	0.395 to 0.040	30	Juncus (37), DisSpi (28), SarPer (13), AtrPro (9)
Middle	25-50	0.039 to -0.200	66	JauCar (55), DisSpi (41), SarPer (18), Juncus (12)
Low	>50	-0.201 to -1.296	31	JauCar (47), SarPer (29), DisSpi (15), TriMar (3)

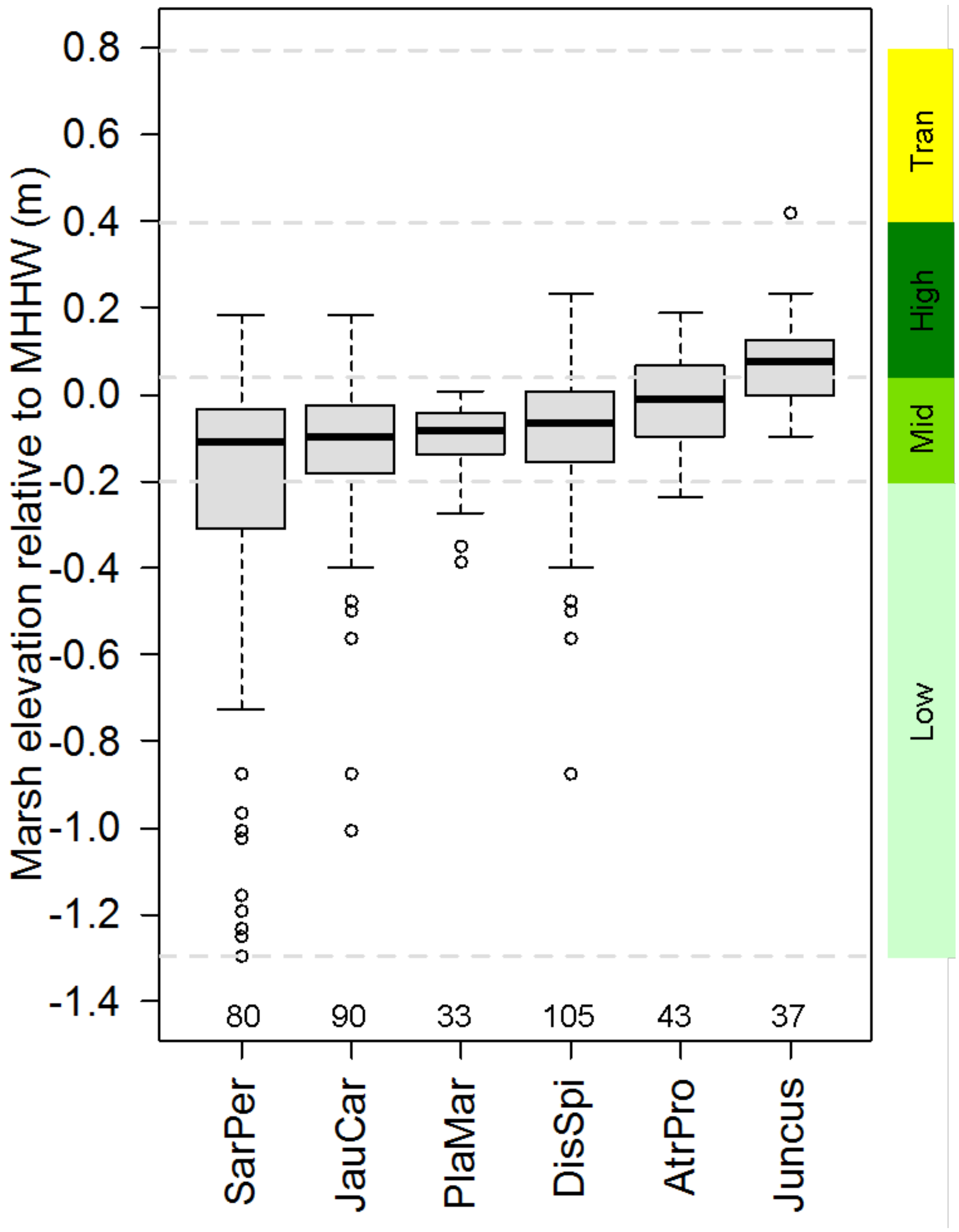

Figure C5. Elevation distribution of the six most common vascular plant species at Skokomish. The black horizontal bars show the median elevation at which the species occurs; shaded boxes indicate the interquartile range; upper and lower whiskers encompass points no greater than 1.5x the length of the shaded box; and open circles indicate outliers. The number of plots in which the species occurred is indicated above the species codes (out of a total of 128 plots). Marsh elevation zones (low, middle, high and transition) are illustrated at right. AtrPro = *Atriplex prostrata*; DisSpi = *Distichlis spicata;* JauCar = *Jaumea carnosa*; Juncus = *J. balticus* (native) and *J. gerardii* (non-native); PlaMar = *Plantago maritima;* SarPer = *Sarcocornia perennis*.

Table C3. Location of water level loggers and deep sediment cores (UTM coordinates).

	Northing (m)	Easting (m)
Water level loggers	489429	5243136
	489259	5242835
Deep core locations	489325	5243350
	489177	5243233
	489027	5243038

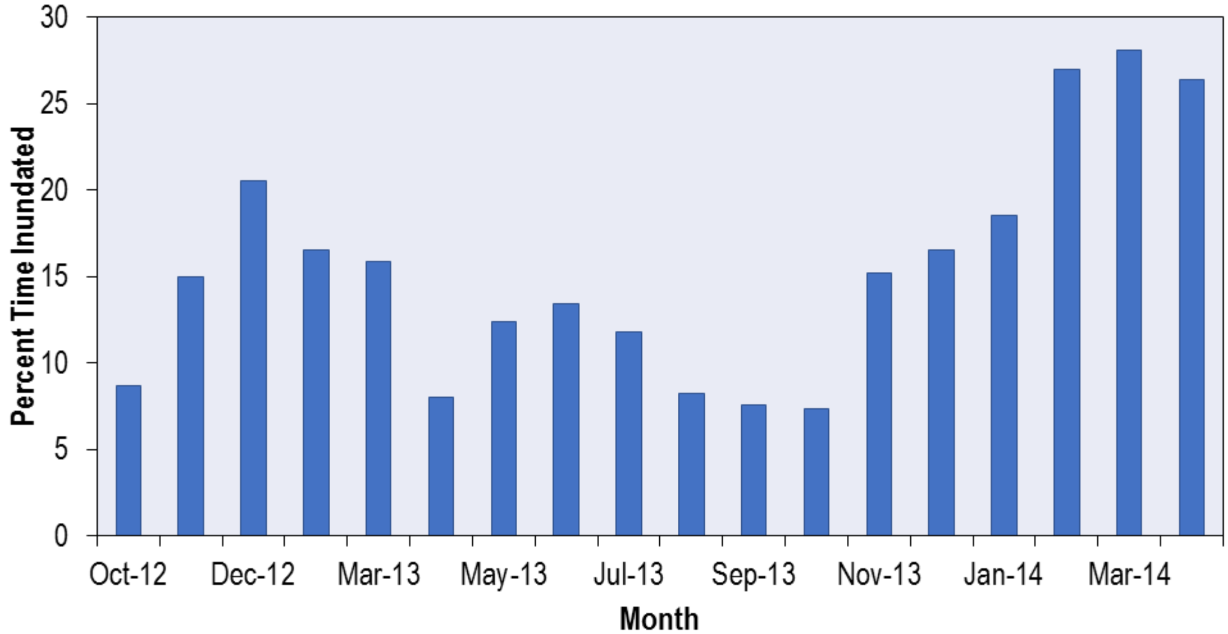

Figure C6. Average monthly inundation of the study site based on an average marsh elevation. Water levels were determined with a water logger deployed at 0.85 m (NAVD88).

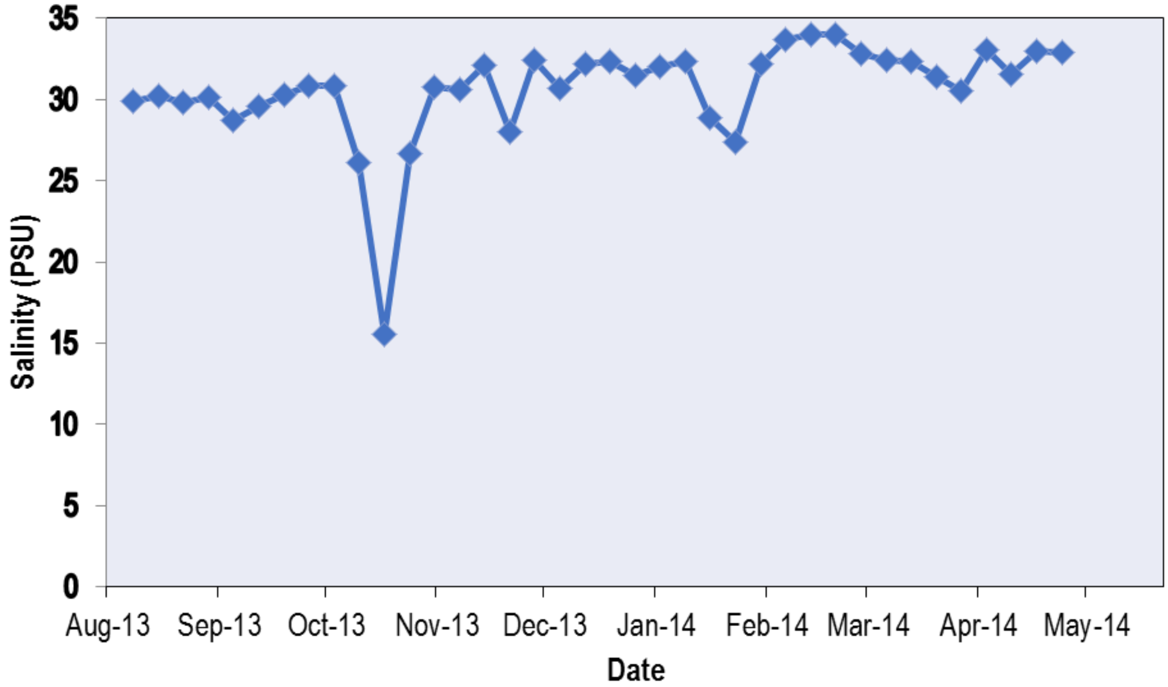

Figure C7. Average weekly maximum salinity from August 2013 – May 2014 at Skokomish. Seawater is approximately 35 PSU.

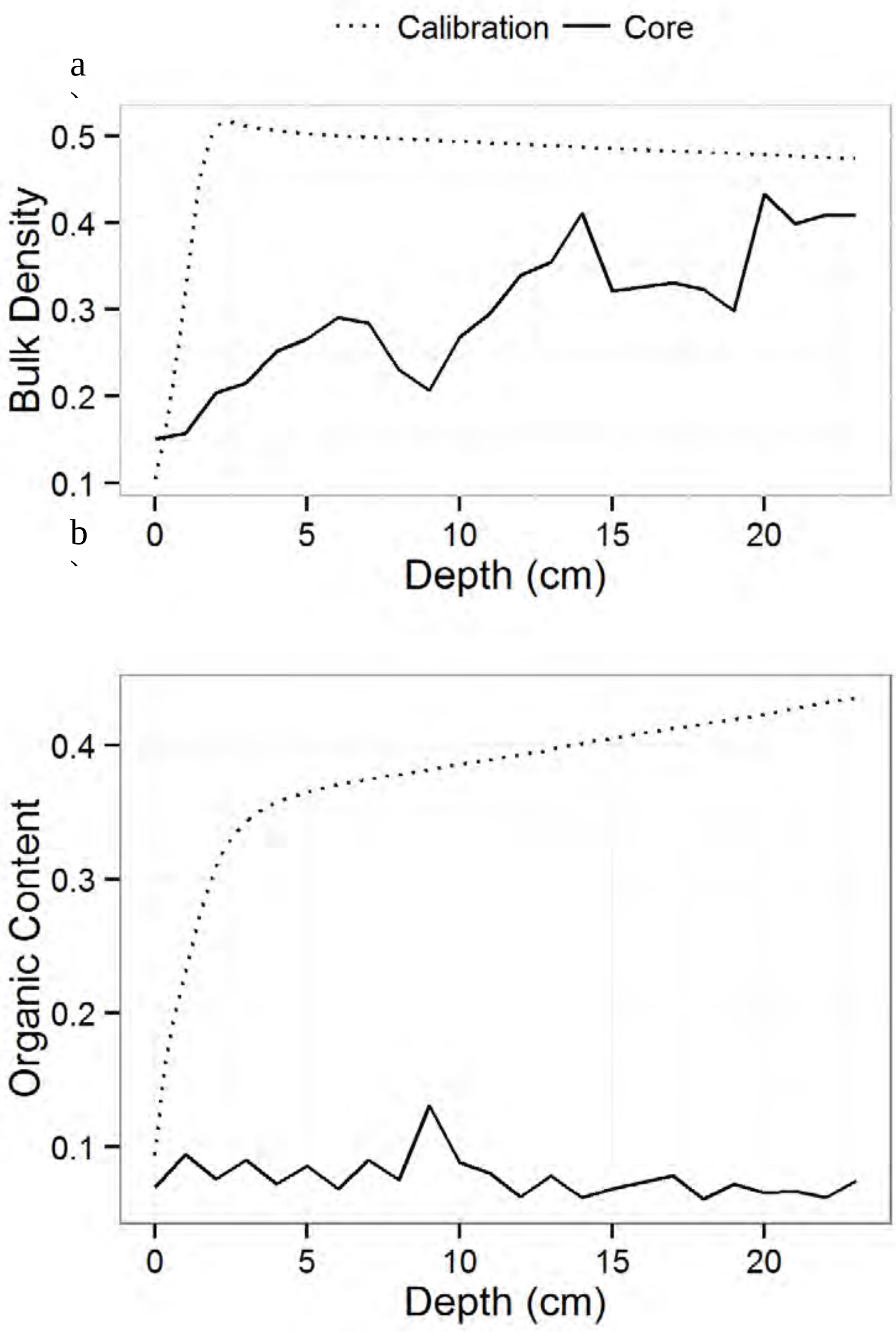

Figure C8. Deep core calibration of the WARMER model using depth profiles of (a) sediment bulk density (g cm^{-3}) and (b) sediment organic matter content (%).

Table C4. Model input parameters for Skokomish. Sediment accumulation rate is reported at the elevation of MSL. NDVI is the Normalized Difference Vegetation Index and NAIP is the National Agriculture Inventory Program.

Model parameter	Value	Source
Sediment accumulation rate (g cm^{-2} yr^{-1})	0.075	Core calibration
Elevation of peak biomass (cm, MSL)	164	NDVI from NAIP
Minimum elevation of vegetation (cm, MSL)	25	Field surveys
Max. aboveground organic accumulation (g cm^{-2} yr^{-1})	0.0097	Core calibration
Root-to-shoot ratio	1.95	C. Janousek, unpub. data
Porosity surface (%)	95	Core
Porosity depth (%)	72	Core
Refractory carbon (%)	61	Core
Maximum astronomical tide (cm, MSL)	236	CERCC water logger
Historic sea-level rise (mm yr^{-1})	1.97	Tacoma tide gauge (NOAA, 9446484)
Organic matter density (g cm^{-3})	1.14	DeLaune 1983
Mineral density (g cm^{-3})	2.61	DeLaune 1983

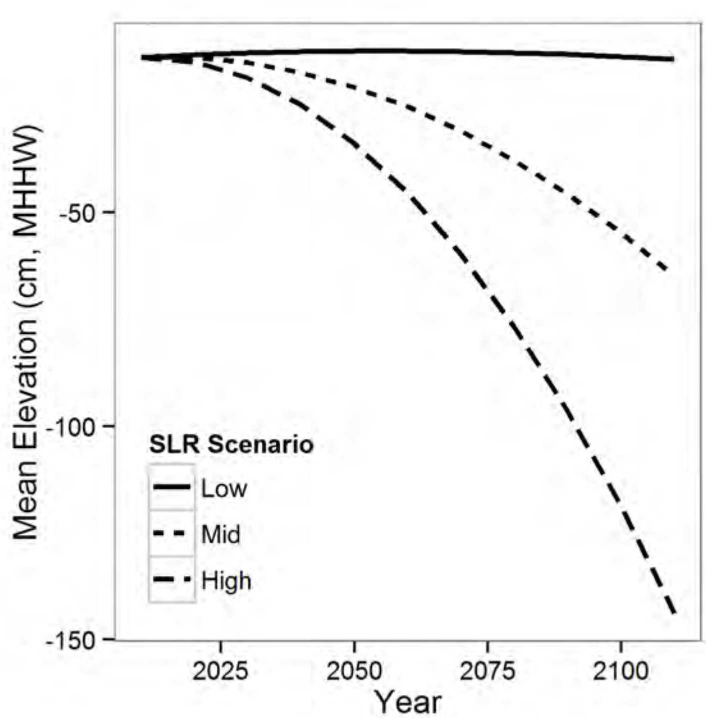

Figure C9. WARMER model results for average marsh elevation change at Skokomish from the present day to the year 2110 under low, mid, and high sea-level rise (SLR) scenarios.

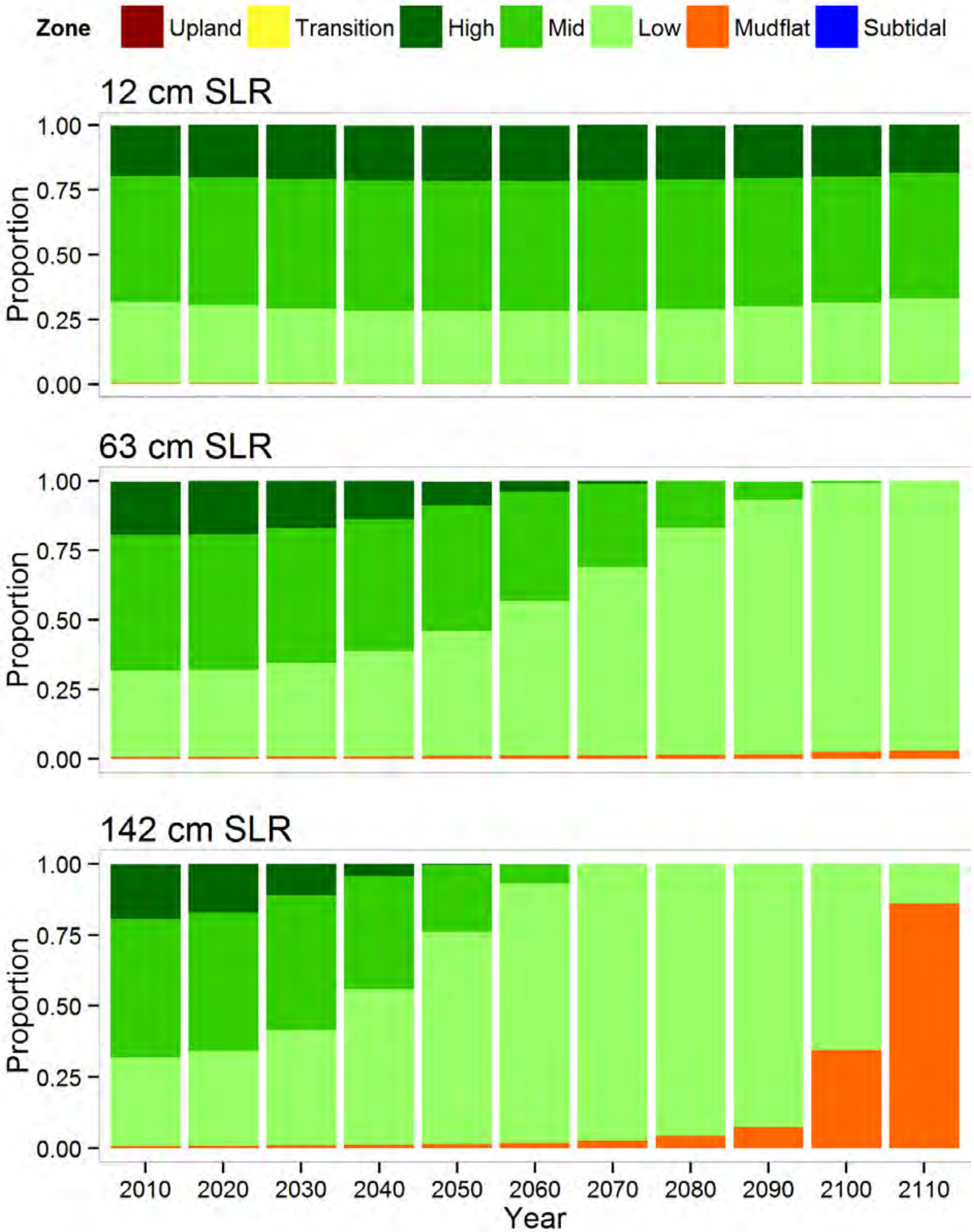

Figure C10. Model projections for change in the relative proportion of upland, transitional, high, mid and low marsh habitat, and mudflat under low (12 cm), mid (63 cm), and high (142 cm) NRC sea-level rise scenarios from 2010 to 2110.

Table C5. Percentage of habitat area modeled for three sea-level rise scenarios for 2010, 2050, and 2110.

	Low SLR (12 cm)			Mid SLR (63 cm)			High SLR (142 cm)		
	2010	2050	2110	2010	2050	2110	2010	2050	2110
Upland	0	0	0	0	0	0	0	0	0
Transition	0	0	0	0	0	0	0	0	0
High	20	21	18	20	9	0	20	1	0
Mid	49	50	48	49	45	0	49	24	0
Low	31	28	33	31	45	97	31	74	14
Mudflat	0	1	1	0	1	3	0	1	86
Subtidal	0	0	0	0	0	0	0	0	0

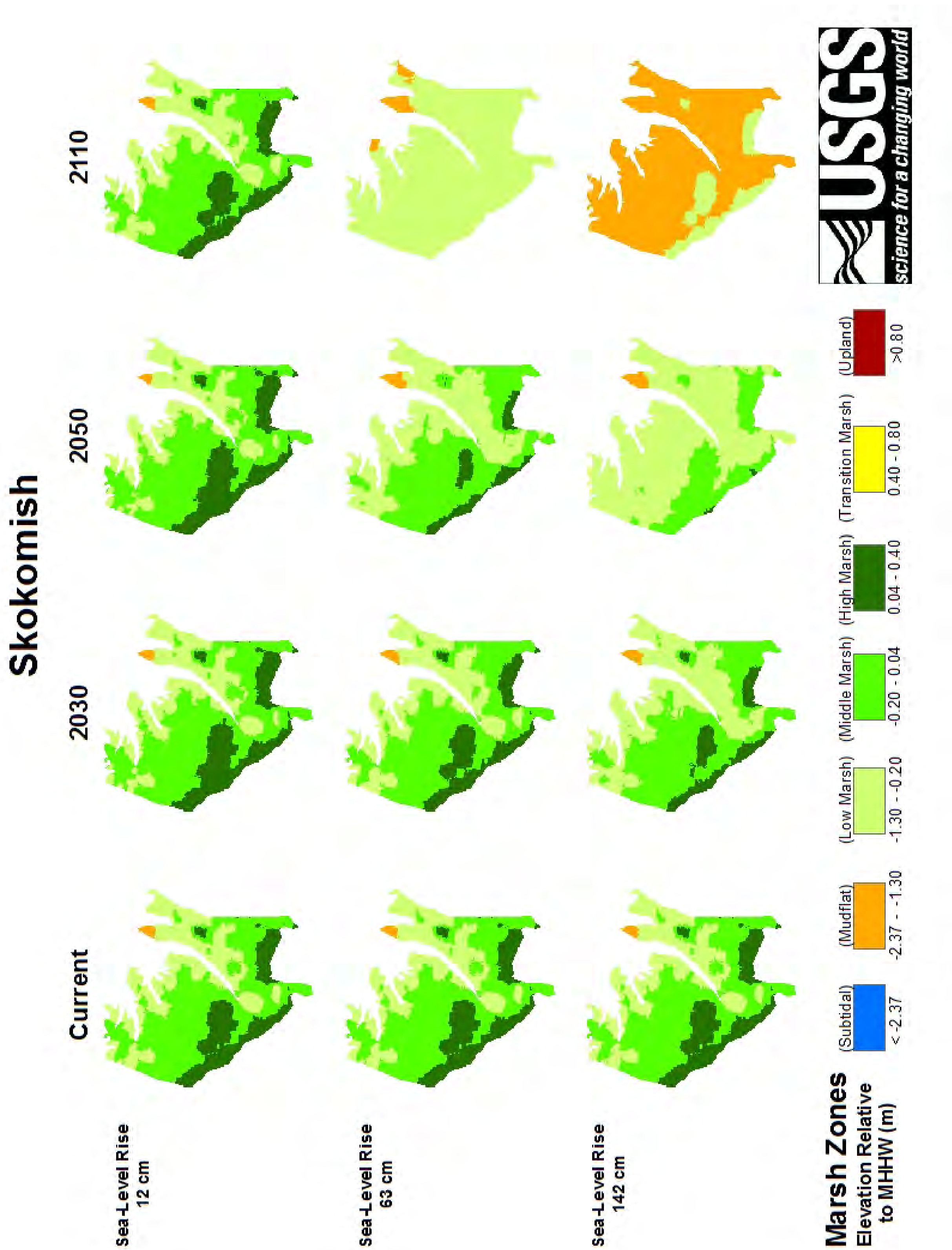

Figure C11. Projected habitat distribution at Skokomish for 2030, 2050 and 2110 with the WARMER model under three sea-level rise scenarios.

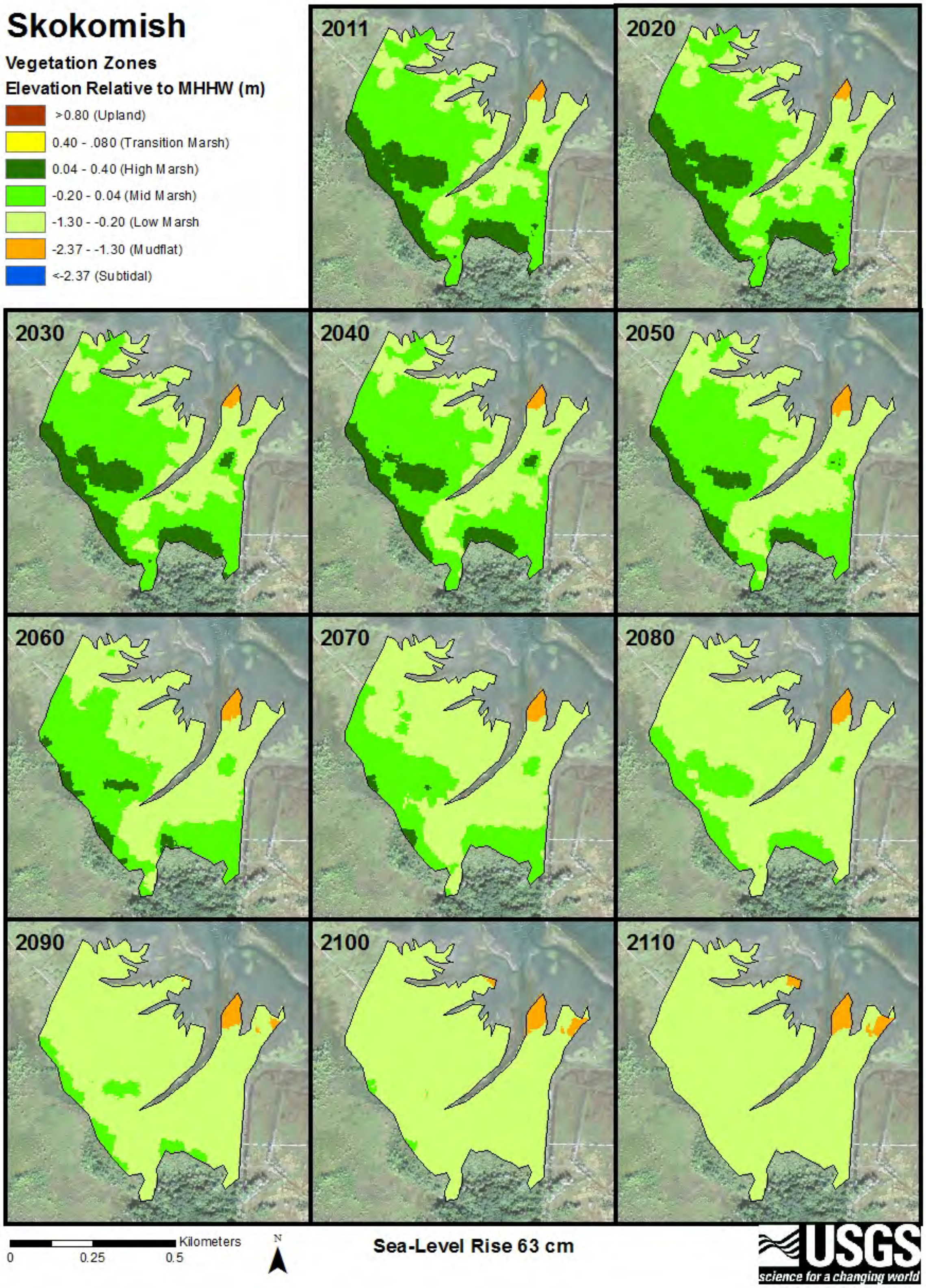

Figure C12. Projected changes in the distribution of Skokomish habitat zones under the NRC's mid (63 cm) sea-level rise scenario.

Appendix D. Site Specific Details for Nisqually Marsh, Nisqually National Wildlife Refuge, Thurston County, Washington

Photo: M. Davis, USGS

Summary:

- *Study site size*: 59.9 hectares
- *Location*: 47° 05' 31" N latitude, 122° 41' 35" W longitude.
- *Site management*: U.S. Fish and Wildlife Service (Nisqually National Wildlife Refuge)
- *Site vegetation and elevation survey*: 31 August – 7 September 2012
- *Sample size*: 1072 (elevation data points), 245 (vegetation quadrats)
- *Marsh elevation model*: This site was among the lowest study sites in the Pacific Northwest, with only 6% of elevation data points occurring above MHHW.
- *Plant community composition*: *Distichlis spicata* was the most frequently-occurring species at the site. *Sarcocornia perennis* and *Jaumea carnosa* were also common.
- *Bathymetric surveys*: 124.9 ha of nearshore habitat were mapped adjacent to the study area.

- *Soil characteristics*: The accumulation rates used in WARMER for this site were: sediment accumulation rate = 0.39 g cm^{-2} yr^{-1}; organic matter accumulation rate = 0.018 g cm^{-2} yr^{-1}; net accretion = 0.50 cm yr^{-1}.
- *Water inundation and salinity monitoring*: water level (January 2013 – December 2013); conductivity (August 2013 – October 2013). Water level and conductivity monitoring is ongoing.
- *Salinity*: Maximum weekly salinity was very consistent during the study period, ranging from about 28-29.
- *Marsh inundation pattern*: Maximum monthly inundation occurred during January 2013; minimum monthly inundation during February 2013.
- *Calculated tidal datums*: MHHW is at 3.11 m NAVD88; MHW is at 2.82 m NAVD88.
- *Sea-level rise marsh response modeling*: Under the NRC low SLR projection (12 cm), high marsh habitat gradually expands until more than 75% of the site is high marsh at 2110. Under the NRC's mid SLR projection (63 cm), high marsh is lost by 2090 and the site becomes mostly low marsh (with some mid marsh) by 2110. Under the NRC's high SLR projection (142 cm), high marsh is lost by 2060, mid marsh is lost by 2070 and the site becomes mostly mudflat by 2110.

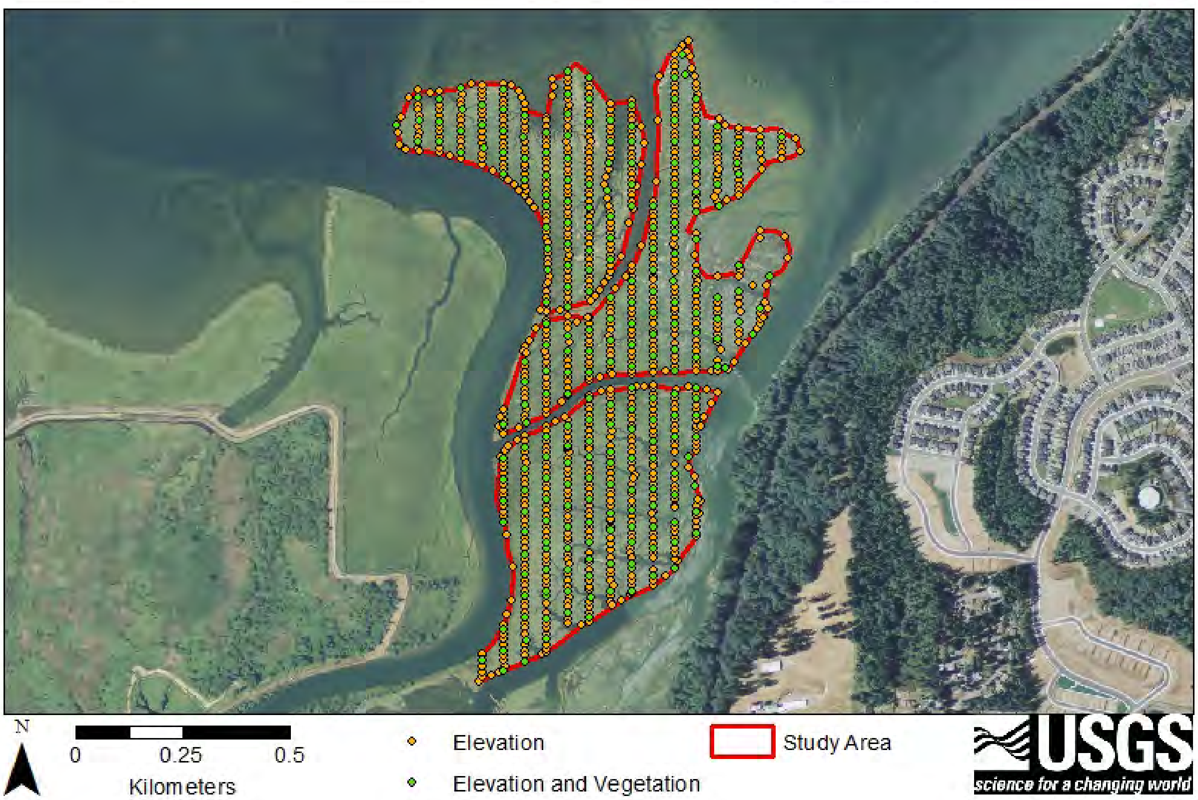

Figure D1. Distribution of elevation and vegetation survey points at Nisqually.

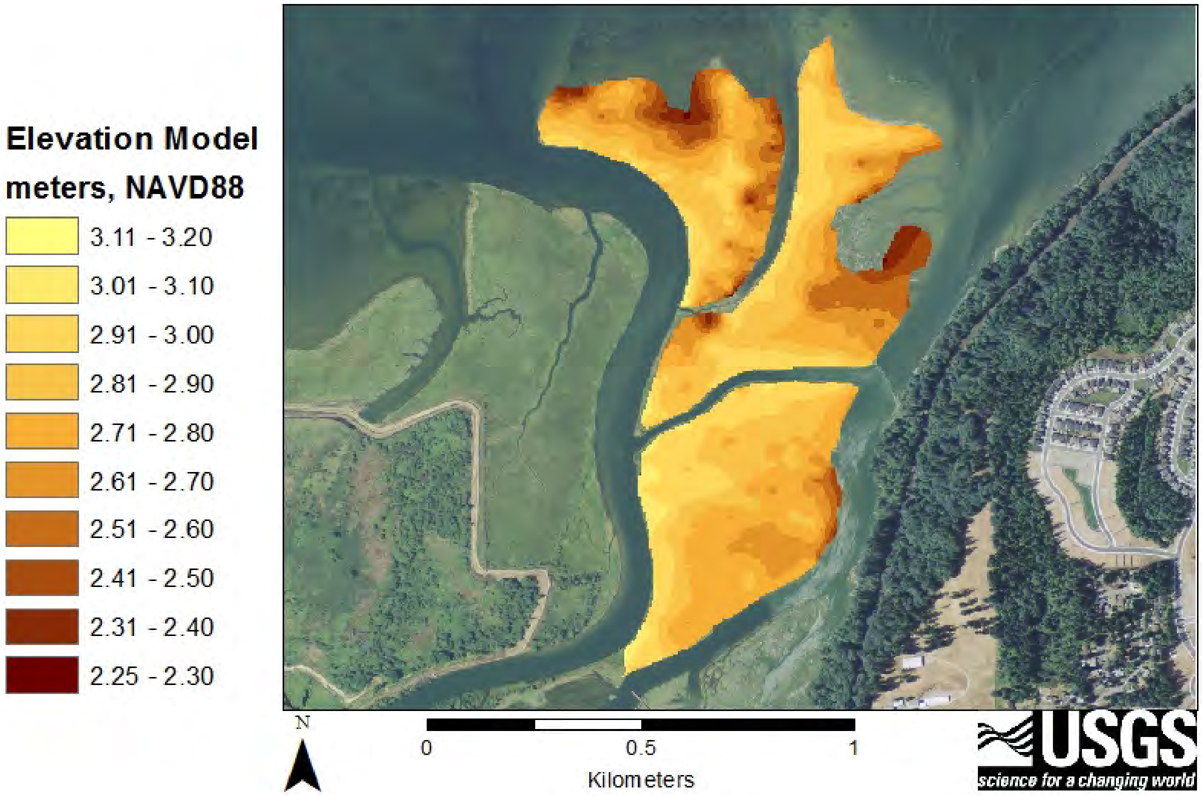

Figure D2. Elevation model (3 m resolution) developed from RTK GPS survey data.

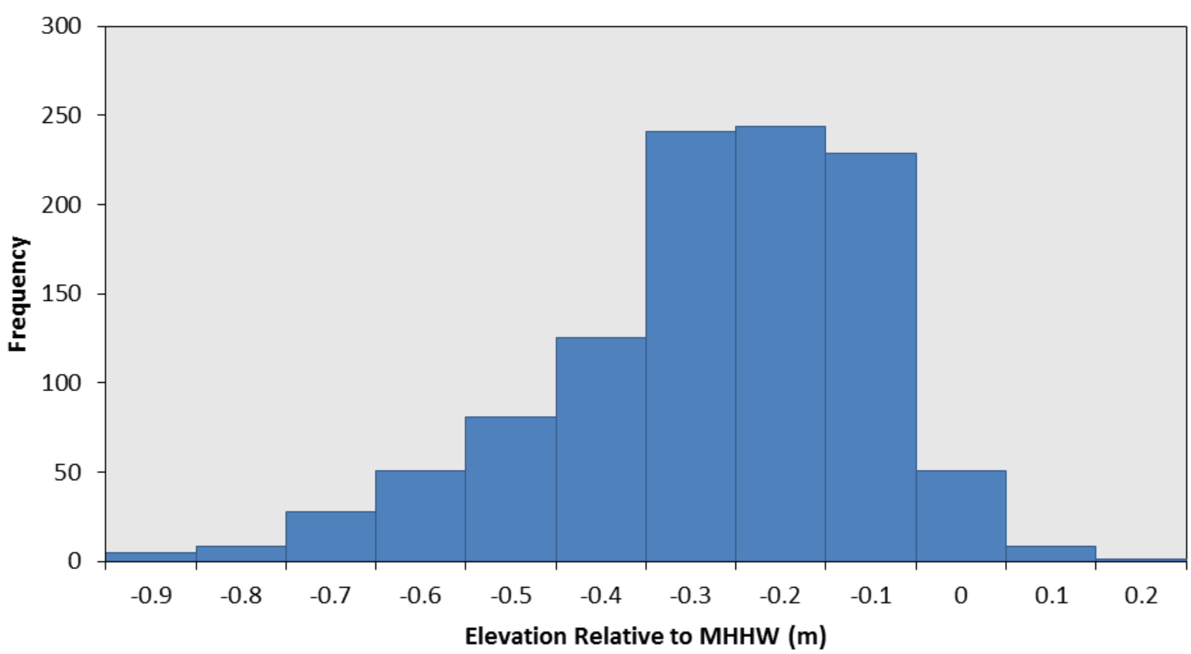

Figure D3. Frequency distribution of marsh surface elevation measurements relative to local mean higher high water (MHHW) at Nisqually.

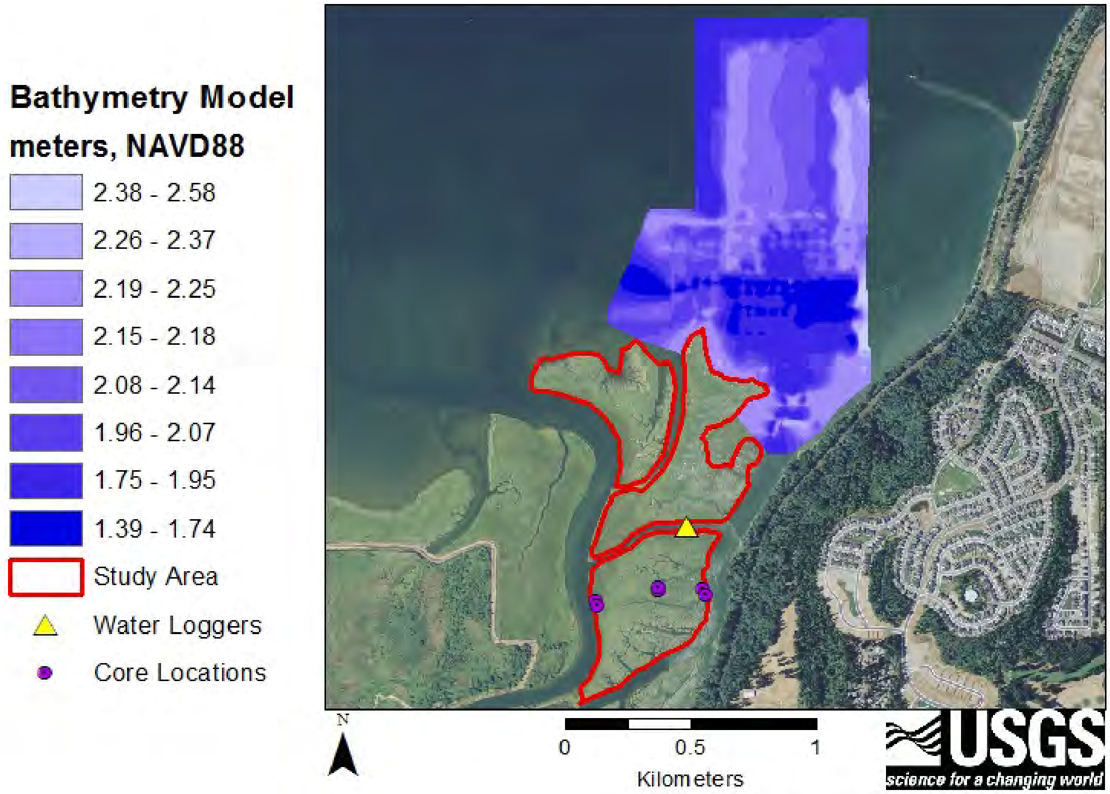

Figure D4. Near-shore bathymetry model at Nisqually. Water level logger and core locations are shown within the marsh study site.

Table D1. Frequency of occurrence, percent cover and height of vascular plant species encountered in sample plots at Nisqually. NA = not measured.

Species	Species characteristics	Freq (%)	Mean cover (%)	Mean height (cm)
Distichlis spicata	Native perennial grass	86.1	51.3	21
Sarcocornia perennis	Native perennial forb	55.5	14.9	14
Jaumea carnosa	Native perennial forb	54.7	18.3	11
Grindelia integrifolia	Native perennial forb	34.3	3.2	21
Triglochin maritima	Native perennial forb	33.9	3.0	34
Plantago maritima	Native perennial forb	22.9	4.1	27
Carex lyngbyei	Native perennial sedge	20.8	5.1	47
Glaux maritima	Native perennial forb	20.8	0.8	16
Atriplex prostrata	Non-native annual forb	18.0	0.4	16
Spergularia sp.	Forb	11.4	0.5	13
Potentilla anserina	Native ann-perennial forb	10.6	0.7	26
Symphyotrichum subspicatum	Native perennial forb	9.8	3.7	46
Agrostis stolonifera	Non-native perennial grass	9.8	2.5	41
Juncus balticus	Native perennial rush	7.8	1.9	37
Deschampsia cespitosa	Native perennial grass	6.1	2.3	54
Puccinellia sp.	Grass	4.5	0.2	28
Cuscuta pacifica	Native ann-perennial parasite	4.1	NA	NA
Phalaris arundinacea	Non-native perennial grass	2.9	2.1	61
Elymus repens	Non-native perennial grass	2.4	0.9	52
Lactuca serriola	Non-native annual forb	2.4	0.2	19
Hordeum jubatum	Native ann-perennial grass	2.0	0.2	40
Cirsium arvense	Non-native perennial forb	1.2	0.2	51
Achillea millefolium	Native perennial forb	0.8	0.1	19
Schedonorus arundinaceus	Non-native perennial grass	0.8	0.0	83
Angelica lucida	Native perennial forb	0.4	0.0	23
Bolboschoenus maritimus	Native perennial sedge	0.4	0.0	22
Plantago lanceolata	Non-native perennial forb	0.4	0.0	15
Hordeum brachyantherum	Native perennial grass	0.4	0.0	38
Poaceae sp.	Grass	0.4	0.0	22

Table D2. Mean percent cover of dominant plant species by marsh zone at Nisqually. Zones were defined by degree of flooding by high tides.

[CarLyn = *Carex lyngbyei*; DisSpi = *Distichlis spicata*; JauCar = *Jaumea carnosa*; SarPer = *Sarcocornia perennis*; SymSub = *Symphyotrichum subspicatum*.]

Marsh zone	% high tides reaching zone	MHHW range (m)	Sample size	Mean cover of top four dominant plants (%)
Transition	0.14-3	0.965 to 0.480	0	*Insufficient sample size*
High	3-25	0.479 to 0.048	1	*Insufficient sample size*
Middle	25-50	0.047 to -0.242	82	DisSpi (41), JauCar (18), SarPer (11), SymSub (7)
Low	>50	-0.243 to -0.960	162	DisSpi (57), JauCar (19), SarPer (17), CarLyn (4)

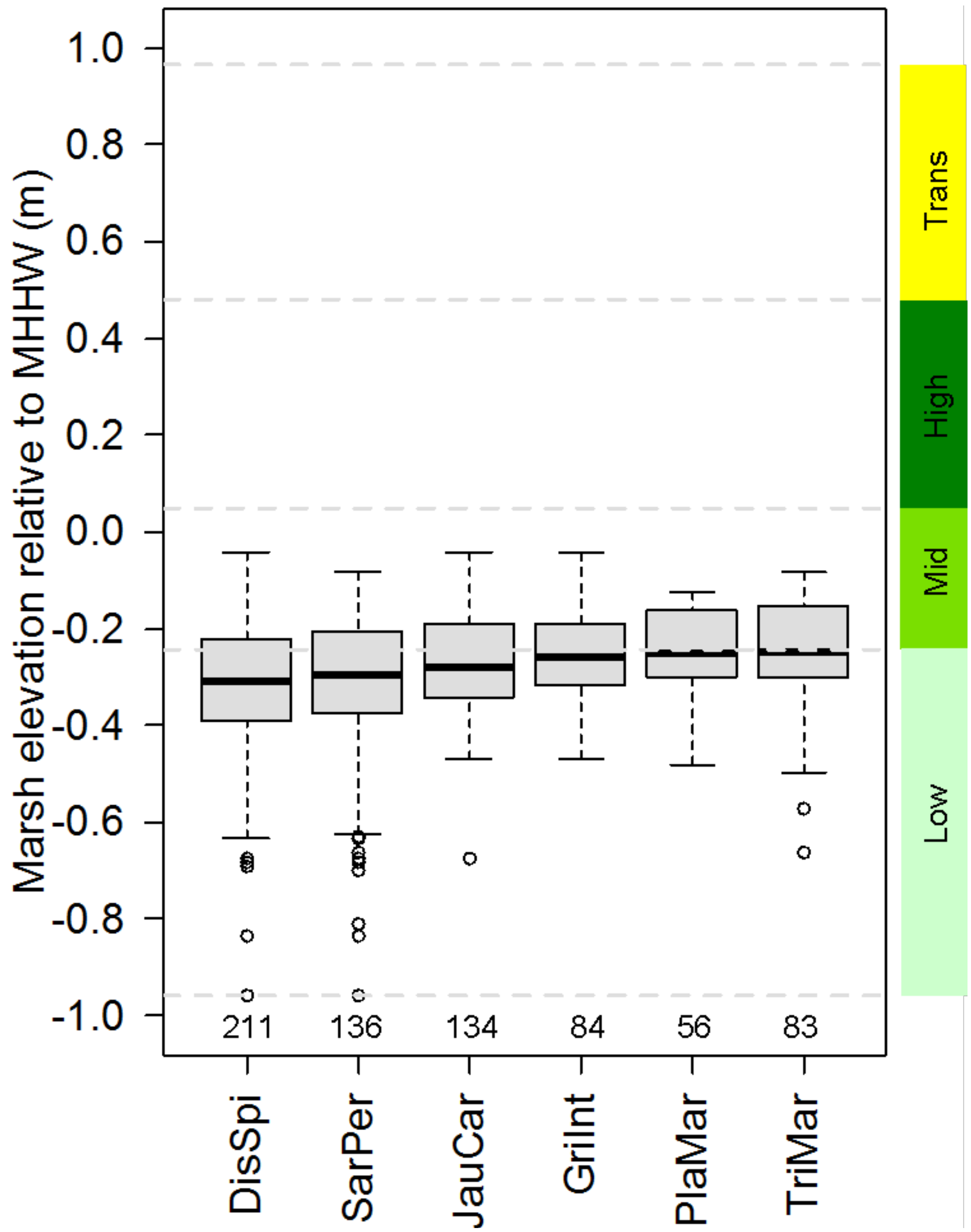

Figure D5. Elevation distribution of the six most common vascular plant species at Nisqually. The black horizontal bars show the median elevation at which the species occurs; shaded boxes indicate the interquartile range; upper and lower whiskers encompass points no greater than 1.5x the length of the shaded box; and open circles indicate outliers. The number of plots in which the species occurred is indicated above the species codes (out of a total of 245 plots). Marsh elevation zones (low, middle, high and transition) are illustrated at right. DisSpi = *Distichlis spicata*; SarPer = *Sarcocornia perennis*; JauCar = *Jaumea carnosa*; GriInt = *Grindelia integrifolia*; PlaMar = *Plantago maritima*; TriMar = *Triglochin maritima*.

Table D3. Location of water level loggers and deep sediment cores (UTM coordinates).

	Northing (m)	Easting (m)
Water level logger	547226	5337780
Deep core locations	523469	5215431
	523290	5215421
	523045	5215380

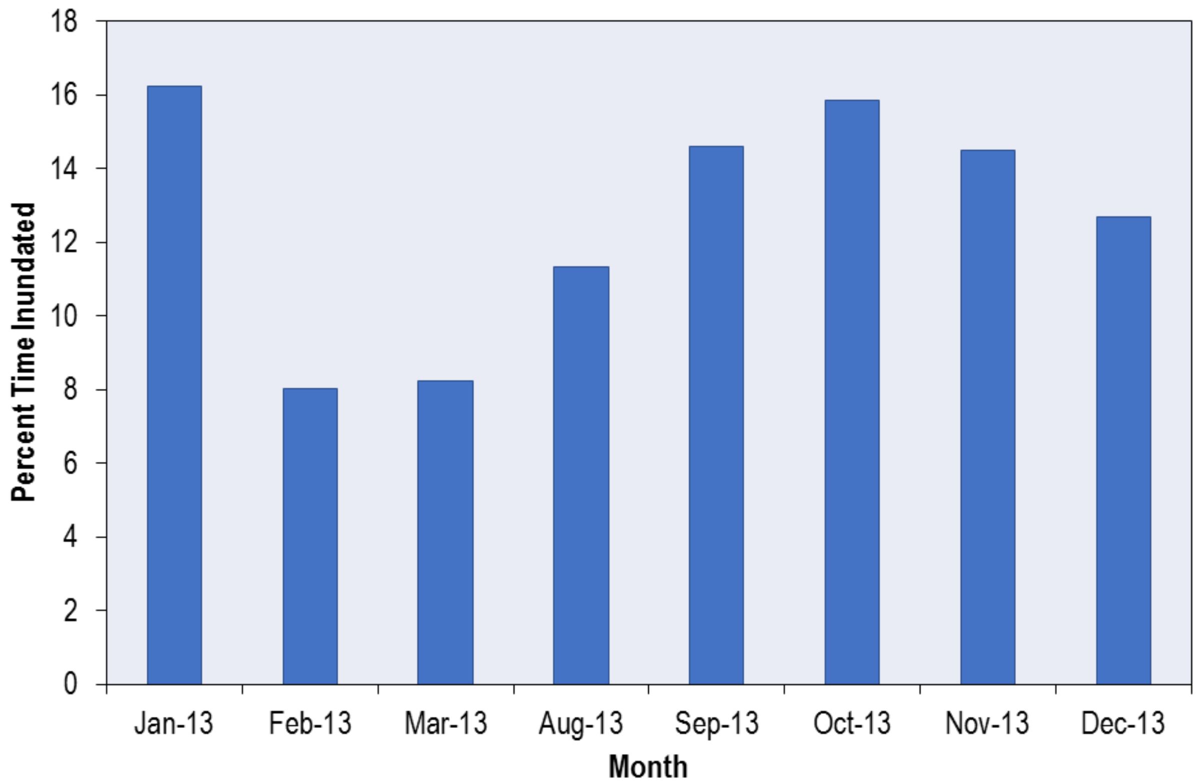

Figure D6. Average monthly inundation of the study site based on an average marsh elevation. Water levels were determined with a water logger deployed at 0.14 m (NAVD88).

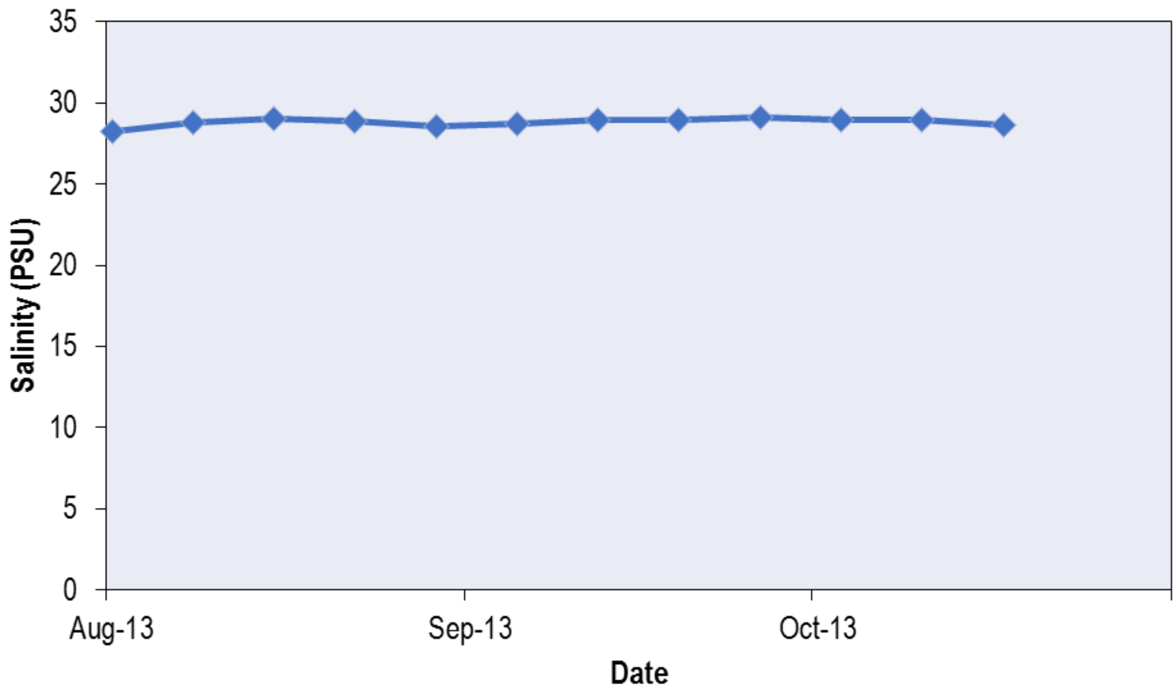

Figure D7. Average weekly maximum salinity from July 2013 – November 2013 at Nisqually. Seawater is approximately 35 PSU.

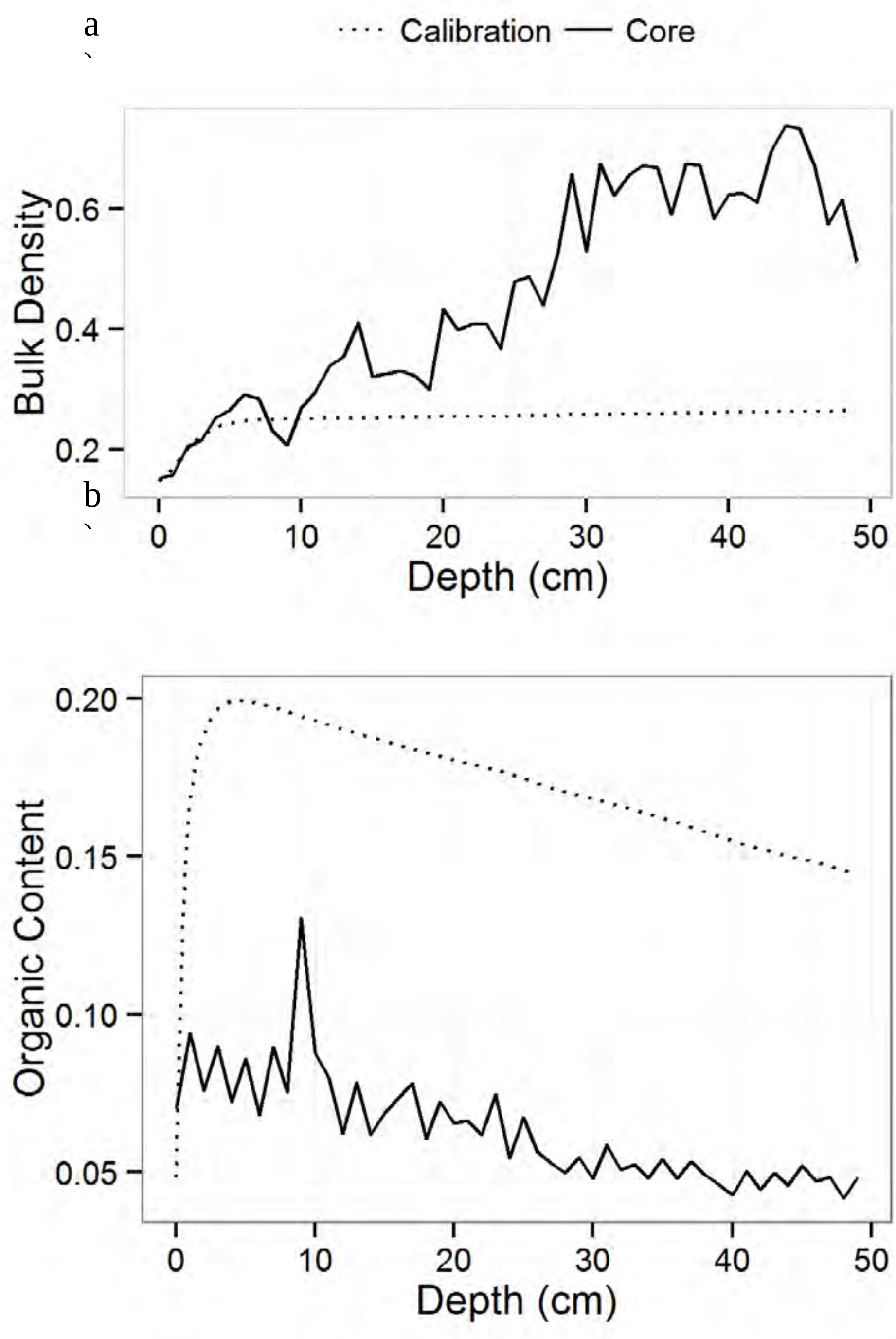

Figure D8. Deep core calibration of the WARMER model using depth profiles of (a) sediment bulk density (g cm^{-3}) and (b) sediment organic matter content (%).

Table D4. Model input parameters for Nisqually. Sediment accumulation rate is reported at the elevation of MSL. NDVI is the Normalized Difference Vegetation Index and NAIP is the National Agriculture Inventory Program.

Model parameter	Value	Source
Sediment accumulation rate (g cm^{-2} yr^{-1})	0.24	Core calibration
Elevation of peak biomass (cm, MSL)	175	NDVI from NAIP
Minimum elevation of vegetation (cm, MSL)	105	Field surveys
Max. aboveground organic accumulation (g cm^{-2} yr^{-1})	0.012	Core calibration
Root-to-shoot ratio	1.95	C. Janousek, unpub data
Porosity surface (%)	94	Core
Porosity depth (%)	88	Core
Refractory carbon (%)	59.7	Core
Maximum astronomical tide (cm, MSL)	286	CERCC water logger
Historic sea-level rise (mm yr^{-1})	1.97	Tacoma tide gauge (NOAA, 9446484)
Organic matter density (g cm^{-3})	1.14	DeLaune 1983
Mineral density (g cm^{-3})	2.61	DeLaune 1983

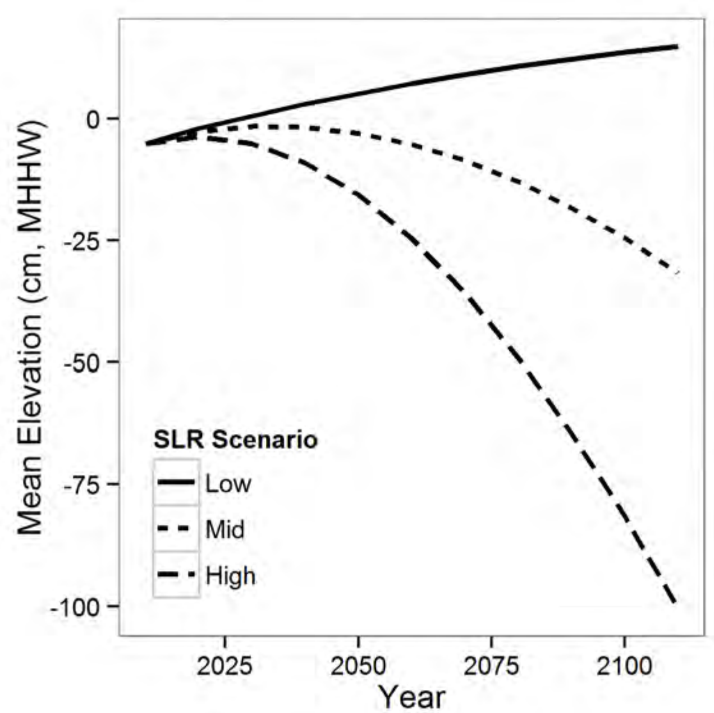

Figure D9. WARMER model projections for the change in average marsh elevation (relative to MHHW) at Nisqually from 2010 to 2110 under low, mid, and high sea-level rise (SLR) scenarios.

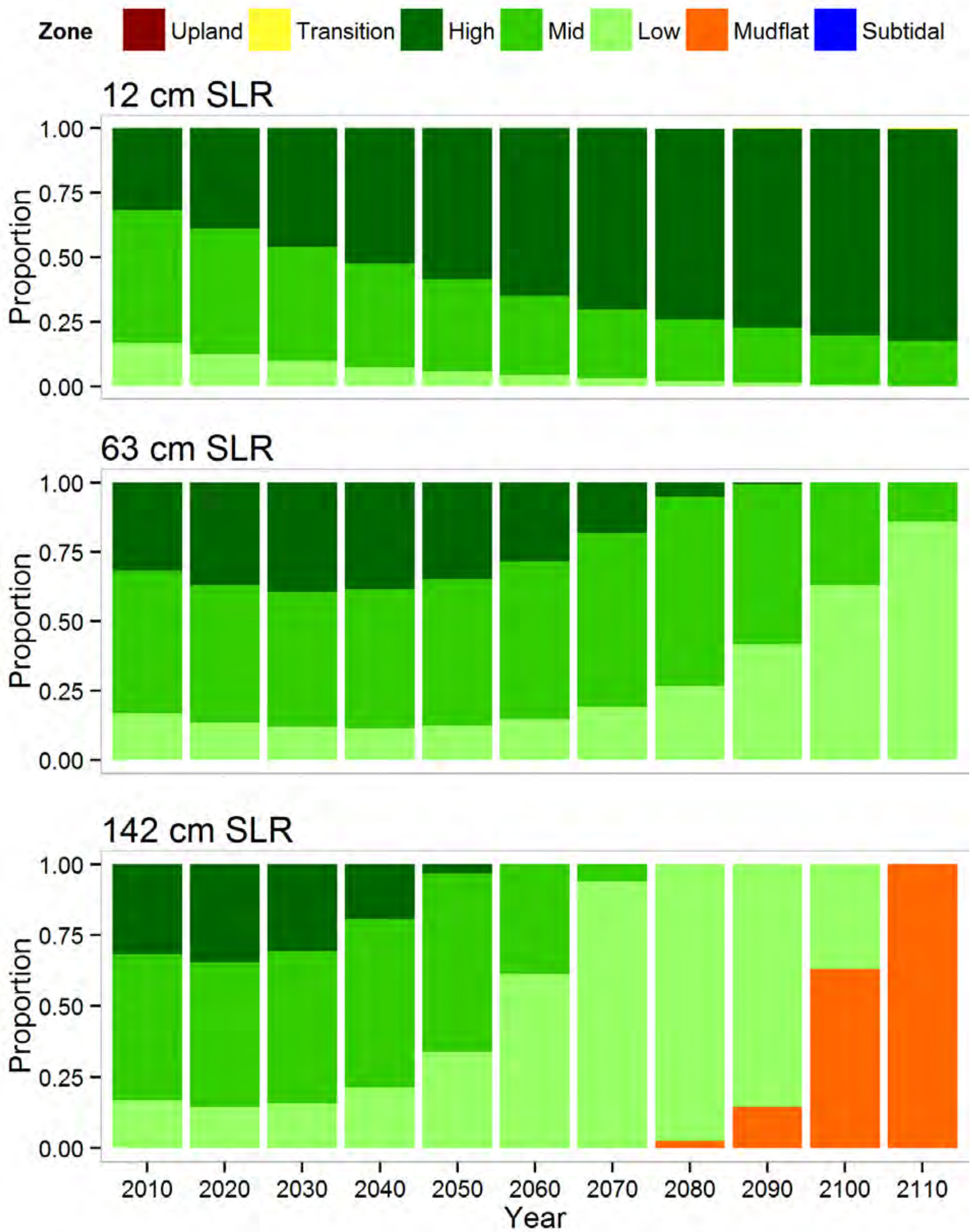

Figure D10. Model projections for change in the relative proportion of upland, transitional, high, mid, and low marsh habitat, and mudflat under low (12 cm), mid (63 cm), and high (142 cm) NRC sea-level rise scenarios from 2010 to 2110.

Table D5. Model projections for change in the percentage of marsh elevation zones for three NRC sea-level rise scenarios between 2010, 2050, and 2110.

	Low SLR (12 cm)			Mid SLR (63 cm)			High SLR (142 cm)		
	2010	2050	2110	2010	2050	2110	2010	2050	2110
Upland	0	0	0	0	0	0	0	0	0
Transition	0	0	0	0	0	0	0	0	0
High	32	58	82	32	35	0	32	3	0
Mid	51	36	18	51	53	14	51	63	0
Low	17	6	0	17	12	86	17	34	0
Mudflat	0	0	0	0	0	0	0	0	100
Subtidal	0	0	0	0	0	0	0	0	0

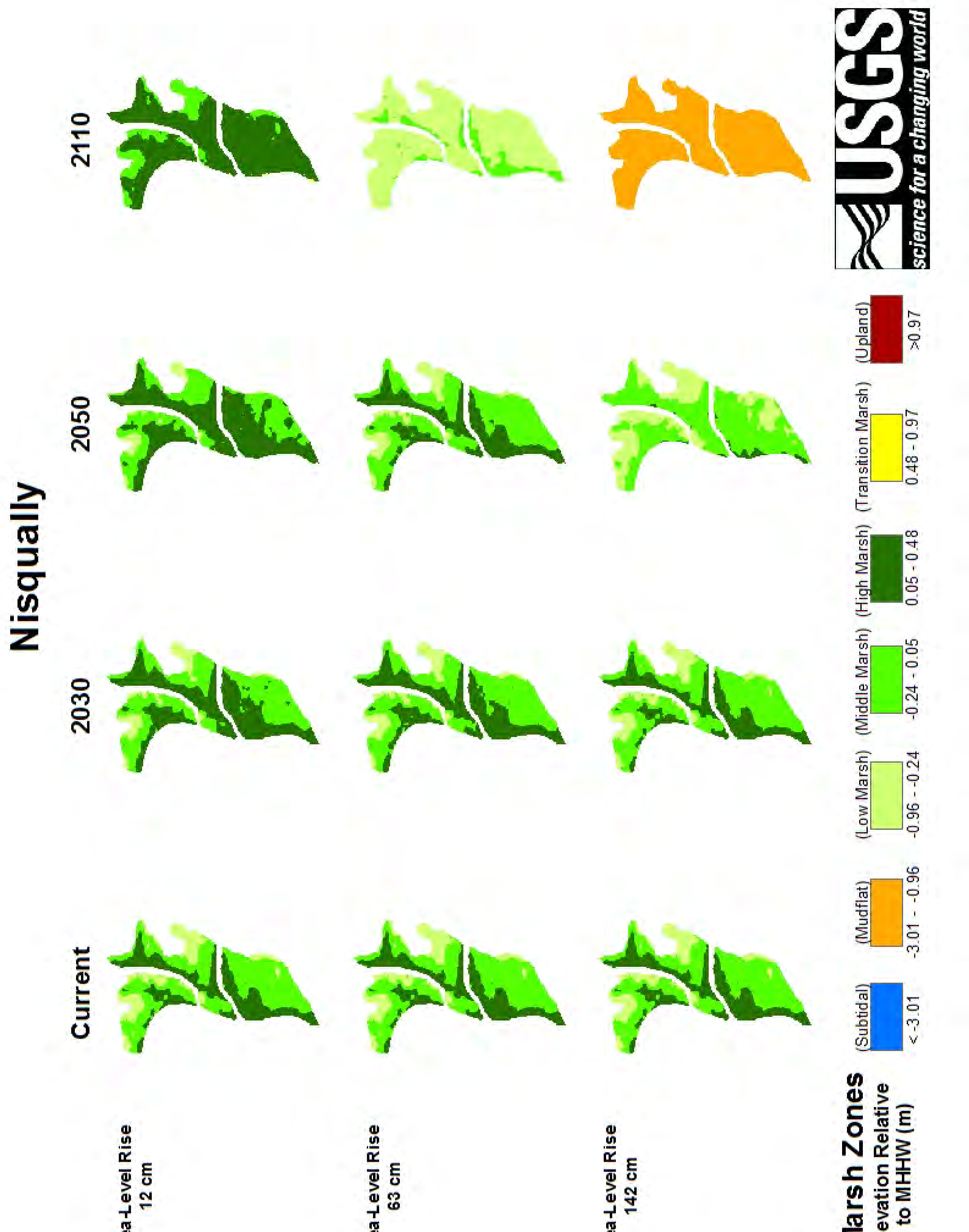

Figure D11. Projected habitat distribution at Nisqually for 2030, 2050 and 2110 with the WARMER model under three NRC sea-level rise scenarios.

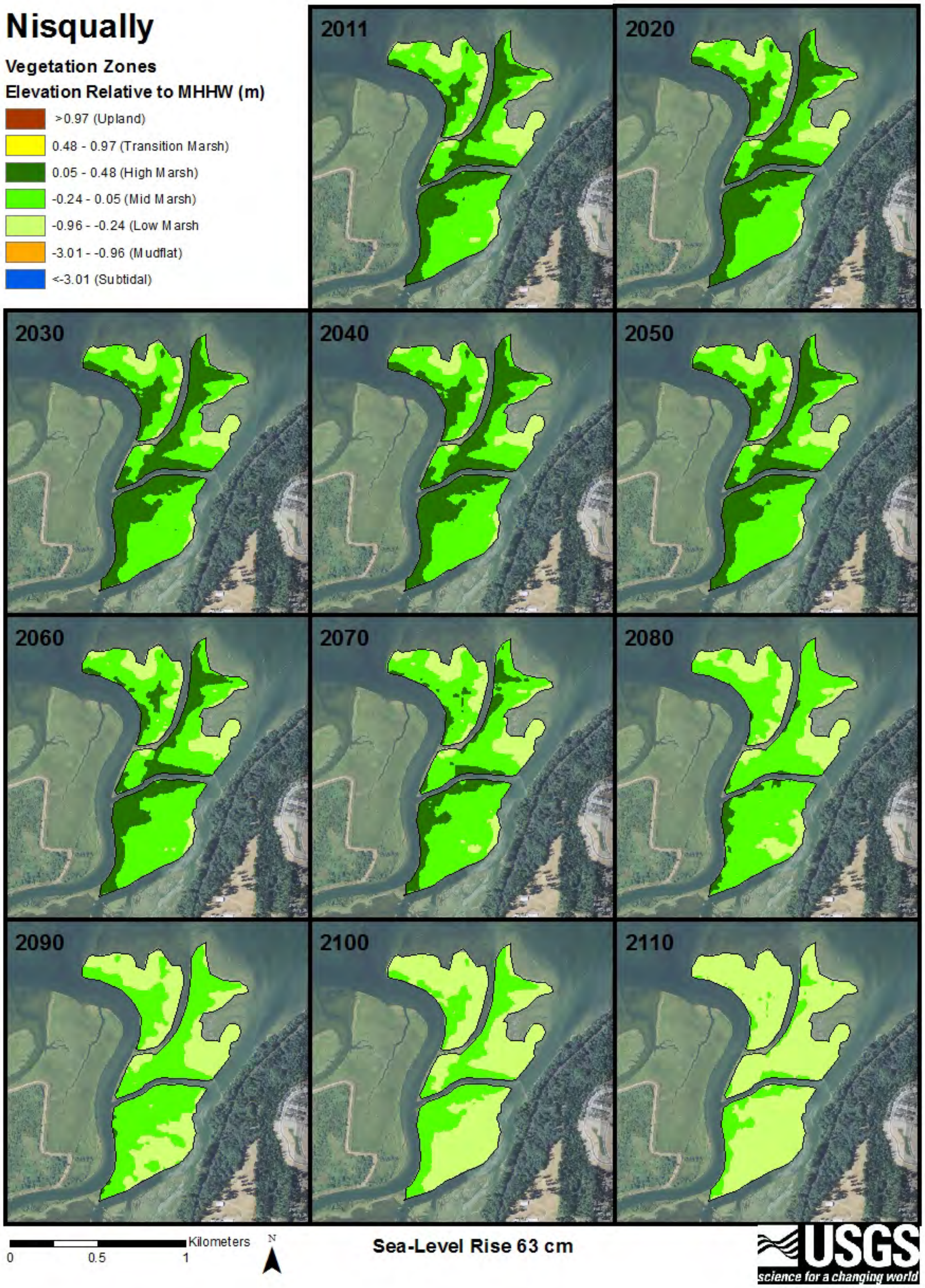

Figure D12. Projected changes in Nisqually elevation zones under the mid NRC sea-level rise scenario (63 cm).

Appendix E. Site Specific Details for Grays Harbor, Grays Harbor National Wildlife Refuge, Grays Harbor County, Washington

Photo: K Powelson, USGS

Summary:

- *Study site size*: 67.8 hectares
- *Location*: 46° 58' 47"N latitude, 123° 55' 60"W longitude.
- *Site management*: U.S. Fish and Wildlife Service (Grays Harbor National Wildlife Refuge)
- *Site vegetation and elevation survey*: 31 August – 7 September 2012
- *Sample size*: 1192 (elevation data points), 271 (vegetation quadrats)
- *Marsh elevation model*: Most of the study site was above MHHW, with 73% of elevation data points occurring above MHHW
- *Plant community composition*: *Carex* spp. (usually *C. lyngbyei* but perhaps including instances of *C. obnupta*) had the highest frequency of occurrence. *Agrostis stolonifera* and *Triglochin maritima* also occurred frequently.
- *Bathymetric surveys*: 117.3 ha of nearshore habitat were mapped adjacent to the study area.

- *Soil characteristics*: WARMER accumulation rates for this site were: mineral accumulation rate = 0.55 g cm^{-2} yr^{-1}; organic matter accumulation rate = 0.0159 g cm^{-2} yr^{-1}; net accretion = 0.5659 cm yr^{-1}.
- *Water inundation and salinity monitoring*: water level (October 2012 – November 2013); conductivity (November 2013 – May 2014). Water level and conductivity monitoring is ongoing.
- *Salinity*: The site had euhaline conditions (33-36) from Nov 2013 to Feb 2014, but was somewhat fresher (26-29) from March 2014 to May 2014 during the rainy season.
- *Marsh inundation pattern*: Maximum monthly inundation occurred during December 2012; minimum monthly inundation occurred during June 2013
- *Calculated tidal datums*: MHHW is at 2.39 m NAVD88; MHW is at 2.17 m NAVD88.
- *Sea-level rise marsh response modeling*: Under the NRC's low SLR projection (12 cm), high marsh at Grays Harbor is projected to expand until the whole site is high marsh by 2080. Under the mid SLR projection (63 cm), high marsh gradually replaces some middle and low marsh between 2010 and 2080. By 2110, the site consists of mostly high marsh, with some remaining mid marsh habitat. Under the NRC's high SLR projection (142 cm), high marsh initially becomes more abundant at the site, but then begins to decrease after 2050 and is lost by 2090. At 2110, the site is projected to consist mostly of low marsh with some mid marsh remaining.

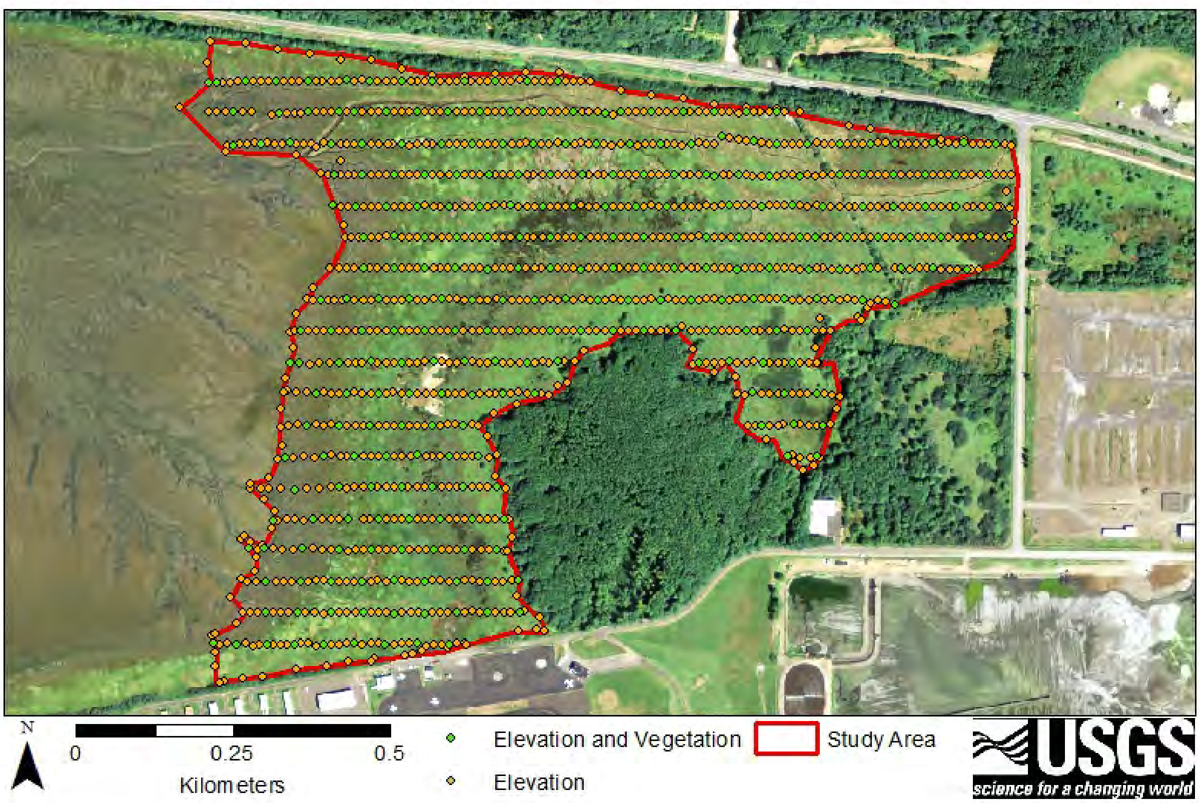

Figure E1. Distribution of elevation and vegetation survey points at Grays Harbor.

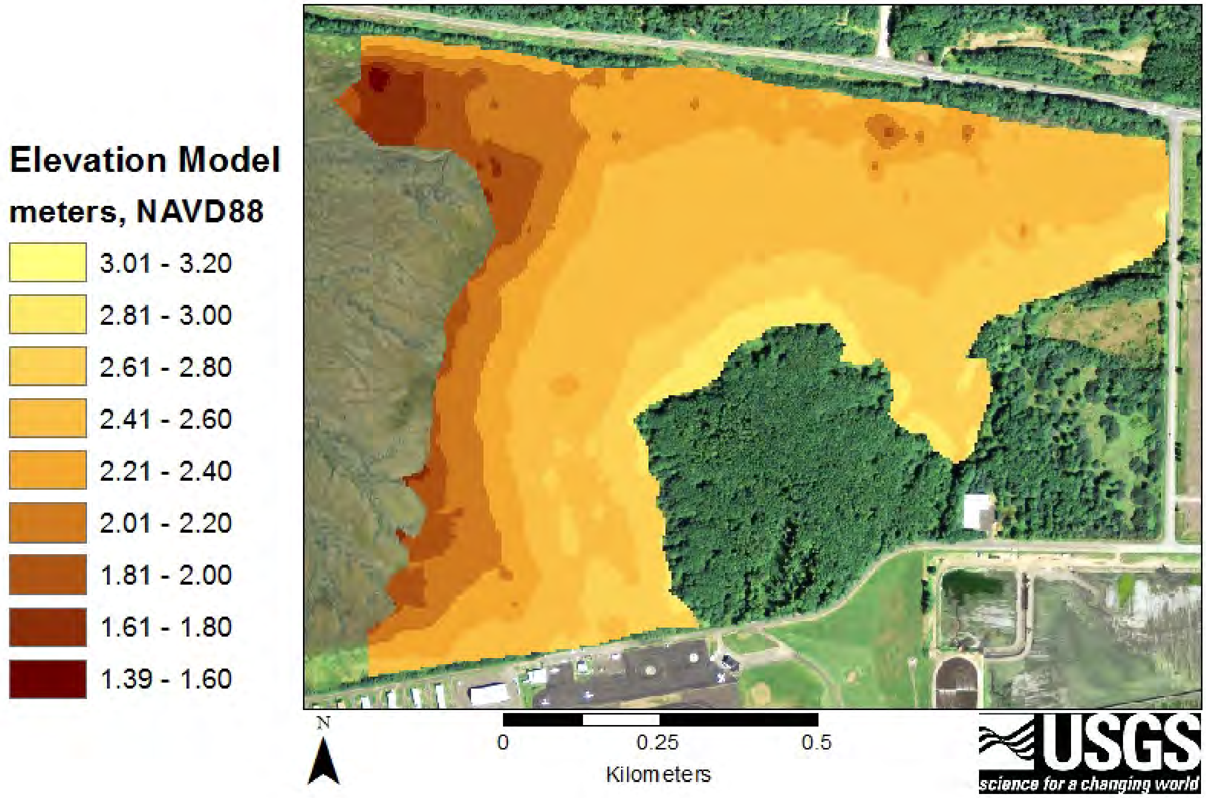

Figure E2. Elevation model (3 m resolution) developed from RTK GPS survey data.

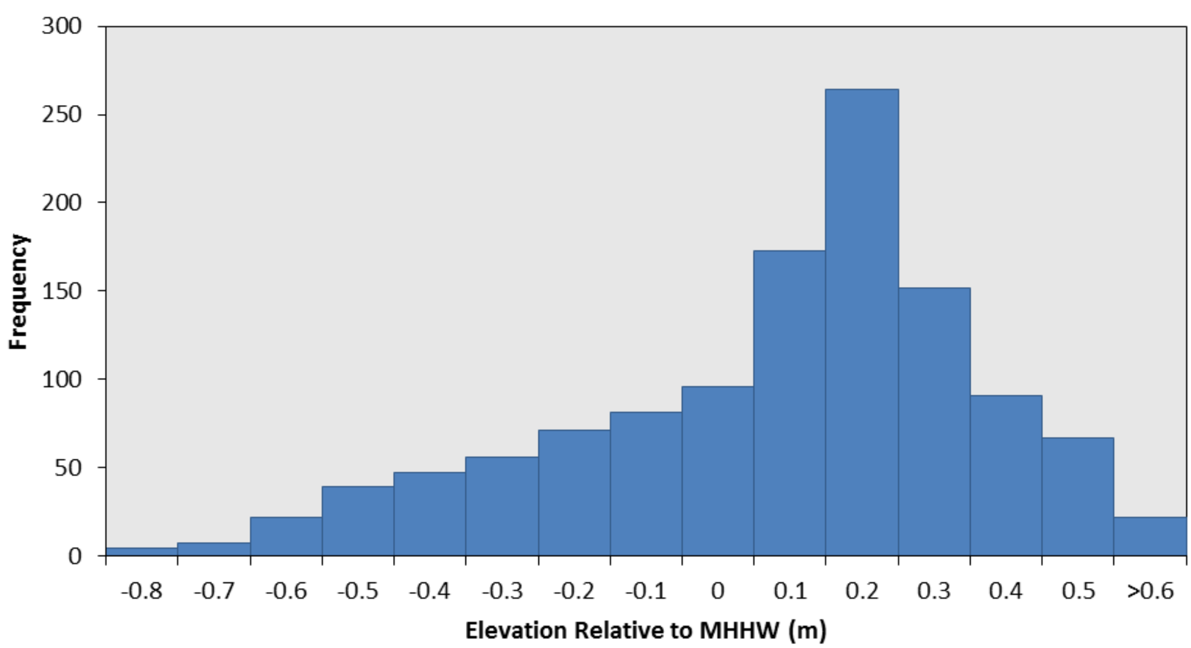

Figure E3. Frequency distribution of marsh surface elevation measurements relative to local mean higher high water (MHHW) at Grays Harbor.

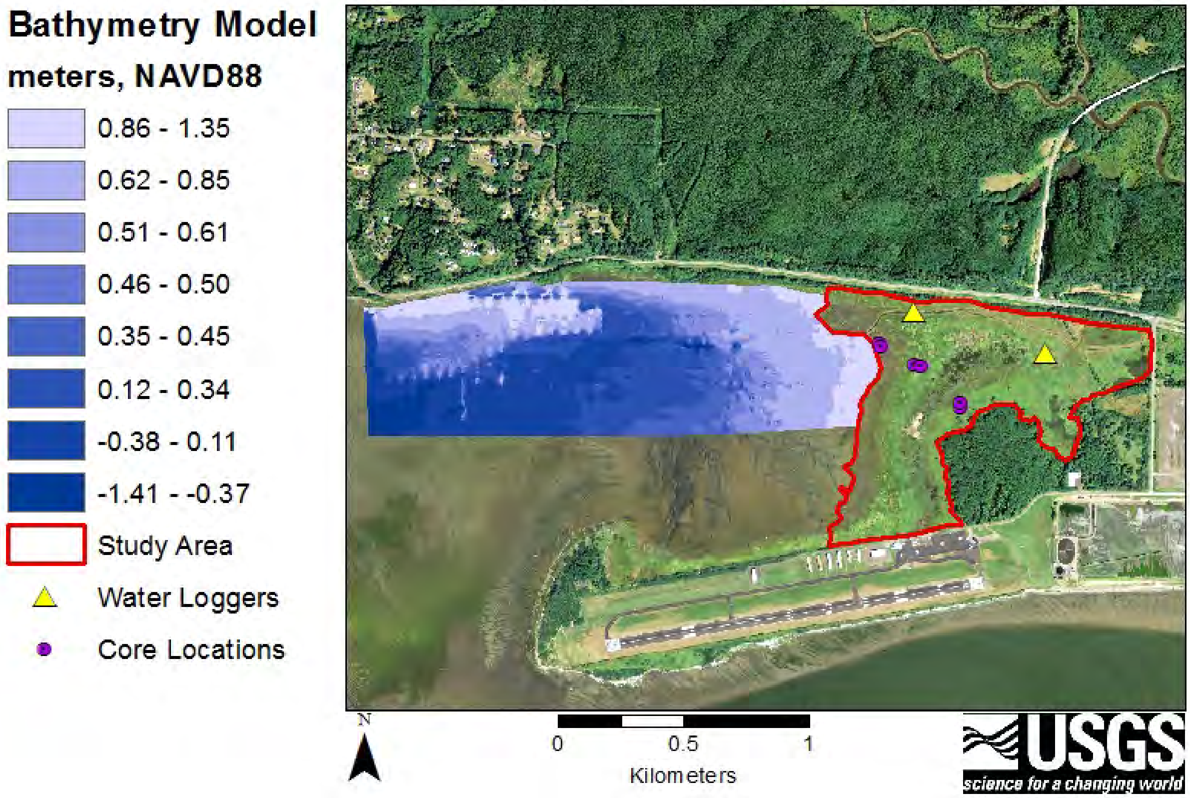

Figure E4. Near-shore bathymetry model at Grays Harbor. Water level logger and core locations are shown within the marsh study site.

Table E1. Frequency of occurrence, percent cover and height of vascular plant species encountered in sample plots at Grays Harbor.

Species	Species characteristics	Freq (%)	Mean cover (%)	Mean height (cm)
*Carex spp.**	Native perennial sedge	47.2	34.9	71
Agrostis stolonifera	Non-native perennial grass	39.5	18.5	47
Triglochin maritima	Native perennial forb	35.8	11.6	47
Potentilla anserina	Native ann-perennial forb	25.5	9.8	44
Sarcocornia perennis	Native perennial forb	20.3	10.2	26
Distichlis spicata	Native perennial grass	15.5	8.2	39
Deschampsia cespitosa	Native perennial grass	10.3	5.4	68
Vicia gigantea	Native perennial legume	7.0	2.6	49
Oenanthe sarmentosa	Native perennial forb	6.6	3.5	74
Juncus balticus	Native perennial rush	5.9	3.9	25
Bolboschoenus maritimus	Native perennial sedge	5.5	2.5	84
Typha latifolia	Native perennial forb	3.7	1.8	166
Holcus lanatus	Non-native ann-perennial forb	1.8	0.6	39
Plantago maritima	Native perennial forb	1.1	0.7	31
Galium trifidum	Native ann-perennial forb	1.1	0.2	41
Phalaris arundinacea	Non-native perennial grass	0.7	0.7	103
Stellaria humifusa	Native perennial forb	0.7	0.1	52
Poaceae sp.	Grass	0.4	0.3	41
Atriplex prostrata	Non-native annual forb	0.4	0.0	29
Hordeum brachyantherum	Native perennial grass	0.4	0.0	30
Festuca sp.	Grass	0.4	0.0	72

* Includes mostly *C. lyngbyei*, but perhaps also instances of *C. obnupta*.

Table E2. Mean percent cover of dominant plant species by marsh zone at Grays Harbor. Zones were defined by degree of flooding by high tides.

[AgrSto = *Agrostis stolonifera*; Carex = *C. lyngbyei*, but perhaps also instances of *C. obnupta*; DesCes = *Deschampsia cespitosa*; DisSpi = *Distichilis spicata*; OenSar = *Oenanthe sarmentosa*; PotAns = *Potentilla anserina*; SarPer = *Sarcocornia perennis*; TriMar = *Triglochin maritima*; VicGig = *Vicia gigantea*.]

Marsh zone	% high tides reaching zone	MHHW range (m)	Sample size	Mean cover of top four dominant plants (%)
Transition	0.14-3	0.884 to 0.459	9	PotAns (34), VicGig (31), Carex (28), OenSar (9)
High	3-25	0.458 to 0.021	164	Carex (37), AgrSto (22), PotAns (14), TriMar (10)
Middle	25-50	0.020 to -0.225	47	Carex (54), AgrSto (28), DesCes (12), DisSpi (9)
Low	>50	-0.226 to -0.791	51	SarPer (41), TriMar (24), DesCes (18), Carex (12)

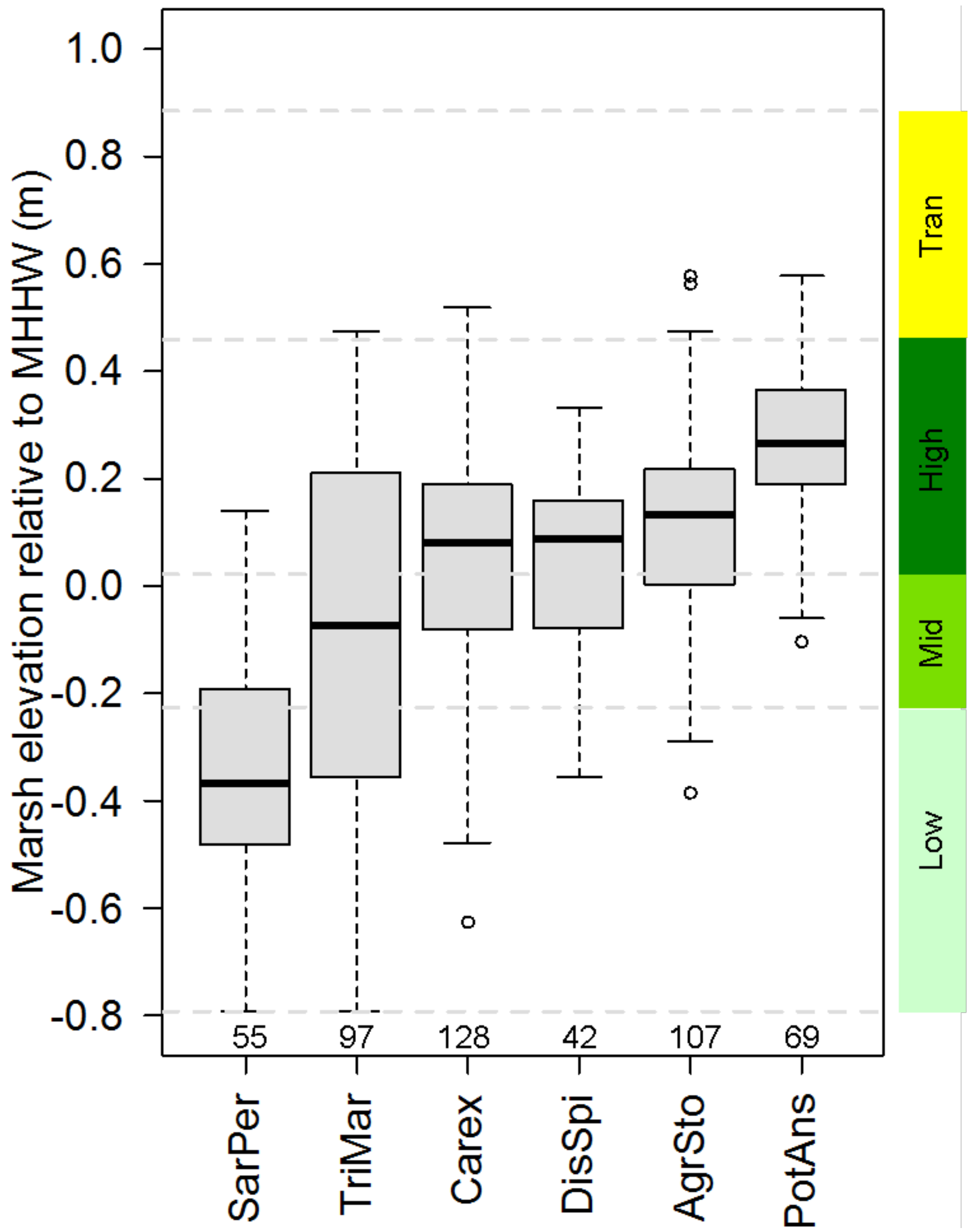

Figure E5. Elevation distribution of the six most common vascular plant species at Grays Harbor. The black horizontal bars show the median elevation at which the species occurs; shaded boxes indicate the interquartile range; upper and lower whiskers encompass points no greater than 1.5x the length of the shaded box; and open circles indicate outliers. The number of plots in which the species occurred is indicated above the species codes (out of a total of 271 plots). The range of marsh elevation zones (low, middle, and high marsh) are illustrated at right. SarPer = *Sarcocornia perennis*; TriMar = *Triglochin maritima*, Carex = *Carex* spp. (mostly *C. lyngbyei*, but including *C. obnupta*); DisSpi = *Distichlis spicata*, AgrSto = *Agrostis stolonifera*; PotAns = *Potentilla anserina*.

Table E3. Location of water level loggers and deep sediment cores (UTM coordinates).

	Northing (m)	Easting (m)
Water level loggers	429762	5203420
	429239	5203585
Deep core locations	429103	5203466
	429244	5203380
	429427	5203208

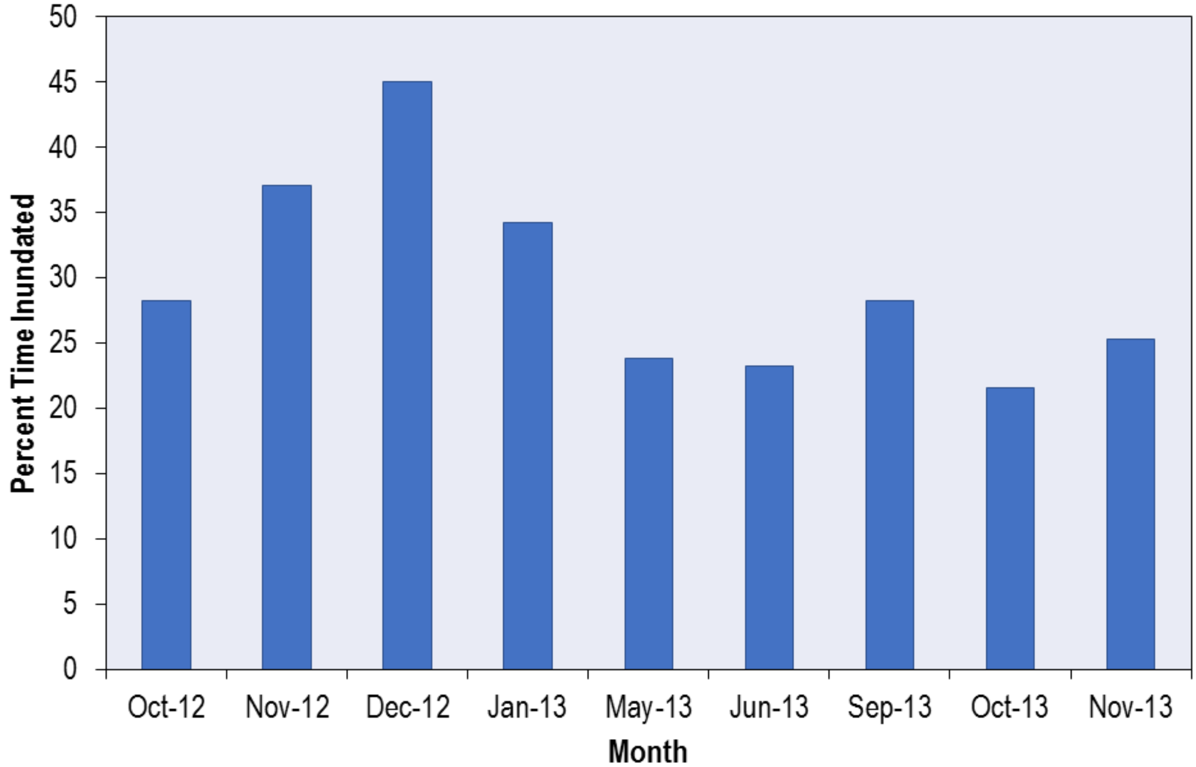

Figure E6. Average monthly inundation of the study site based on an average marsh elevation. Water levels were determined with a water level logger deployed at 1.01 m (NAVD88).

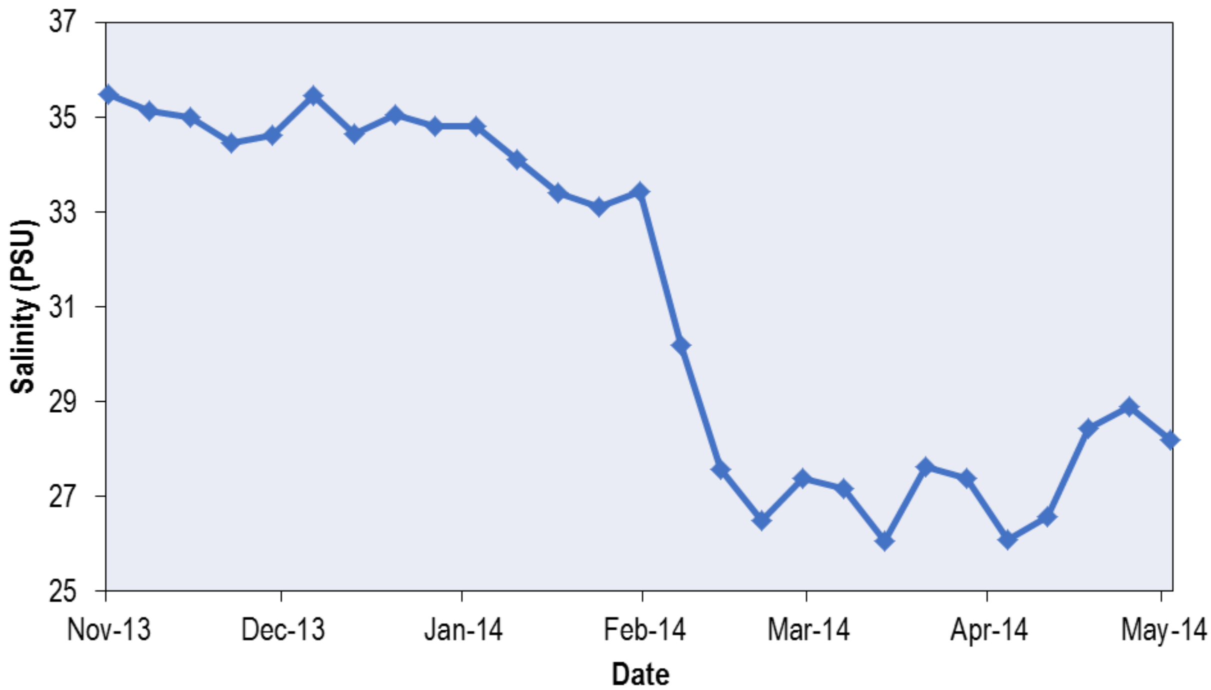

Figure E7. Average weekly maximum salinity from November 2013 – May 2014 at Grays Harbor. Seawater is approximately 35 PSU.

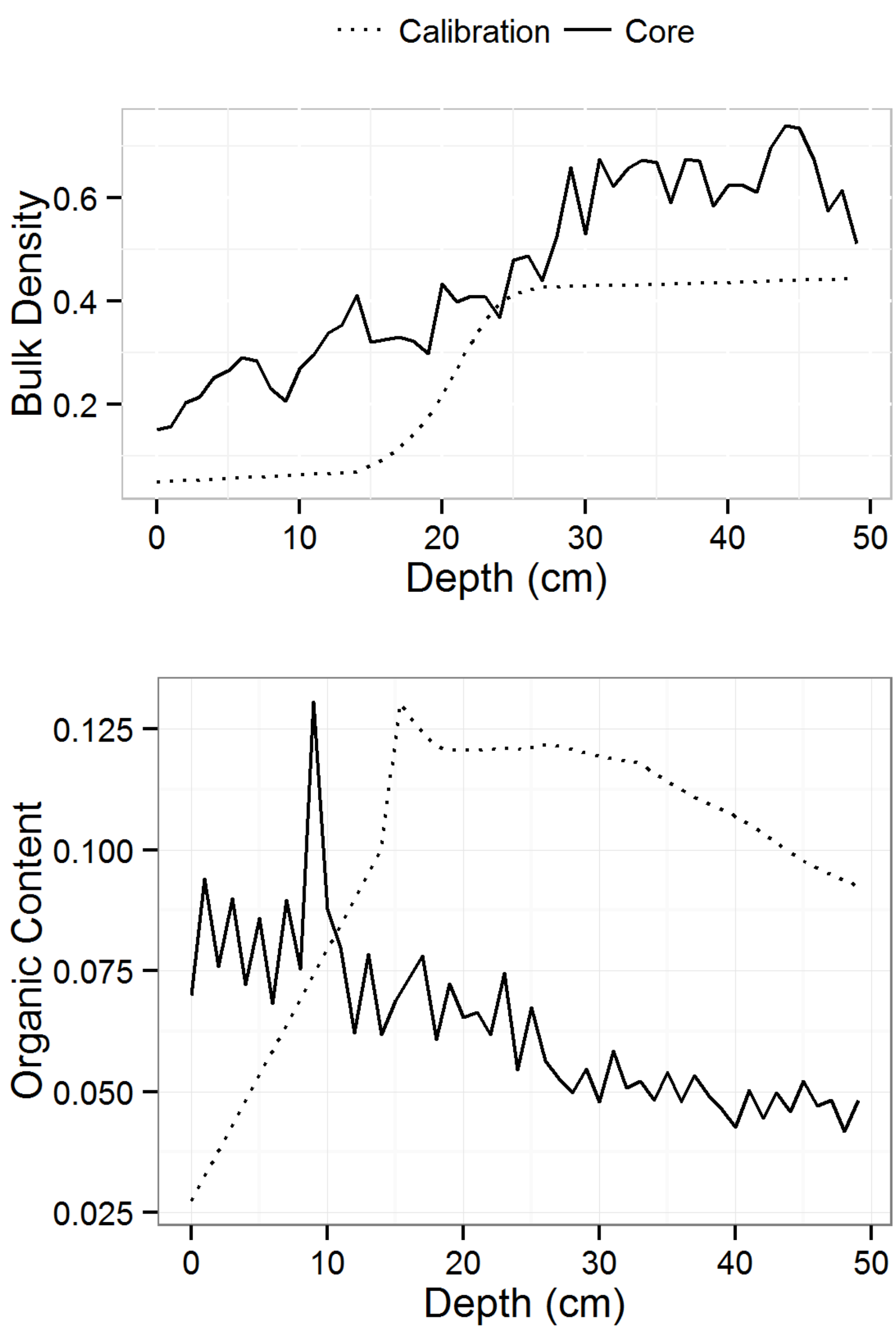

Figure E8. Deep core calibration of the WARMER model using depth profiles of (a) sediment bulk density (g cm^{-3}) and (b) sediment organic matter content (%).

Table E4. Model input parameters for Grays Harbor. Sediment accumulation rate is reported at the elevation of MSL. NDVI is the Normalized Difference Vegetation Index and NAIP is the National Agriculture Inventory Program.

Model parameter	Value	Source
Sediment accumulation rate (g cm^{-2} yr^{-1})	1.67	Core calibration
Elevation of peak biomass (cm, MSL)	159	NDVI from NAIP
Minimum elevation of vegetation (cm, MSL)	11	Field surveys
Max. aboveground organic accumulation (g cm^{-2} yr^{-1})	0.0677	Core calibration
Root-to-shoot ratio	1.95	C. Janousek, unpub data
Porosity surface (%)	98	Core
Porosity depth (%)	81	Core
Refractory carbon (%)	52.5	Core
Maximum astronomical tide (cm, MSL)	200	CERCC water logger
Historic sea-level rise (mm yr^{-1})	1.05	Westport tide gauge (NOAA, 9441102)
Organic matter density (g cm^{-3})	1.14	DeLaune 1983
Mineral density (g cm^{-3})	2.61	DeLaune 1983

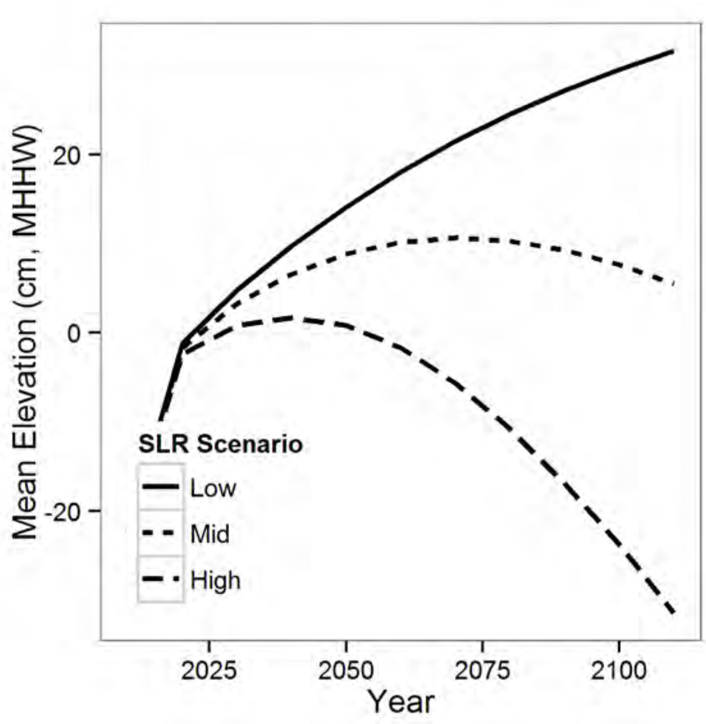

Figure E9. WARMER model projections for the change in average marsh elevation (relative to MHHW) at Grays Harbor from 2010 to 2110 under low, mid, and high NRC sea-level rise (SLR) scenarios.

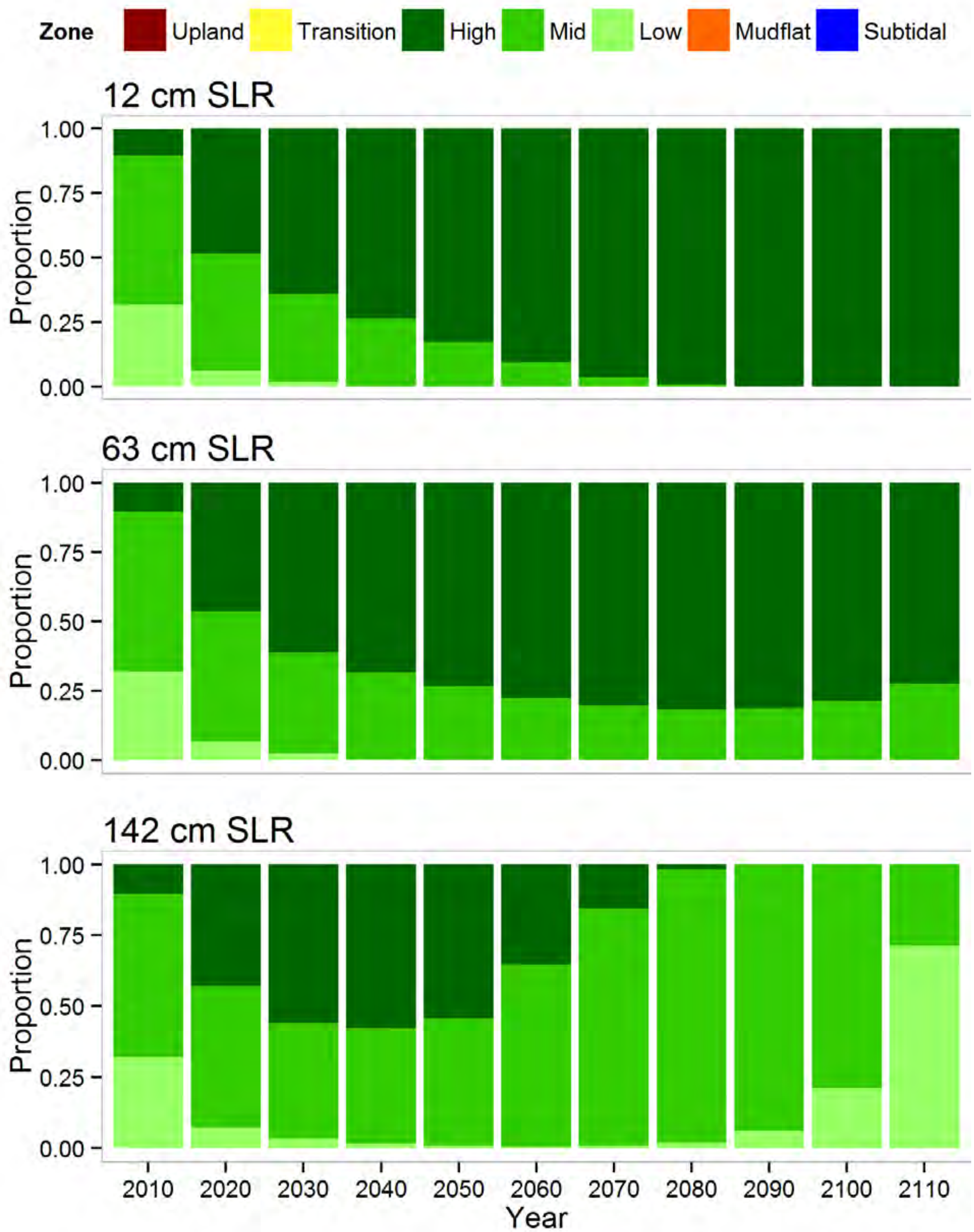

Figure E10. Model projections for change in the relative proportion of upland, transitional, high, mid, and low marsh habitat, and mudflat under low (12 cm), mid (63 cm), and high (142 cm) NRC sea-level rise scenarios from 2010 to 2110.

Table E5. Model projections for change in the percentage of marsh elevation zones for three NRC sea-level rise scenarios between 2010, 2050, and 2110.

	Low SLR (12 cm)			Mid SLR (63 cm)			High SLR (142 cm)		
	2010	2050	2110	2010	2050	2110	2010	2050	2110
Upland	0	0	0	0	0	0	0	0	0
Transition	0	0	0	0	0	0	0	0	0
High	10	83	100	10	73	72	10	54	0
Mid	58	17	0	58	27	28	58	45	29
Low	32	0	0	32	0	0	32	1	71
Mudflat	0	0	0	0	0	0	0	0	0
Subtidal	0	0	0	0	0	0	0	0	0

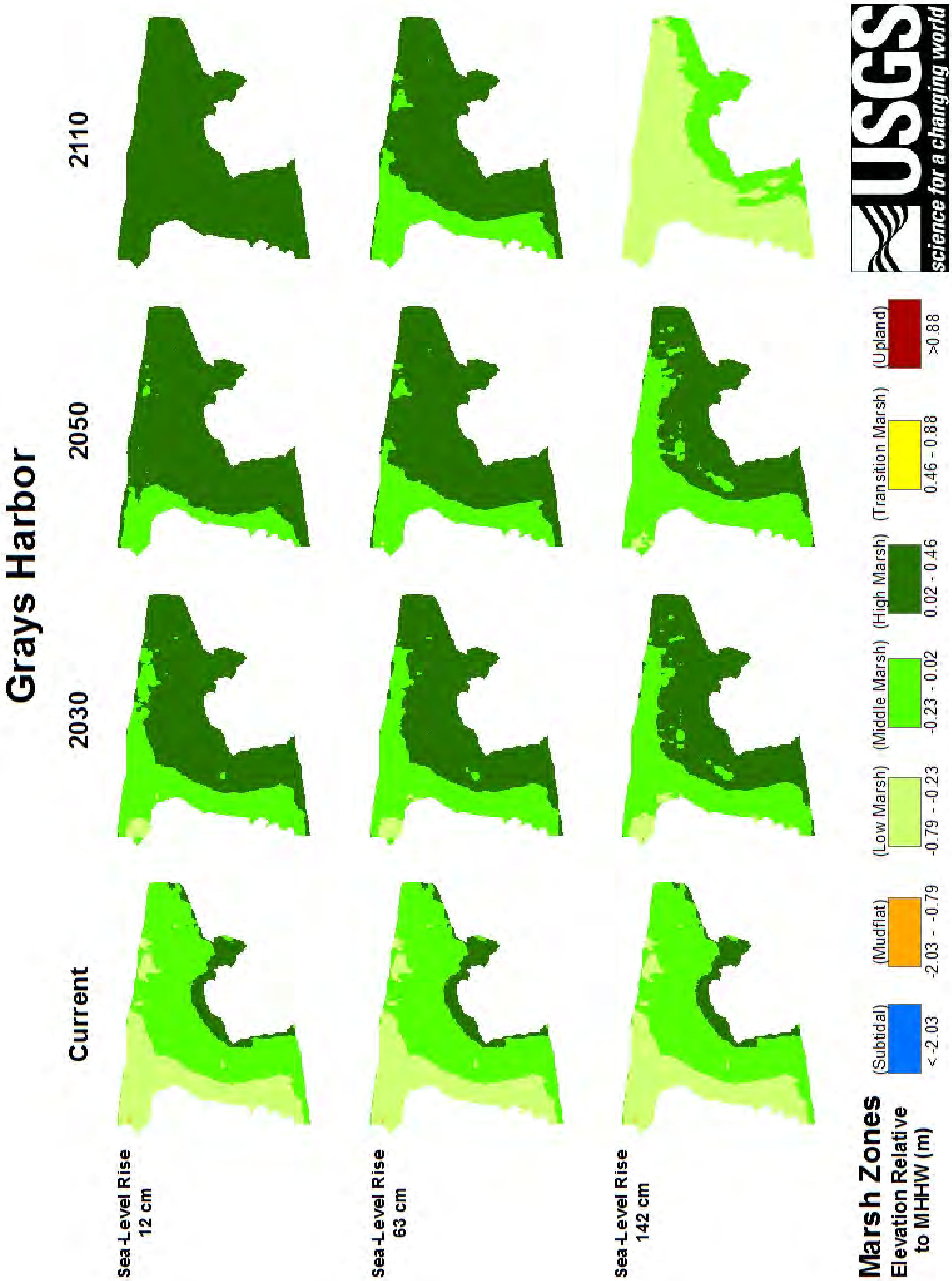

Figure E11. Projected habitat distribution at Grays Harbor for 2030, 2050 and 2110 with the WARMER model under three NRC sea-level rise scenarios.

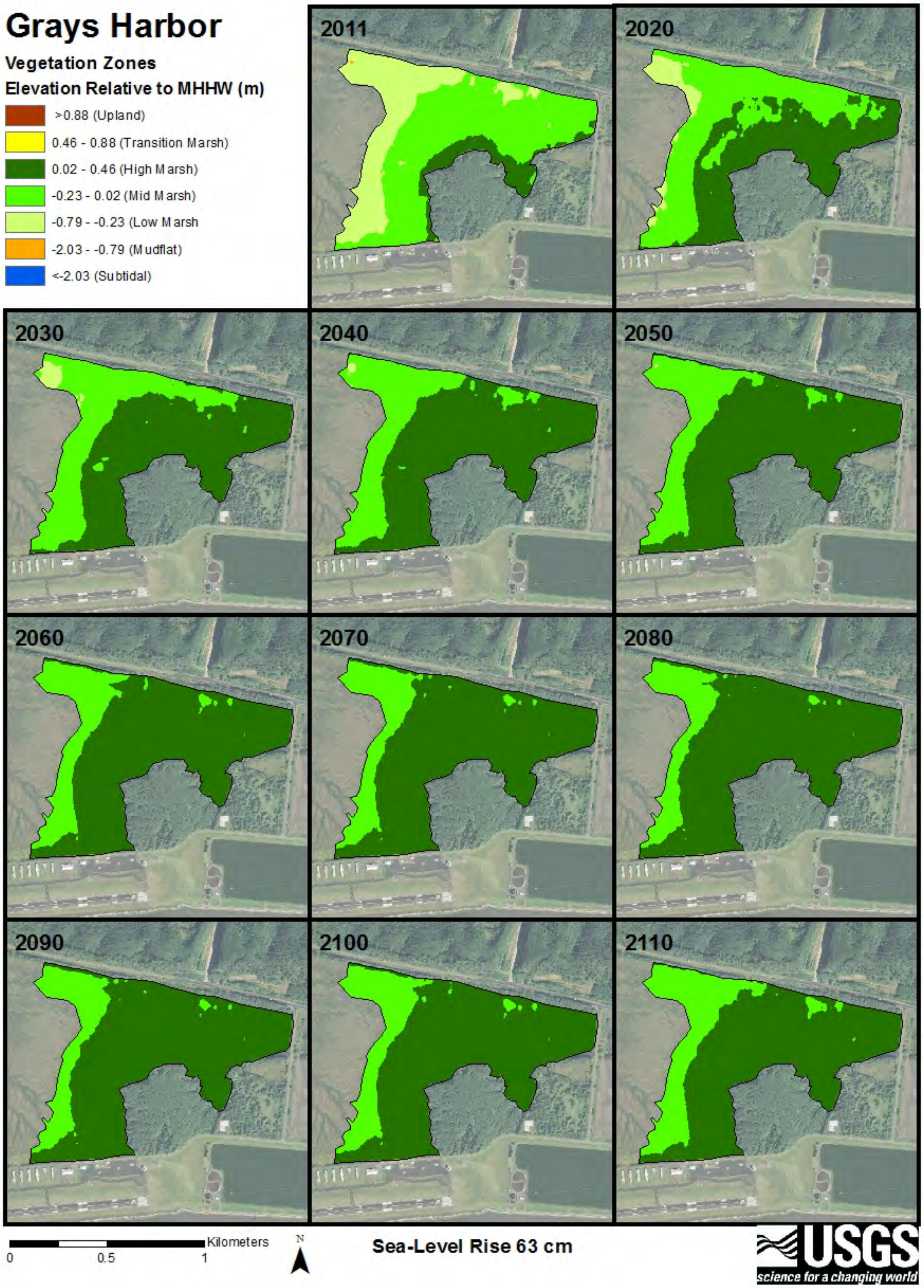

Figure E12. Projected changes in Grays Harbor elevation zones under the mid NRC sea-level rise scenario (63 cm).

Appendix F. Site Specific Details for Willapa, Tartlatt Slough, Willapa Bay National Wildlife Refuge, Pacific County, Washington

Photo: K. Powelson, USGS

Summary:

- *Study site size*: 74.8 hectares
- *Location*: 46° 22' 32"N latitude, 124° 00' 21"W longitude.
- *Site management*: U.S. Fish and Wildlife Service (Willapa Bay National Wildlife Refuge)
- *Site vegetation and elevation survey*: 12-17 September 2012
- *Sample size*: 1230 (elevation data points), 276 (vegetation quadrats)
- *Marsh elevation model*: Most of the study site was above MHHW, with 56% of elevation data points occurring above MHHW.
- *Plant community composition*: *Distichlis spicata* was the most frequently occurring species. *Triglochin maritima* and *Sarcocornia perennis* were also very common.
- *Bathymetric surveys*: 84.1 ha of nearshore habitat were mapped adjacent to the study area.

- *Soil characteristics*: The accumulation rates used in WARMER for this site were: sediment accumulation rate = 1.53 g cm^{-2} yr^{-1}; organic matter accumulation rate = 0.024 g cm^{-2} yr^{-1}; net accretion = 1.554 cm yr^{-1}.
- *Water inundation and salinity monitoring*: water level (October 2012 – July 2013); conductivity (August 2013 – December 2013). Water level and conductivity monitoring is ongoing.
- The maximum recorded salinity throughout the study period was 35 PSU.
- *Marsh inundation pattern*: Maximum monthly inundation occurred during January 2013; minimum monthly inundation occurred during October 2012 and July 2013.
- *Calculated tidal datums*: MHHW is at 2.24 m NAVD88; MHW is at 2.01 m NAVD88.
- *Sea-level rise marsh response modeling*: Under the NRC low SLR projection (12 cm), Willapa Bay gains high and middle marsh habitat and low marsh is lost by 2060. Under the NRC's mid SLR projection (63 cm), the site is projected to have a temporary expansion of mid marsh, followed by loss of high marsh by 2110. Under the NRC's high SLR projection (142 cm), high marsh is lost by 2080, mid marsh is lost by 2090, and the site is projected to consist primarily of low marsh with some mudflat by 2110.

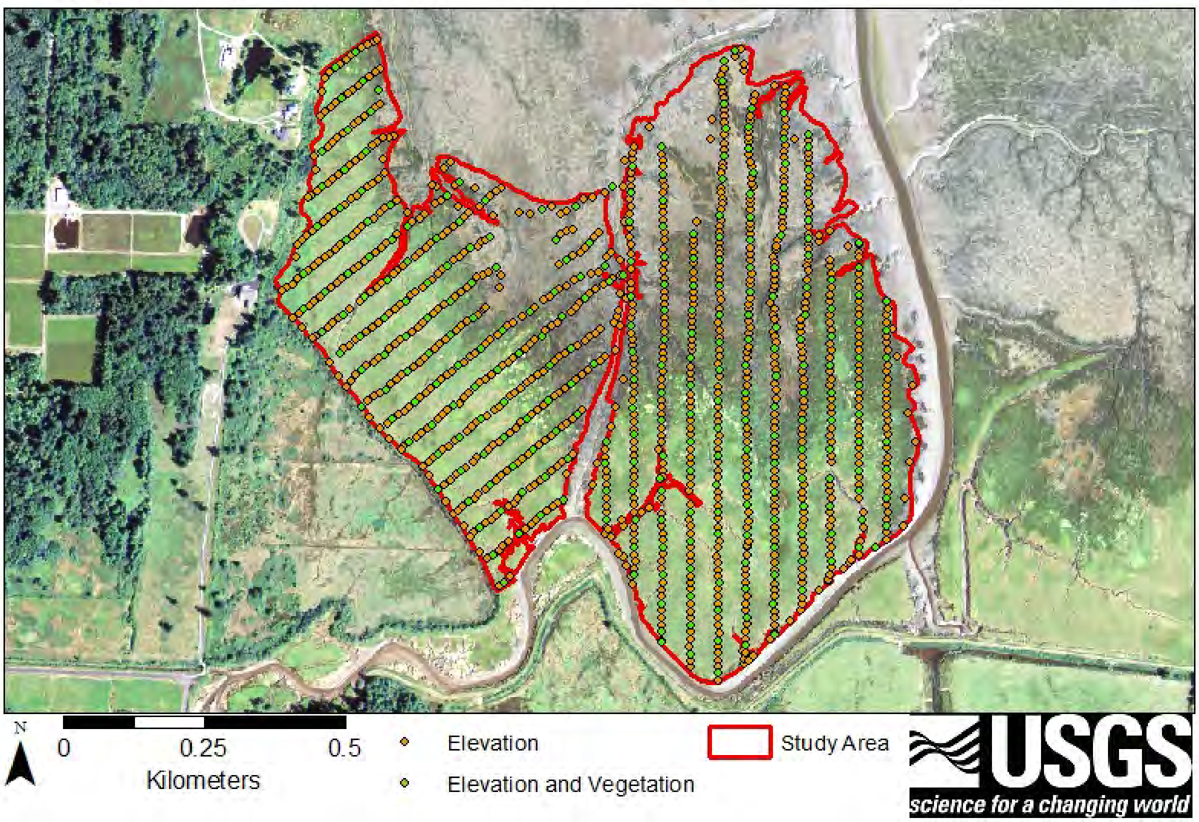

Figure F1. Distribution of elevation and vegetation survey points at Willapa.

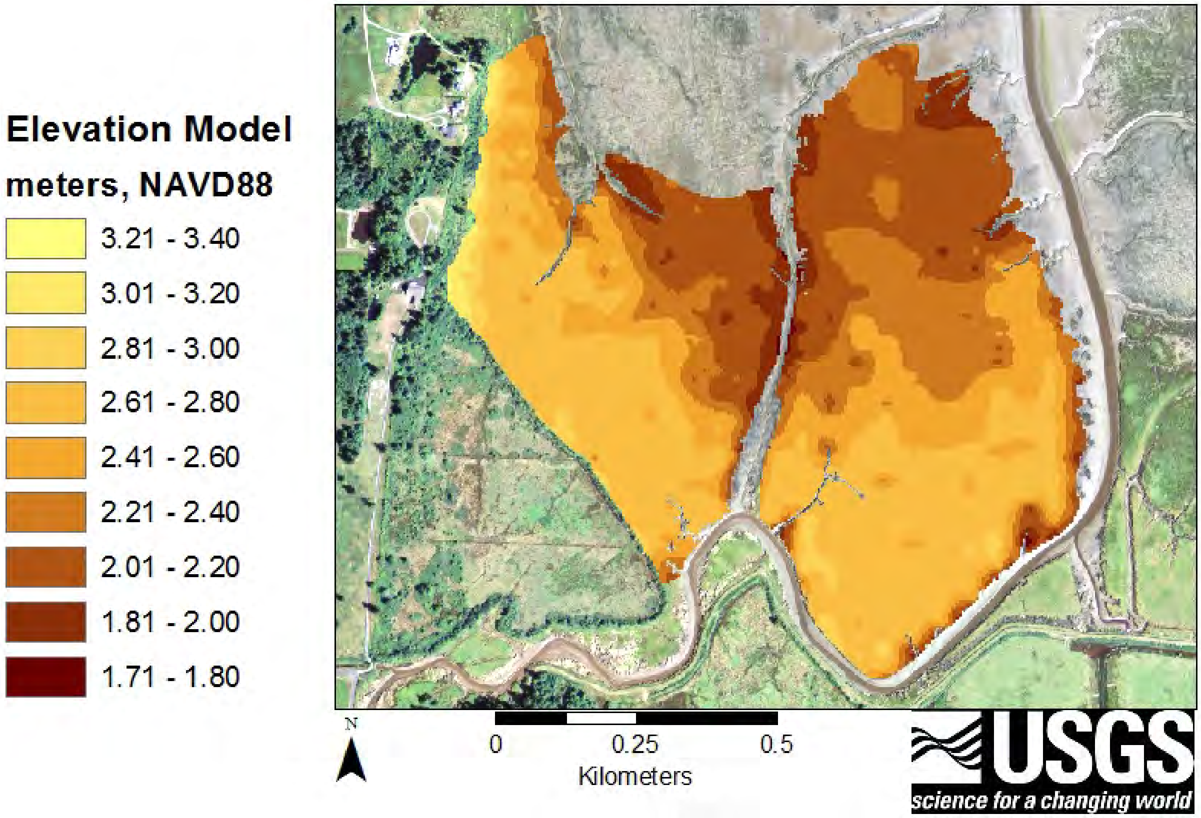

Figure F2. Elevation model (3 m resolution) developed from RTK GPS survey data.

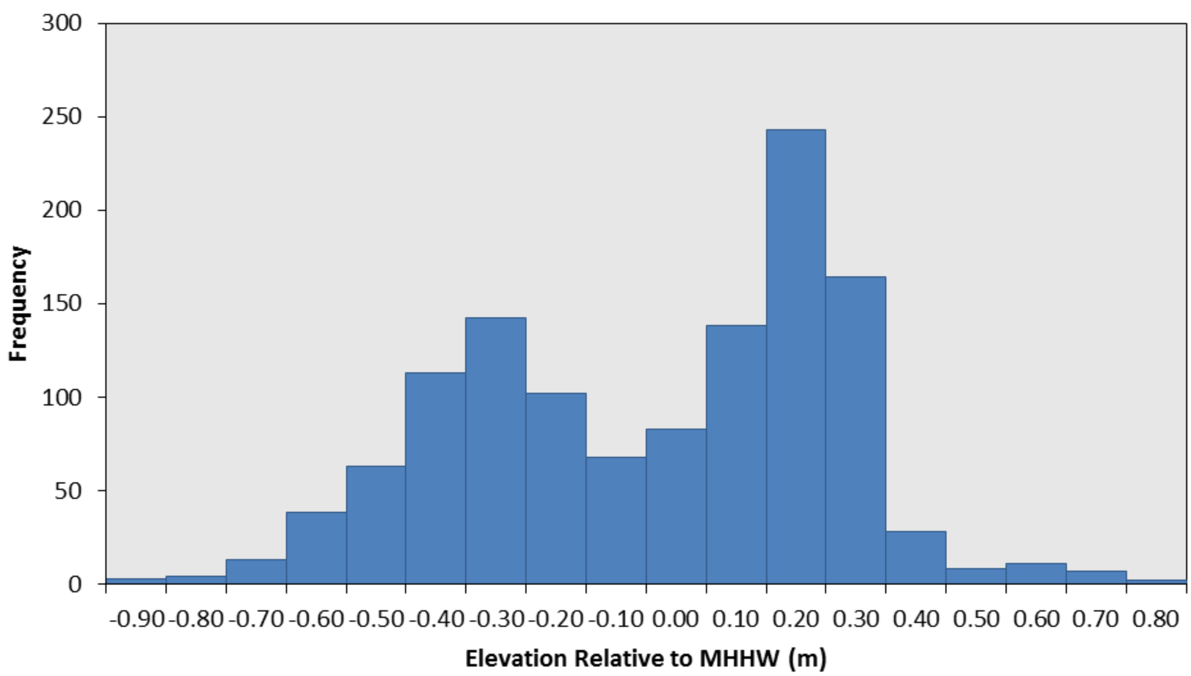

Figure F3. Frequency distribution of marsh surface elevation measurements relative to local mean higher high water (MHHW) at Willapa.

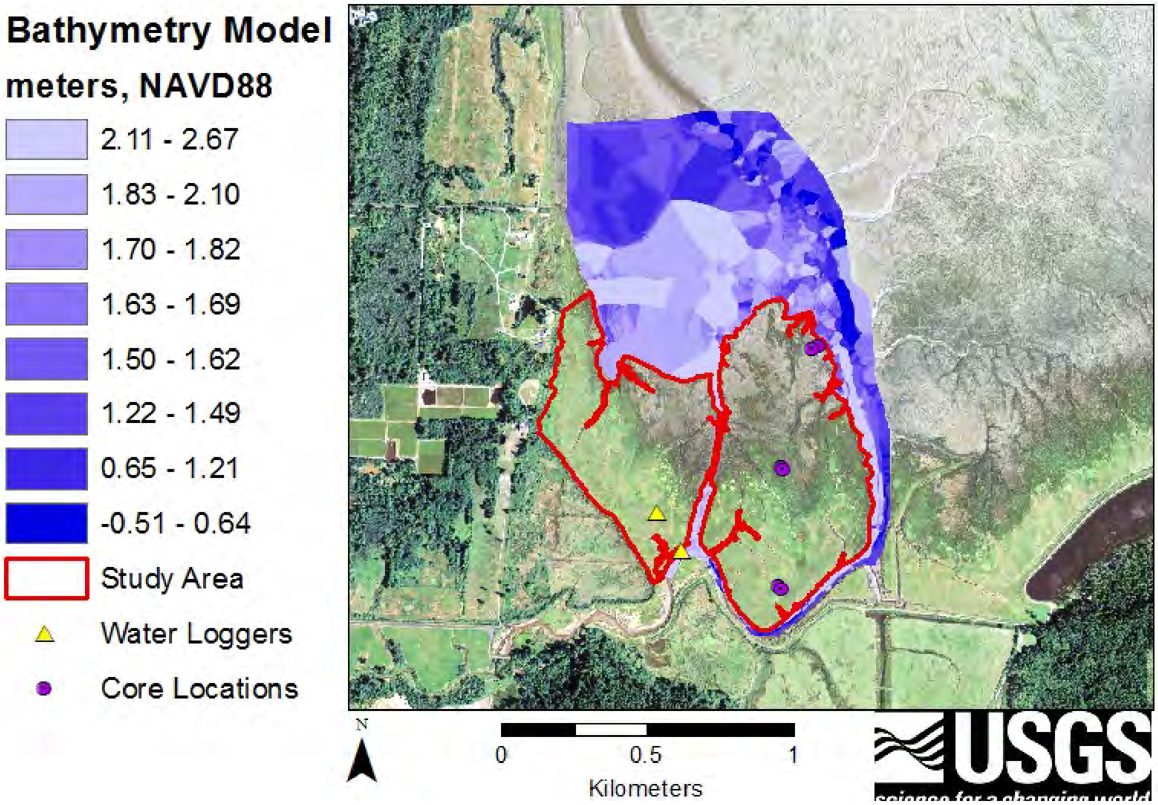

Figure F4. Near-shore bathymetry model for Willapa. Water level logger and core locations are shown within the marsh study site.

Table F1. Frequency of occurrence, percent cover, and height of vascular plant species encountered in sample plots at Willapa. NA = not measured.

Species	Species Characteristic	Freq (%)	Mean cover (%)	Mean height (cm)
Distichlis spicata	Native perennial grass	62.3	37.8	35
Triglochin maritima	Native perennial forb	47.8	13.4	38
Sarcocornia perennis	Native perennial forb	41.7	14.1	23
Deschampsia cespitosa	Native perennial grass	40.9	17.4	61
Carex lyngbyei	Native perennial sedge	34.1	14.4	59
Jaumea carnosa	Native perennial forb	12.3	3.6	24
Stellaria humifusa	Native perennial forb	10.5	1.0	30
Spergularia canadensis	Native annual forb	7.2	0.3	6
Agrostis stolonifera	Non-native perennial grass	6.9	3.0	36
Atriplex prostrata	Non-native annual forb	5.8	0.2	28
Hordeum brachyantherum	Native perennial grass	5.8	0.3	58
Potentilla anserina	Native ann-perennial forb	5.1	1.7	37
Juncus balticus	Native perennial rush	1.8	1.4	52
Cotula coronopifolia	Non-native perennial forb	1.1	0.1	7
Glaux maritima	Native perennial forb	0.7	0.0	15
Cuscuta pacifica	Native ann-perennial parasite	0.4	NA	NA
Hordeum jubatum	Native ann-perennial grass	0.4	0.0	68
Plantago maritima	Native perennial forb	0.4	0.0	15
Symphyotrichum subspicatum	Native perennial forb	0.4	0.0	59

Table F2. Mean percent cover of dominant plant species by marsh zone at Willapa. Zones were defined by degree of flooding by high tides.

[AgrSto = *Agrostis stolonifera*; CarLyn = *Carex lyngbyei*; DisSpi = *Distichlis spicata*, DesCes = *Deschampsia cespitosa*; SarPer = *Sarcocornia perennis*; TriMar = *Triglochin maritima*.]

Marsh zone	% high tides reaching zone	MHHW range (m)	Sample size	Mean cover of top four dominant plants (%)
Transition	0.14-3	1.162 to 0.603	0	*Insufficient sample size*
High	3-25	0.602 to 0.028	138	DisSpi (55), DesCes (28), CarLyn (18), AgrSto (6)
Middle	25-50	0.027 to -0.296	61	DisSpi (32), SarPer (29), TriMar (22), CarLyn (16)
Low	>50	-0.297 to -0.948	77	TriMar (26), SarPer (19), DisSpi (11), CarLyn (6)

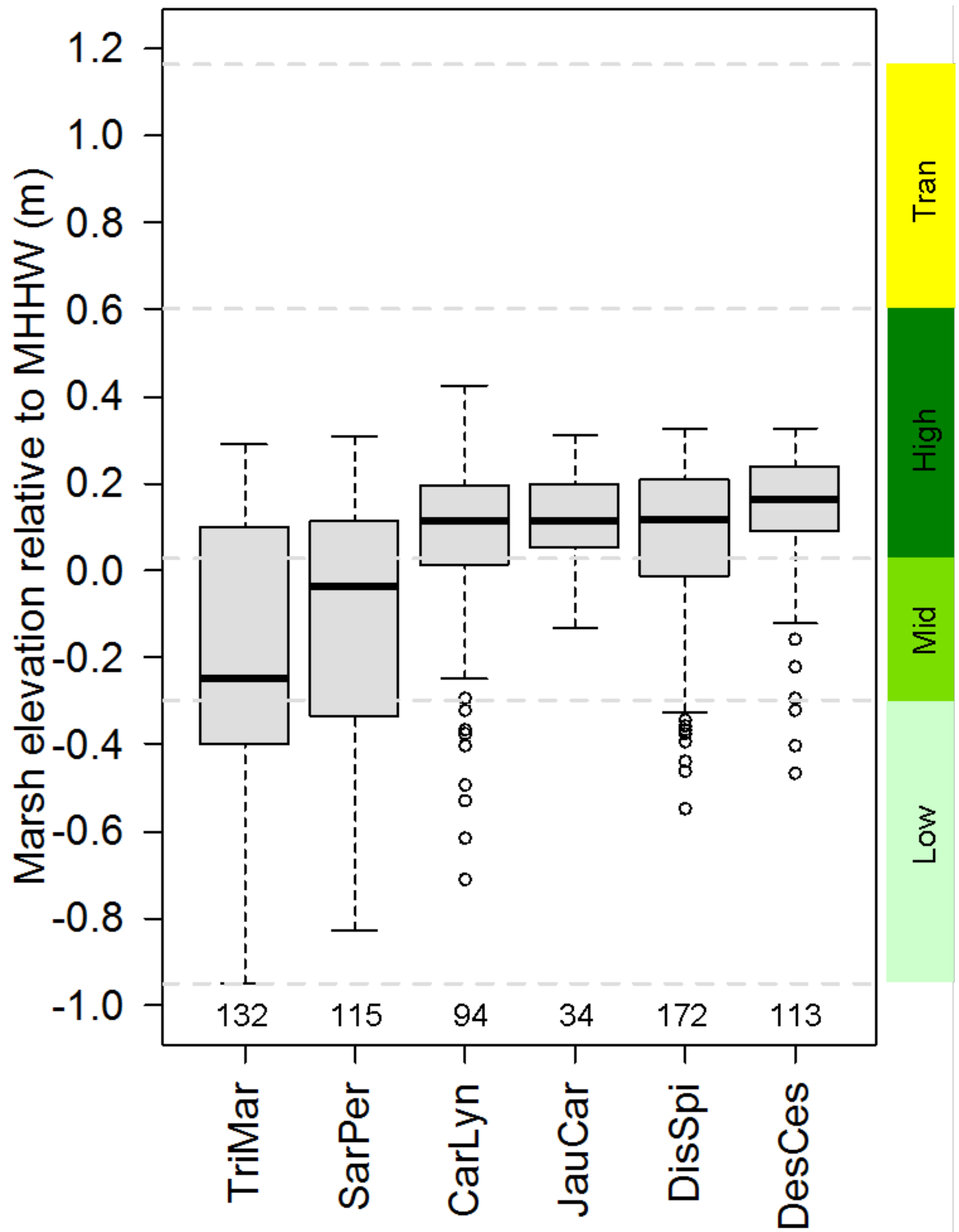

Figure F5. Elevation distribution of the six most common vascular plant species at Willapa. The black horizontal bars show the median elevation at which the species occurs; shaded boxes indicate the interquartile range; upper and lower whiskers encompass points no greater than 1.5x the length of the shaded box; and open circles indicate outliers. The number of plots in which the species occurred is indicated above the species codes (out of a total of 276 plots). Marsh elevation zones (low, middle, and high) are illustrated at right. TriMar = *Triglochin maritima*; SarPer = *Sarcocornia perennis*; CarLyn = *Carex lyngbyei*, JauCar = *Jaumea carnosa*, DisSpi = *Distichlis spicata*; DesCes = *Deschampsia cespitosa*.

Table F3. Location of water level loggers and deep sediment cores (UTM coordinates).

	Northing (m)	Easting (m)
Water level loggers	422302	5135993
	422220	5136127
Deep core locations	422774	5136697
	422645	5136284
	422647	5135865

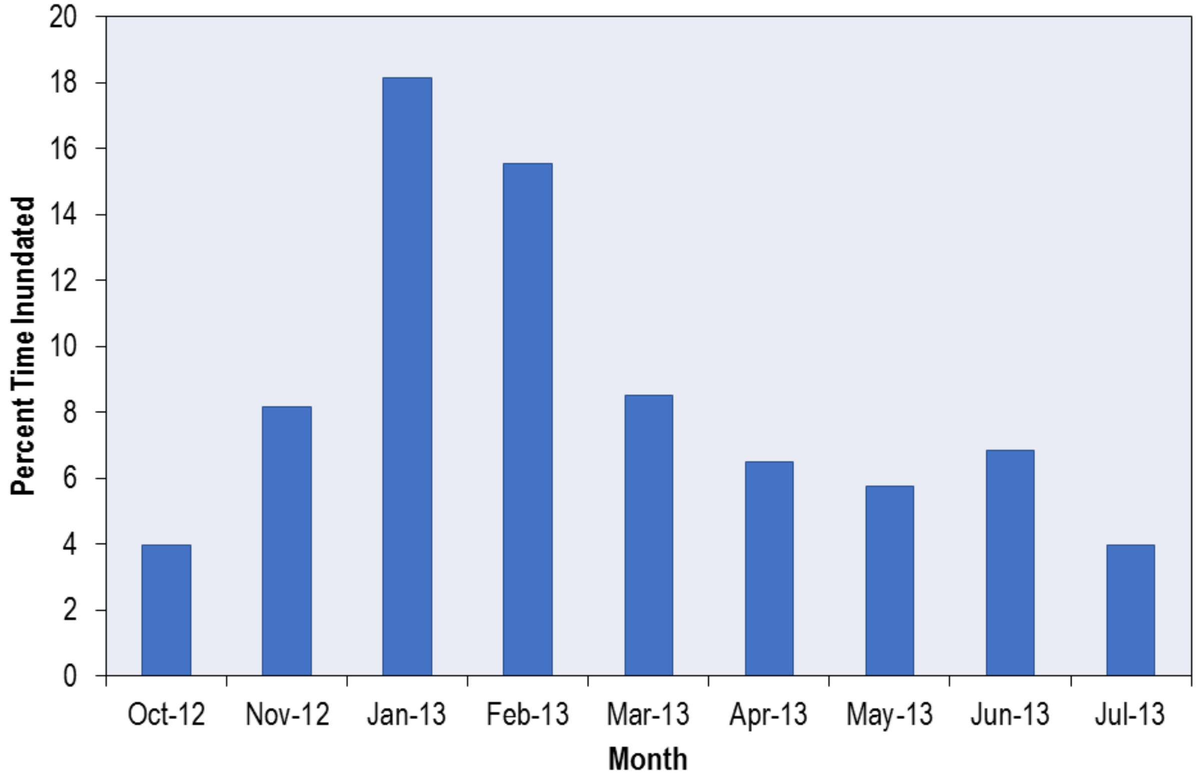

Figure F6. Average monthly inundation of the study site based on an average marsh elevation.

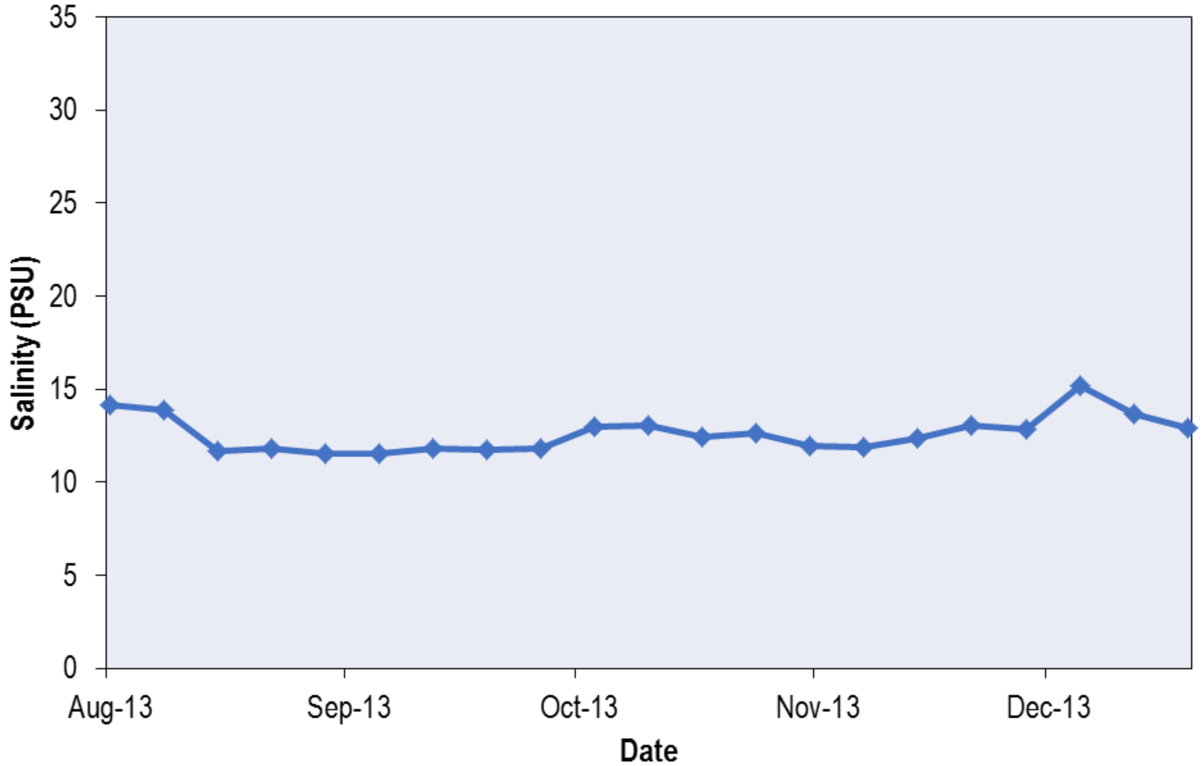

Figure F7. Maximum weekly salinity from August 2013 – December 2013 at Willapa. Seawater is approximately 35 PSU.

a

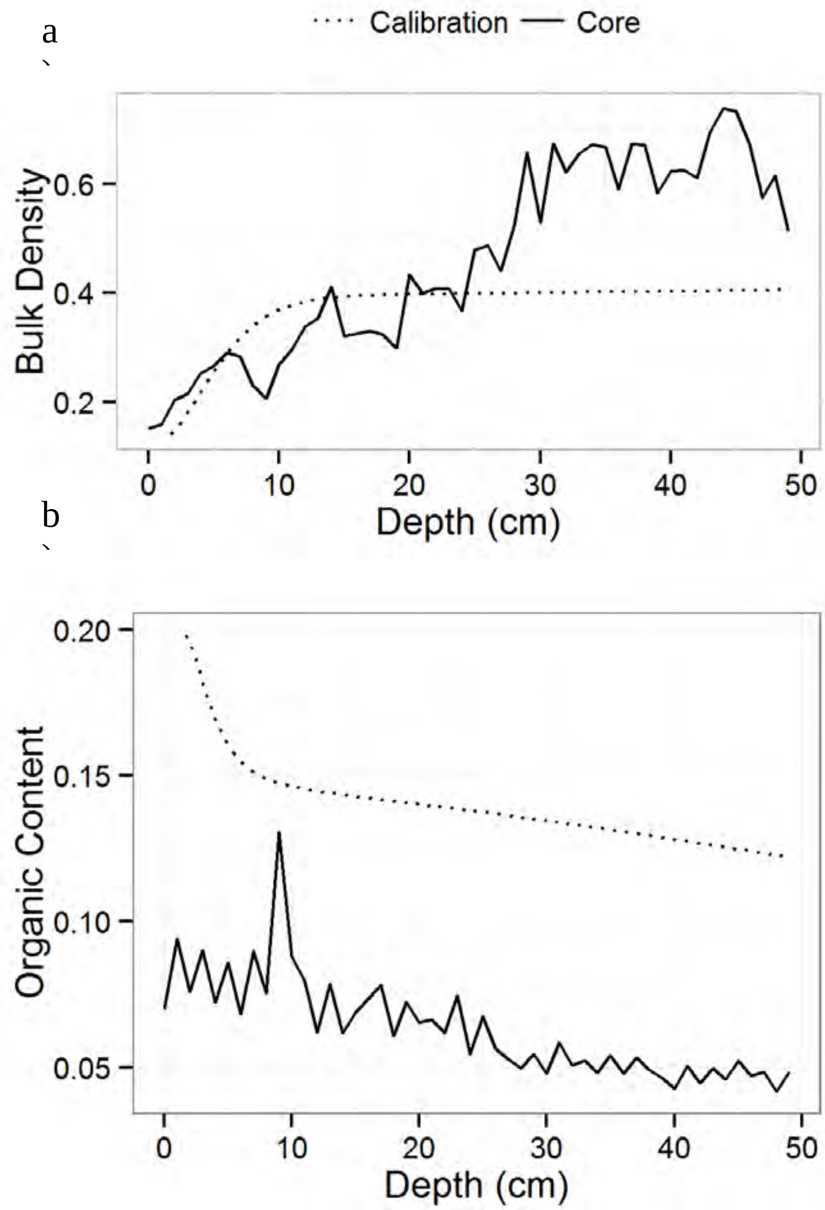

Figure F8. Deep core calibration of the WARMER model using depth profiles of (a) sediment bulk density (g cm^{-3}) and (b) sediment organic matter content (%).

Table F4. Model input parameters for Willapa. Sediment accumulation rate is reported at the elevation of MSL. NDVI is the Normalized Difference Vegetation Index and NAIP is the National Agriculture Inventory Program.

Model parameter	Value	Source
Sediment accumulation rate (g cm^{-2} yr^{-1})	1.10	Core calibration
Elevation of peak biomass (cm, MSL)	163	NDVI from NAIP
Minimum elevation of vegetation (cm, MSL)	40	Field surveys
Max. aboveground organic accumulation (g cm^{-2} yr^{-1})	0.0252	Core calibration
Root-to-shoot ratio	1.95	C. Janousek, unpub data
Porosity surface (%)	92	Core
Porosity depth (%)	75	Core
Refractory carbon (%)	63.4	Core
Maximum astronomical tide (cm, MSL)	232	CERCC water logger
Historic sea-level rise (mm yr^{-1})	1.6	Toke Point tide gauge (NOAA, 9440910)
Organic matter density (g cm^{-3})	1.14	DeLaune 1983
Mineral density (g cm^{-3})	2.61	DeLaune 1983

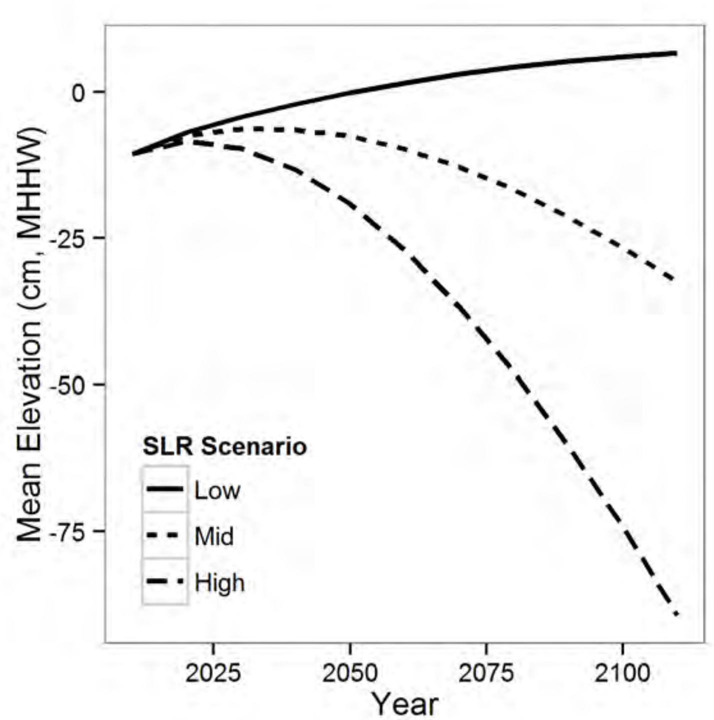

Figure F9. WARMER model projections for the change in average marsh elevation (relative to MHHW) at Willapa from 2010 to 2110 under low, mid, and high NRC sea-level rise (SLR) scenarios.

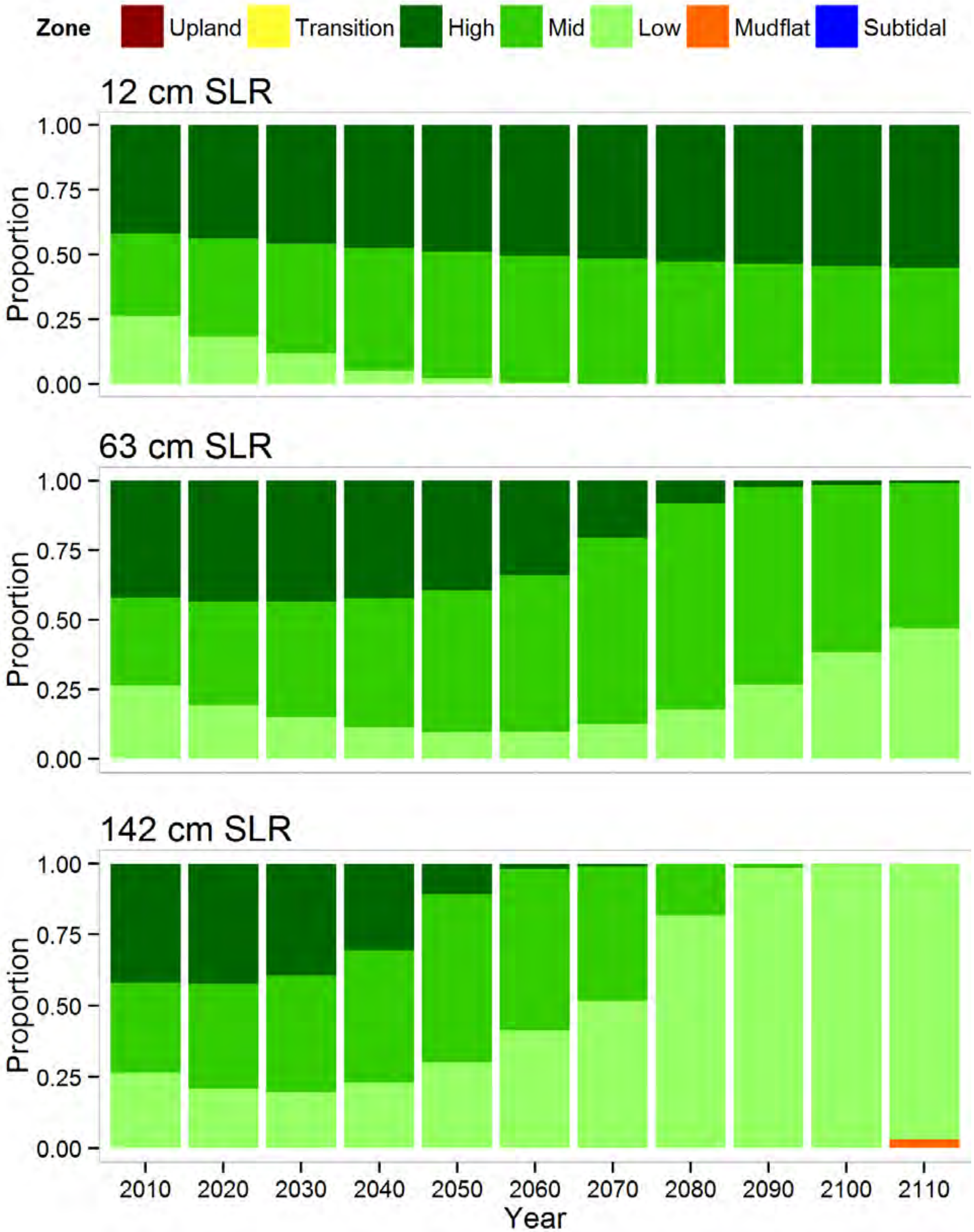

Figure F10. Model projections for change in the relative proportion of upland, transitional, high, mid and low marsh habitat, and mudflat under low (12 cm), mid (63 cm), and high (142 cm) NRC sea-level rise scenarios from 2010 to 2110.

Table F5. Model projections for change in the percentage of marsh elevation zones for three NRC sea-level rise scenarios between 2010, 2050, and 2110.

	Low SLR (12 cm)			Mid SLR (63 cm)			High SLR (142 cm)		
	2010	2050	2110	2010	2050	2110	2010	2050	2110
Upland	0	0	0	0	0	0	0	0	0
Transition	0	0	0	0	0	0	0	0	0
High	42	49	55	42	39	1	42	11	0
Mid	32	49	45	32	51	52	32	59	0
Low	26	2	0	26	10	47	26	30	97
Mudflat	0	0	0	0	0	0	0	0	3
Subtidal	0	0	0	0	0	0	0	0	0

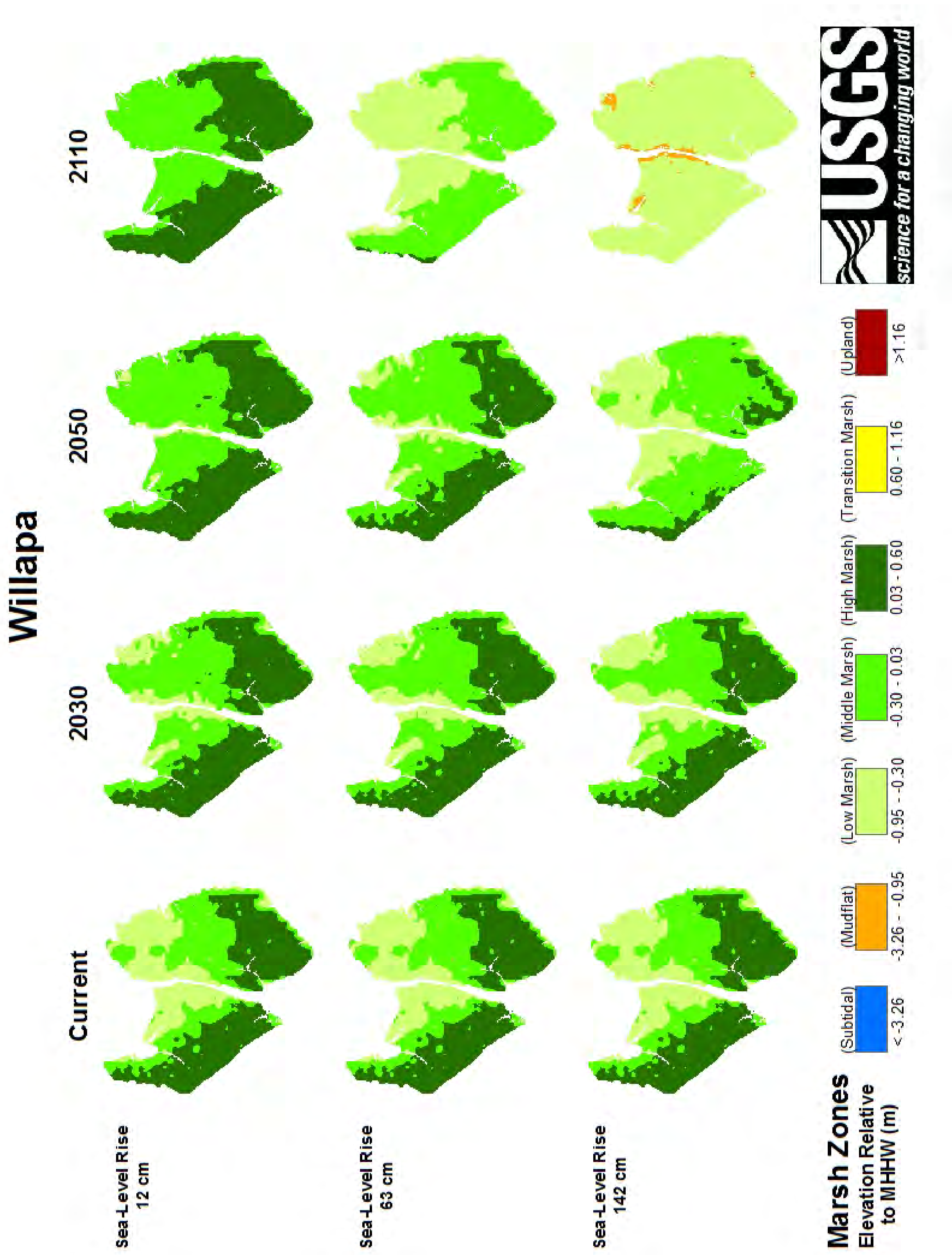

Figure F11. Projected habitat distribution at Willapa for 2030, 2050 and 2110 with the WARMER model under three NRC sea-level rise scenarios.

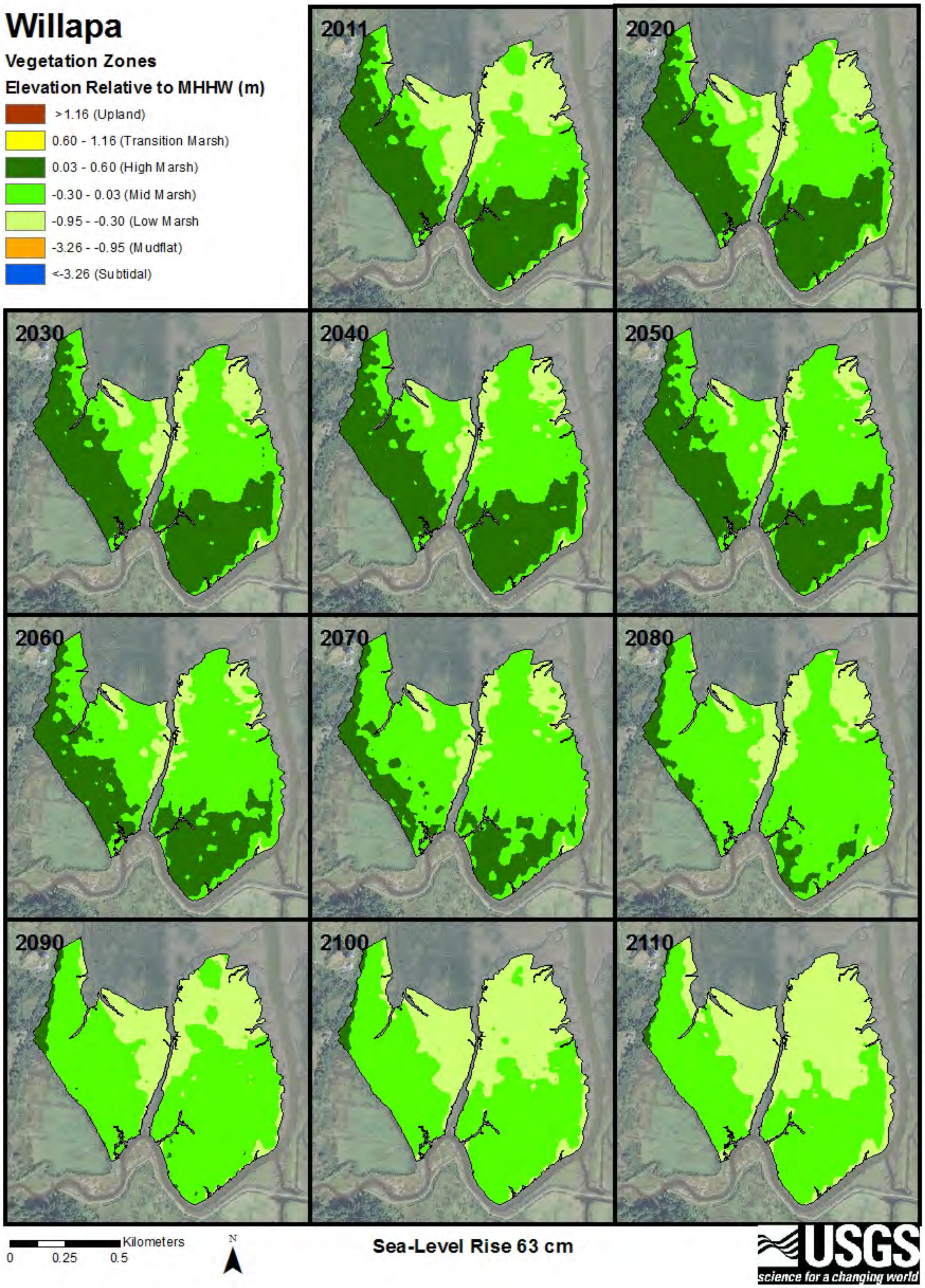

Figure F12. Projected changes in Willapa habitat zones under the mid NRC sea-level rise scenario (63 cm).

Appendix G. Site Specific Details for Siletz, Siletz Bay National Wildlife Refuge, Lincoln County, Oregon

Photo: K Buffington, Oregon State University & USGS

Summary:

- *Study site size*: 69.2 hectares
- *Location*: 44° 53' 41"N latitude, 124° 00' 59"W longitude.
- *Site management*: U.S. Fish and Wildlife Service (Siletz National Wildlife Refuge)
- *Site vegetation and elevation survey*: 25 August – 4 September 2014
- *Sample size*: 1196 (elevation data points), 126 (vegetation quadrats)
- *Marsh elevation model*: Most of the study site was above MHHW, with 79% of elevation data points occurring above MHHW.
- *Plant community composition*: *Agrostis stolonifera* was the most frequently occurring species. *Juncus balticus*, *Potentilla anserina* and *Deschampsia cespitosa* were also common.
- *Bathymetric surveys*: Not conducted

- *Soil characteristics*: The accumulation rates used in WARMER for this site were: sediment accumulation rate = 0.79 g cm^{-2} yr^{-1}; organic matter accumulation rate = 0.0302 g cm^{-2} yr^{-1}; net accretion = 0.8202 cm yr^{-1}.
- *Water inundation and salinity monitoring*: water level (January 2014– August 2014); conductivity (April 2014 – August 2014). Water level and conductivity monitoring is ongoing.
- The maximum recorded salinity throughout the study period was 32 PSU.
- *Marsh inundation pattern*: Maximum monthly inundation occurred during June 2014; minimum monthly inundation during July 2014.
- *Calculated tidal datums*: MHHW is at 2.32 m NAVD88; MHW is at 2.11 m NAVD88.
- *Sea-level rise marsh response modeling*: Under the low NRC SLR projection (12 cm), Siletz becomes dominated by high and transitional marsh by 2080. Under the NRC's mid SLR projection (63 cm), the composition of marsh zones at the site remains relatively unchanged over the coming century. High marsh initially increases slightly in area but then decreases. Under the NRC's high SLR projection (142 cm), there is rapid loss of high marsh between 2050 and 2070, complete loss of mid marsh by 2100, and almost complete conversion to mudflat by 2110.

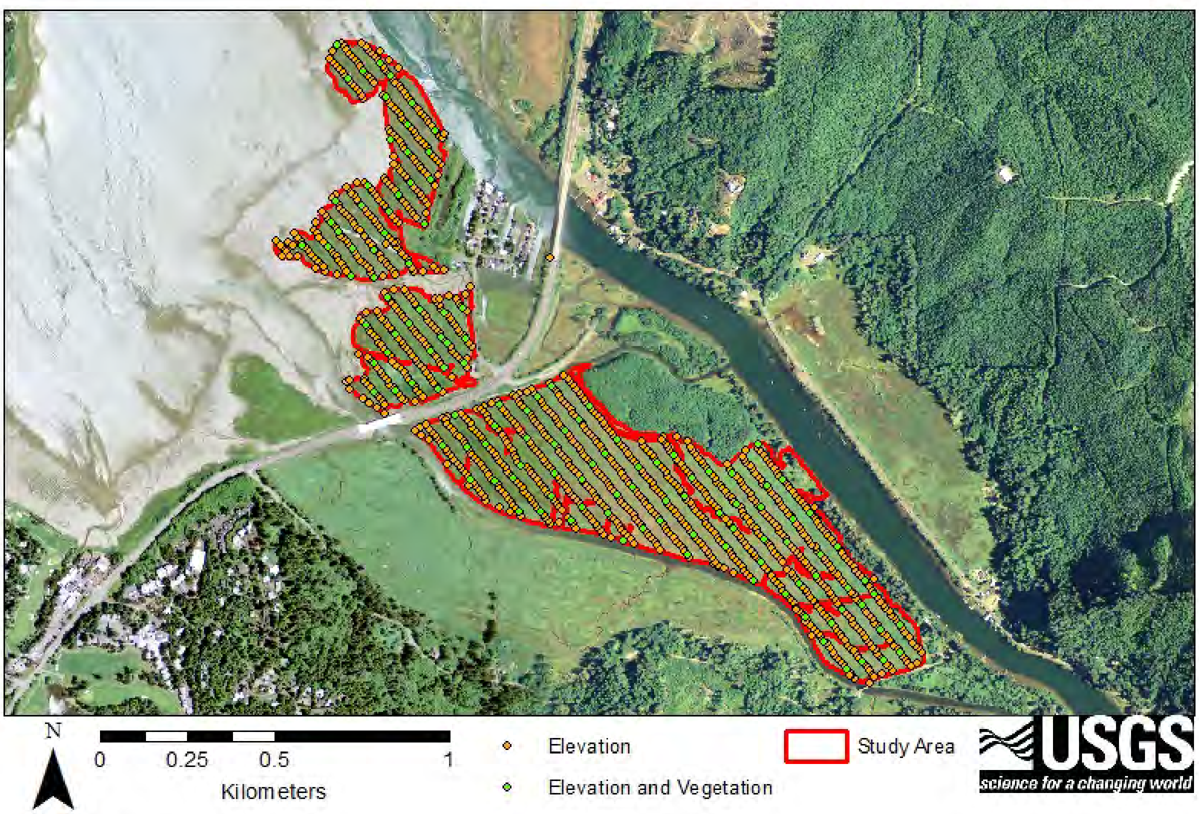

Figure G1. Distribution of elevation and vegetation survey points at Siletz.

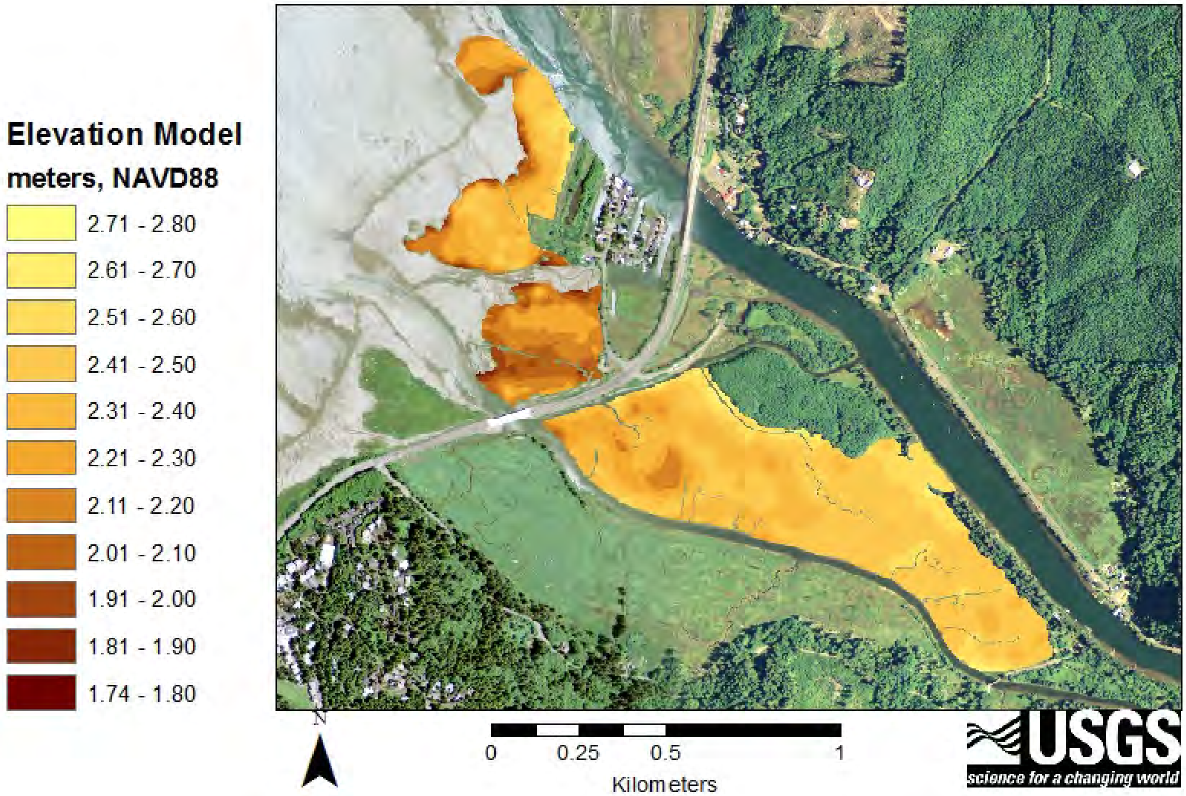

Figure G2. Elevation model (3 m resolution) developed from RTK GPS survey data.

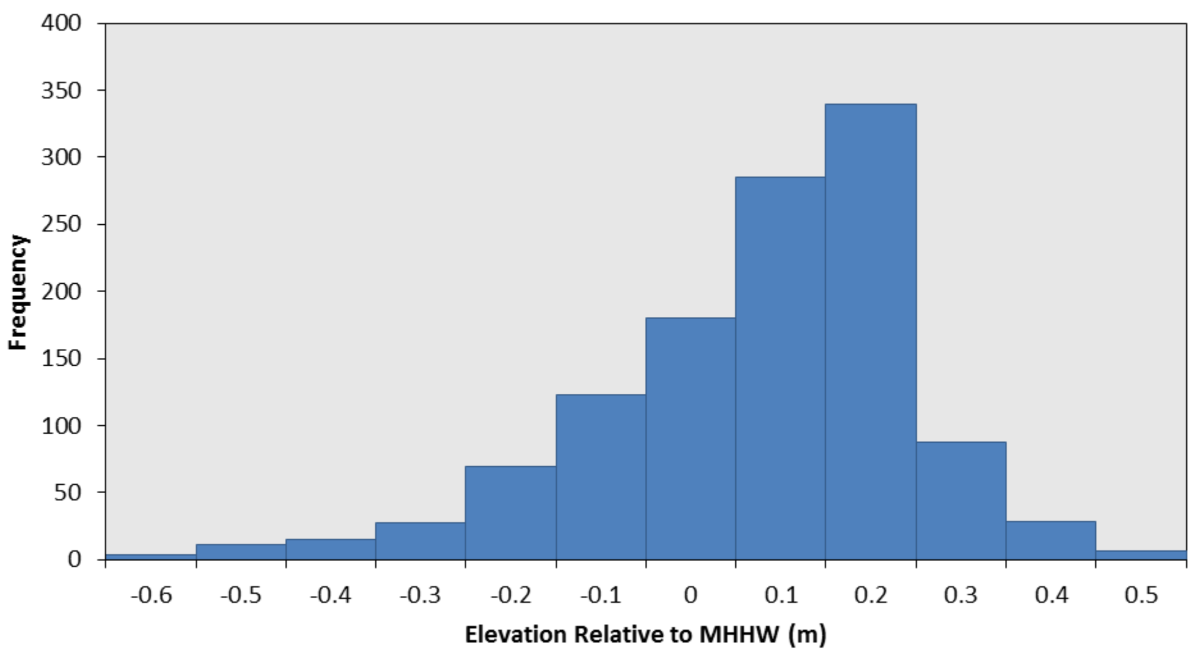

Figure G3. Frequency distribution of marsh surface elevation data points relative to local mean higher high water (MHHW) at Siletz.

Table G1. Frequency of occurrence, percent cover and height of vascular plant species encountered in sample plots at Siletz. NA = not available.

Species	Species characteristics	Freq (%)	Mean cover (%)
Agrostis stolonifera	Non-native perennial grass	84.1	58.5
Juncus balticus	Native perennial rush	53.2	21.8
Potentilla anserina	Native ann-perennial forb	50.8	23.0
Deschampsia cespitosa	Native perennial grass	46.0	16.3
Carex lyngbyei	Native perennial sedge	34.1	9.7
Distichlis spicata	Native perennial grass	25.4	6.2
Triglochin maritima	Native perennial forb	25.4	2.7
Sarcocornia perennis	Native perennial forb	21.4	5.9
Atriplex prostrata	Native annual forb	15.9	2.8
Glaux maritima	Native perennial forb	15.1	1.0
Symphyotrichum subspicatum	Native perennial forb	12.7	2.3
Galium trifidum	Native ann-perennial forb	8.7	0.4
Heracleum maximum	Native perennial forb	7.1	0.4
Grindelia stricta	Native perennial forb	6.3	2.0
Jaumea carnosa	Native perennial forb	5.6	2.6
Achillea millefolium	Native perennial forb	5.6	2.0
Vicia gigantea	Native perennial legume	4.8	0.4
Hordeum brachyantherum	Native perennial grass	3.2	0.2
Atriplex patula	Native annual forb	3.2	0.2
Stellaria humifusa	Native perennial forb	3.2	0.1
Cirsium sp.	Forb	1.6	0.2
Plantago maritima	Native perennial forb	1.6	0.1
Rumex sp.	Forb	1.6	0.1
Holcus lanatus	Non-native ann-perennial grass	1.6	0.1
Phalaris arundinacea	Perennial grass	0.8	0.8
Carex obnupta	Native perennial sedge	0.8	0.8
Unidentified species 1	NA	0.8	0.1
Isolepis cernua	Native annual sedge	0.8	0.1
Lathrys palustris	Native perennial legume	0.8	0.0
Lilaeopsis occidentalis	Native perennial forb	0.8	0.0
Unidentified species 2	NA	0.8	0.0

Table G2. Mean percent cover of dominant plant species by marsh zone at Siletz. Zones were defined by degree of flooding by high tides.

[AgrSto = *Agrostis stolonifera*; PotAns = *Potentilla anserina*; JunBal = *Juncus balticus*; DesCes = *Deschampsia cespitosa*; CarLyn = *Carex lyngbyei*; DisSpi = *Distichlis spicata*.]

Marsh zone	% high tides reaching zone	MHHW range (m)	Sample size	Mean cover of top four dominant plants (%)
Transition	0.14-3	0.850 to 0.473	0	*Insufficient sample size*
High	3-25	0.472 to 0.022	72	AgrSto (63), PotAns (38), JunBal (27), DesCes (13)
Middle	25-50	0.021 to -0.235	45	AgrSto (59), CarLyn (20), DesCes (19), JunBal (17)
Low	>50	-0.236 to -0.488	9	CarLyn (34), DesCes (32), AgrSto (24), DisSpi (22)

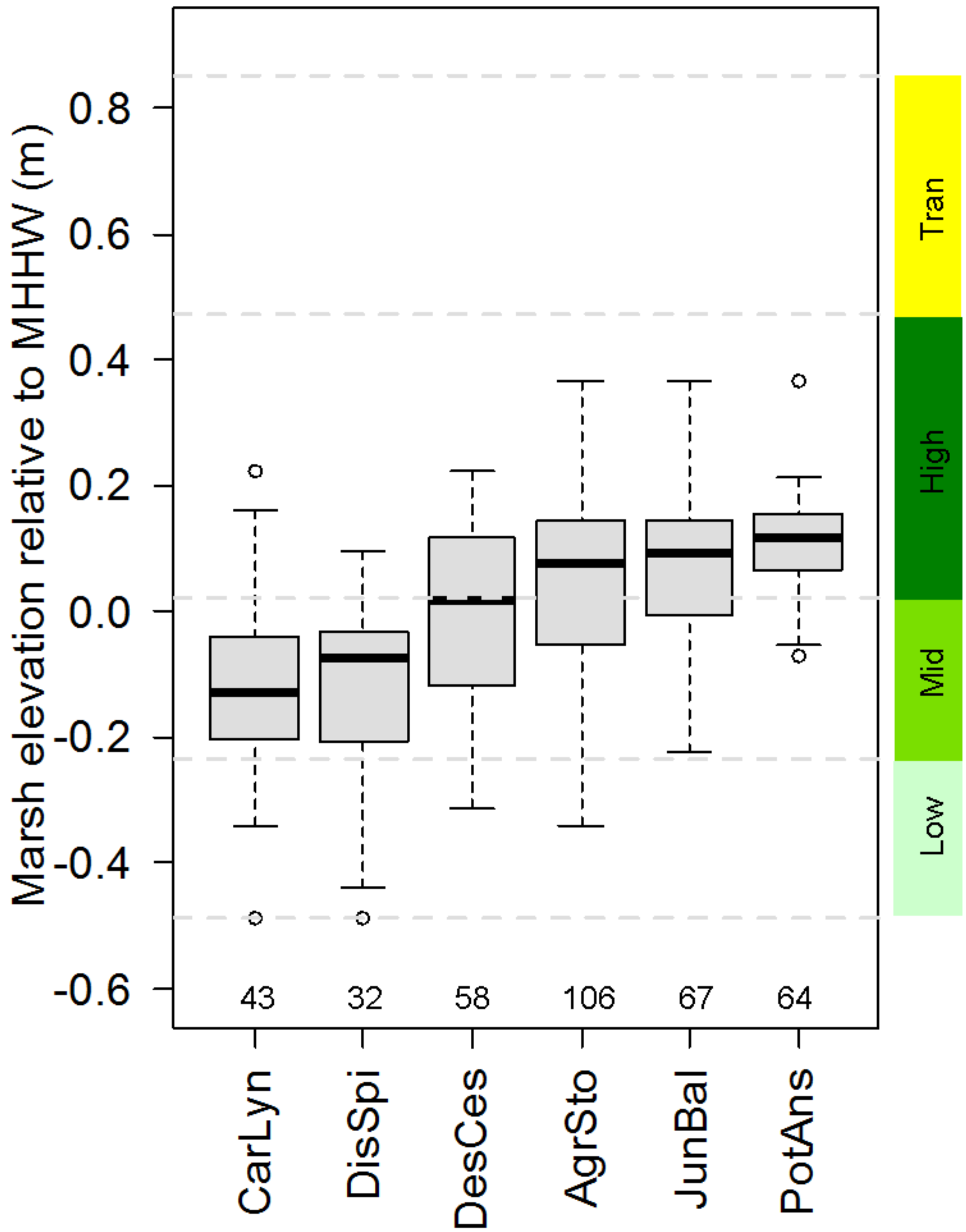

Figure G4. Elevation distribution of the six most common vascular plant species at Siletz. The black horizontal bars show the median elevation at which the species occurs; shaded boxes indicate the interquartile range; upper and lower whiskers encompass points no greater than 1.5x the length of the shaded box; and open circles indicate outliers. The number of plots in which the species occurred is indicated above the species codes (out of a total of 126 quadrats). Marsh elevation zones (low, middle, high and transition) are illustrated at right. CarLyn = *Carex lyngbyei*; DisSpi = *Distichlis spicata*; DesCes = *Deschampsia cespitosa*; AgrSto = *Agrostis stolonifera*; JunBal = *Juncus balticus*; PotAns = *Potentilla anserina*.

Table G3. Location of water level loggers and deep sediment cores (UTM coordinates).

	Northing (m)	Easting (m)
Water level loggers	4971681	419970
	4971330	421129
Deep core locations	420040	4971938
	420817	4971477
	421376	4971001

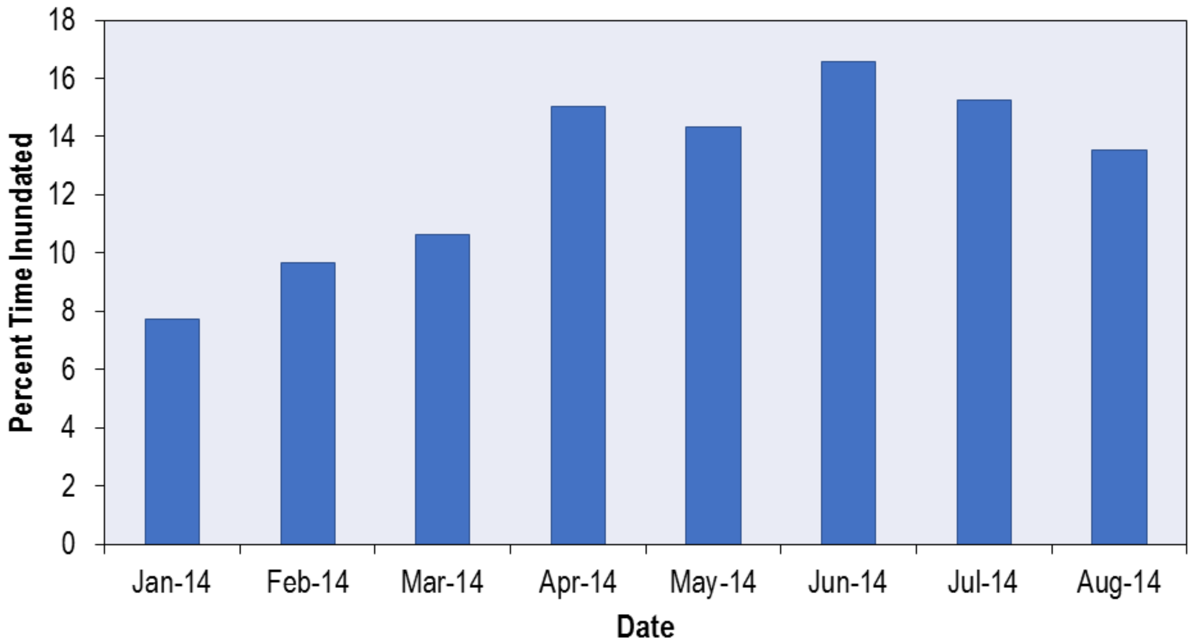

Figure G5. Average monthly inundation of the study site based on an average marsh elevation.

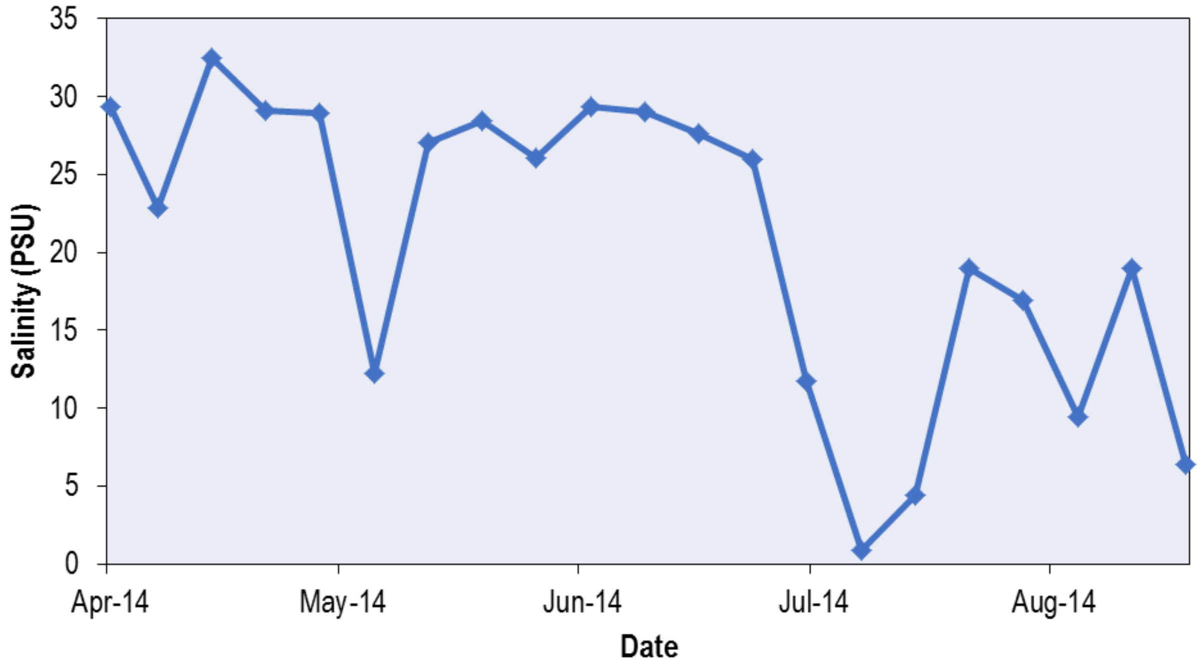

Figure G6. Average weekly maximum salinity from April 2014 – August 2014 at Siletz. Seawater is approximately 35 PSU.

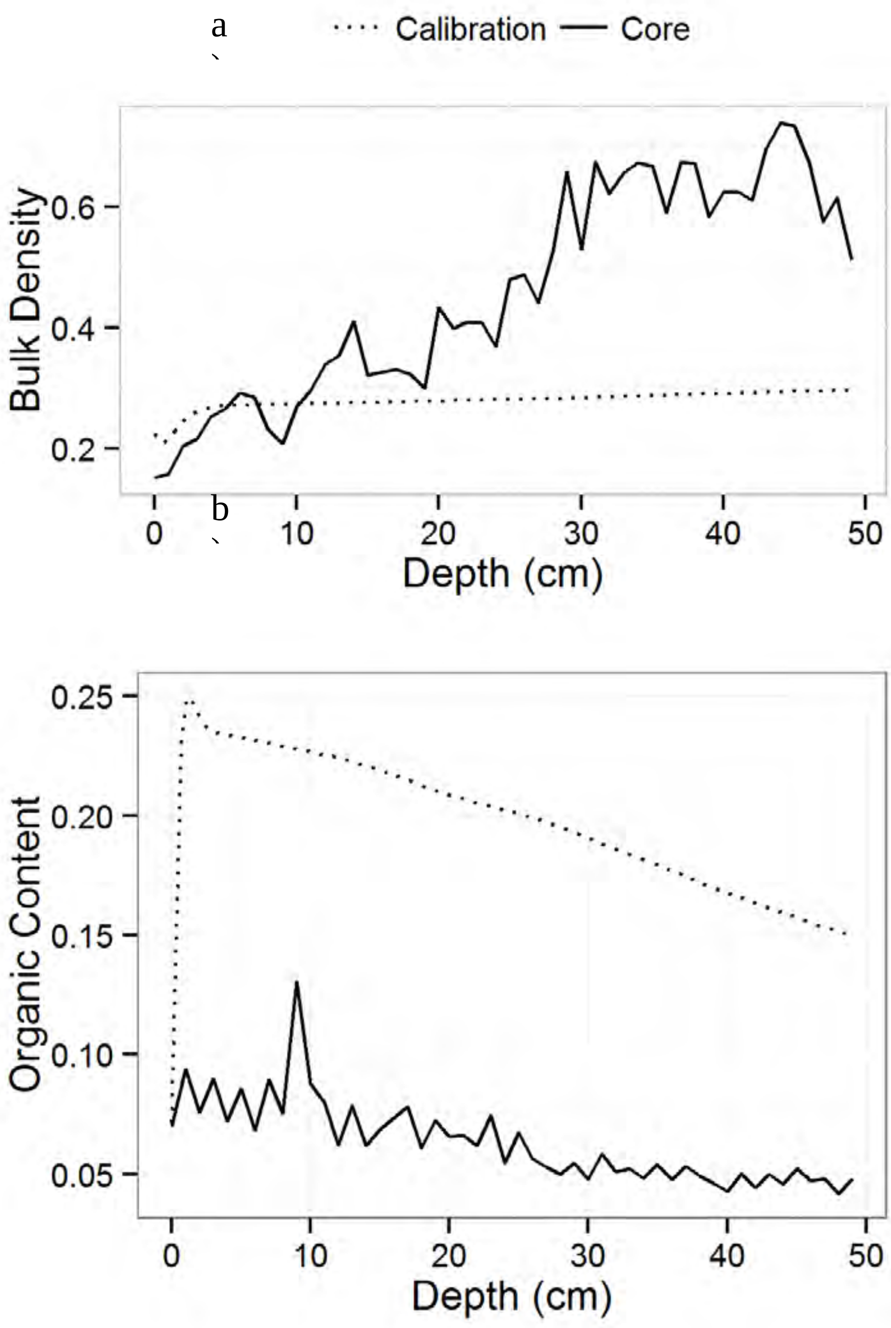

Figure G7. Deep core calibration of the WARMER model using depth profiles of (a) sediment bulk density (g cm^{-3}) and (b) sediment organic matter content (%).

Table G4. Model input parameters for Siletz. Sediment accumulation rate is reported at the elevation of MSL. NDVI is the Normalized Difference Vegetation Index and NAIP is the National Agriculture Inventory Program.

Model parameter	Value	Source
Sediment accumulation rate (g cm^{-2} yr^{-1})	0.59	Core calibration
Elevation of peak biomass (cm, MSL)	133	NDVI from NAIP
Minimum elevation of vegetation (cm, MSL)	7	Field surveys
Max. aboveground organic accumulation (g cm^{-2} yr^{-1})	0.0337	Core calibration
Root-to-shoot ratio	1.95	C. Janousek, unpub data
Porosity surface (%)	91	Core
Porosity depth (%)	86	Core
Refractory carbon (%)	40.9	Core
Maximum astronomical tide (cm, MSL)	180	CERCC water logger
Historic sea-level rise (mm yr^{-1})	2.35	South Beach tide gauge (NOAA, 9435380)
Organic matter density (g cm^{-3})	1.14	DeLaune 1983
Mineral density (g cm^{-3})	2.61	DeLaune 1983

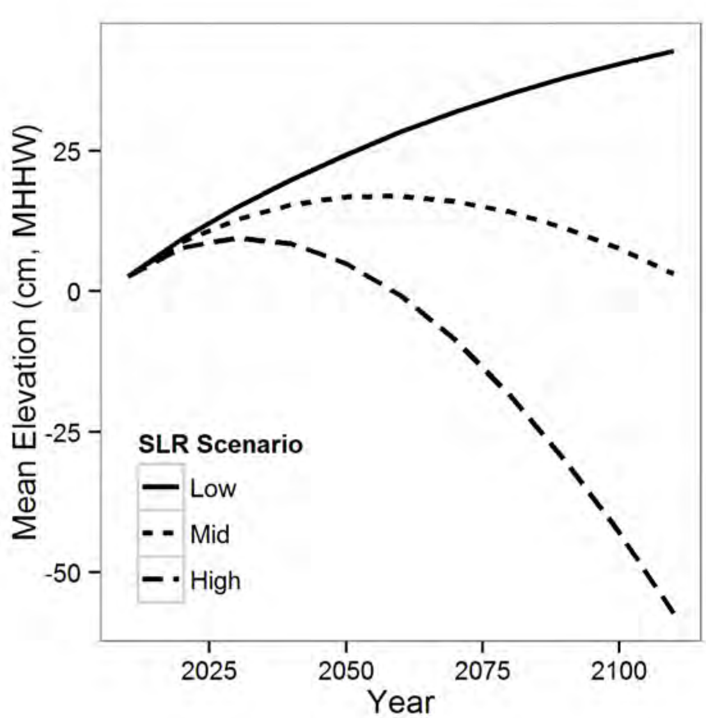

Figure G8. WARMER model projections for the change in average marsh elevation (relative to MHHW) at Siletz from 2010 to 2110 under low, mid, and high sea-level rise (SLR) scenarios.

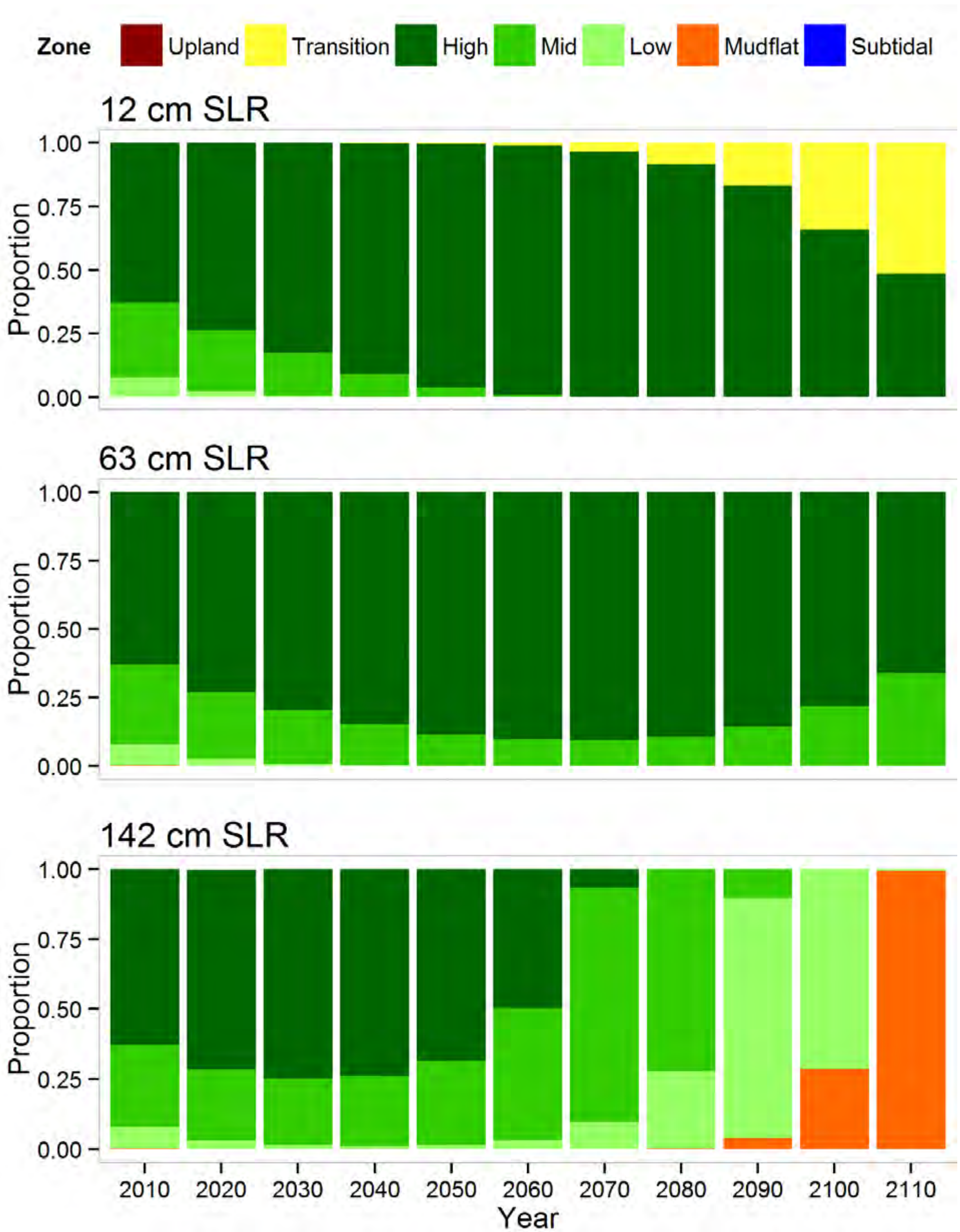

Figure G9. Model projections for change in the relative proportion of upland, transitional, high, mid and low marsh habitat, and mudflat under low (12 cm), mid (63 cm), and high (142 cm) sea-level rise scenarios from 2010 to 2110 at Siletz.

Table G5. Model projections for change in the percentage of marsh elevation zones for three sea-level rise scenarios between 2010, 2050, and 2110 at Siletz.

	Low SLR (12 cm)			Mid SLR (63 cm)			High SLR (142 cm)		
	2010	2050	2110	2010	2050	2110	2010	2050	2110
Upland	0	0	0	0	0	0	0	0	0
Transition	0	1	51	0	0	0	0	0	0
High	63	95	49	63	88	0	63	68	0
Mid	29	4	0	29	12	66	29	30	0
Low	8	0	0	8	0	34	8	2	1
Mudflat	0	0	0	0	0	0	0	0	99
Subtidal	0	0	0	0	0	0	0	0	0

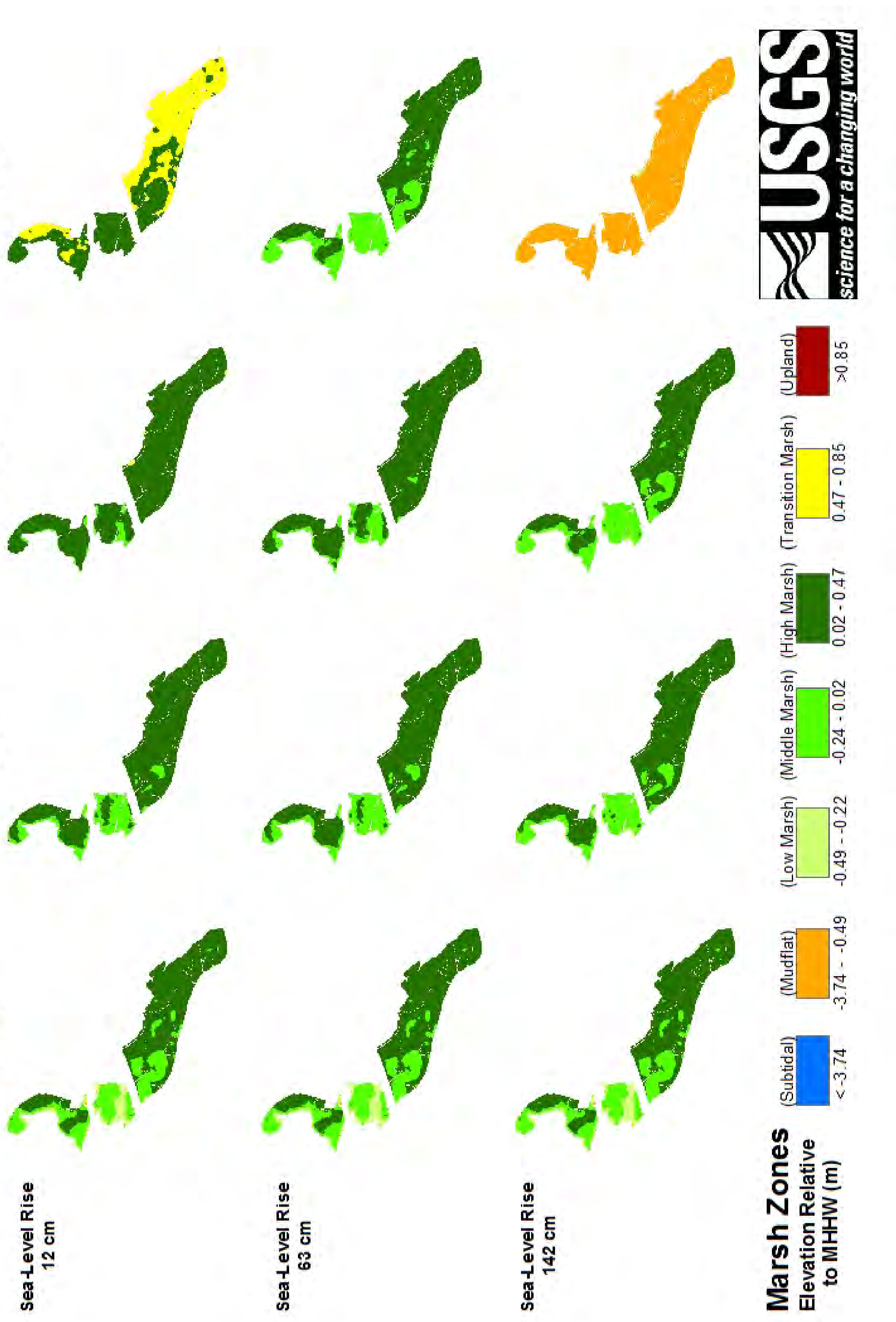

Figure G10. Projected habitat distribution at Siletz for 2030, 2050 and 2110 with the WARMER model under three NRC sea-level rise scenarios.

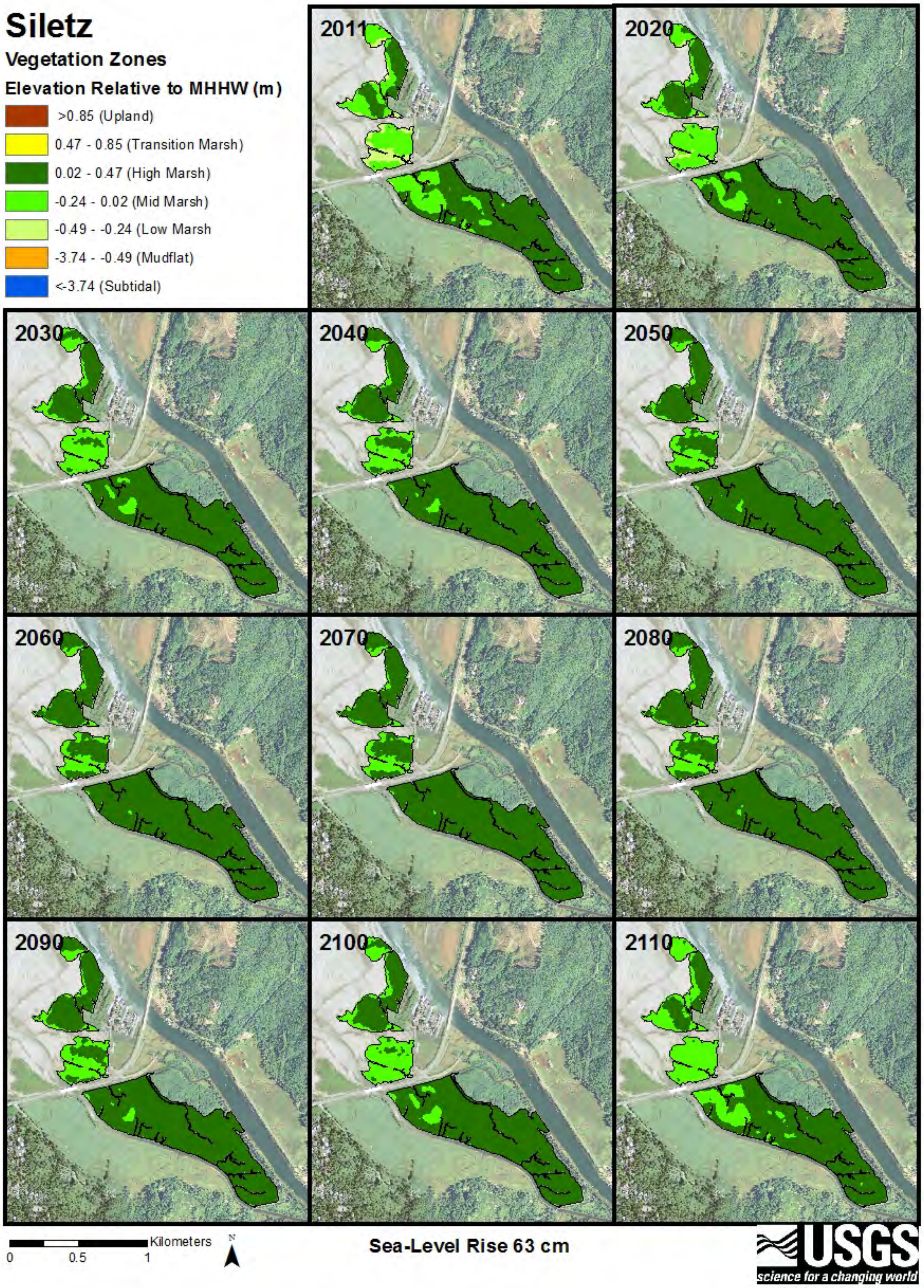

Figure G11. Projected changes in Siletz elevation zones under the mid NRC sea-level rise scenario (63 cm).

Appendix H. Site Specific Details for Bull Island, Coos Bay, Coos County, Oregon

Photo: C Janousek, Oregon State University and USGS

Summary:

- *Study site size*: 97.2 hectares
- *Location*: 43° 22' 36"N latitude, 124° 10' 35"W longitude.
- *Site management*: South Slough National Estuarine Research Reserve (NOAA)
- *Site vegetation and elevation survey*: 10-17 October 2012
- *Sample size*: 1605 (elevation data points), 380 (vegetation quadrats)
- *Marsh elevation model*: Most of the study site was below MHHW, with only 11% of elevation points occurring above MHHW.
- *Plant community composition*: *Carex lyngbyei* was the most frequently occurring species. *Sarcocornia perennis* and *Distichlis spicata* were also common.
- *Bathymetric surveys*: 182.3 ha of nearshore habitat were mapped adjacent to the study area.

- *Soil characteristics*: The accumulation rates used in WARMER for this site were: sediment accumulation rate = 0.19 g cm^{-2} yr^{-1}; organic matter accumulation rate = 0.0079 g cm^{-2} yr^{-1}; net accretion = 0.1979 cm yr^{-1}.
- *Water inundation and salinity monitoring*: water level (September 2012 – April 2014); conductivity (August 2013 – May 2014). Water level and conductivity monitoring is ongoing.
- *Salinity*: The maximum recorded salinity throughout the study period was 29 PSU.
- *Marsh inundation pattern*: Maximum monthly inundation occurred during February 2014; minimum monthly inundation during May 2013.
- *Calculated tidal datums*: MHHW is at 2.33 m NAVD88; MHW is at 2.12 m NAVD88.
- *Sea-level rise marsh response modeling*: Presently, Bull Island is dominated by low marsh with about 25% mid marsh and a small amount of high marsh vegetation. Under the NRC's low sea-level rise scenario (12 cm) we project a gradual expansion of mid marsh between 2010 and 2070. However, under mid sea-level rise (63 cm) mid marsh is expected to initially increase in proportion and then begin to decrease after 2060. The site is projected to be almost completely low marsh at 2110. Under high sea-level rise (142 cm) there is loss of mid marsh by 2080 and rapid conversion of most low marsh to mudflat between 2090 and 2110.

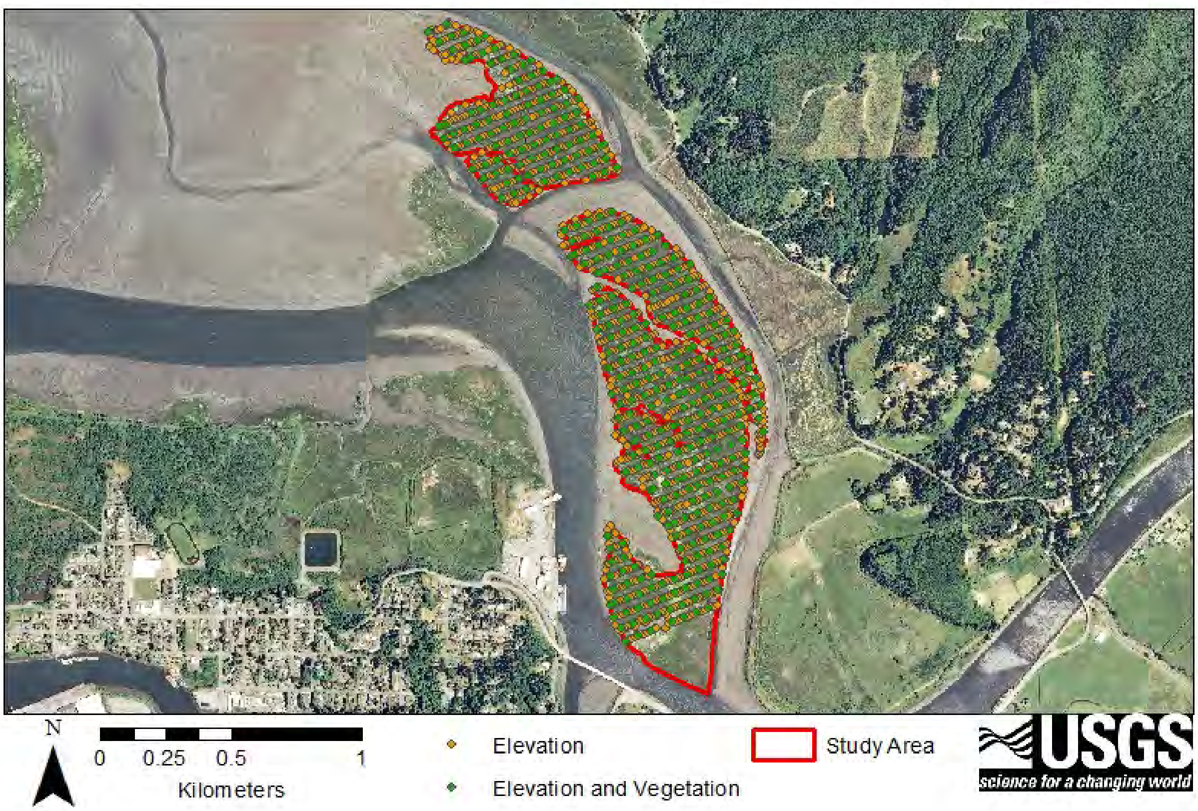

Figure H1. Distribution of elevation and vegetation survey points at Bull Island.

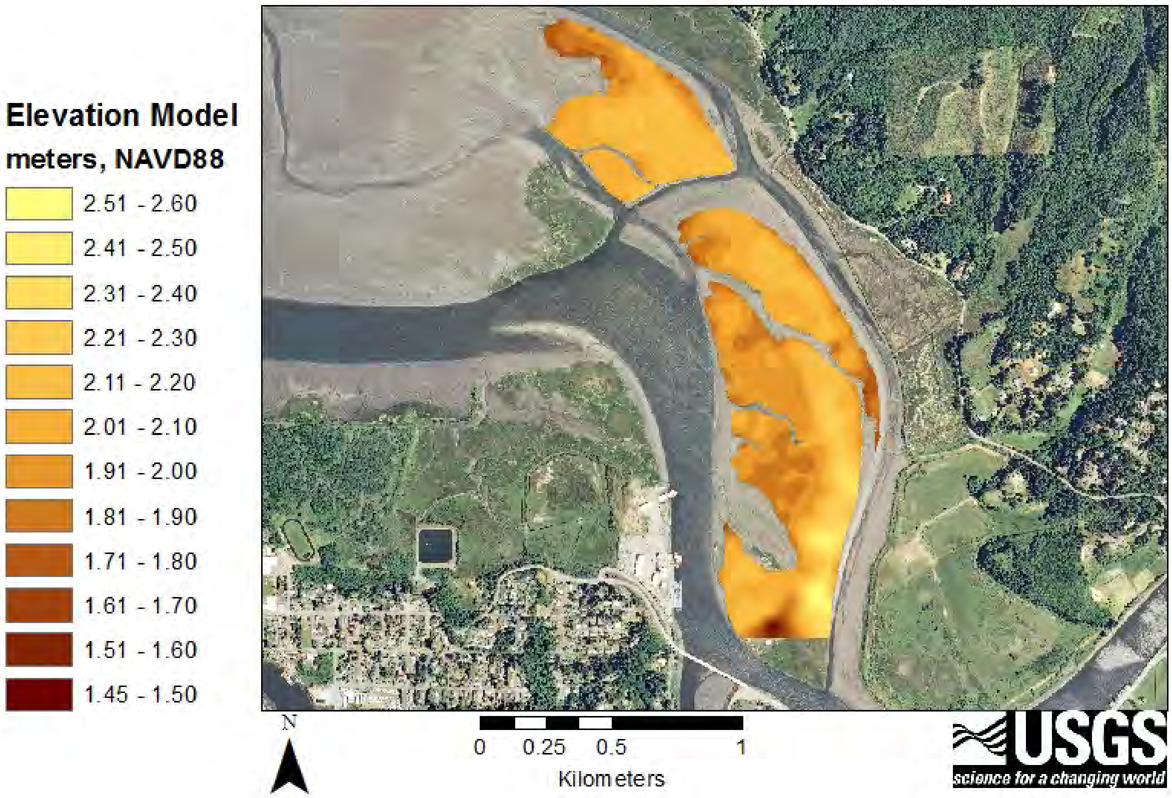

Figure H2. Elevation model (3 m resolution) developed from RTK GPS survey data.

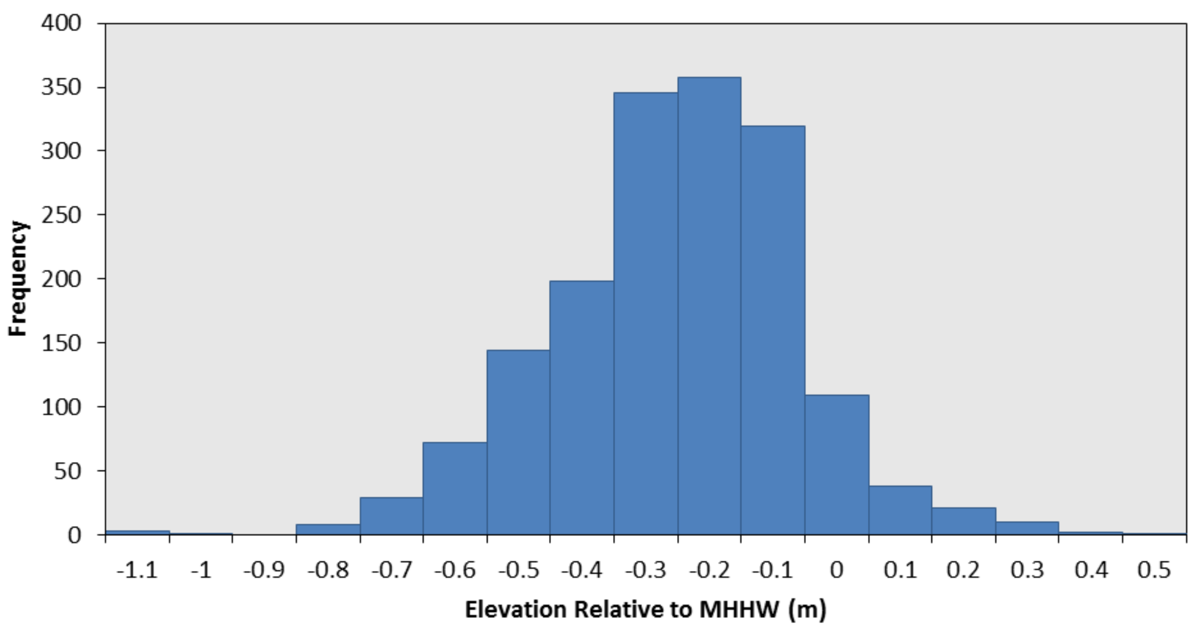

Figure H3. Frequency distribution of marsh surface elevation data points relative to local mean higher high water (MHHW) at Bull Island.

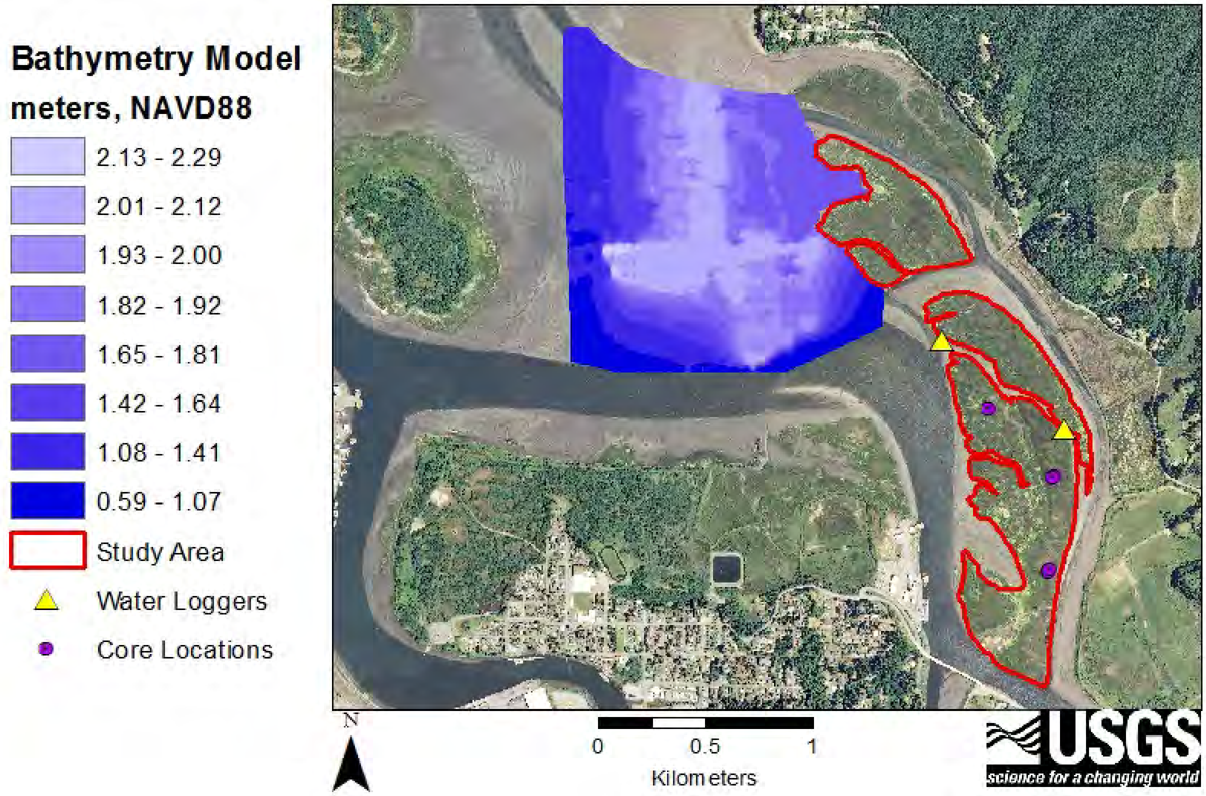

Figure H4. Near-shore bathymetry model for Bull Island. Water level logger and core locations are shown within the marsh study site.

Table H1. Vascular plant species frequency of occurrence, percent cover and height at Bull Island. NA = not measured.

Species	Species characteristics	Freq (%)	Mean cover (%)	Mean height (cm)
Carex lyngbyei	Native perennial sedge	76.1	46.5	39
Sarcocornia perennis	Native perennial forb	48.7	11.7	28
Distichlis spicata	Native perennial grass	43.4	13.5	31
Deschampsia cespitosa	Native perennial grass	38.7	17.6	43
Triglochin maritima	Native perennial forb	23.2	1.2	34
Juncus balticus	Native perennial rush	16.8	9.3	31
Agrostis stolonifera	Non-native perennial grass	13.7	6.2	31
Jaumea carnosa	Native perennial forb	3.2	1.3	19
Isolepis cernua	Native annual sedge	1.3	0.6	3
Grindelia stricta	Native perennial forb	1.3	0.3	39
*Spergularia canadensis**	Native annual forb	1.1	0.1	5
Lilaeopsis occidentalis	Native perennial forb	0.8	0.0	2
Hordeum brachyantherum	Native perennial grass	0.8	0.0	38
Potentilla anserina	Native ann-perennial forb	0.5	0.0	24
Atriplex prostrata	Native annual forb	0.5	0.0	16
Cuscuta pacifica	Native ann-perennial parasite	0.3	NA	NA
Baccharis pilularis	Native perennial shrub	0.3	0.2	165
Fabaceae species	Legume	0.3	0.0	29

* May also include *Spergularia marina*

Table H2. Mean percent cover of dominant plant species by marsh zone at Bull Island. Zones were defined by degree of flooding by high tides.

[AgrSto = *Agrostis stolonifera*; CarLyn= *Carex lyngbyei*; DesCes = *Deschampsia cespitosa*; DisSpi = *Distichilis spicata*; JunBal = *Juncus balticus*; SarPer = *Sarcocornia perennis*.]

Marsh zone	% high tides reaching zone	MHHW range (m)	Sample size	Mean cover of top four dominant plants (%)
Transition	0.14-3	0.891 to 0.496	0	*Insufficient sample size*
High	3-25	0.495 to 0.023	13	JunBal (42), DesCes (31), AgrSto (28), DisSpi (7)
Middle	25-50	0.022 to -0.246	150	CarLyn (27), DesCes (24), DisSpi (23), JunBal (19)
Low	>50	-0.247 to -0.787	217	CarLyn (63), SarPer (13), DesCes (12), DisSpi (7)

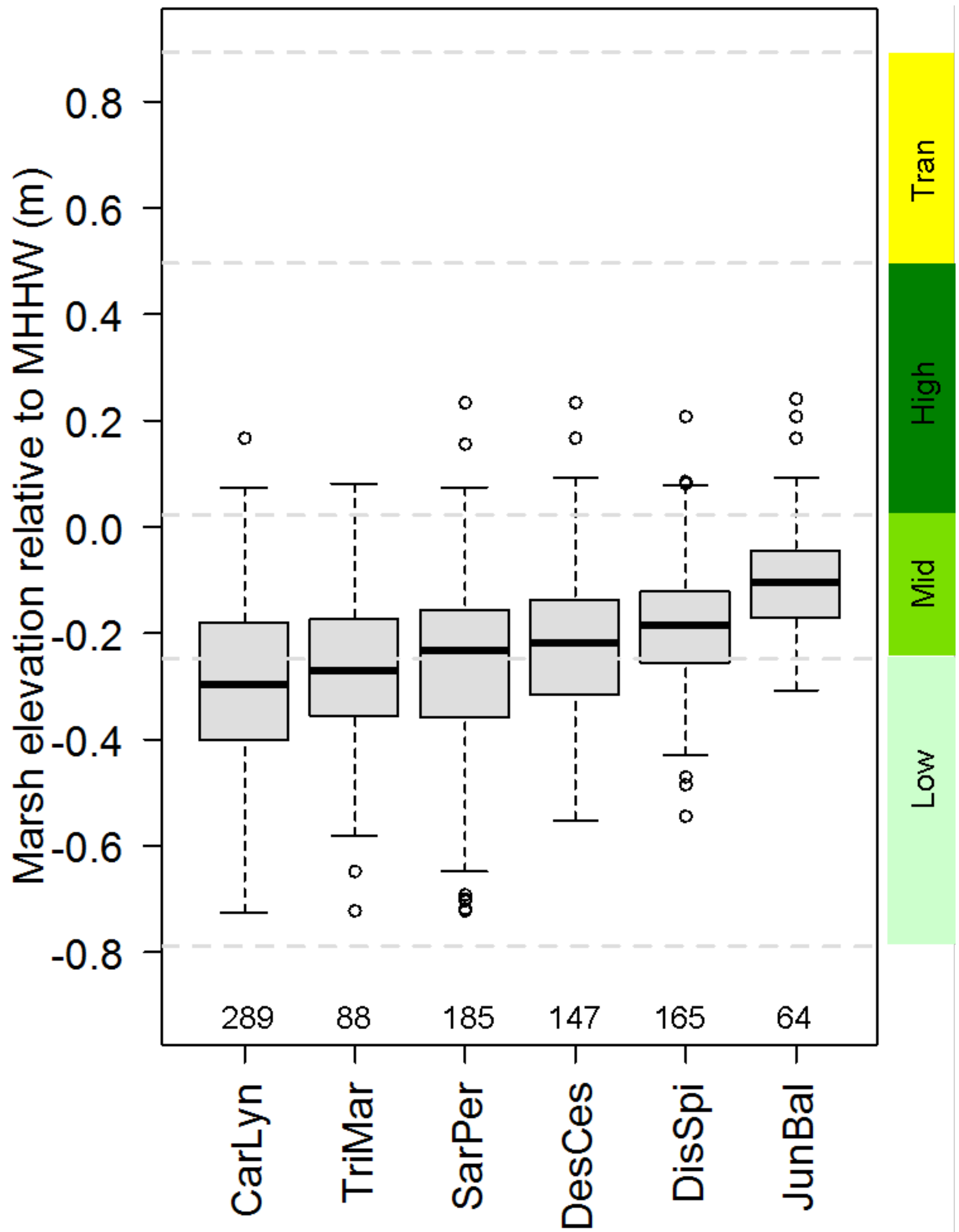

Figure H5. Elevation distribution of the six most common vascular plant species at Bull Island. The black horizontal bars show the median elevation at which the species occurs; shaded boxes indicate the interquartile range; upper and lower whiskers encompass points no greater than 1.5x the length of the shaded box; and open circles indicate outliers. The number of plots in which the species occurred is indicated above the species codes (out of a total of 380 plots). Marsh elevation zones (low, middle, high and transition) are illustrated at right. CarLyn= *Carex lyngbyei*; DesCes = *Descahmpsia cespitosa*; DisSpi = *Distichilis spicata*; TriMar = *Triglochin maritima;* SarPer = *Sarcocornia perennis;* JunBal = *Juncus balticus*.

Table H3. Location of water level loggers and deep sediment cores (UTM coordinates).

	Northing (m)	Easting (m)
Water level loggers	404695	4803321
	405266	4802907
Deep core locations	405190	4802242
	405215	4802682
	404915	4803003

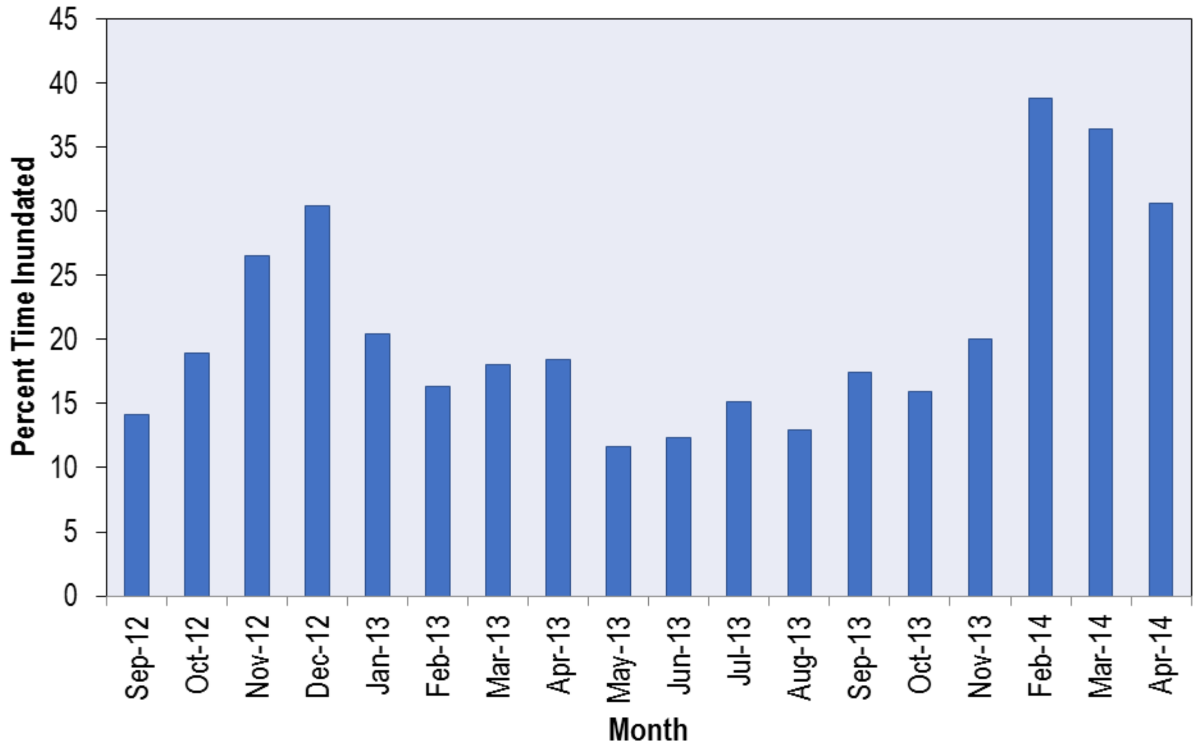

Figure H6. Average monthly inundation of the study site based on an average marsh elevation. Water levels were determined with a Hobo water logger deployed at -0.19 m NAVD88.

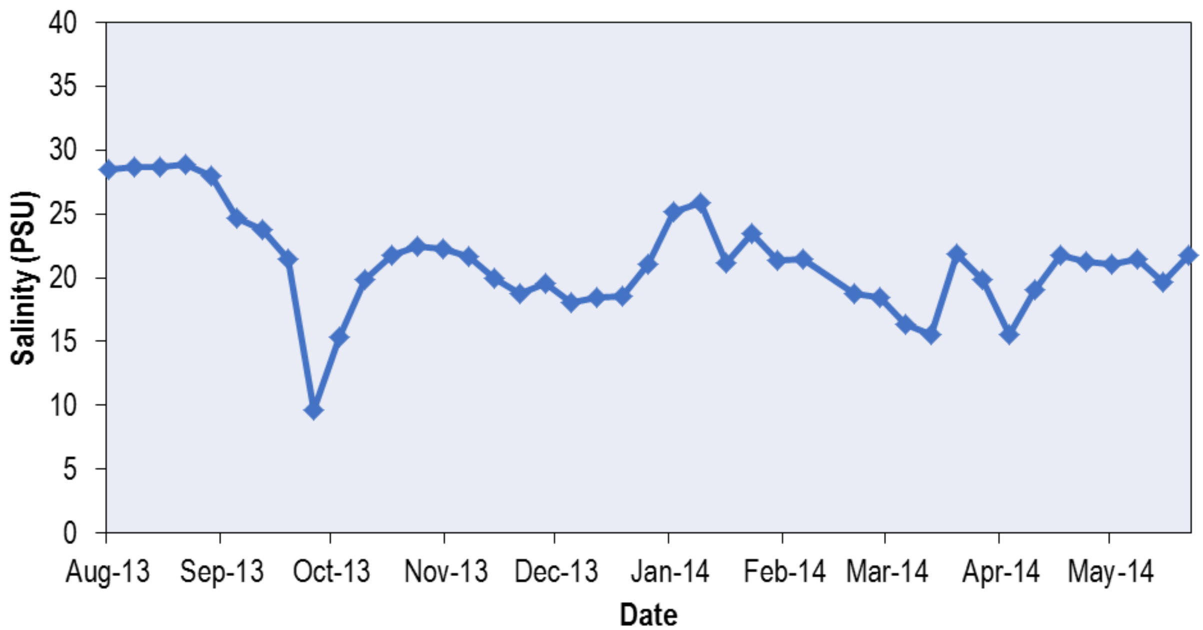

Figure H7. Average weekly maximum salinity from August 2013 – May 2014 at Bull Island. Seawater is approximately 35 PSU.

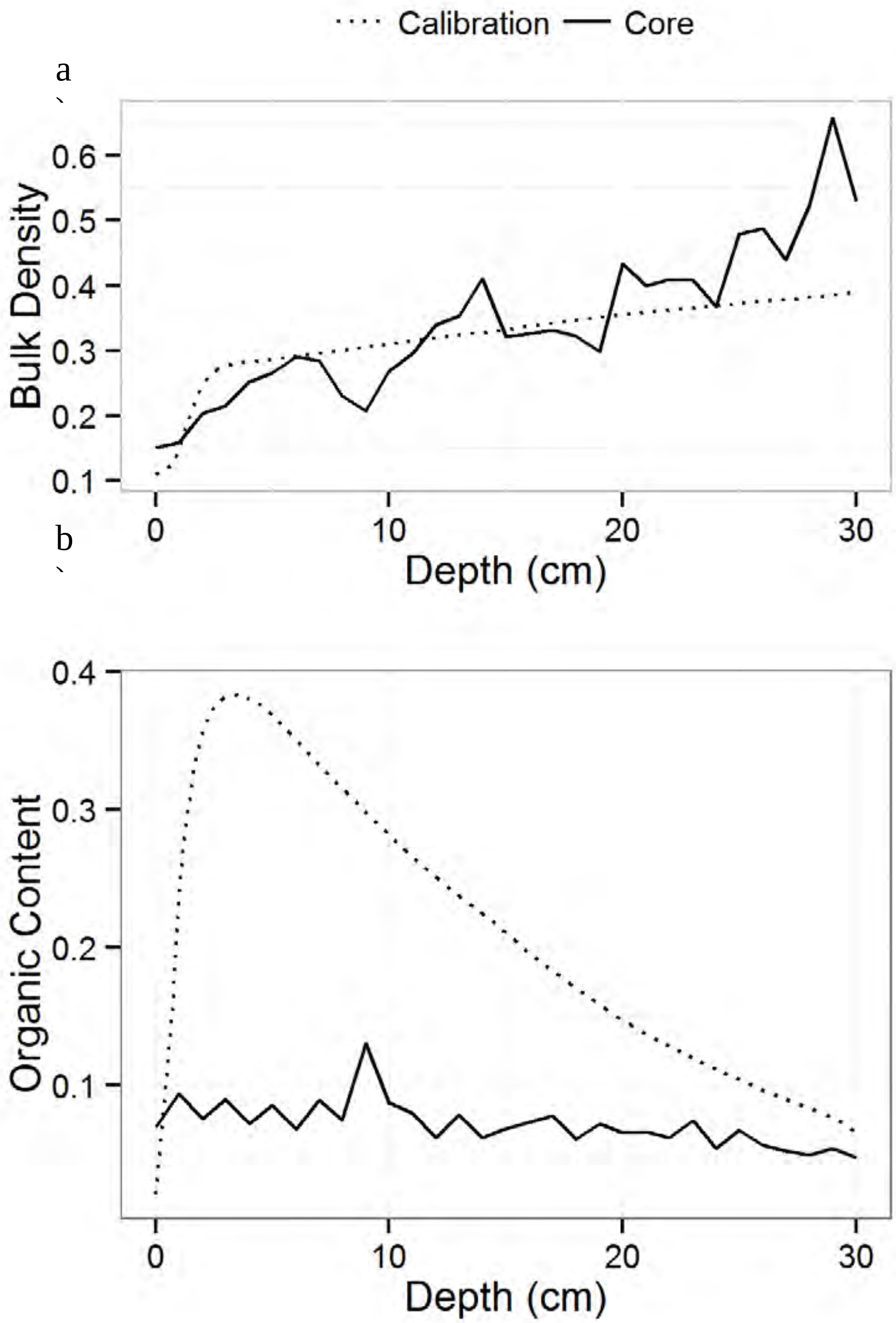

Figure H8. Deep core calibration of the WARMER model using depth profiles of (a) sediment bulk density ($g\ cm^{-3}$) and (b) sediment organic matter content (%).

Table H4. Model input parameters for Bull Island. Sediment accumulation rate is reported at the elevation of MSL. NDVI is the Normalized Difference Vegetation Index and NAIP is the National Agriculture Inventory Program.

Model parameter	Value	Source
Sediment accumulation rate (g cm^{-2} yr^{-1})	0.44	Core calibration
Elevation of peak biomass (cm, MSL)	101	NDVI from NAIP
Minimum elevation of vegetation (cm, MSL)	34	Field surveys
Max. aboveground organic accumulation (g cm^{-2} yr^{-1})	0.0051	Core calibration
Root-to-shoot ratio	1.95	C. Janousek, unpub data
Porosity surface (%)	95	Core
Porosity depth (%)	84	Core
Refractory carbon (%)	64.5	Core
Maximum astronomical tide (cm, MSL)	224	CERCC water logger
Historic sea-level rise (mm yr^{-1})	0.59	Charleston tide gauge (NOAA, 9432780)
Organic matter density (g cm^{-3})	1.14	DeLaune 1983
Mineral density (g cm^{-3})	2.61	DeLaune 1983

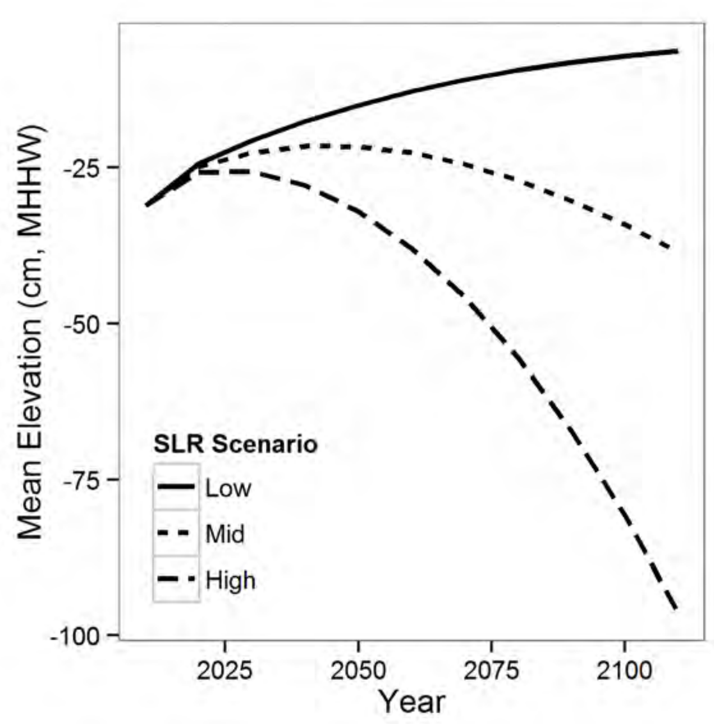

Figure H9. WARMER model results for average marsh elevation change at Bull Island from the present to the year 2110 under low, mid, and high sea-level rise (SLR) scenarios.

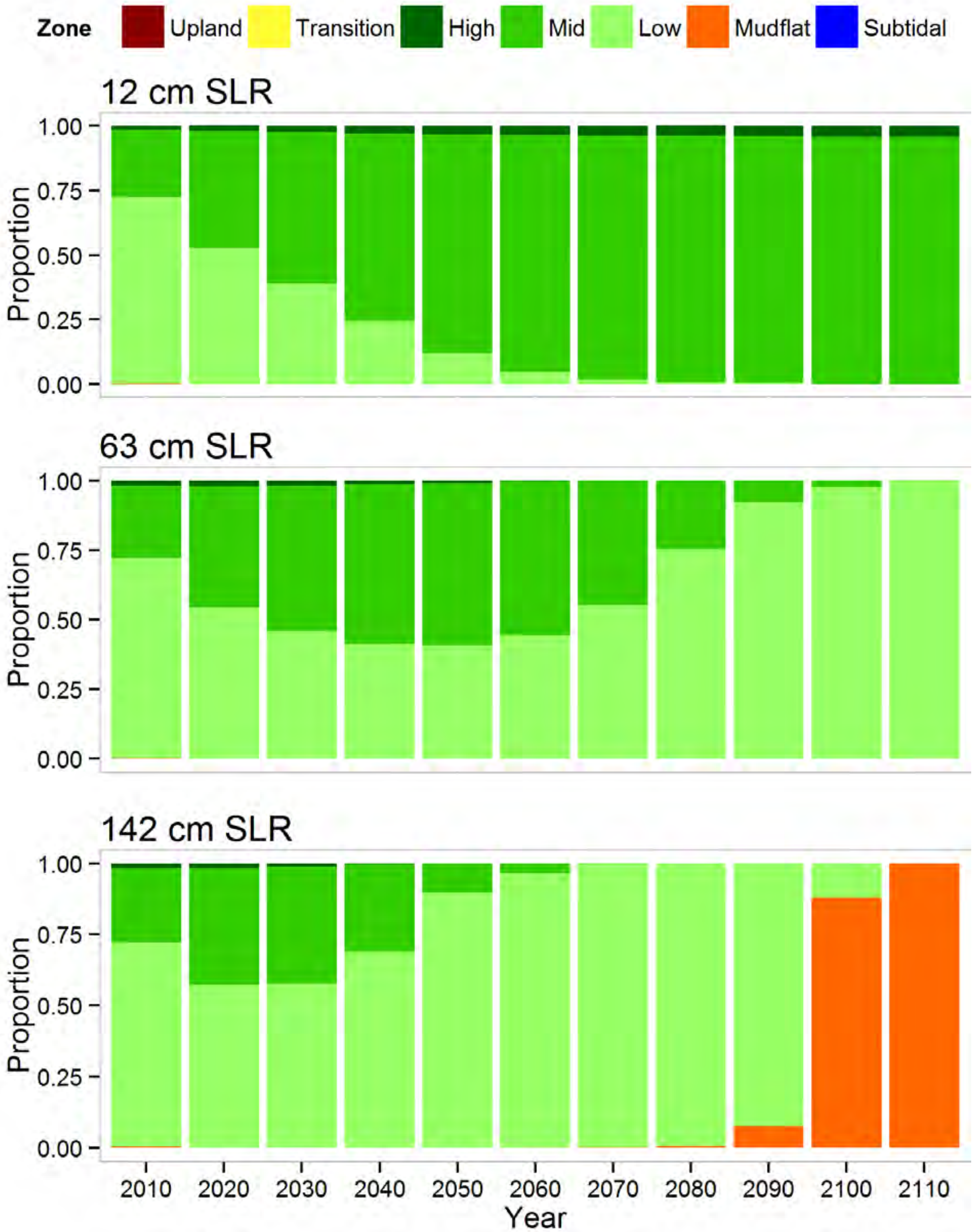

Figure H10. Model projections for change in the relative proportion of upland, transitional, high, mid and low marsh habitat, and mudflat under low (12 cm), mid (63 cm), and high (142 cm) NRC sea-level rise scenarios from 2010 to 2110.

Table H5. Model projections for change in the percentage of marsh elevation zones for three NRC sea-level rise scenarios between 2010, 2050, and 2110.

	Low SLR (12 cm)			Mid SLR (63 cm)			High SLR (142 cm)		
	2010	2050	2110	2010	2050	2110	2010	2050	2110
Upland	0	0	0	0	0	0	0	0	0
Transition	0	0	0	0	0	0	0	0	0
High	2	3	4	2	1	0	2	0	0
Mid	26	85	96	26	59	0	26	10	0
Low	72	12	0	72	40	0	72	90	0
Mudflat	0	0	0	0	0	100	0	0	100
Subtidal	0	0	0	0	0	0	0	0	0

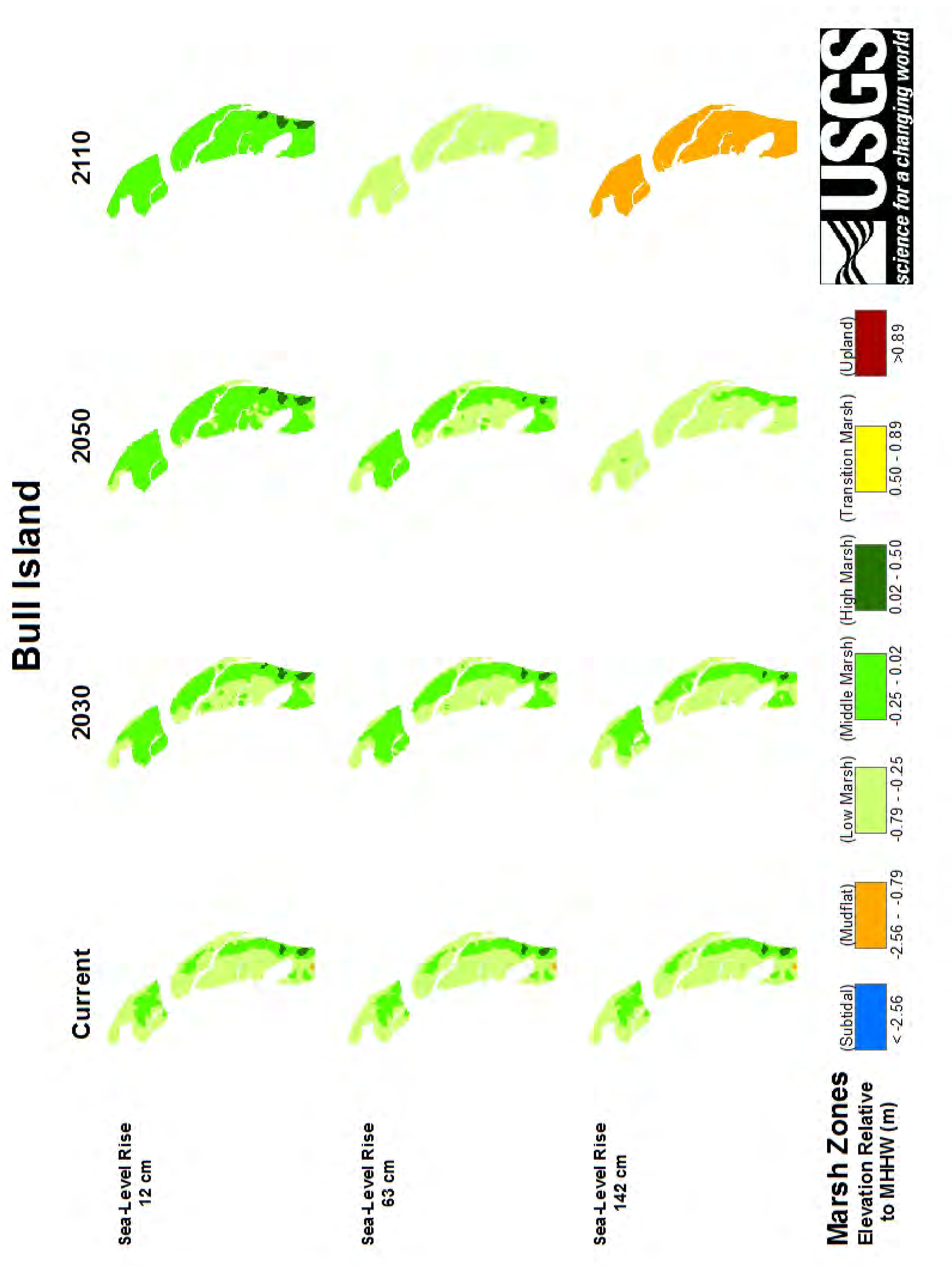

Figure H11. Projected habitat distribution at Bull Island for 2030, 2050 and 2110 with the WARMER model under three NRC sea-level rise scenarios.

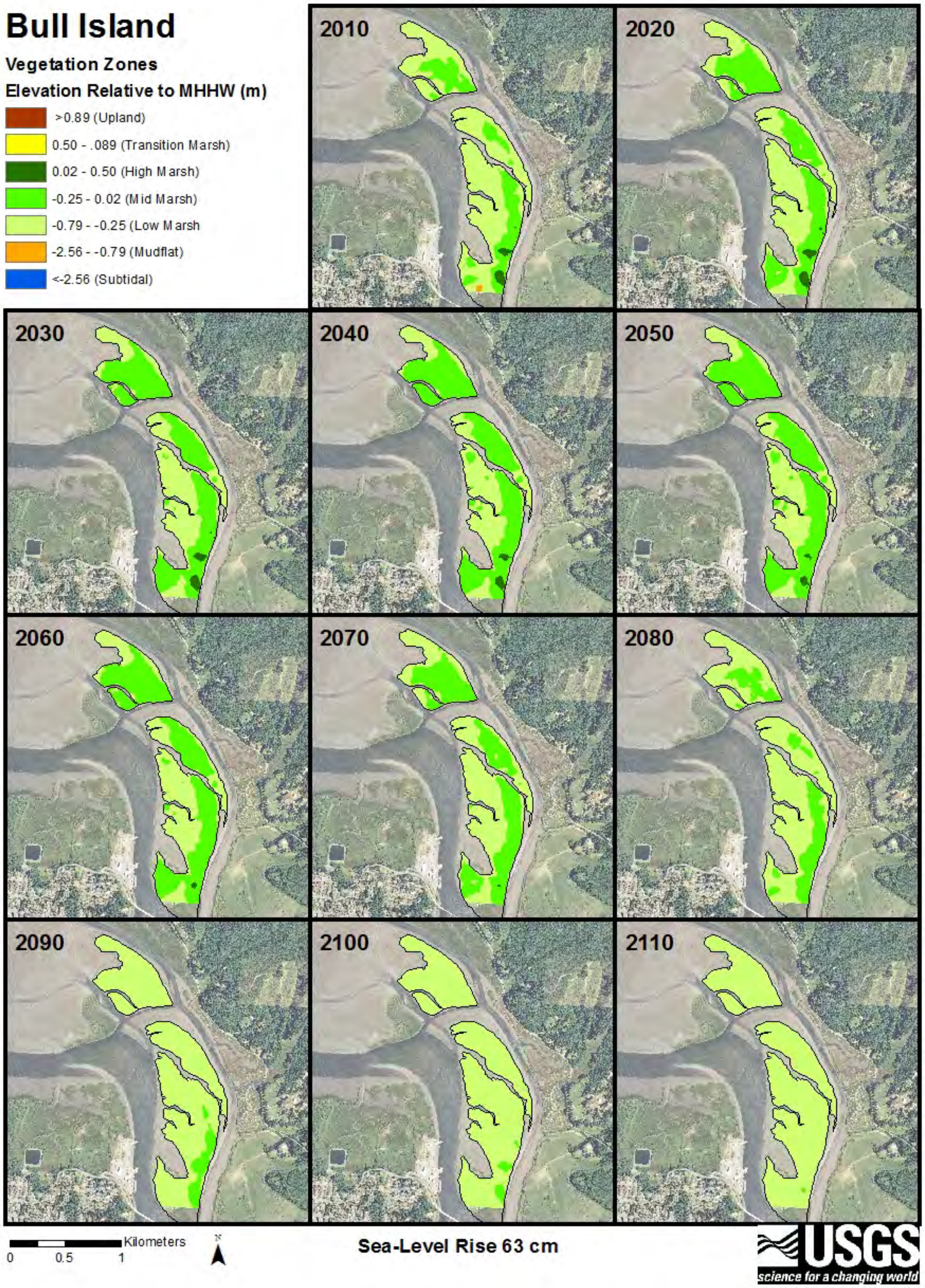

Figure H12. Projected changes in Bull Island elevation zones under the mid NRC sea-level rise scenario (63 cm).

Appendix I. Site Specific Details for Bandon marsh, Bandon Marsh National Wildlife Refuge, Coos County, Oregon

Photo: K Powelson, USGS

Summary:

- *Study site size*: 96.7 hectares
- *Location*: 43° 07' 50"N latitude, 124° 24' 25"W longitude.
- *Site management*: U.S. Fish and Wildlife Service (Bandon National Wildlife Refuge)
- *Site vegetation and elevation survey*: 19-28 August 2012
- *Sample size*: 1710 (elevation points), 373 (vegetation quadrats)
- *Marsh elevation model*: Most of the study site was above MHHW, with 67% of elevation points occurring above MHHW.
- *Plant community composition*: *Sarcocornia perennis* was the most frequently occurring species. *Distichlis spicata*, *Jaumea carnosa* and *Deschampsia cespitosa* were also common.
- *Bathymetric surveys*: 46.7 ha of nearshore habitat were mapped adjacent to the study area.

- *Soil characteristics:* The accumulation rates used in WARMER for this site were: sediment accumulation rate = 0.22 g cm^{-2} yr^{-1}; organic matter accumulation rate = 0.0085 g cm^{-2} yr^{-1}; net accretion = 0.2285 cm yr^{-1}.
- *Water inundation and salinity monitoring*: water level (August 2013 – May 2014); conductivity (August 2013 – May 2014). Water level and conductivity monitoring is ongoing.
- *Salinity*: Weekly maximum salinity varied throughout the study period, but declined between Jan-May 2014.
- *Marsh inundation pattern*: Maximum monthly inundation occurred during February 2014; minimum monthly inundation occurred during October 2013.
- *Calculated local tidal datums*: MHHW is at 2.04 m, NAVD88; MHW is at 1.84 m NAVD88.
- *Sea-level rise marsh response modeling:* Presently, Bandon has an equal proportion of low and mid marsh vegetation with about 10% of the total area occupied by high marsh. Under the low NRC sea-level rise scenario (12 cm), modeling suggests that the site will remain relatively unchanged. However, under the NRC's mid sea-level rise scenario (63 cm) there is gradual loss of mid and high marsh between 2020 and 2110. At 2110, the site is comprised mostly of low marsh and mudflat. Under the NRC's high sea-level rise scenario (142 cm), mid and high marsh are lost more rapidly and mudflat begins to replace most vegetated marsh at the site by 2090.

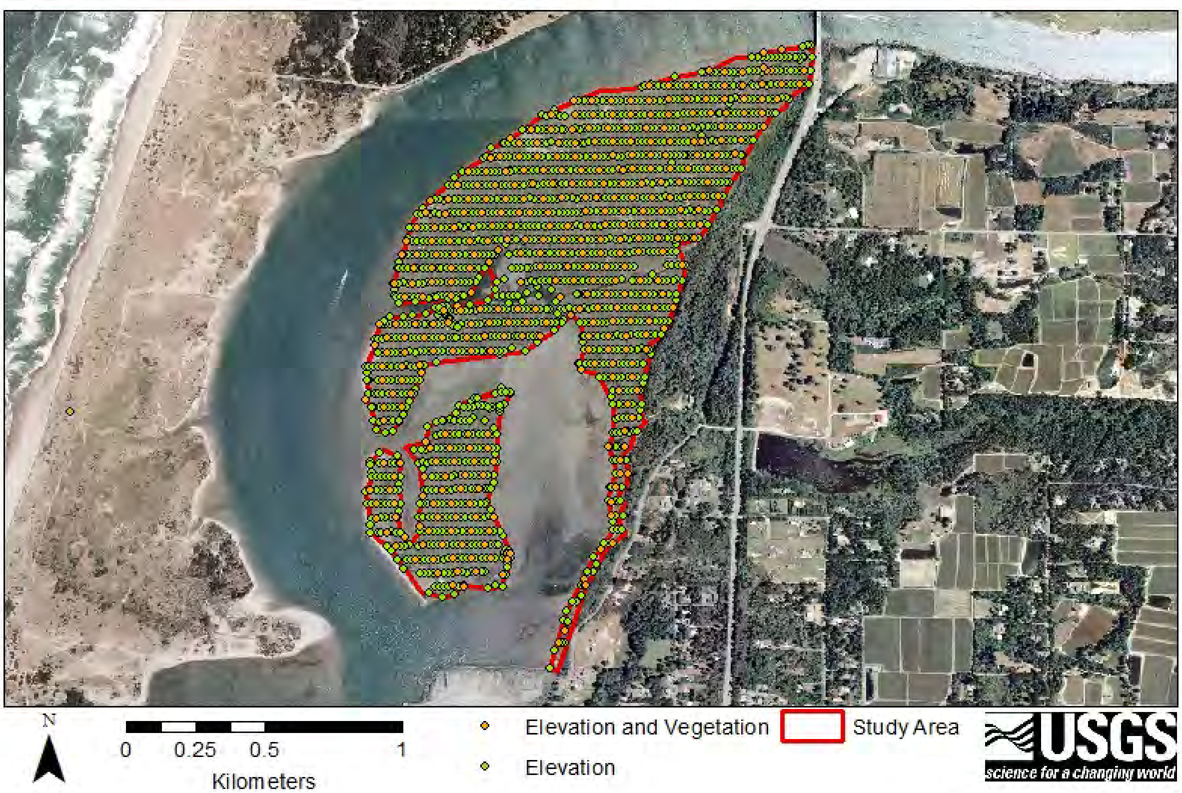

Figure I1. Distribution of elevation and vegetation survey points collected at Bandon.

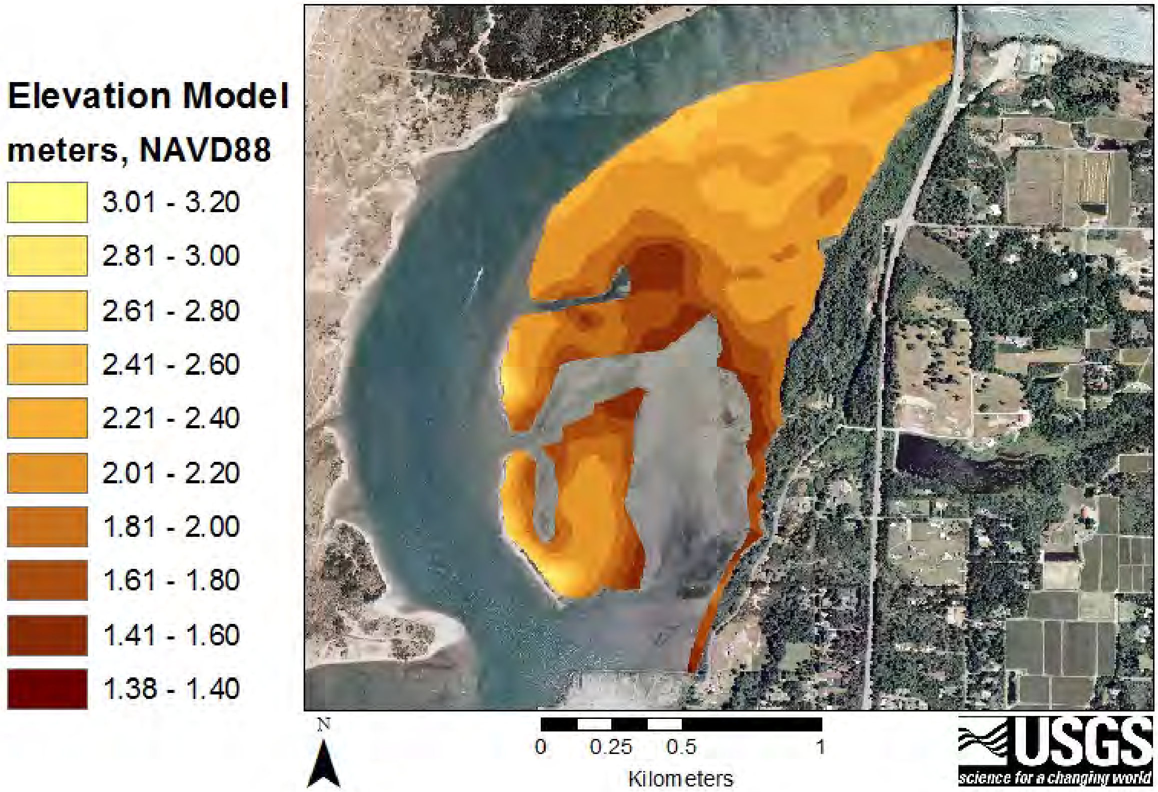

Figure I2. Elevation model (3 m resolution) developed from RTK GPS survey data.

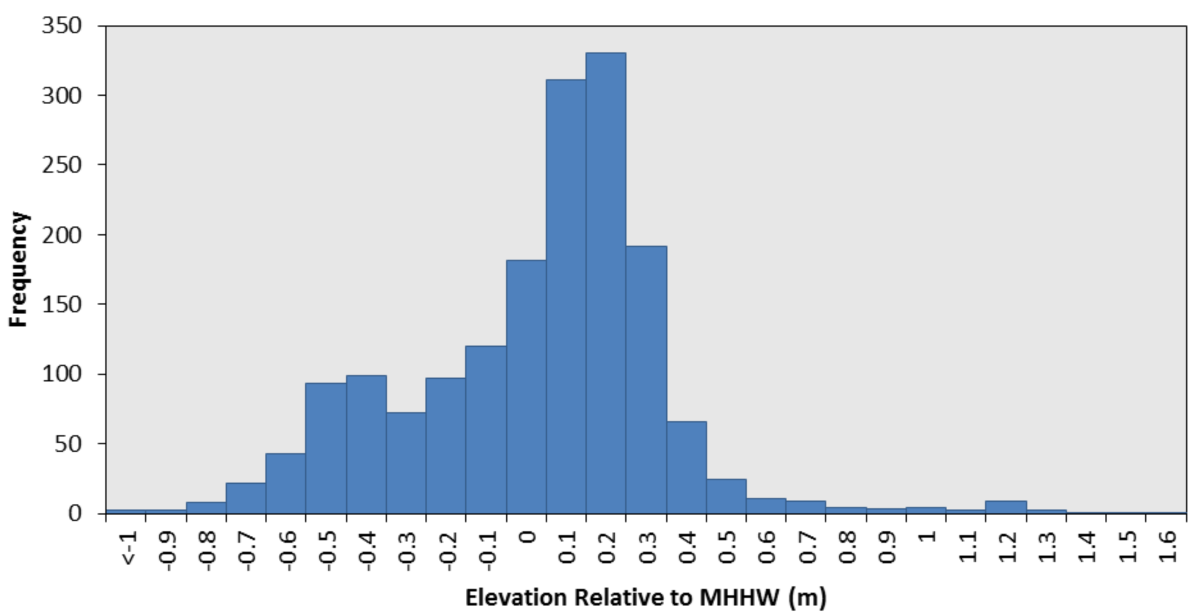

Figure I3. Frequency distribution of marsh surface elevation measurements relative to local mean higher high water (MHHW).

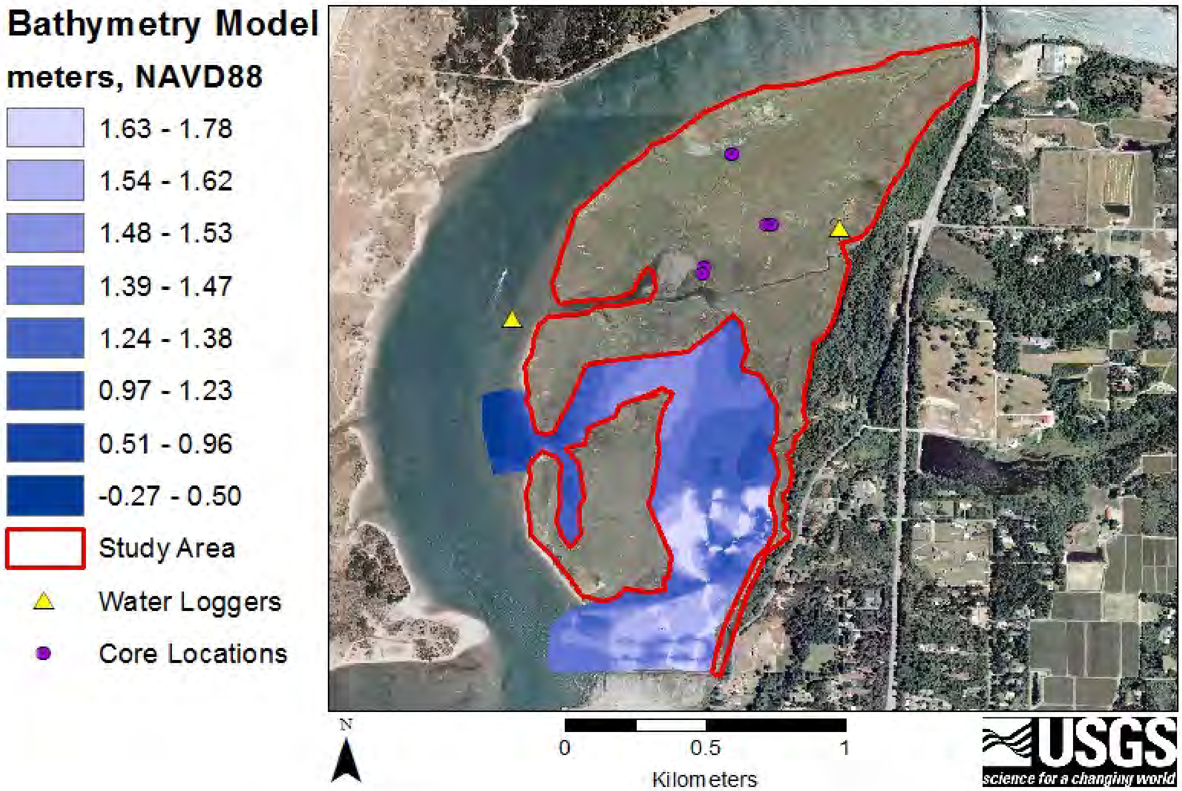

Figure I4. Near-shore bathymetry model at Bandon. Water level logger and core locations are shown within the marsh study site.

Table I1. Vascular plant species frequency of occurrence, percent cover, and height at Bandon.

Species	Species characteristics	Freq (%)	Mean cover (%)	Mean height (cm)
Sarcocornia perennis	Native perennial forb	65.4	21.0	30
Distichlis spicata	Native perennial grass	63.3	12.9	33
Jaumea carnosa	Native perennial forb	59.0	14.7	24
Deschampsia cespitosa	Native perennial grass	50.9	23.4	55
Carex lyngbyei	Native perennial sedge	34.0	6.8	52
Triglochin maritima	Native perennial forb	32.7	3.9	40
Juncus balticus	Native perennial rush	28.7	9.4	58
Agrostis stolonifera	Non-native perennial grass	24.7	10.1	52
Glaux maritima	Native perennial forb	20.9	1.8	29
Cuscuta pacifica	Native ann-perennial parasite	19.0	NA	NA
Potentilla anserina	Native ann-perennial forb	12.1	3.8	40
Schedonorus arundinaceus	Non-native perennial grass	7.5	2.0	52
Holcus lanatus	Non-native ann-perennial grass	6.4	1.2	66
Isolepis cernua	Native annual sedge	6.2	2.1	10
Atriplex sp.	Forb	5.1	0.9	32
Symphyotrichum subspicatum	Native perennial forb	3.5	0.8	78
Achillea millefolium	Native perennial forb	3.2	0.6	61
Vicia gigantea	Native perennial legume	2.9	0.8	60
Plantago maritima	Native perennial forb	2.9	0.3	18
Lilaeopsis occidentalis	Native perennial forb	1.9	0.3	10
Angelica lucida	Native perennial forb	1.1	0.3	50
Hordeum brachyantherum	Native perennial grass	1.1	0.0	51
Juncus breweri	Native perennial rush	0.8	0.2	52
Trifolium sp.	Legume	0.8	0.2	50
Tanacetum sp.	Forb	0.8	0.1	23
Spergularia canadiensis	Native annual forb	0.8	0.0	14
Grindelia stricta	Native perennial forb	0.5	0.1	49
Schedonorus arundinaceus	Perennial grass	0.5	0.1	155
Hordeum jubatum	Ann-perennial grass	0.5	0.0	41
Unknown Poaceae 3	Grass	0.3	0.2	37
Unknown Poaceae 5	Grass	0.3	0.2	37
Lotus corniculatus	Non-native perennial legume	0.3	0.2	26
Unknown Poaceae 1	Grass	0.3	0.1	55
Schoenoplectus tabernaemontani	Native perennial sedge	0.3	0.1	141
Phalaris arundinacea	Perennial grass	0.3	0.1	45
Carex pansa	Native perennial sedge	0.3	0.0	ND
Galium aparine	Native annual forb	0.3	0.0	95
Linum sp.	Forb	0.3	0.0	41
Unknown Poaceae 2	Grass	0.3	0.0	43
Galium trifidum	Native ann-perennial forb	0.3	0.0	47
Plantago lanceolata	Perennial forb	0.3	0.0	36
Unknown	NA	0.3	0.0	22
Eleocharis parvula	Native perennial sedge	0.3	0.0	1
Rumex sp.	Forb	0.3	0.0	10
Unknown Poaceae 4	Grass	0.3	0.0	51

Table I2. Mean percent cover of dominant plant species by marsh zone at Bandon. Zones were defined by degree of flooding.

[Atriplex = *Atriplex sp(*p); AgrSto = *Agrostis stolonifera*; CarLyn = *Carex lyngbyei*; DesCes = *Deschampsia cespitosa*; DisSpi = *Distichilis spicata*; JauCar = *Jaumea carnosa*; JunBal = *Juncus balticus*; SarPer = *Sarcocornia perennis*; VicGig = *Vicia gigantea*.]

Marsh zone	% high tides reaching zone	MHHW range (m)	Sample size	Mean cover of top four dominant plants (%)
Transition	0.14-3	0.669 to 0.373	15	JunBal (13), Atriplex (12), SarPer (11), VicGig (11)
High	3-25	0.372 to 0.018	198	DesCes (28), SarPer (21), JunBal (16), AgrSto (14)
Middle	25-50	0.017 to -0.185	81	DesCes (35), SarPer (23), CarLyn (12), DisSpi (12)
Low	>50	-0.186 to -0.749	78	DisSpi (25), JauCar (24), SarPer (22), CarLyn (14)

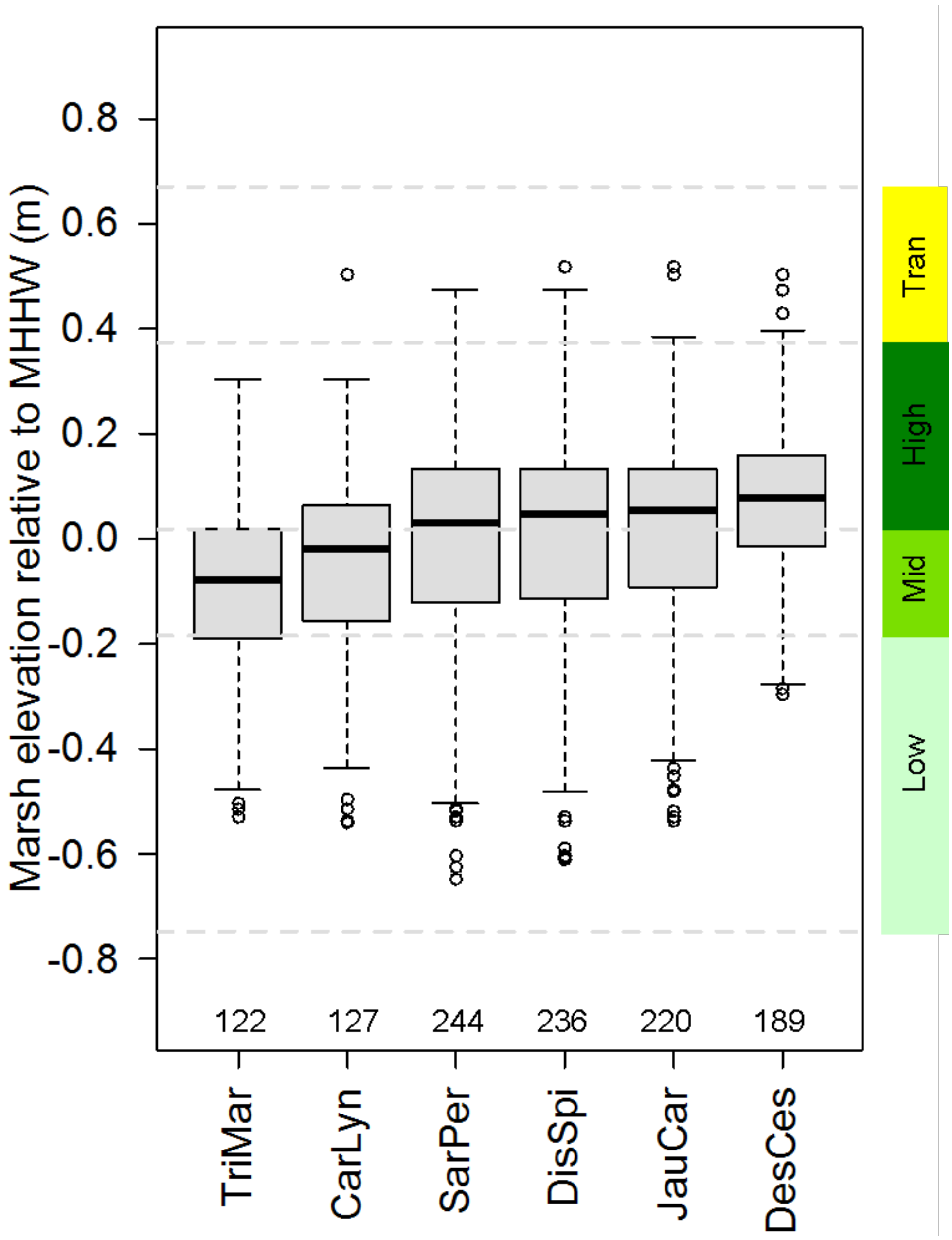

Figure I5. Elevation distribution of the six most common vascular plant species at Bandon. The black horizontal bars show the median elevation at which the species occurs; shaded boxes indicate the interquartile range; upper and lower whiskers encompass points no greater than 1.5x the length of the shaded box; and open circles indicate outliers. The number of plots in which the species occurred is indicated above the species codes (out of a total of 372 plots). Marsh elevation zones (low, middle, high and transition) are illustrated at right. CarLyn = *Carex lyngbyei;* DesCes = *Deschampsia cespitosa*; DisSpi = *Distichilis spicata;* JauCar = *Jaumea carnosa*; SarPer = *Sarcocornia perennis;* TriMar = *Triglochin maritima.*

Table I3. Location of water level loggers and deep sediment cores (UTM coordinates).

	Northing (m)	Easting (m)
Water level loggers	385283	4777000
	386142	4777309
Deep core locations	385870	4777581
	385789	4777178
	385955	4777328

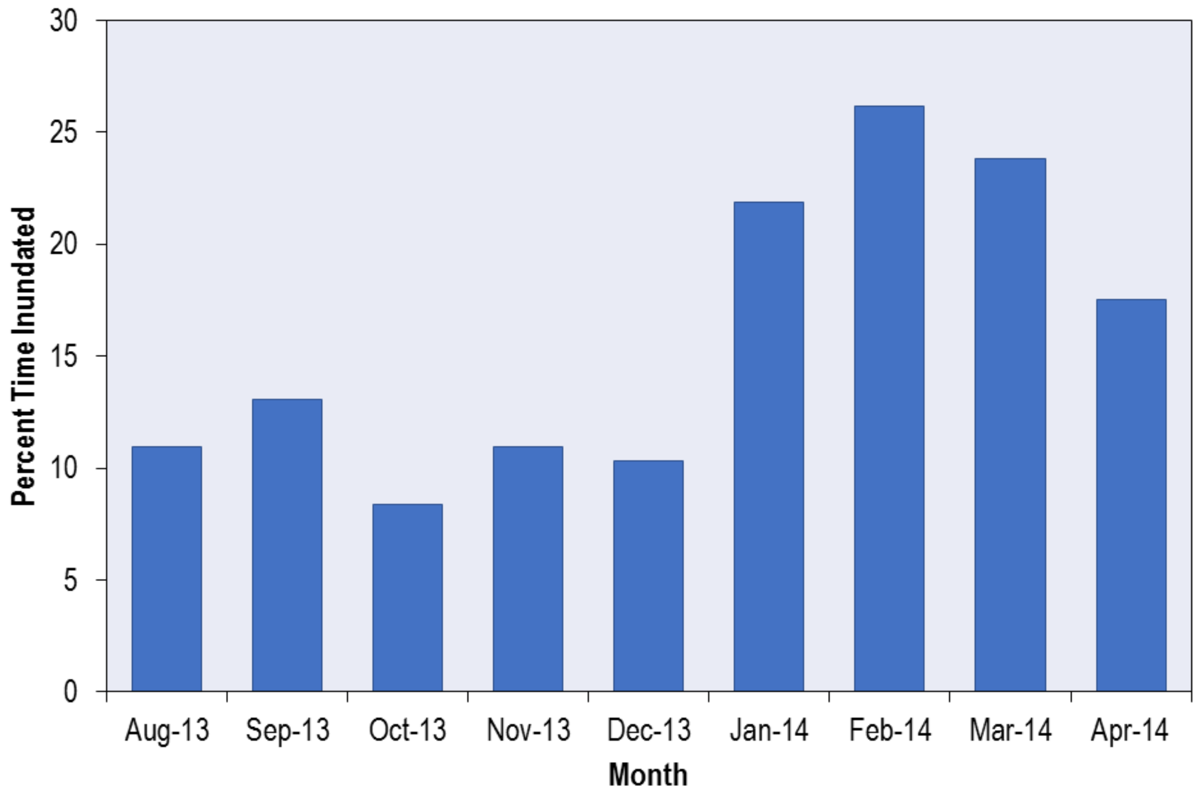

Figure I6. Variation in monthly inundation duration (at the average marsh elevation) at Bandon. Water levels were determined with a water level logger deployed at 0.25 m (NAVD88).

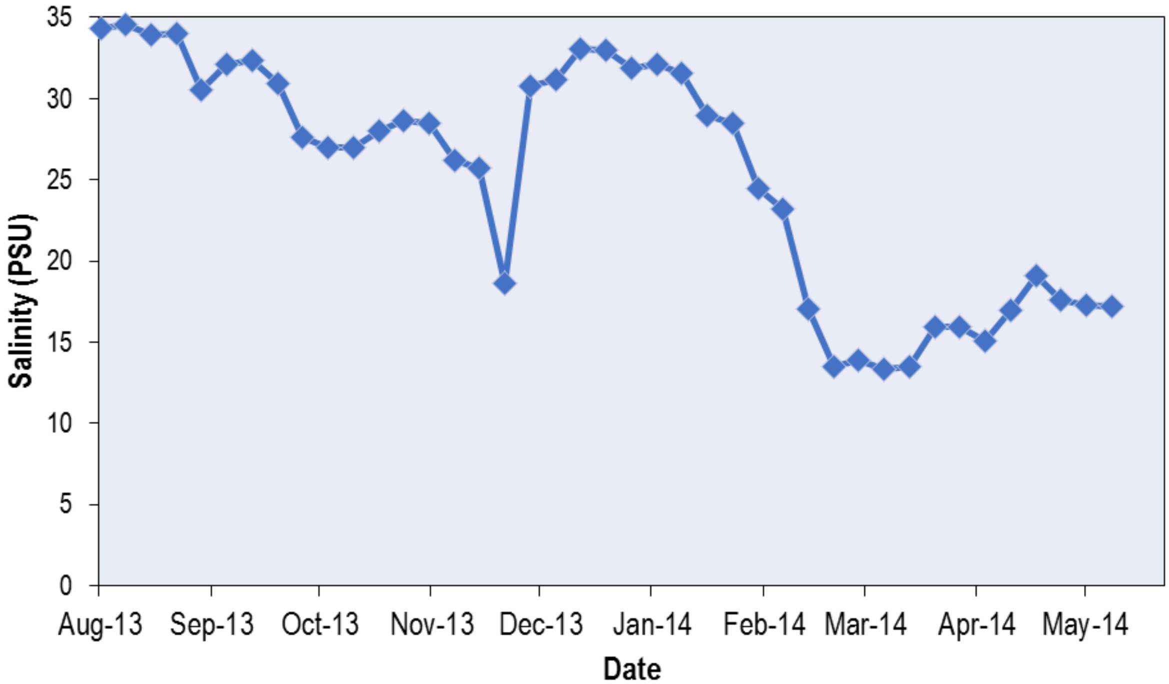

Figure I7. Average weekly maximum salinity from August 2013 – May 2014 at Bandon. Seawater is approximately 35 PSU.

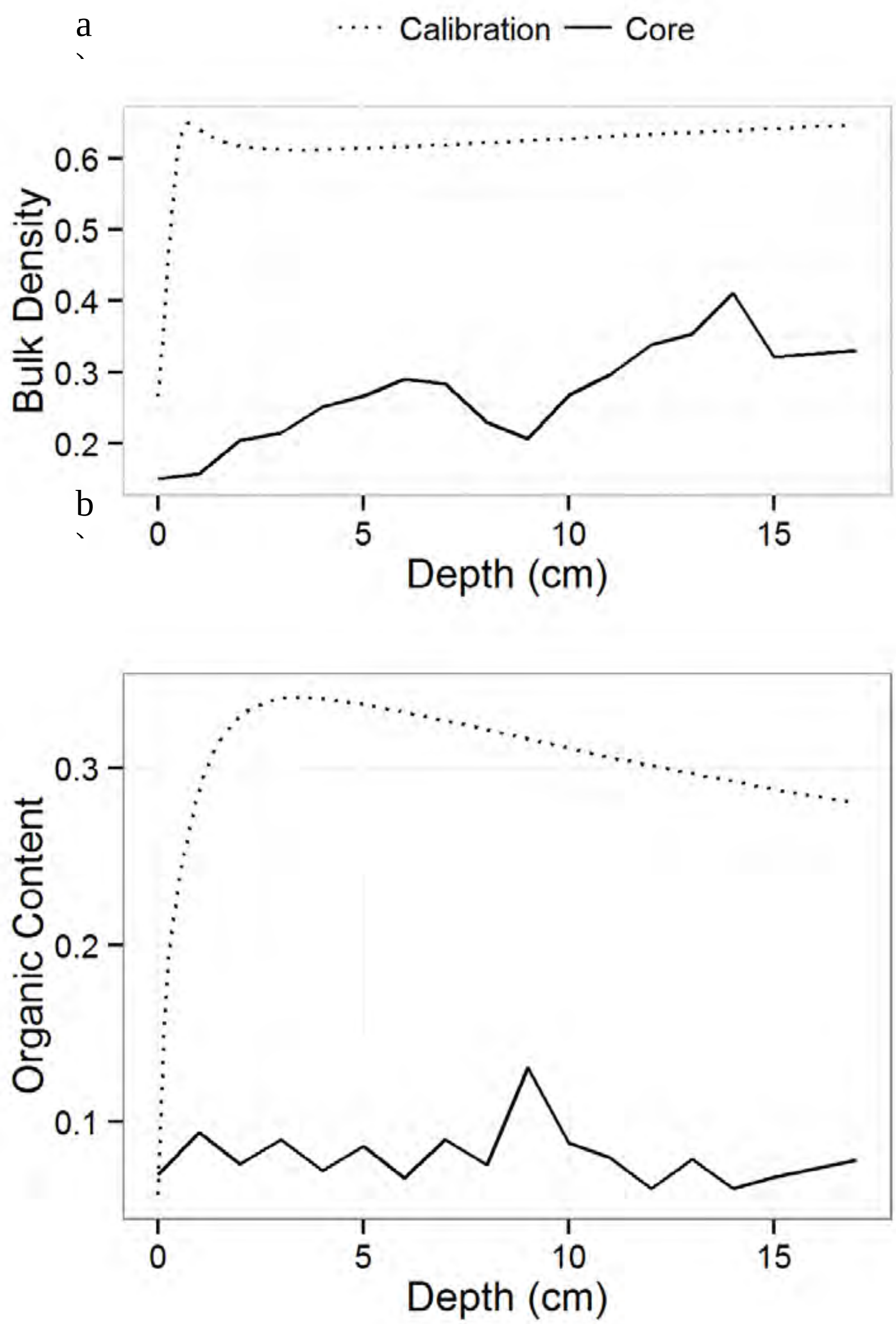

Figure I8. Deep core calibration of the WARMER model using depth profiles of (a) sediment bulk density (g cm^{-3}) and (b) sediment organic matter content (%).

Table I4. Model input parameters for Bandon. Sediment accumulation rate is reported at the elevation of MSL. NDVI is the Normalized Difference Vegetation Index and NAIP is the National Agriculture Inventory Program.

Model parameter	Value	Source
Sediment accumulation rate (g cm^{-2} yr^{-1})	0.13	Core calibration
Elevation of peak biomass (cm, MSL)	123	NDVI from NAIP
Minimum elevation of vegetation (cm, MSL)	12	Field Surveys
Max. aboveground organic accumulation (g cm^{-2} yr^{-1})	0.0079	Core calibration
Root-to-shoot ratio	1.95	C. Janousek, unpub data
Porosity surface (%)	89	Core
Porosity depth (%)	66	Core
Refractory carbon (%)	28.1	Core
Maximum astronomical tide (cm, MSL)	183	CERCC water logger
Historic sea-level rise (mm yr^{-1})	0.59	Charleston tide gauge (NOAA, 9432780)
Organic matter density (g cm^{-3})	1.14	DeLaune 1983
Mineral density (g cm^{-3})	2.61	DeLaune 1983

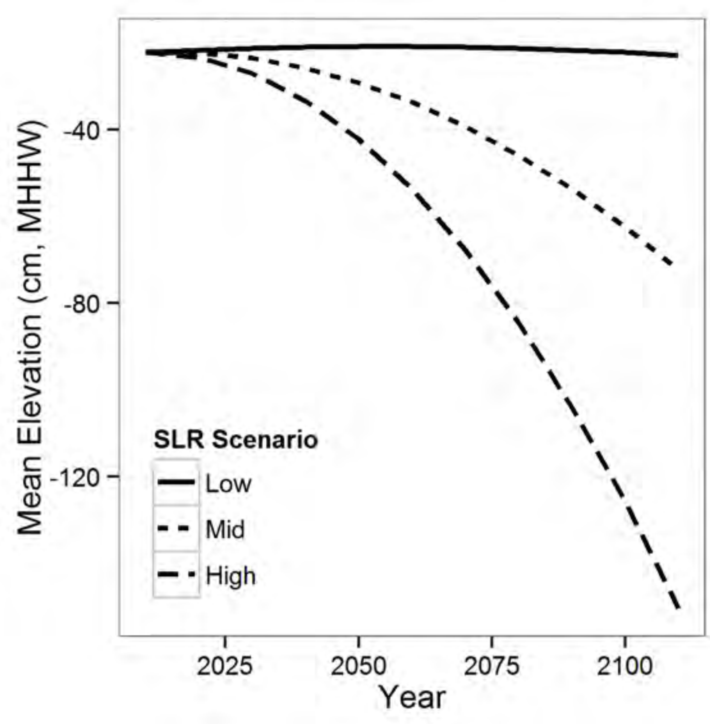

Figure I9. WARMER model projections for the change in average marsh elevation change at Bandon from 2010 to 2110 under low, mid, and high sea-level rise (SLR) scenarios.

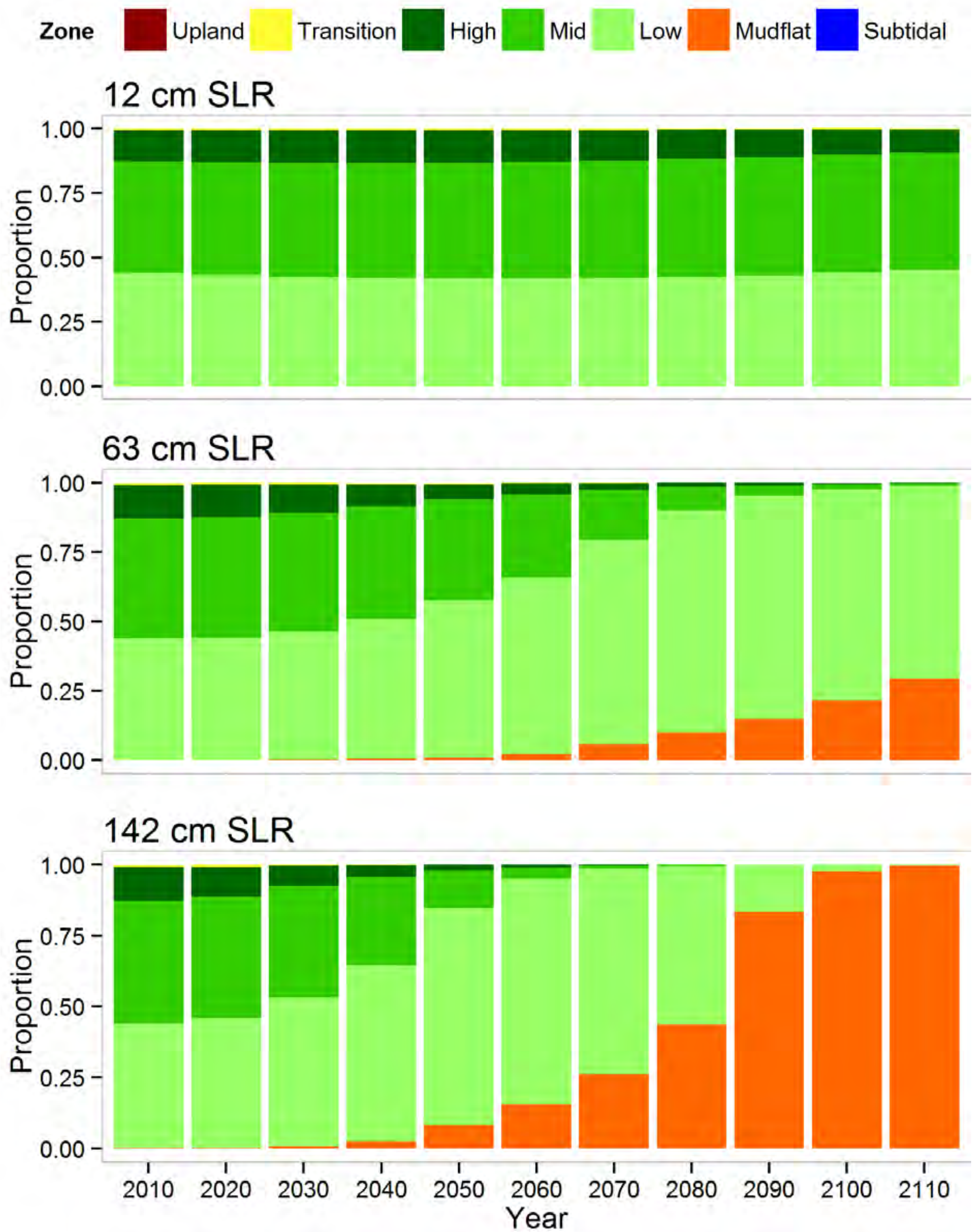

Figure I10. Model projections for change in the relative proportion of upland, transitional, high, mid, and low marsh habitat, and mudflat under low (12 cm), mid (63 cm), and high (142 cm) NRC sea-level rise scenarios from 2010 to 2110.

Table I5. Percentage of habitat area modeled for three sea-level rise scenarios for 2010, 2050, and 2110.

	Low SLR (12 cm)			Mid SLR (63 cm)			High SLR (142 cm)		
	2010	2050	2110	2010	2050	2110	2010	2050	2110
Upland	0	0	0	0	0	0	0	0	0
Transition	1	1	1	1	0	0	1	0	0
High	12	13	9	12	6	0	12	2	0
Mid	43	45	45	43	36	1	43	13	0
Low	44	42	45	44	57	70	44	77	0
Mudflat	0	0	0	0	1	29	0	8	100
Subtidal	0	0	0	0	0	0	0	0	0

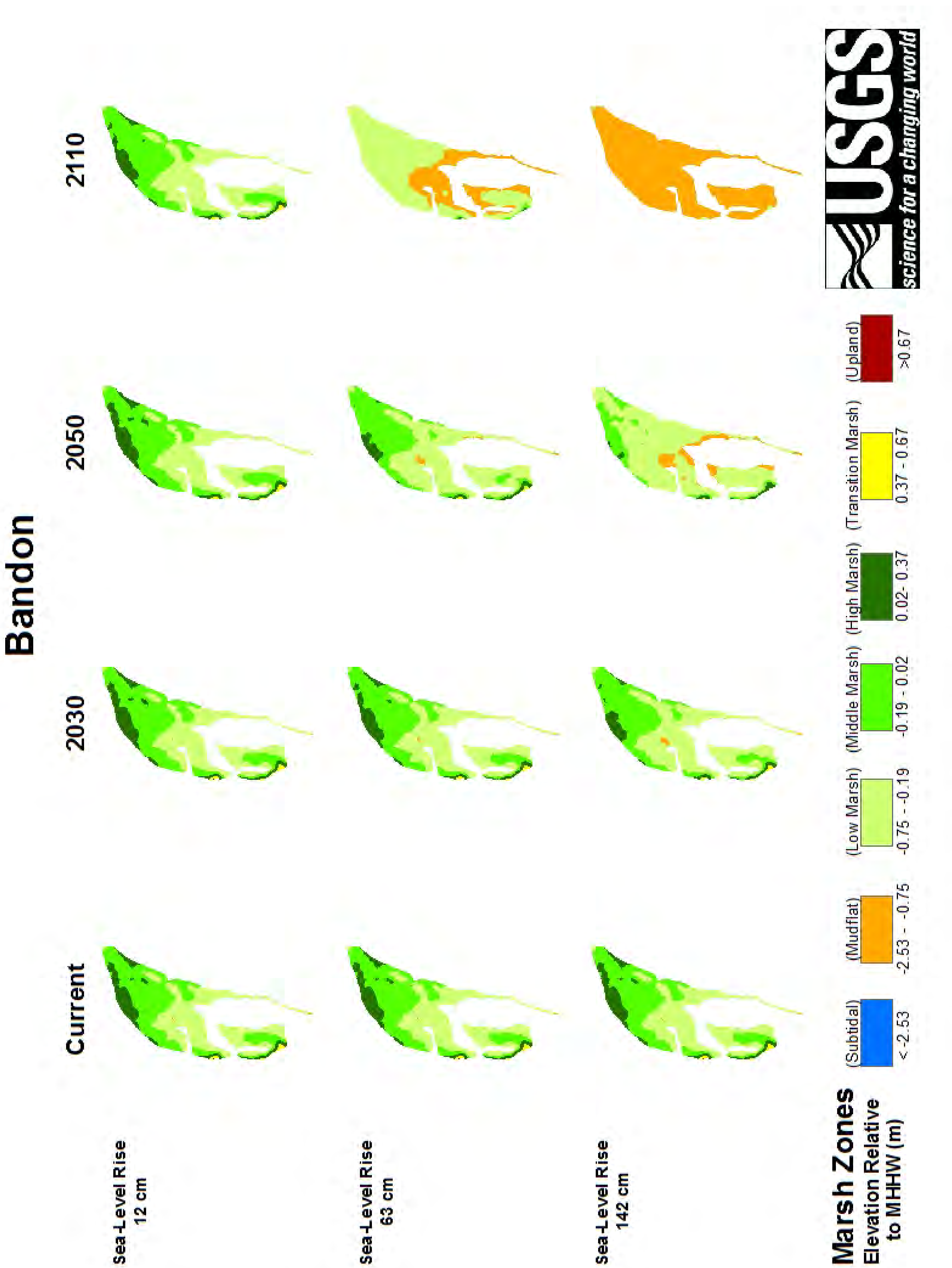

Figure I11. Projected habitat distribution at Bandon for 2030, 2050 and 2110 with the WARMER model under three NRC sea-level rise scenarios.

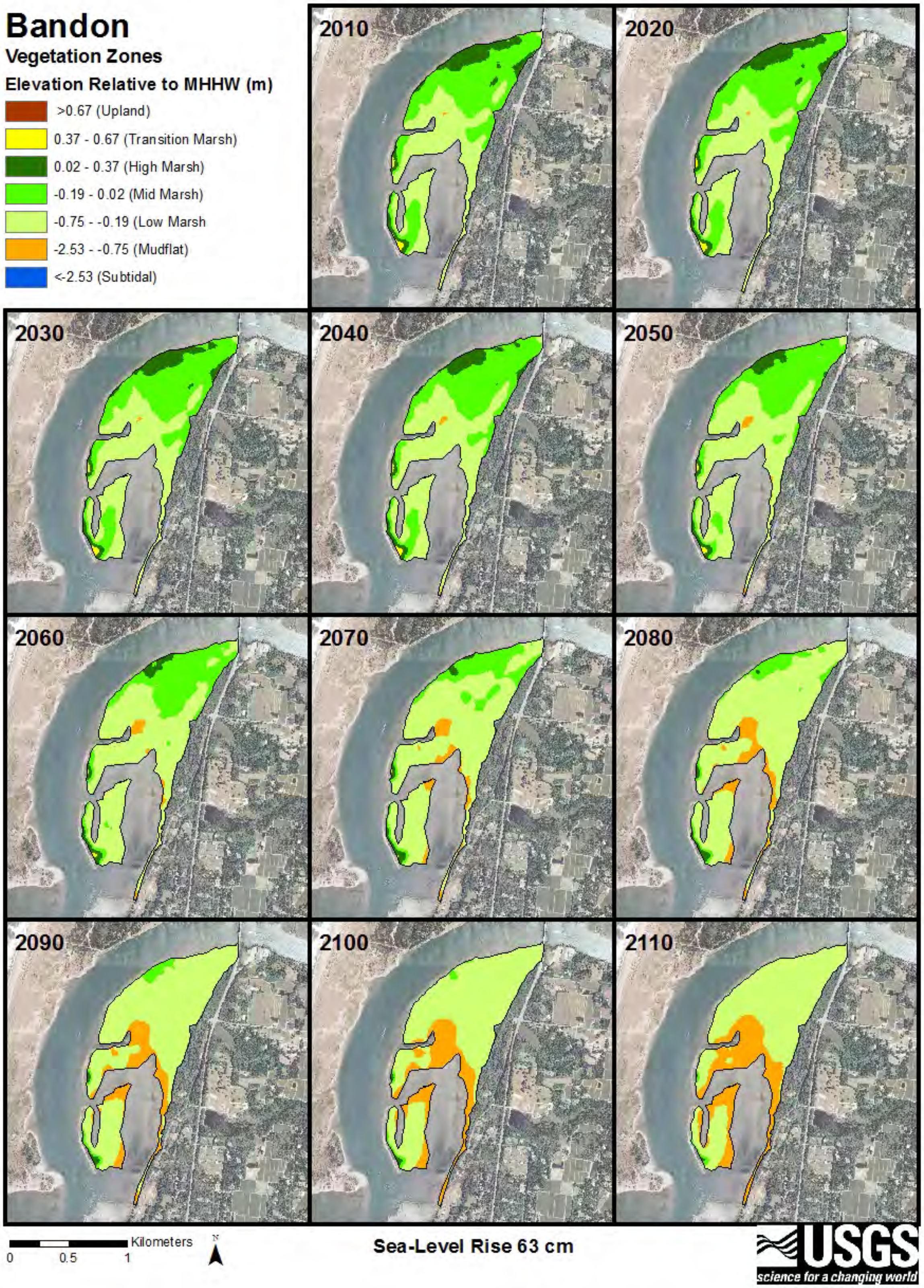

Figure I12. Projected changes in Bandon habitat zones under the mid NRC sea-level rise scenario (63 cm).