Appendixes

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Appendix A. Site Specific Details for Mad River Slough, Arcata Bay, Humboldt County, California

Photo: C. Janousek, OSU/USGS

Summary:

- *Study site size*: 38.3 hectares
- *Location*: 40°41'19.61"N latitude, 124°12'36.08"W longitude.
- *Site management*: U.S. Fish and Wildlife Service
- *Site vegetation and elevation survey*: May 24–June 24, 2012
- *Sample size*: 852 elevation points, 173 vegetation plots
- *Marsh elevation model*: 66% of elevation data points occurred above MHHW
- *Plant community composition*: The dominant species was *Sarcocornia pacifica*, but *Distichlis spicata* and *Jaumea carnosa* were also very common. Common species occupied similar elevation ranges.
- *Bathymetric surveys*: 38.3 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 = 0.192 g cm^{-2} yr^{-1}; organic matter accumulation rate = 0.039 g cm^{-2} yr^{-1}; net accretion = 0.50 cm yr^{-1}.

- *Water monitoring data collection*: water level (June 2012–May 2013); conductivity (July 2013–May 2014). Water level and conductivity monitoring is ongoing.
- *Calculated tidal datums*: MHHW was at 2.005 m NAVD88; MHW was at 1.786 m NAVD88.
- *Marsh inundation pattern*: Maximum monthly inundation occurred during December 2012; minimum monthly inundation during April 2013.
- *SETs*: Two high marsh SETs and two low marsh SETs were installed on June 19–20, 2013. During the first year of monitoring, cumulative elevation change was +0.89 mm in high marsh and +3.86 mm in low marsh.
- *Sea-level rise marsh response modeling*: Under the NRC's low SLR scenario, the site remains composed of high and mid marsh through the coming century. The mid SLR scenario is projected to result in a gradual shift in habitat composition with high marsh lost by 2080 and mid marsh lost by 2100. By 2110, the site is projected to be comprised of mostly low marsh with some mudflat habitat. High SLR is projected to lead to a rapid transition in habitat zones. By 2090, the site becomes 100% non-vegetated mudflat

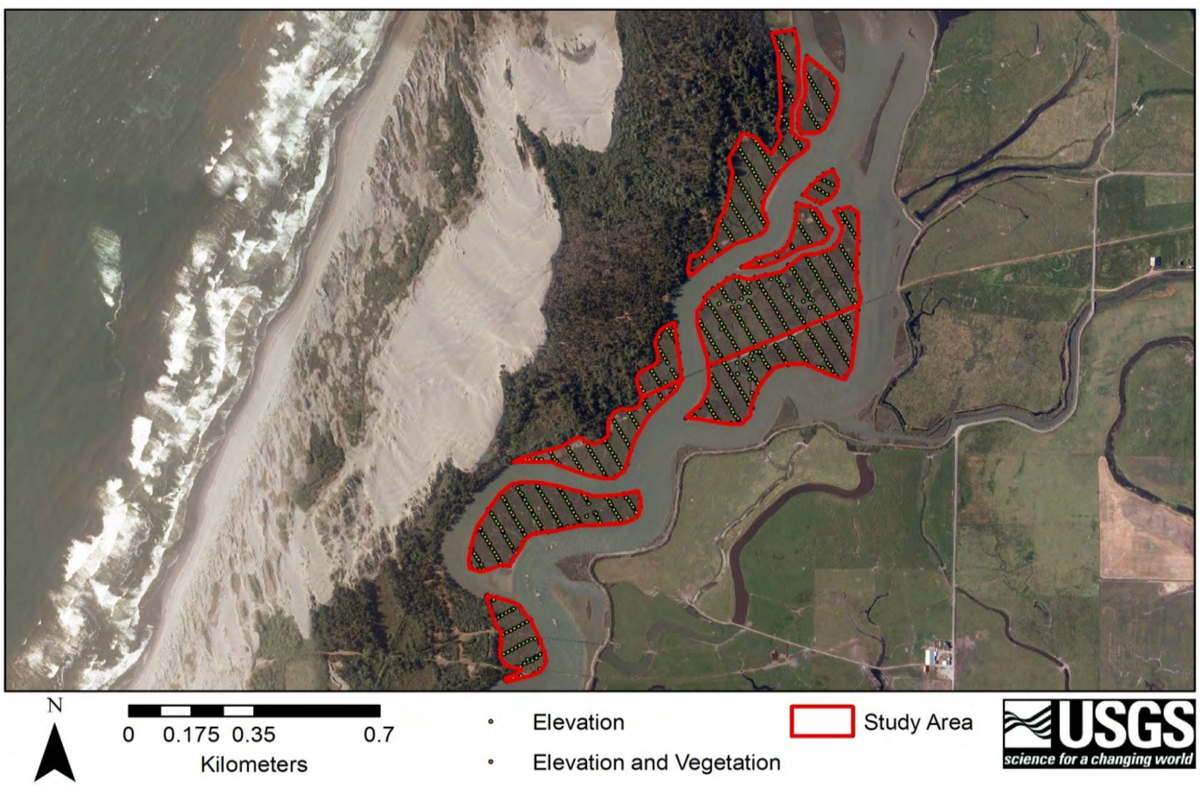

Figure A1. Distribution of elevation and vegetation survey points at Mad River Slough.

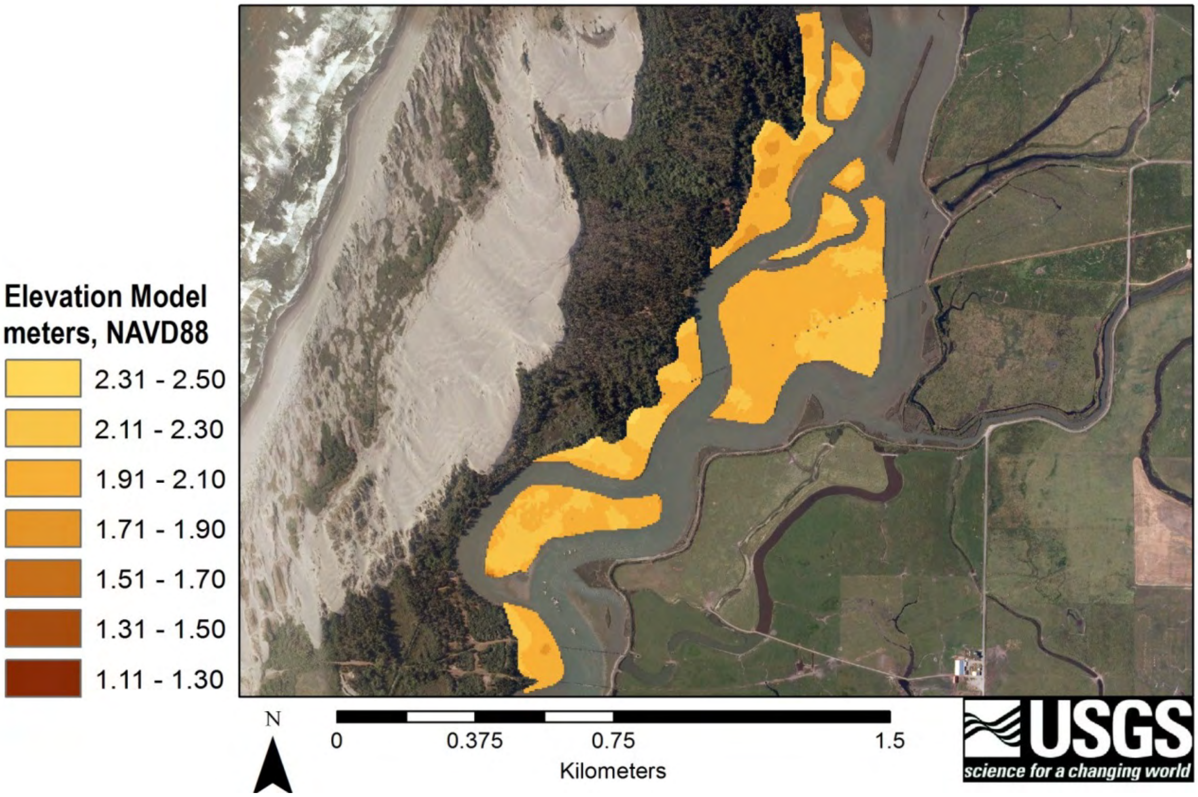

Figure A2. Elevation model (3 m resolution) of tidal marsh at Mad River Slough developed from RTK GPS survey data.

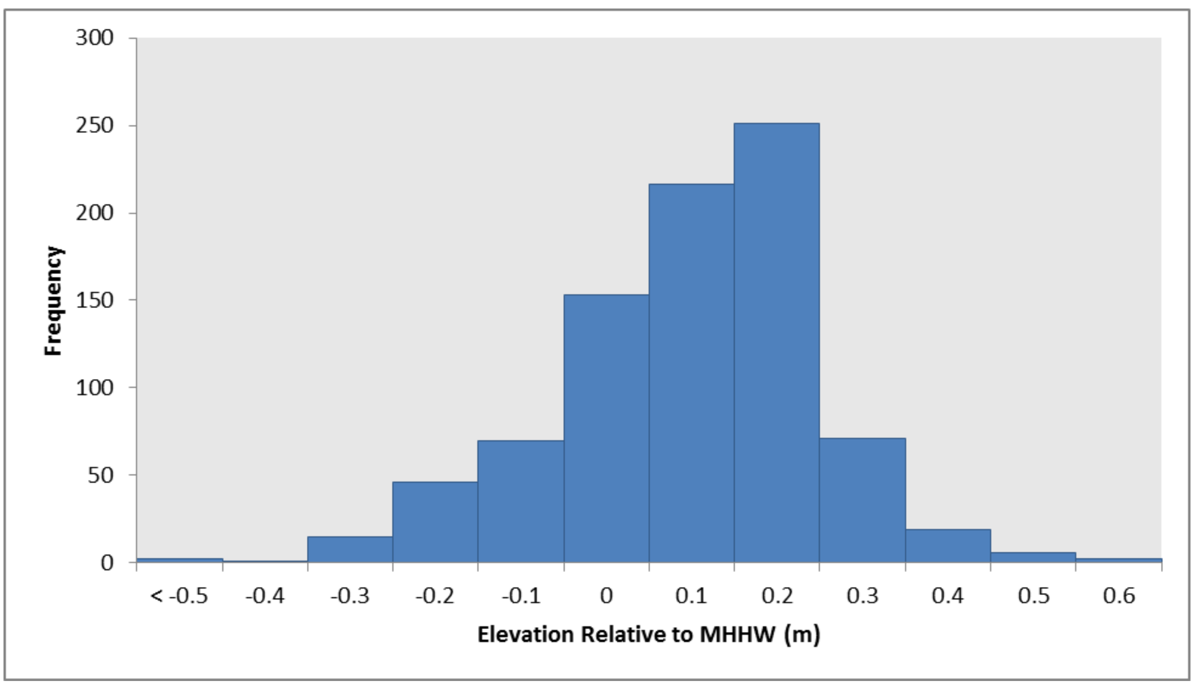

Figure A3. Frequency distribution of marsh surface elevation measurements relative to local mean higher high water (MHHW) at Mad River Slough.

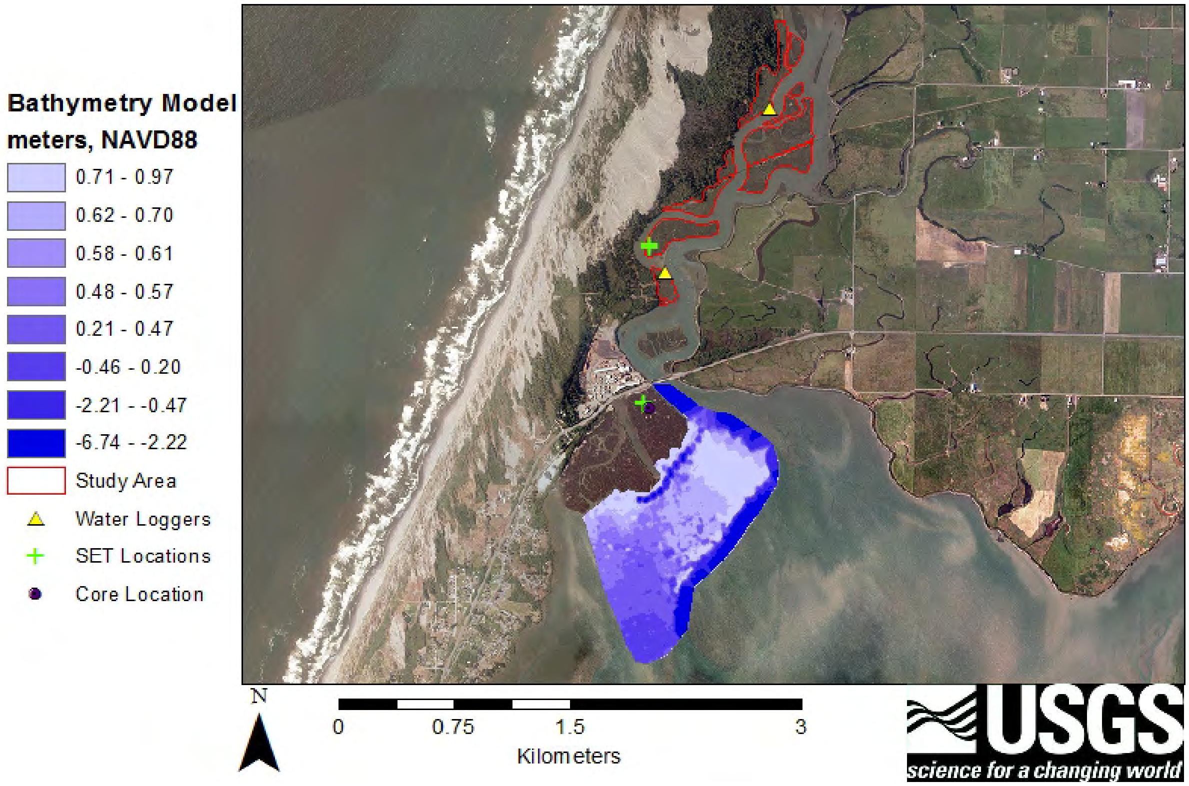

Figure A4. Near-shore bathymetry model for Mad River Slough and locations of water level loggers, surface elevation tables (SET), and the deep sediment core.

Table A1. Frequency of occurrence, percent cover and height of vascular plant species encountered in vegetation plots at Mad River Slough.

[NA = not measured]

Species	Description	Frequency of occurrence (%)	Percent cover		Plant height (cm)	
			Mean	Max	Mean	Max
Sarcocornia pacifica	Perennial forb	91.9	30	100	19	50
Distichlis spicata	Perennial grass	89.0	45	95	20	58
Jaumea carnosa	Perennial forb	72.8	18	95	9	23
Orobanchaceae spp.	Annual hemiparasites	39.9	5	85	11	26
Limonium californicum	Perennial forb	39.3	4	35	10	42
Triglochin concinna	Perennial forb	38.2	13	80	17	45
Spartina densiflora	Perennial grass	35.3	6	95	29	91
Plantago maritima	Perennial forb	34.7	6	70	16	29
Triglochin maritima	Perennial forb	20.2	3	75	36	100
Spergularia canadensis	Annual forb	13.9	1	35	7	15
Grindelia stricta	Perennial subshrub	8.1	1	25	23	60
Salicornia bigelovii	Annual forb	5.8	0	40	4	9
Juncus balticus	Perennial rush	4.6	3	100	54	96
Spergularia macrotheca	Perennial forb	3.5	0	25	15	23
Atriplex prostrata	Annual forb	2.3	0	20	16	20
Potentilla anserina	Ann-perennial forb	2.3	0	15	37	73
Isolepis cernua	Annual sedge	1.7	0	40	8	12
Cuscuta pacifica	Ann-perennial parasite	1.2	NA	NA	NA	NA
Schoenoplectus acutus	Perennial sedge	1.2	1	100	162	238
Carex lyngbyei	Perennial sedge	1.2	0	25	50	75
Glaux maritima	Perennial forb	1.2	0	5	40	40
Hordeum brachyantherum	Perennial grass	0.6	0	5	37	39
Festuca rubra	Perennial grass	0.6	0	1	51	51
Undetermined	NA	0.6	0	1	55	55

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

[JunBal = *Juncus balticus*; SarPac = *Sarcocornia pacifica*; DisSpi = *Distichlis spicata*; PotAns = *Potentilla anserina*; JauCar = *Jaumea carnosa*; TriCon = *Triglochin concinna*; TriMar = *Triglochin maritima*.]

Marsh zone	% high tides reaching zone	MHHW range (m)	n	Mean cover of top four dominant plants (%)
Transition	0.14-3	0.758 to 0.421	2	JunBal (50), SarPac (50), DisSpi (3), PotAns (3)
High	3-25	0.421 to 0.019	119	DisSpi (47), SarPac (27), JauCar (16), TriCon (15)
Middle	25-50	0.019 to -0.211	44	DisSpi (45), SarPac (29), JauCar (25), TriCon (12)
Low	>50	-0.211 to -0.503	8	SarPac (68), DiSpi (31), JauCar (13), TriMar (1)

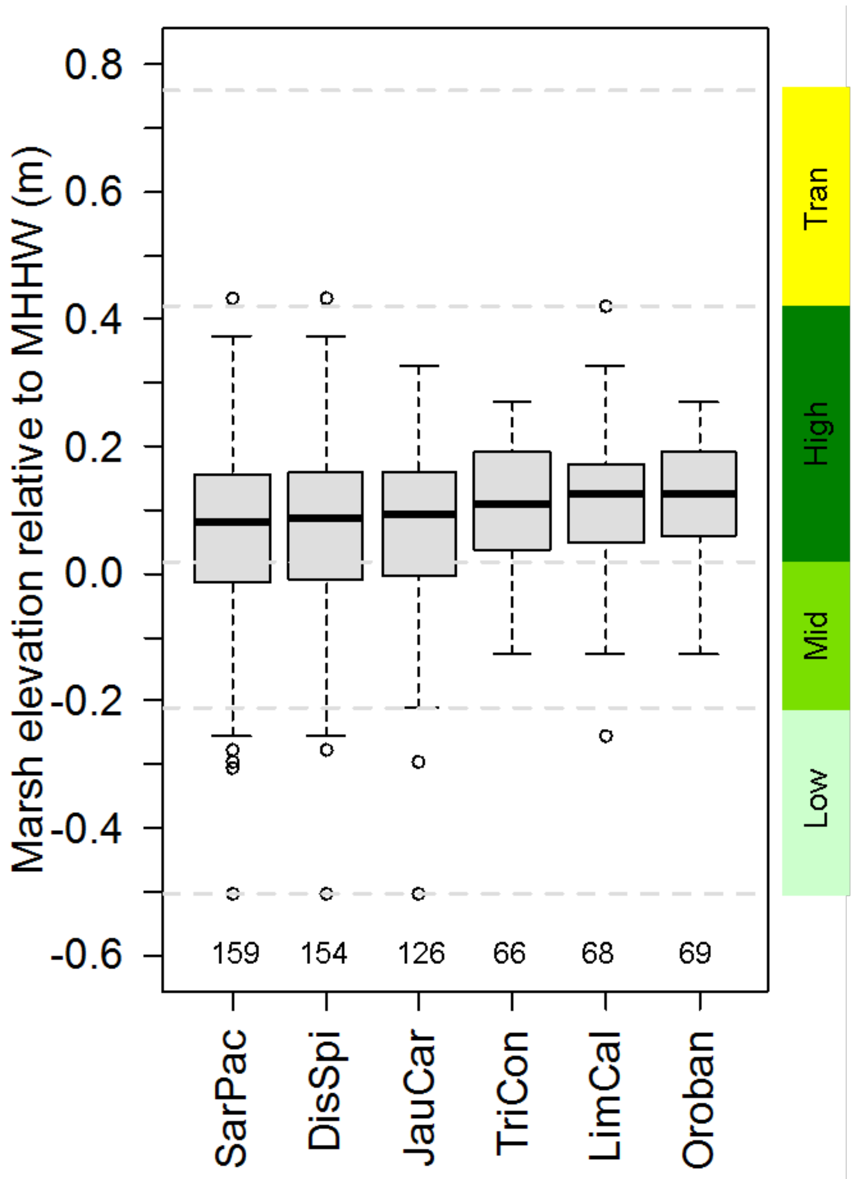

Figure A5. Elevation distribution of the six most commonly-occurring vascular plant species at Mad River Slough. The black horizontal bars show the median elevation at which the species occurs; shaded boxes indicate the interquartile range; upper and lower whiskers encompass points up to 1.5 times the 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 173 plots). Marsh elevation zones (low, middle, high and transition) are illustrated at right. SarPac = *Sarcocornia pacifica*; DisSpi = *Distichlis spicata*; JauCar = *Jaumea carnosa*; TriCon = *Triglochin concinna*; LimCal = *Limonium californicum*; Oroban = Orobanchaceae, undifferentiated between *Chloropyron maritimum* ssp. *palustre* and *Castilleja ambigua* ssp. *humboldtensis*.

Table A3 . Locations of water level loggers, surface elevation tables (SET), and deep sediment core at Mad River Slough (UTM zone 10).

Location	Easting (m)	Northing (m)
water logger	403141	4525142
SET	403010	4524287
	403002	4524274
	403044	4525312
	403048	4525335
core sample	403010	4524275

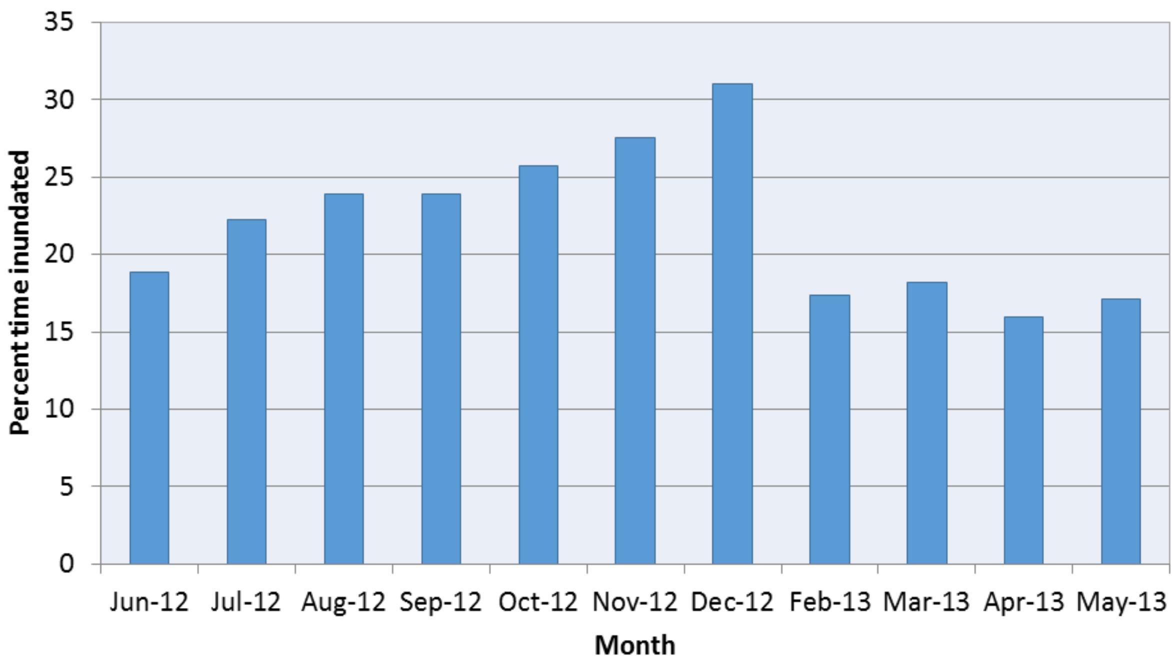

Figure A6. Average monthly inundation of the study site based on an average marsh elevation. Water levels were determined with a Solinst water logger deployed at 0.76 m above NAVD88.

Figure A7. Average weekly maximum salinity from November 2013–May 2014 at Mad River Slough.

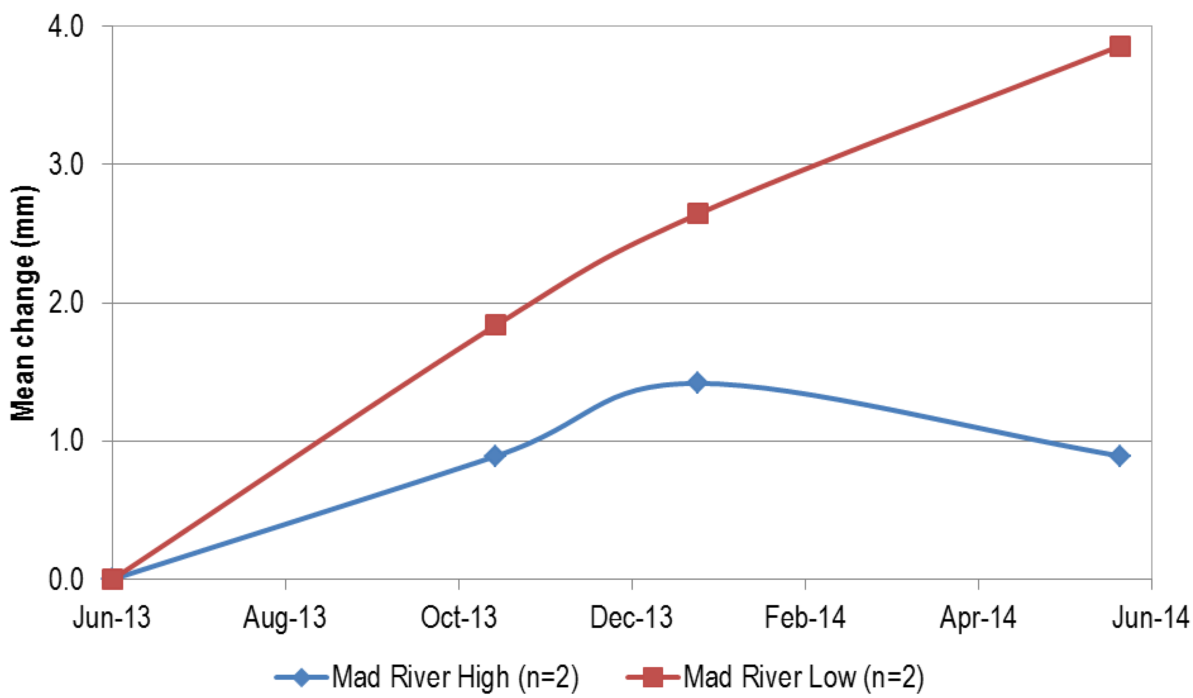

Figure A8. Baseline measurements of net marsh surface elevation change at Mad River Slough at the surface elevation tables (SET).

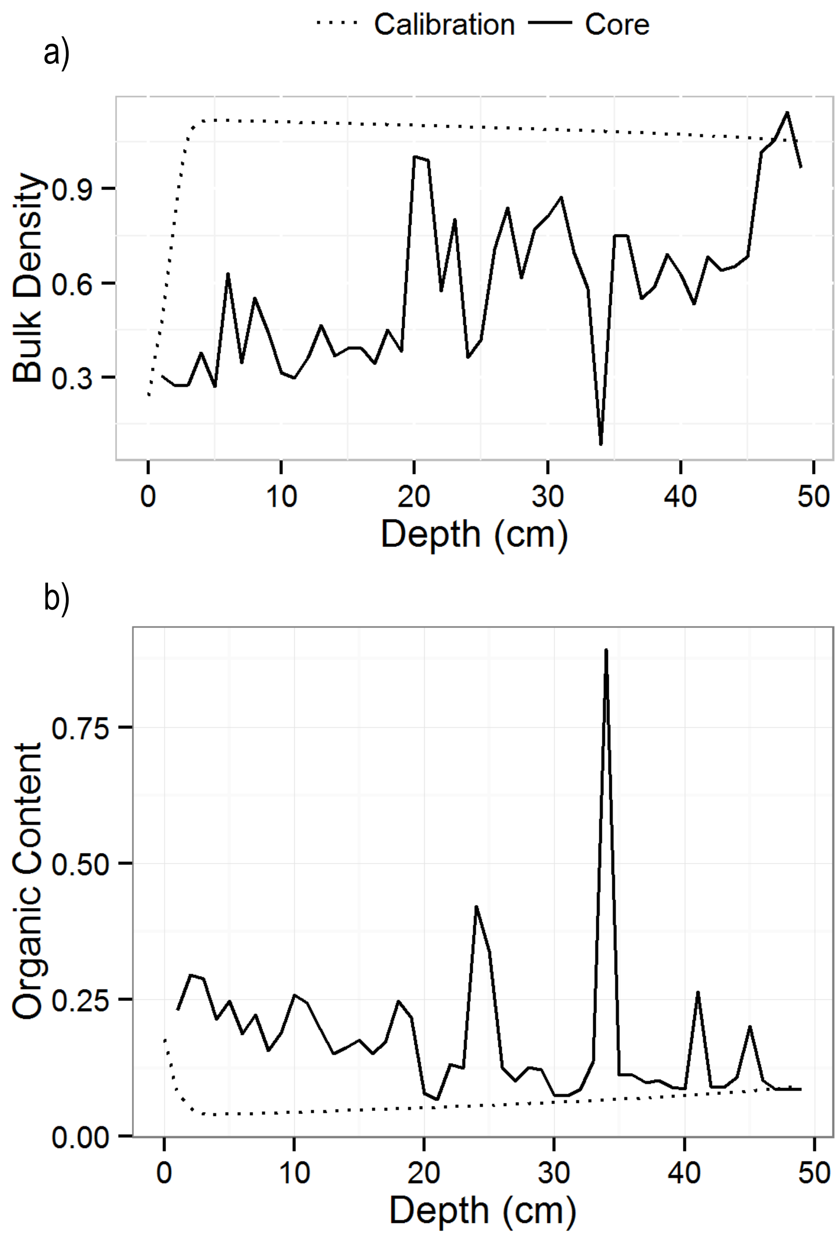

Figure A9. Deep sediment core calibration of the WARMER model using depth profiles of (a) bulk density (g cm^{-3}) and (b) organic matter content (%).

Table A4. WARMER parameters and soil core characteristics used for SLR model calibration at Mad River.

[NAIP = National Agriculture Inventory Program]

Model parameter	Value	Source
Sediment accumulation rate (g cm^{-2} yr^{-1})	0.392	Core calibration
Elevation of peak biomass (cm, MSL)	110	NDVI from NAIP
Minimum elevation of vegetation (cm, MSL)	40	Field surveys
Max. aboveground organic accumulation (g cm^{-2} yr^{-1})	0.0629	Core calibration
Root-to-shoot ratio	0.458	C. Janousek, unpub data
Porosity at sediment surface (%)	89	Core
Porosity at depth (%)	55	Core
Refractory carbon (%)	25.8	Core
Maximum astronomical tide (cm, MSL)	257	North Spit tide gauge (NOAA,9418767)
Historic sea-level rise (mm yr^{-1})	4.7	North Spit tide gauge (NOAA,9418767)
Organic matter density (g cm^{-3})	1.14	DeLaune 1983
Mineral density (g cm^{-3})	2.61	DeLaune 1983

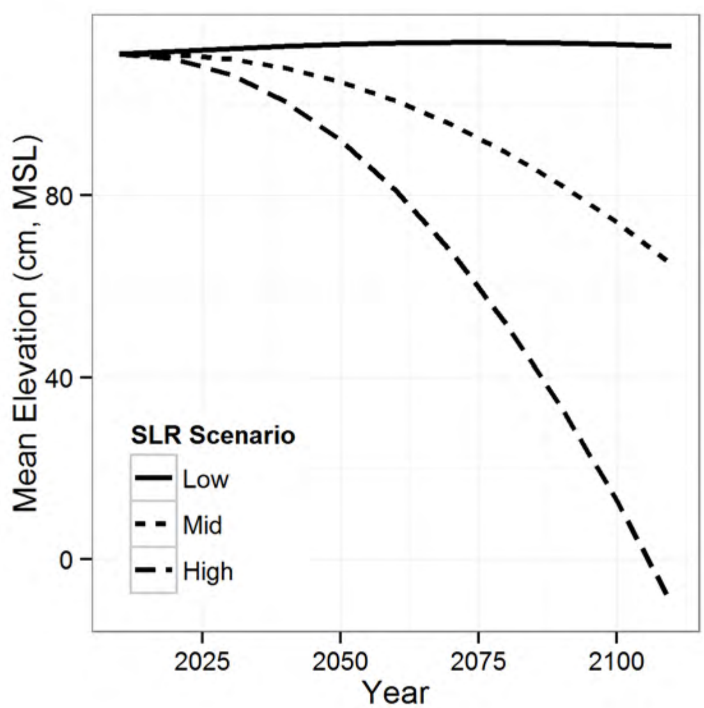

Figure A10. WARMER model projections for the change in average marsh elevation (relative to MSL) at Mad River Slough from 2010 to 2110 under low, mid, and high NRC sea-level rise scenarios.

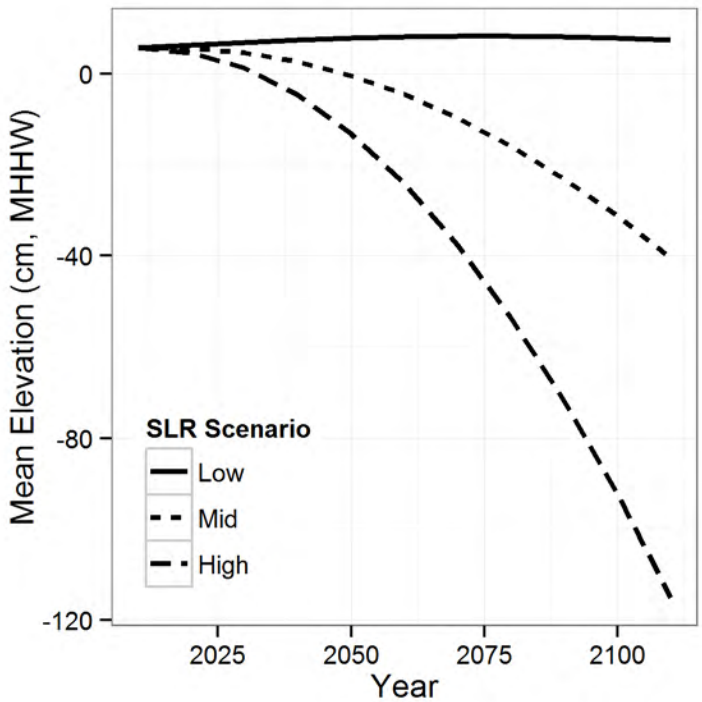

Figure A11. WARMER model projections for the change in average marsh elevation (relative to MHHW) at Mad River Slough from 2010 to 2110 under low, mid, and high NRC sea-level rise scenarios.

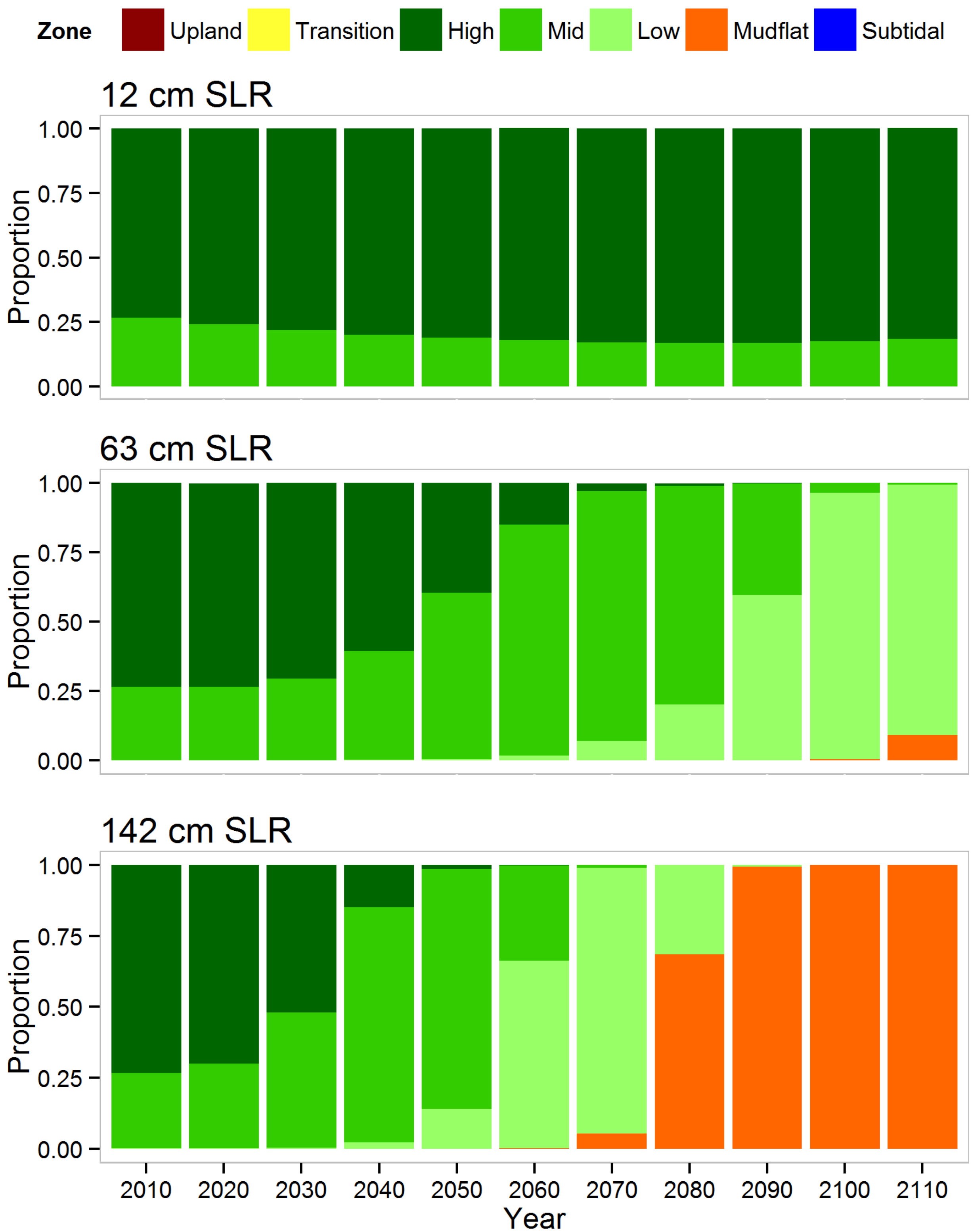

Figure A12. WARMER projections for change in the relative proportion of upland; transitional, high, mid and low marsh; and mudflat habitat at Mad River Slough under the NRC's low (44 cm), mid (93 cm), and high (166 cm) sea-level rise scenarios from 2010 to 2110.

Table A5. 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)		
Habitat	**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	73	81	82	73	40	0	73	2	0
Mid	27	19	18	27	60	1	27	84	0
Low	0	0	0	0	0	90	0	14	0
Mudflat	0	0	0	0	0	9	0	0	100

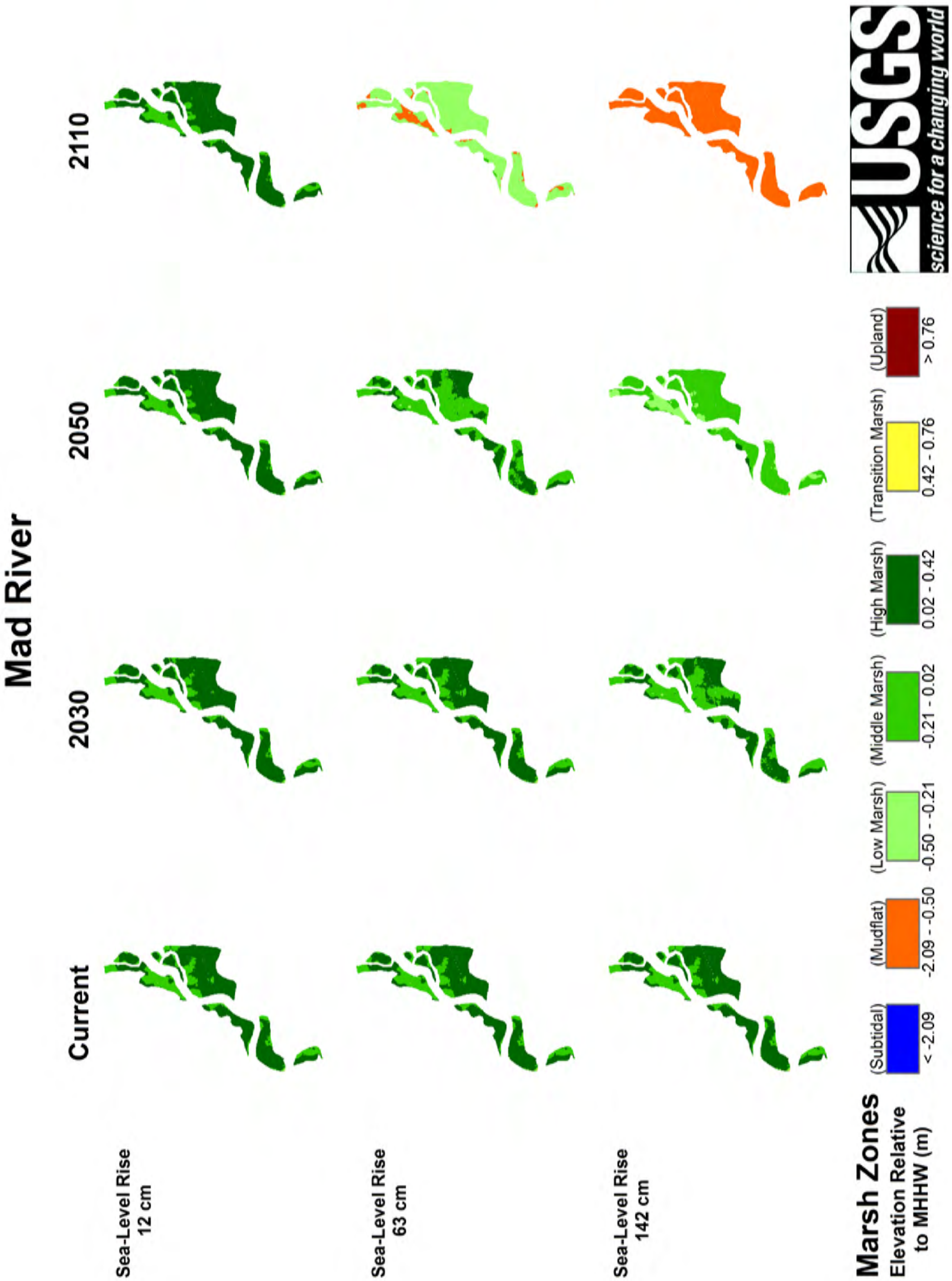

Figure A13. Projected habitat distribution at Mad River Slough for 2030, 2050 and 2110 with the WARMER model under three NRC sea-level rise scenarios.

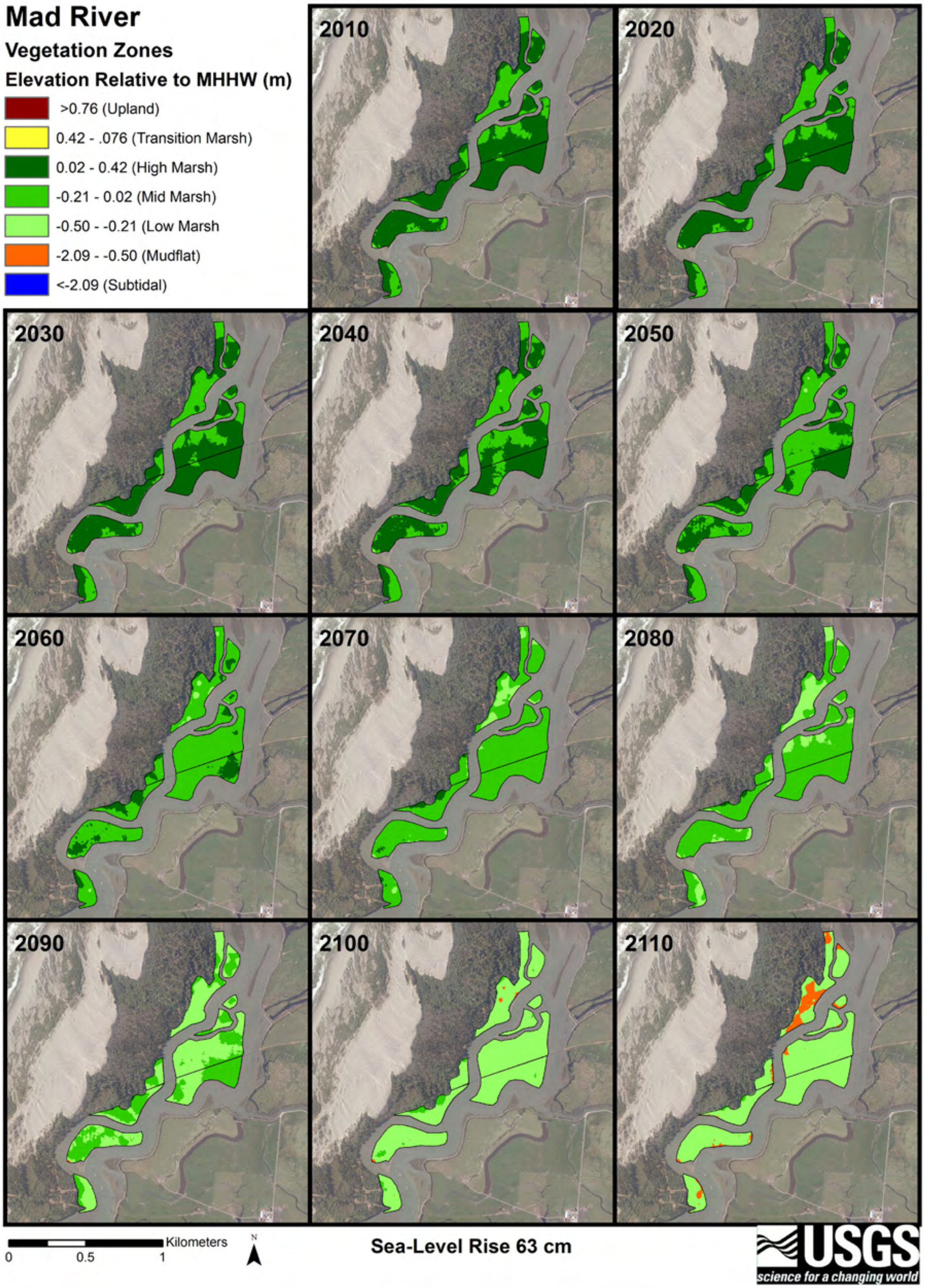

Figure A14. Projected changes in Mad River habitat zones under the mid NRC sea-level rise scenario (63 cm).

Appendix B. Site Specific Details for San Pablo, San Pablo Bay, Sonoma County, California

Photo: K. Powelson, USGS

Summary:

- *Study site:* 136.3 ha
- *Location*: 38° 8'40.21"N latitude, 122°23'45.54"W longitude.
- *Site management:* U.S. Fish and Wildlife Service
- *Site vegetation and elevation survey*: June 2009–August 2009
- *Sample size*: 314 (elevation points), 309 (vegetation plots)
- *Marsh elevation model:* 62% of elevation points were above MHHW
- *Plant community composition*: The dominant species was *Sarcocornia pacifica*, occurring from low marsh to the marsh-upland transition zone. *Spartina foliosa* occupied low marsh at the edge of San Pablo Bay.
- *Bathymetric surveys*: 221.6 hectares of nearshore habitat were mapped adjacent to the study area.
- *Water monitoring*: water level (Dec 2009-Jan 2010); conductivity (Feb 2014-present).
- *Tidal datums*: MHHW is 1.88 m NAVD88; MHW is 1.70 m NAVD88
- *Marsh inundation pattern*: Maximum monthly inundation occurred August 2013; minimum monthly inundation occurred October 2013.

- *SETs*: Two high marsh SETs and two low marsh SETs were installed on April 14, 2013. During the first year of monitoring, cumulative elevation change was -8.80 mm in high marsh and +0.38 mm in low marsh.
- *Modeling*: WARMER modeling is published in Takekawa and others (2012) and a separate modeling effort is published in Thorne and others (2015).

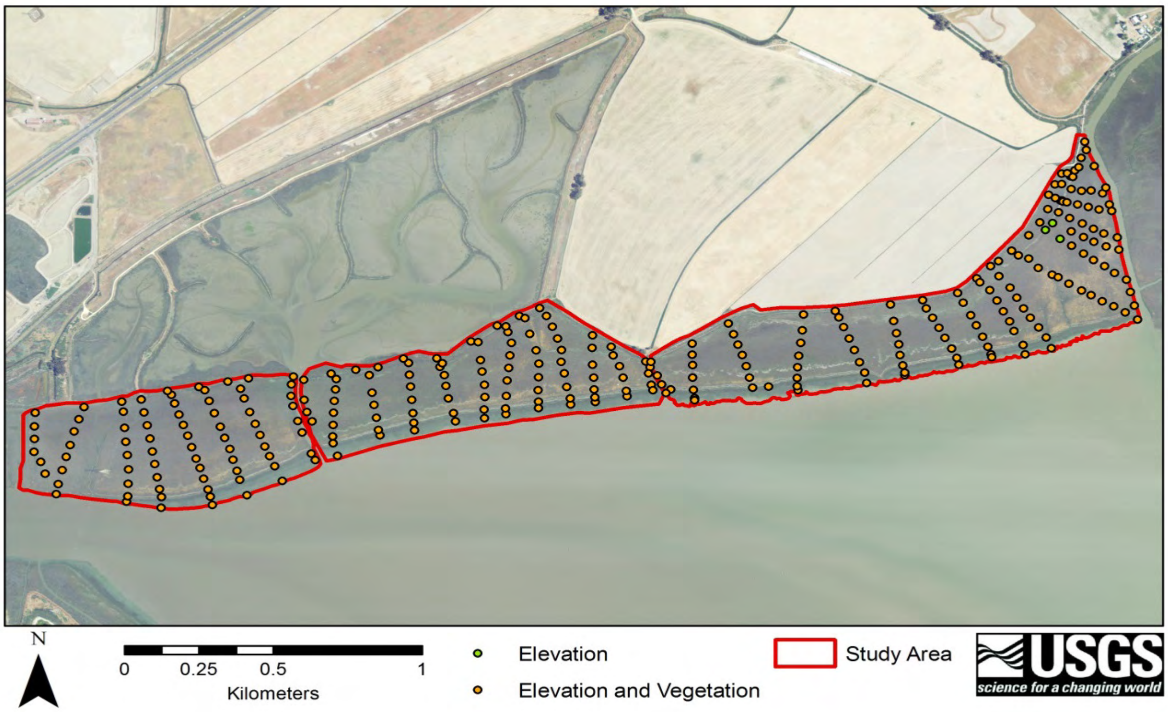

Figure B1. Distribution of elevation and vegetation survey points at San Pablo.

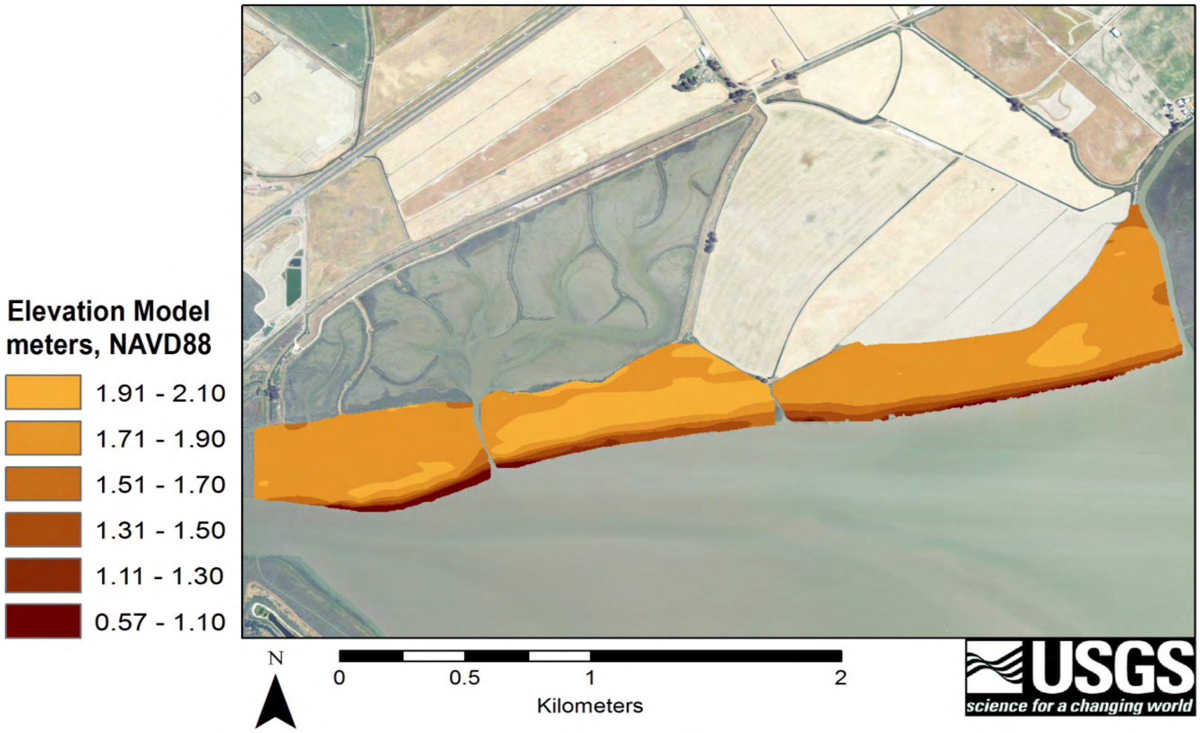

Figure B2. Elevation model (3 m resolution) of tidal marsh at San Pablo developed from RTK GPS survey data.

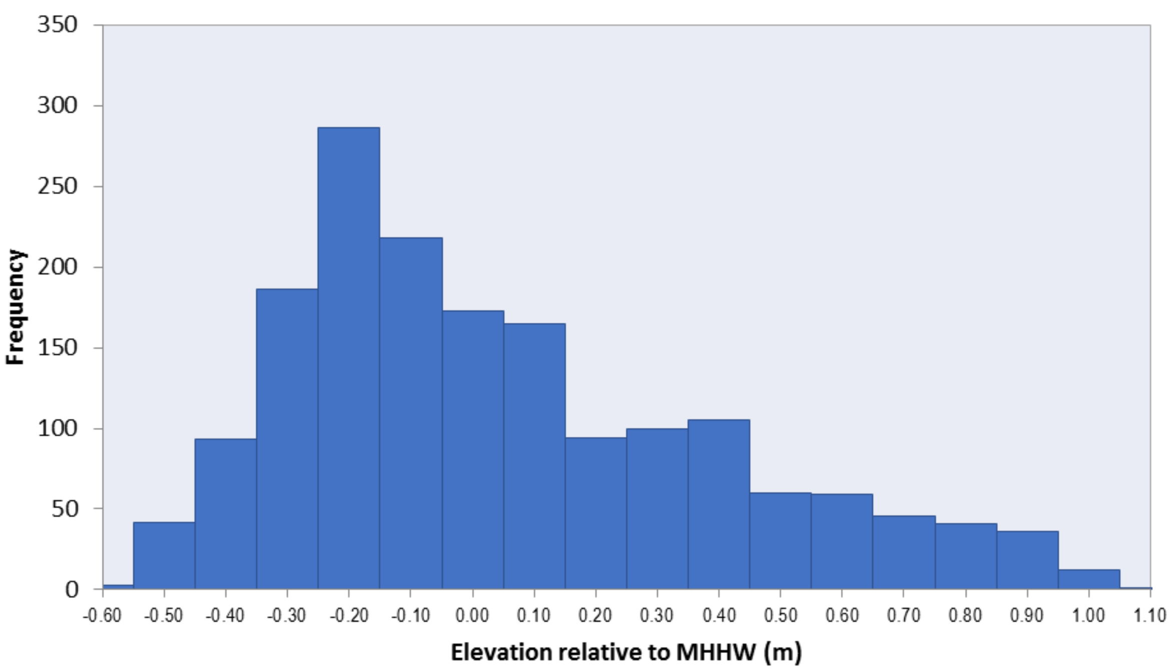

Figure B3. Frequency distribution of marsh surface elevation measurements relative to local mean higher high water (MHHW).

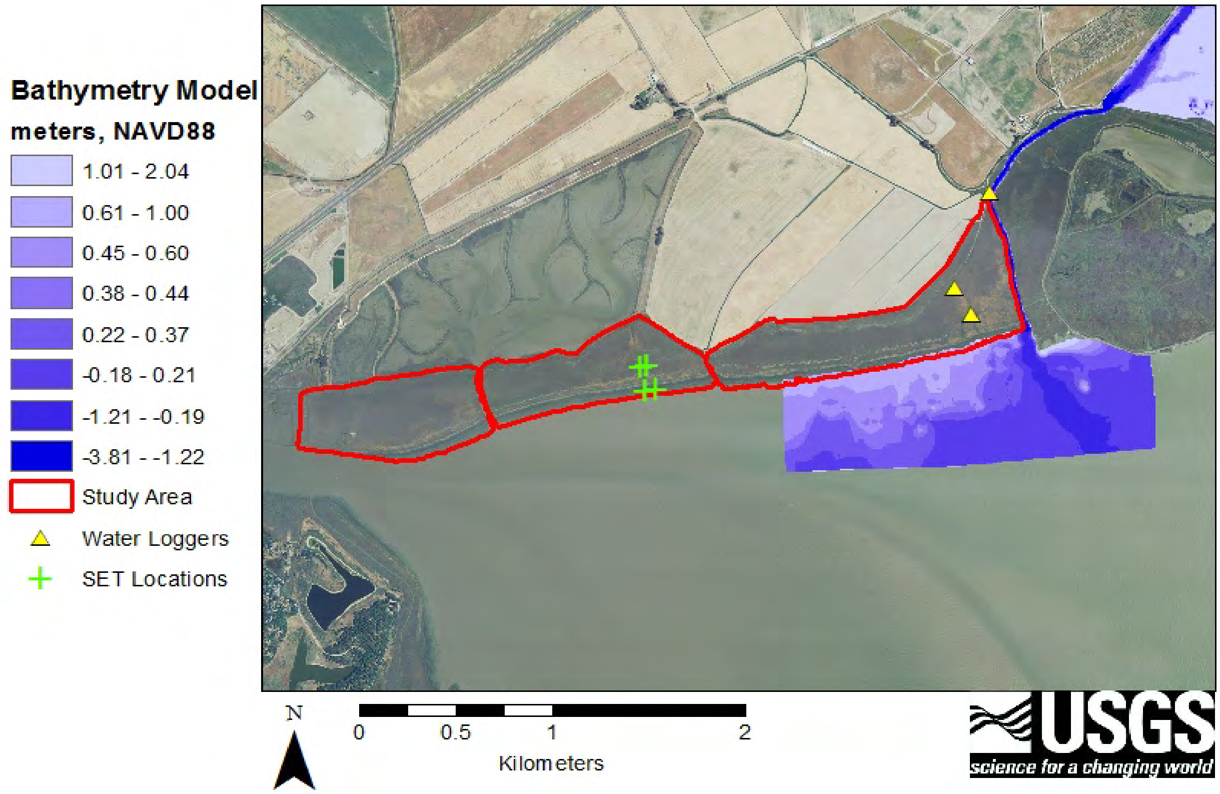

Figure B4. Near-shore bathymetry model for San Pablo and location of water level loggers and surface elevation tables (SET).

Table B1. Location of water level loggers, surface elevation tables (SET), and deep sediment core at San Pablo (UTM zone 10).

Location	Easting (m)	Northing (m)
water level logger	544122	4218447
SET	546078	4218709
	546133	4218717
	546056	4218836
	546083	4218844
core sample	NA	NA

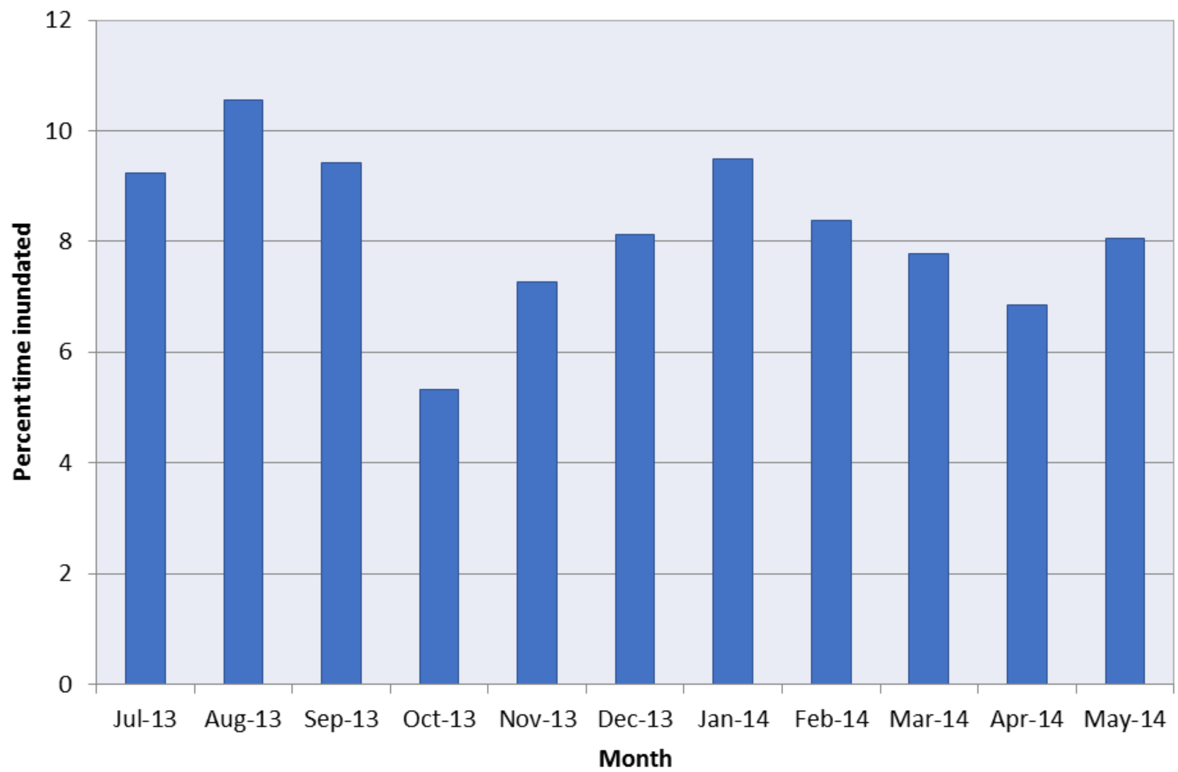

Figure B5. Average monthly inundation of the study site based on an average marsh elevation.

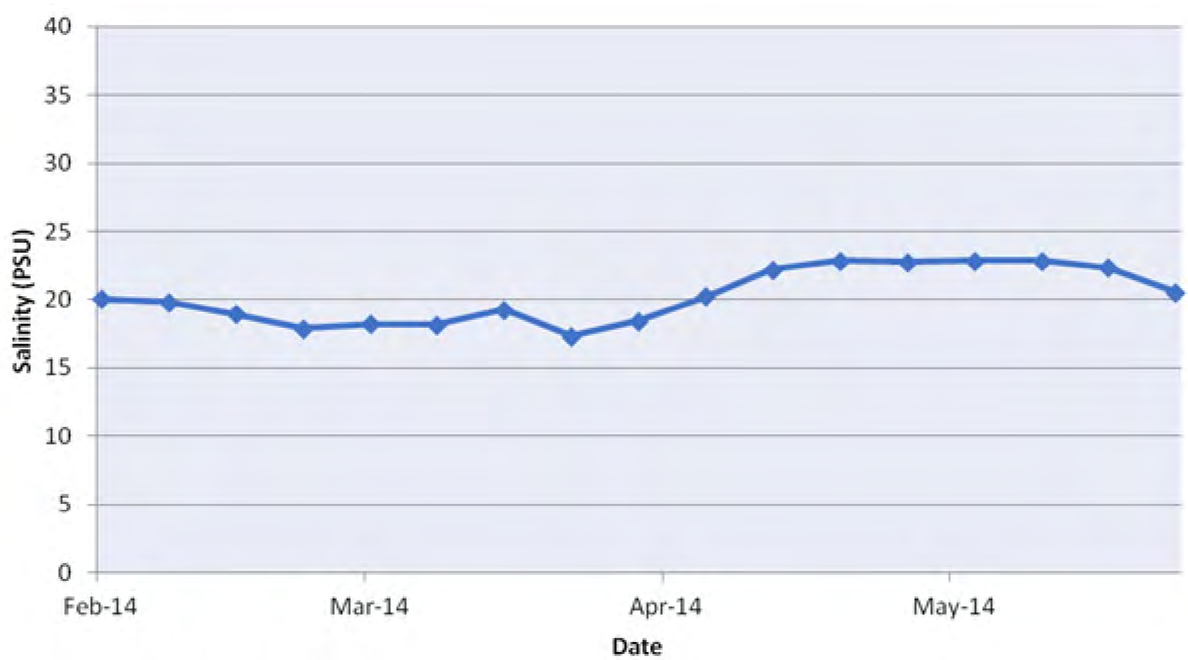

Figure B6. Average weekly maximum salinity from February–May 2014 at San Pablo.

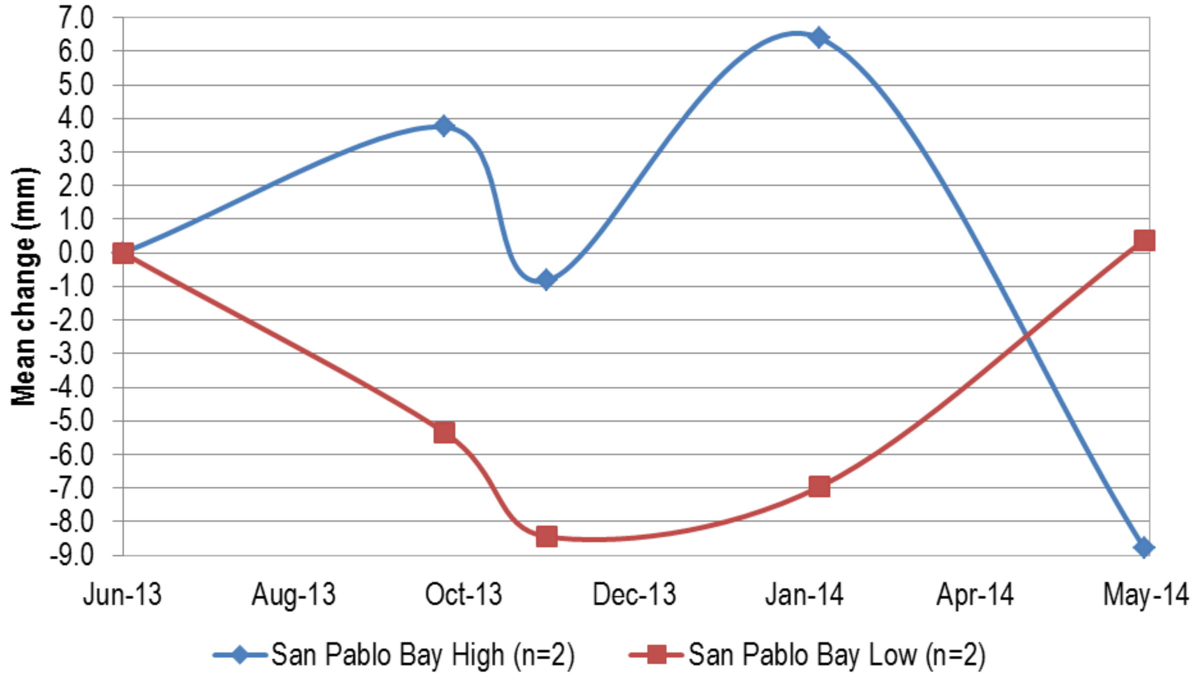

Figure B7. Baseline measurements of net marsh surface elevation change at San Pablo using surface elevation tables (SET).

Appendix C. Site Specific Details for Bolinas Lagoon, Marin County, California

Photo: C. Freeman, USGS

Summary:

- *Study area*: 83.7 ha
- *Location*: 37°55'7.18"N latitude, 122°41'21.20"W longitude
- *Site management*: Marin County Parks
- *Site vegetation and elevation survey*: June 27-July 12, 2012
- *Sample size*: 1,622 elevation points, 308 vegetation plots
- *Marsh elevation model:* 29% of elevation data points were above MHHW
- *Plant community composition*: The dominant species was *Sarcocornia pacifica*, occurring from low marsh to the marsh-upland transition zone. Common species at the site exhibited modest vertical zonation, but tended to have overlapping distributions.
- *Bathymetric surveys*: 340.1 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 = 1.05 g cm^{-2} yr^{-1}; organic matter accumulation rate = 0.0783 g cm^{-2} yr^{-1}; net accretion = 0.7 cm/yr^{-1}.

- *Water monitoring data collection*: water level (January 2013- March 2014). Water level and conductivity monitoring is ongoing.
- *Calculated tidal datums*: MHHW is at 1.63 m NAVD88; MHW is at 1.45 m NAVD88. NOAA station 9412110 was used to develop datums because the CERCC logger was too high in the tidal frame.
- *Marsh inundation pattern*: Maximum monthly inundation occurred during January 2014; minimum monthly inundation during August - October 2013.
- *SETs*: Two high marsh and two low marsh SETs were installed on April 15, 2013. During the first year of *monitoring*, cumulative elevation change was 0.95 mm in high marsh and 9.86 mm in low marsh.
- *Sea-level rise marsh response modeling:* Under the NRC's low SLR scenario high and mid marsh expands until 2080 and then begins to decline until the site is predominantly low marsh by 2110. Vegetated marsh also persists through the century at mid SLR rates. Under mid SLR, low marsh expands until 2080 at which point mudflat expands and the site becomes predominantly mudflat by 2110. Under the high SLR scenario, low marsh expands until 2050 at which point mudflat expands and the site becomes 100% mudflat by 2100.

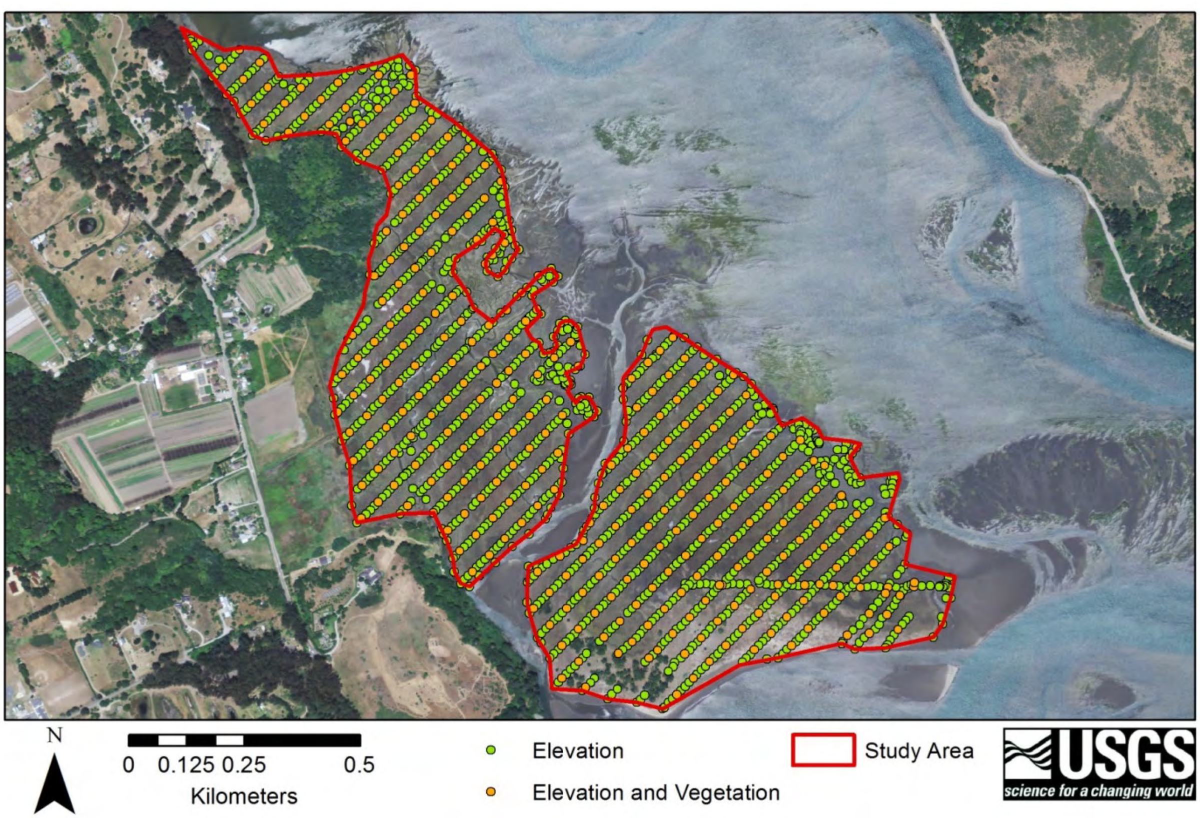

Figure C1. Distribution of elevation and vegetation survey points at Bolinas Lagoon.

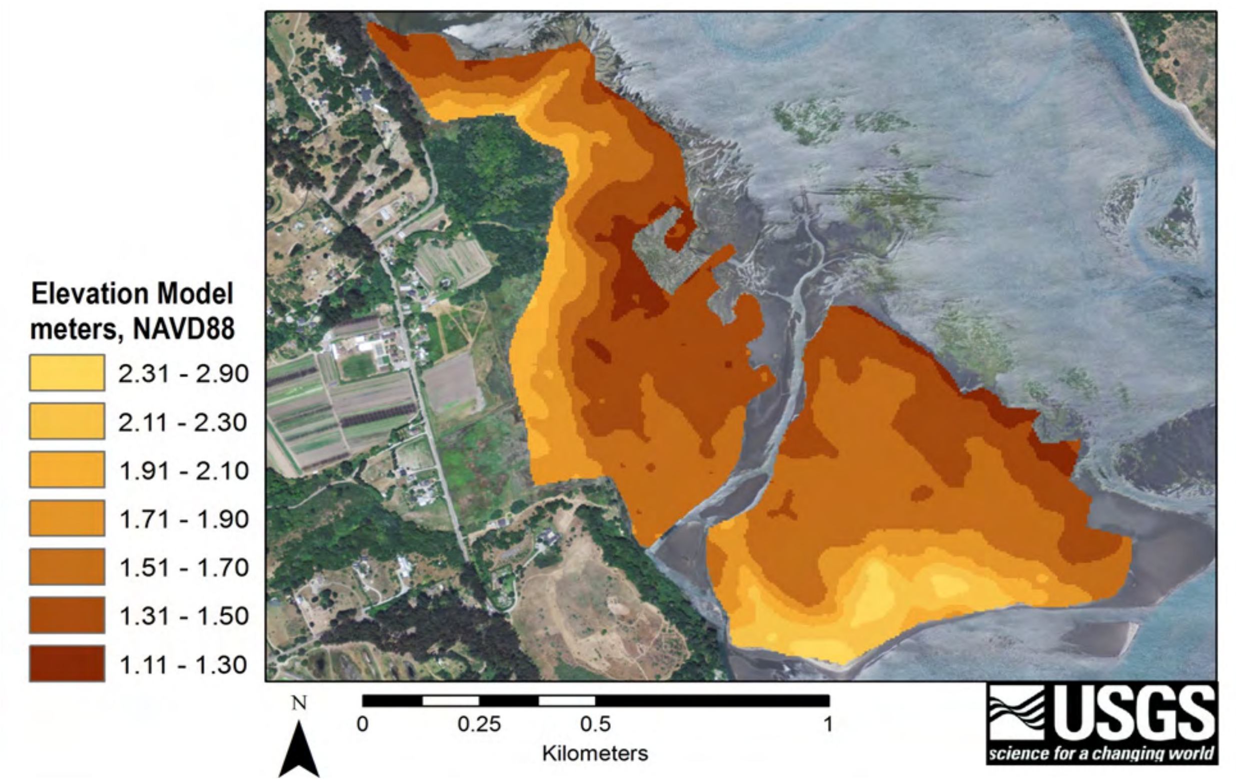

Figure C2. Elevation model (3 m resolution) of tidal marsh at Bolinas Lagoon developed from RTK GPS survey data.

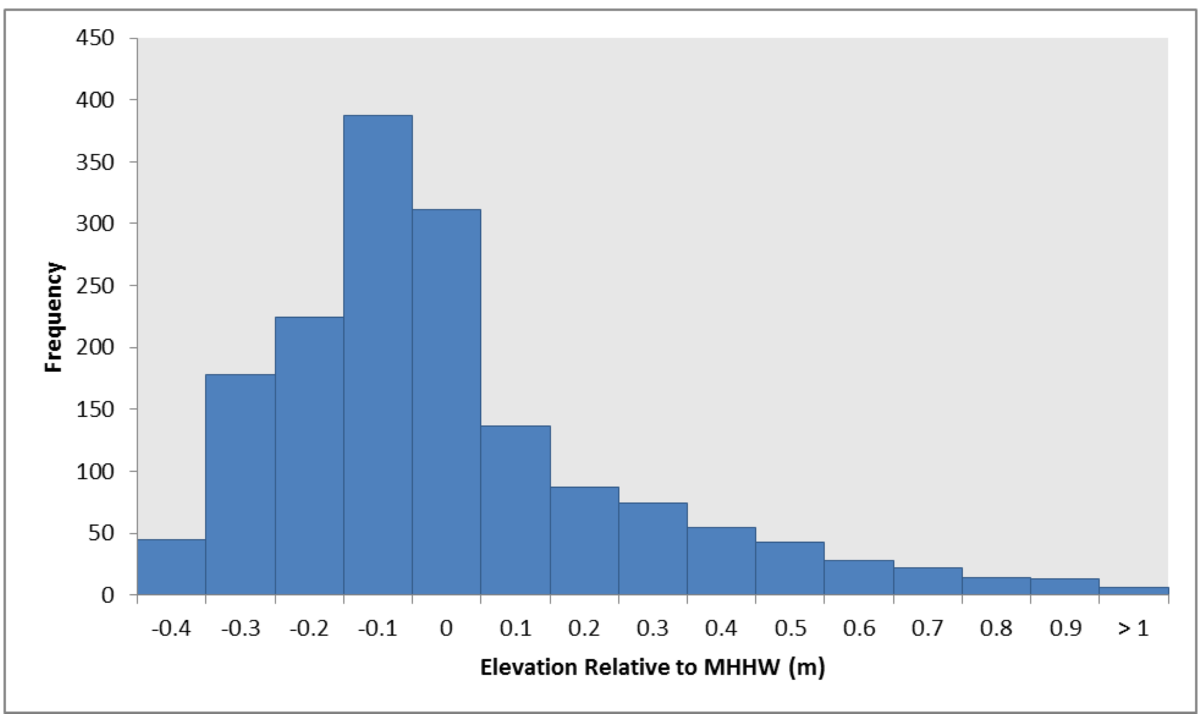

Figure C3 . Frequency distribution of marsh surface elevation measurements relative to local mean higher high water (MHHW) at Bolinas Lagoon

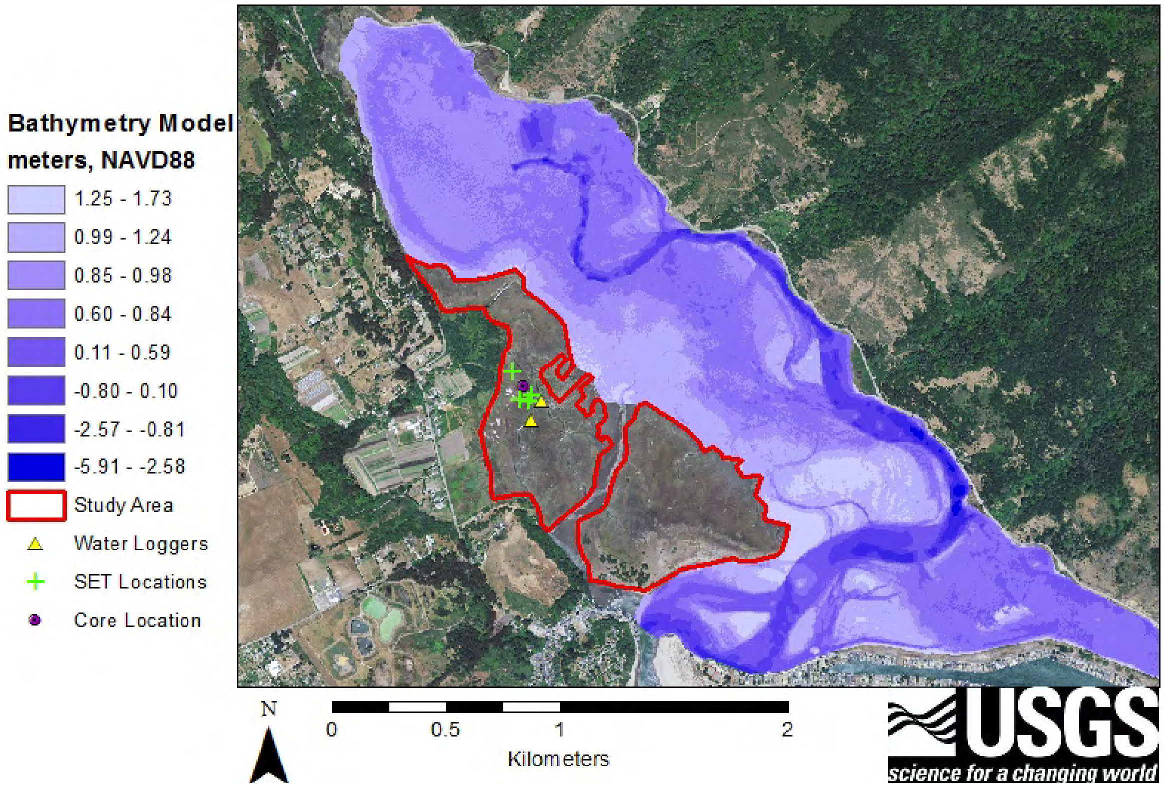

Figure C4. Near-shore bathymetry model for Bolinas Lagoon and location of water level loggers, surface elevation tables (SET), and deep sediment cores

Table C1. Frequency of occurrence, percent cover and height of vascular plant species encountered in sample plots at Bolinas Lagoon.

[NA = not measured]

Species	Description	Frequency of occurrence (%)	Percent cover Mean	Percent cover Max	Plant heights (cm) Mean	Plant heights (cm) Max
Sarcocornia pacifica	Perennial forb	93.4	57	100	20	46
Distichlis spicata	Perennial grass	46.7	14	100	20	46
Jaumea carnosa	Perennial forb	38.2	10	95	13	27
Triglochin concinna	Perennial forb	31.6	5	55	13	36
Spartina foliosa	Perennial grass	25.7	1	50	29	55
Frankenia salina	Perennial forb	23.0	5	95	12	34
Limonium californicum	Perennial forb	17.1	2	40	9	35
Spergularia canadensis	Annual forb	7.2	1	45	11	18
Plantago maritima	Perennial forb	4.9	1	40	15	31
Cuscuta pacifica	Ann-perennial parasite	3.6	NA	NA	NA	NA
Grindelia stricta	Perennial subshrub	1.6	1	95	62	113
Juncus balticus	Perennial rush	1.3	0	90	50	72
Carpobrotus chilensis	Perennial forb	1.3	0	40	13	24
Chloropyron maritimum ssp. palustre	Annual hemiparasite	1.3	0	35	4	7
Atriplex prostrata	Annual forb	1.0	0	30	25	36
Polypogon monspeliensis	Annual grass	0.7	0	40	33	44
Bolboschoenus maritimus	Perennial sedge	0.3	0	5	74	83
Isolepis cernua	Annual sedge	0.3	0	5	15	18
Spergularia macrotheca	Perennial forb	0.3	0	3	12	14

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

[SarPac = Sarcocornia pacifica; DisSpi = Distichlis spicata; FraSal = Frankenia salina; GriStr = Grindelia stricta; PucNut = Puccinellia nutkaensis; JauCar = Jaumea carnosa; TriCon = Triglochin concinna.]

Marsh zone	% high tides reaching zone	MHHW range (m)	n	Mean cover of top four dominant plants (%)
Transition	0.14-3	0.431 to 0.244	21	SarPac (34), DisSpi (11), FraSal (9), GriStr (9), PucNut (9)
High	3-25	0.244 to 0.010	55	SarPac (34), DisSpi (20), TriCon (11) FraSal (11)
Middle	25-50	0.010 to -0.162	139	SarPac (55), DisSpi (18), JauCar (13), TriCon (7)
Low	>50	-0.162 to -0.454	93	SarPac (77), JauCar (7), DisSpi (4), FraSal (3)

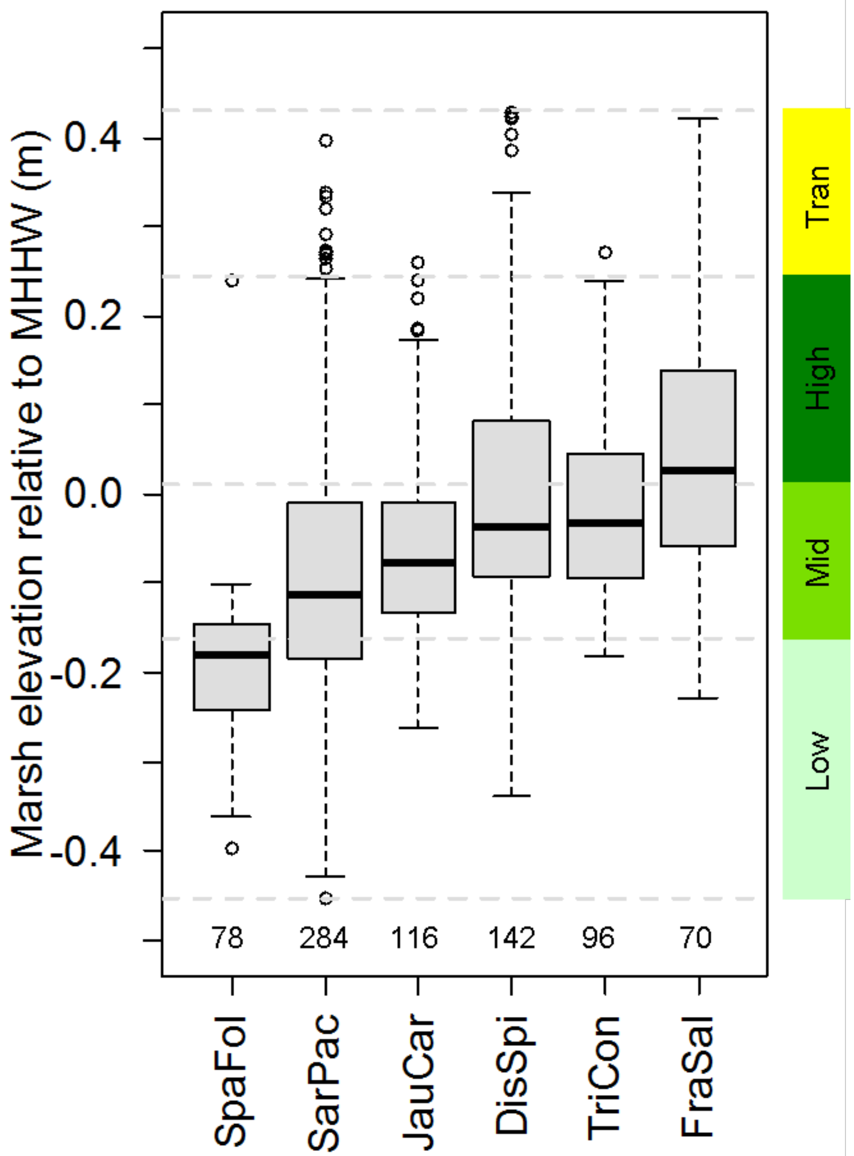

Figure C5. Elevation distribution of the six most common vascular plant species at Bolinas Lagoon. The black horizontal bars show the median elevation at which the species occurs; shaded boxes indicate the interquartile range; upper and lower whiskers encompass points no greater than 1.5 x the length 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 308 plots). Marsh elevation zones (low, middle, high and transition) are illustrated at right. SpaFol = *Spartina foliosa*; SarPac = *Sarcocornia pacifica*; JauCar = *Jaumea carnosa*; DisSpi = *Distichlis spicata*; TriCon = *Triglochin concinna*; FraSal = *Frankenia salina*.

Table C3. Locations of water level loggers, surface elevation tables (SET), and deep sediment cores at Bolinas Lagoon (UTM zone 10).

Location	Easting (m)	Northing (m)
water logger	527481	4196805
SET	527389	4196941
	527422	4196824
	527462	4196826
	527459	4196817
core sample	527426	4196824

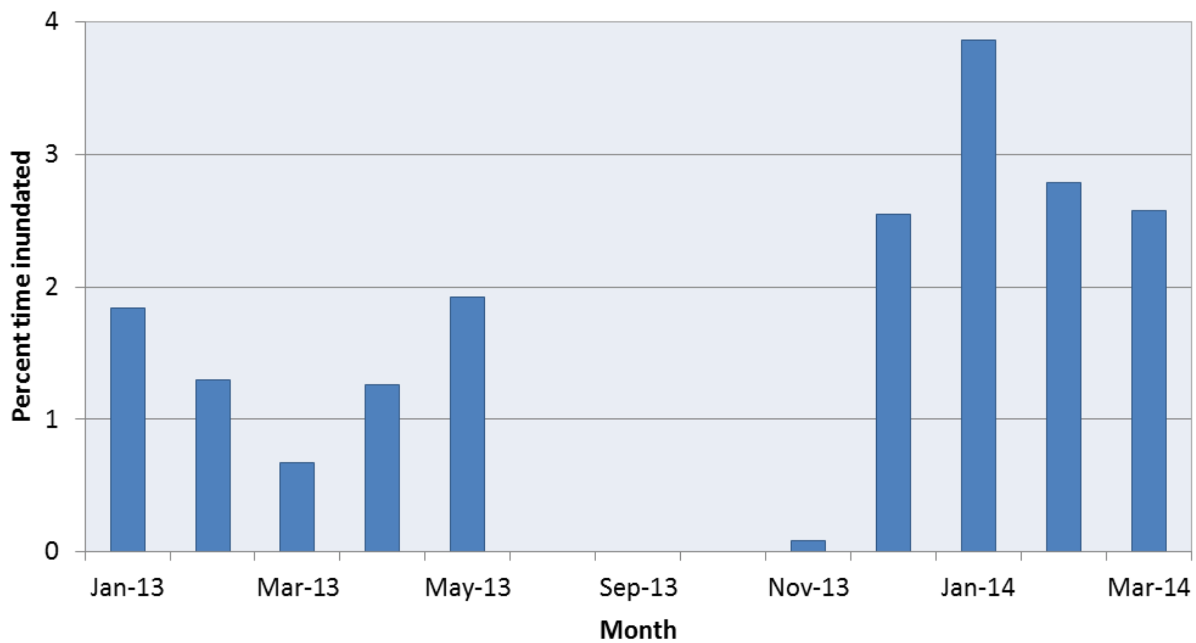

Figure C6. Average monthly inundation of the study site based on an average marsh elevation. Water levels were determined with a Hobo water logger deployed at 0.48 m above NAVD88.

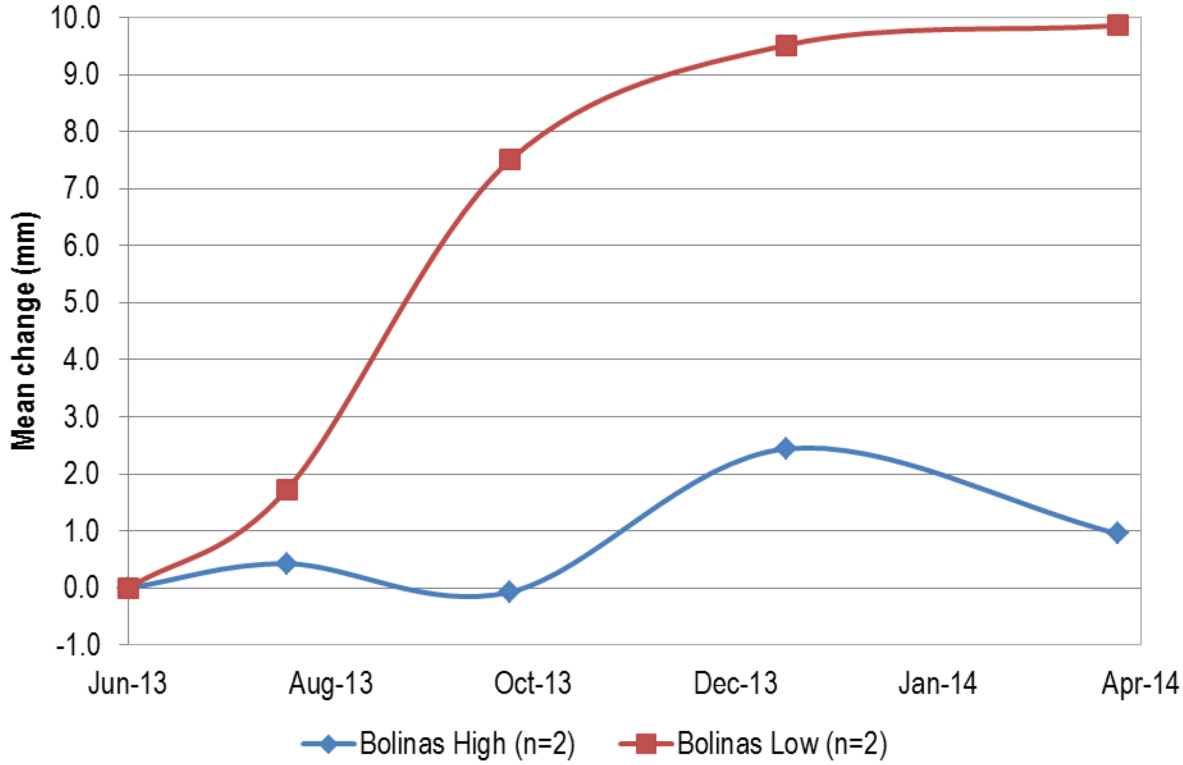

Figure C7. Baseline measurements of net marsh surface elevation change at Bolinas Lagoon using surface elevation tables (SET).

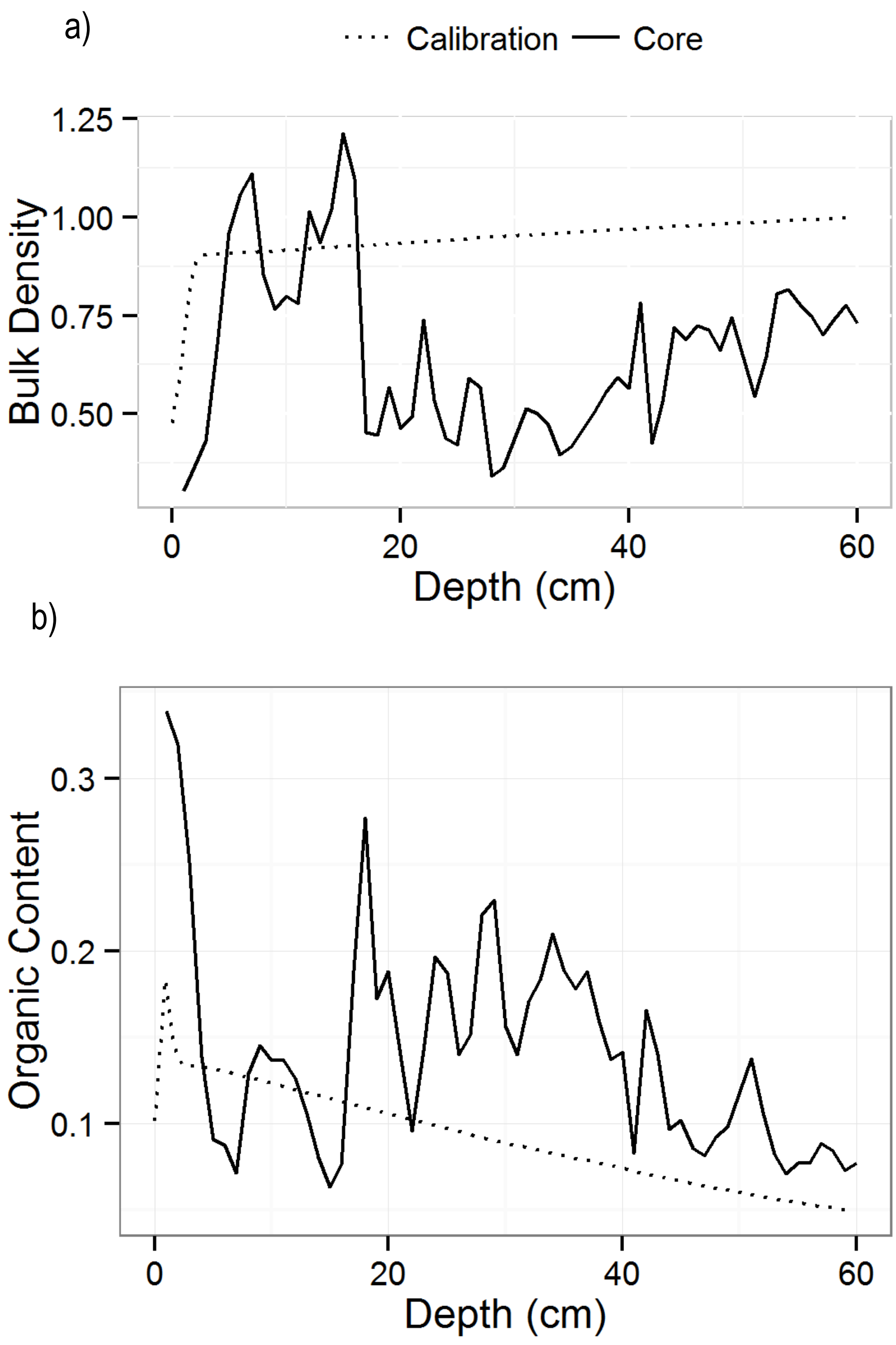

Figure C8. Deep sediment core calibration of the WARMER model using depth profiles of (a) bulk density (g cm^{-3}) and (b) organic matter content (%).

Table C4. WARMER parameters and soil core characteristics used for SLR model calibration at Bolinas Lagoon.

[NDVI = Normalized Difference Vegetation Index; NAIP = National Agriculture Inventory Program]

Model parameter	Value	Source
Sediment accumulation rate (g cm^{-2} yr^{-1})	1.05	Core calibration
Elevation of peak biomass (cm, MSL)	91	NDVI from NAIP
Minimum elevation of vegetation (cm, MSL)	21	Field surveys
Max. aboveground organic accumulation (g cm^{-2} yr^{-1})	0.0783	Core calibration
Root-to-shoot ratio	0.458	C. Janousek, unpub data
Porosity at sediment surface (%)	79	Core
Porosity at depth (%)	59	Core
Refractory carbon (%)	26	Core
Maximum astronomical tide (cm, MSL)	142	Bolinas tide gauge (NOAA,9414958)
Historic sea-level rise (mm yr^{-1})	2.10	Bolinas tide gauge (NOAA,9414958)
Organic matter density (g cm^{-3})	1.14	DeLaune 1983
Mineral density (g cm^{-3})	2.61	DeLaune 1983

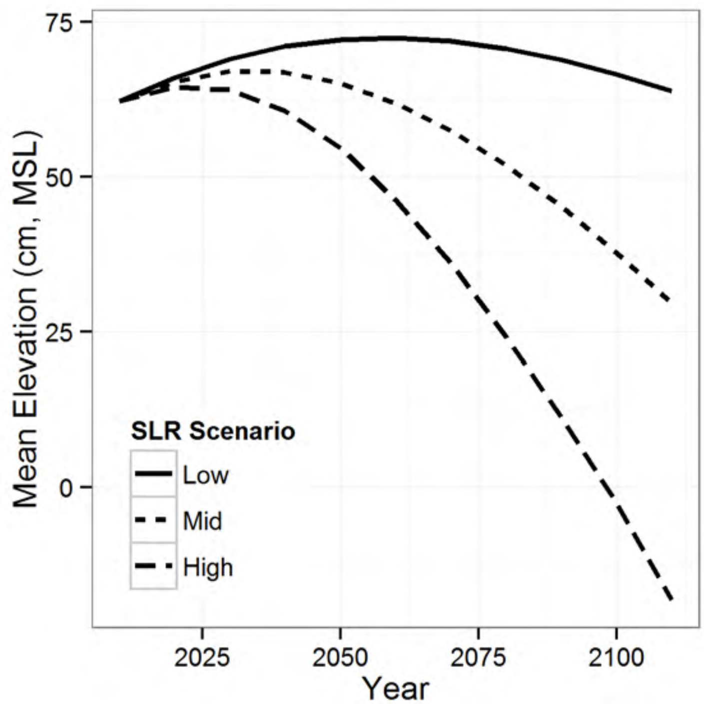

Figure C9. WARMER model projections for the change in average marsh elevation (relative to MHHW) at Bolinas Lagoon from 2010 to 2110 under low, mid, and high NRC sea-level rise scenarios.

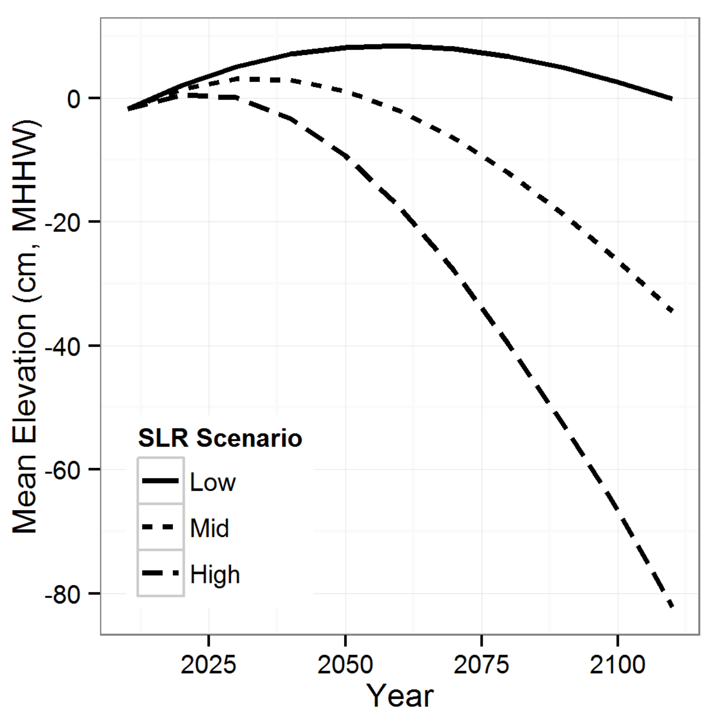

Figure C10. WARMER model projections for the change in average marsh elevation (relative to MSL) at Bolinas Lagoon from 2010 to 2110 under low, mid, and high NRC sea-level rise scenarios.

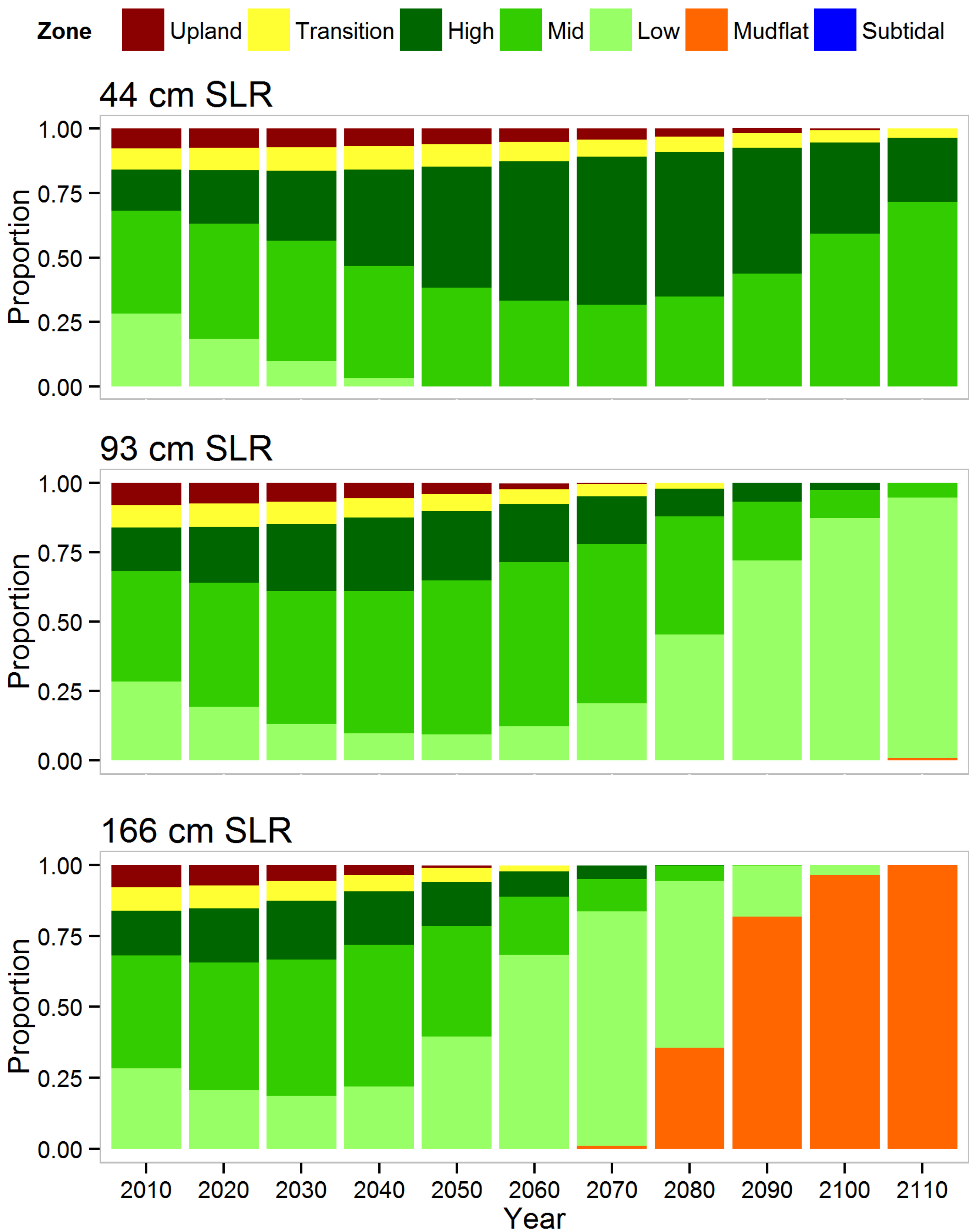

Figure C11. Model projections for change in the relative proportion of upland; transitional, high, mid and low marsh; and mudflat habitat at Bolinas Lagoon under the NRC's low (44 cm), mid (93 cm), and high (166 cm) sea-level rise scenarios from 2010 to 2110.

Table C5. 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 (44 cm)			Mid SLR (93 cm)			High SLR (166 cm)		
	2010	2050	2110	2010	2050	2110	2010	2050	2110
Upland	8	6	0	8	4	0	8	1	0
Transition	8	9	4	8	6	0	8	5	0
High	16	47	25	16	25	0	16	16	0
Mid	40	38	71	40	56	5	40	39	0
Low	28	0	0	28	9	94	28	39	0
Mudflat	0	0	0	0	0	1	0	0	100
Subtidal	0	0	0	0	0	0	0	0	0

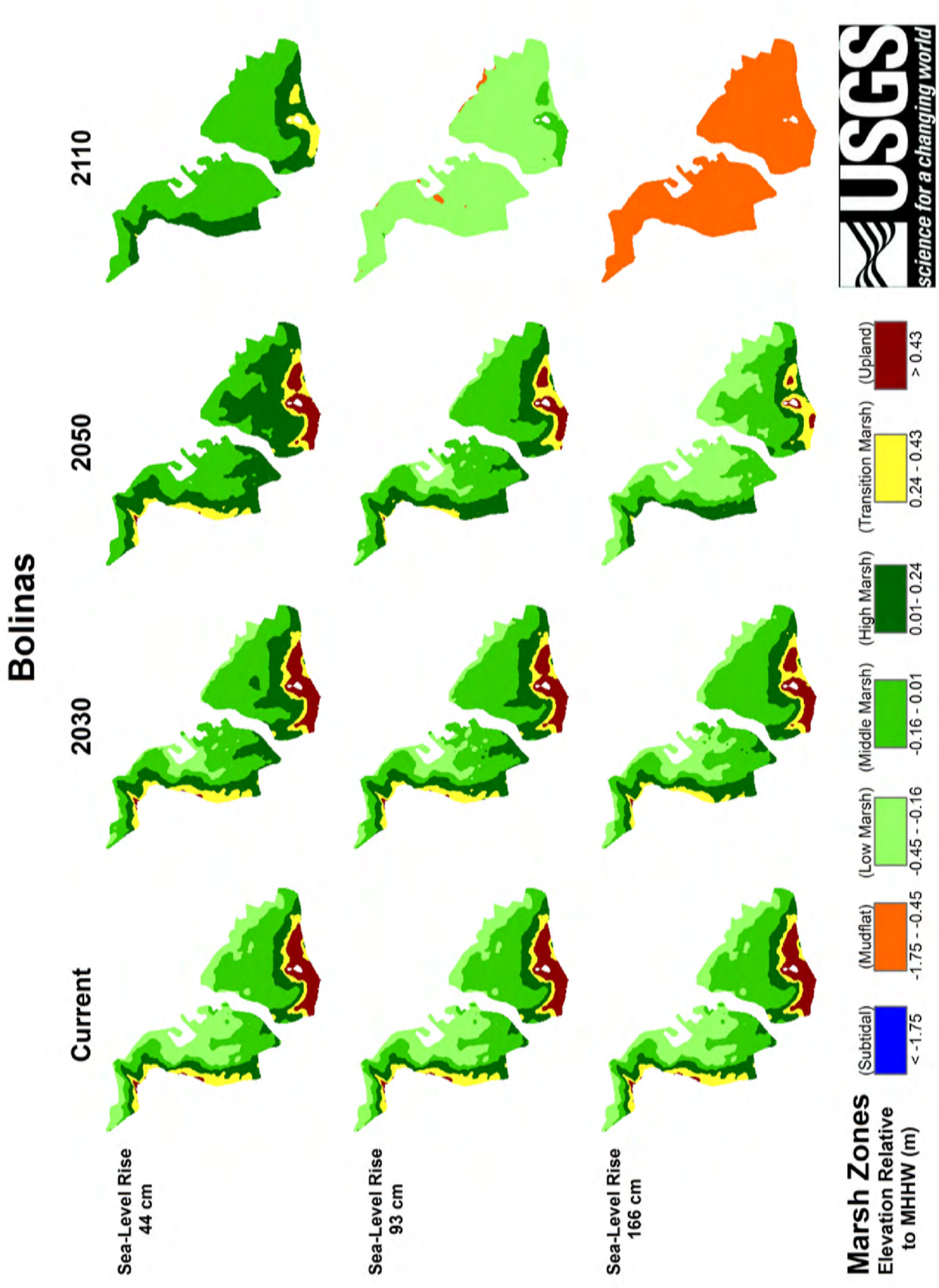

Figure C12. Projected habitat distribution at Bolinas Lagoon for 2030, 2050 and 2110 with the WARMER model under three sea-level rise scenarios.

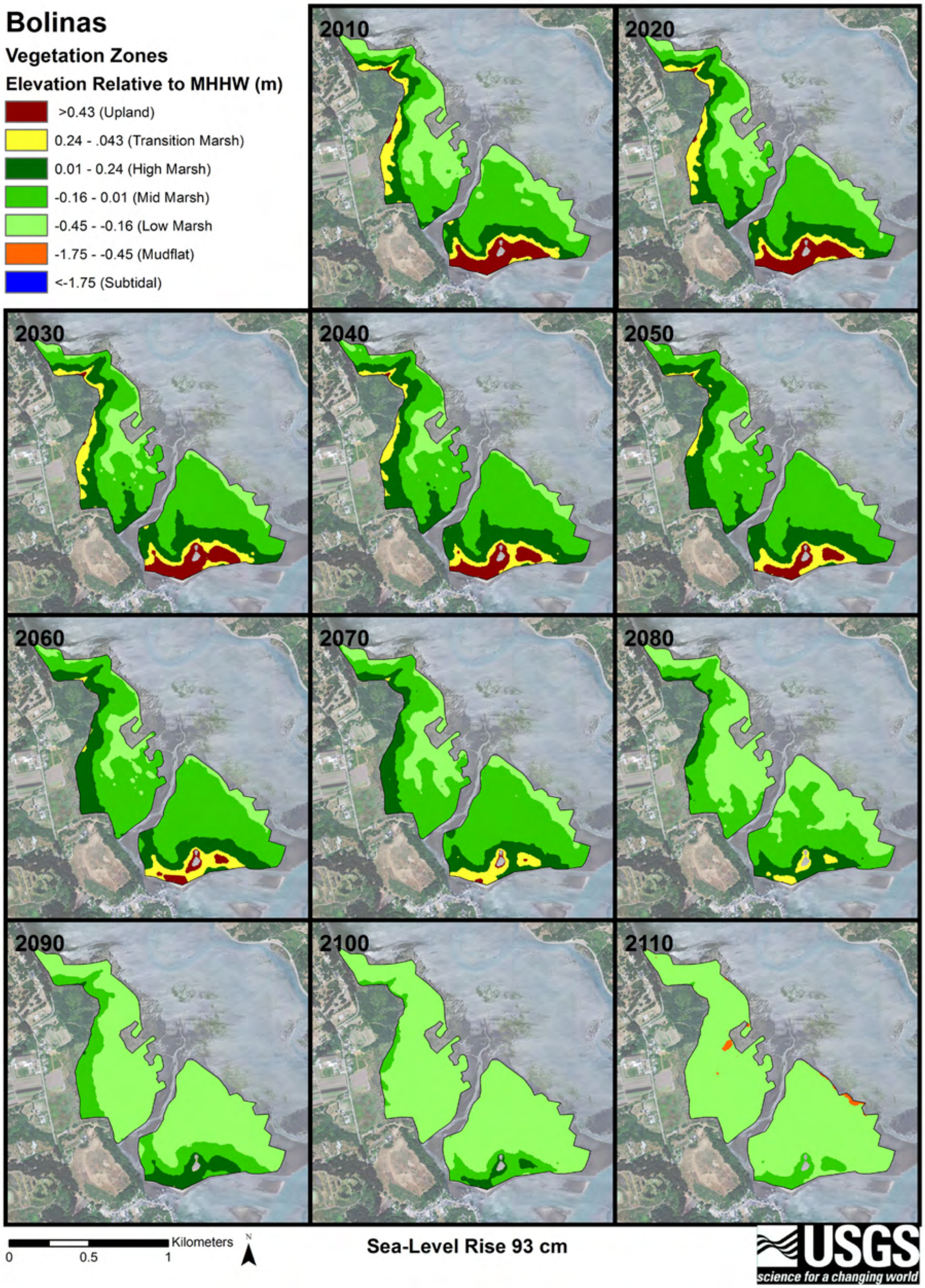

Figure C13. Projected changes in Bolinas Lagoon habitat zones under mid NRC sea-level rise scenario (93 cm).

Appendix D. Site Specific Details for Morro Bay, San Luis Obispo County, California

Photo: C. Janousek, OSU/USGS

Summary of results

- *Study site size*: 150.3 ha
- *Location:* 35°20'48.52"N latitude, 120°49'58.03"W longitude
- *Site management:* California State Parks
- *Site vegetation and elevation survey:* June 3–14, 2014
- *Sample size:* 2,575 elevation points, 616 vegetation plots
- *Marsh elevation model:* 39% of elevation data points were above MHHW
- *Plant community composition*: The dominant species was *Sarcocornia pacifica*, occurring from low marsh to the marsh-upland transition zone. *Jaumea carnosa* and *Triglochin concinna* also occurred frequently at the site.
- *Lidar surveys*: 150.10 ha of nearshore habitat were mapped adjacent to the study area using Lidar. Data was provided by the California Coastal Commission (www.opc.ca.gov).

- *Paleoenvironmental cores*: Accretion rate varied, ranging from 1.5–13.2 mm yr^{-1}. The oldest measured core value was 3030 YBP (year before present).
- *Soil characteristics*: The accumulation rates used in WARMER were: mineral accumulation rate = 0.052 g cm^{-2} yr^{-1}; organic matter accumulation rate = 0.014 g cm^{-2} yr^{-1}; net accretion = 0.20 cm yr^{-1}.
- *Water monitoring data collection*: water level (November 2013–May 2014); conductivity (November 2013–May 2014). Water level and conductivity monitoring is ongoing.
- *Calculated tidal datums*: MHHW was at 1.65 m NAVD88; MHW was at 1.44 m NAVD88.
- *Marsh inundation pattern:* Maximum monthly inundation occurred during January 2014; monthly inundation during April 2014
- *SETs:* Two high marsh SETs and two low marsh SETs were installed on April 17, 2013. During the first year of monitoring, cumulative elevation change was -0.10 mm in high marsh and +3.14 mm in low marsh.
- *Sea-level rise marsh response modeling*: Under the NRC's low SLR scenario, habitat composition remains relatively unchanged at the site until 2050, but there are declines in mid and high marsh thereafter. Under the mid SLR scenario, beginning in 2030, there is loss of mid and high marsh habitat and significant expansion of mudflat between 2070 and 2110. Habitat composition changes rapidly under the NRC's high SLR scenario, transitioning from a mix of low, mid and high marsh in 2030 to almost complete dominance of mudflat across the site by 2080.

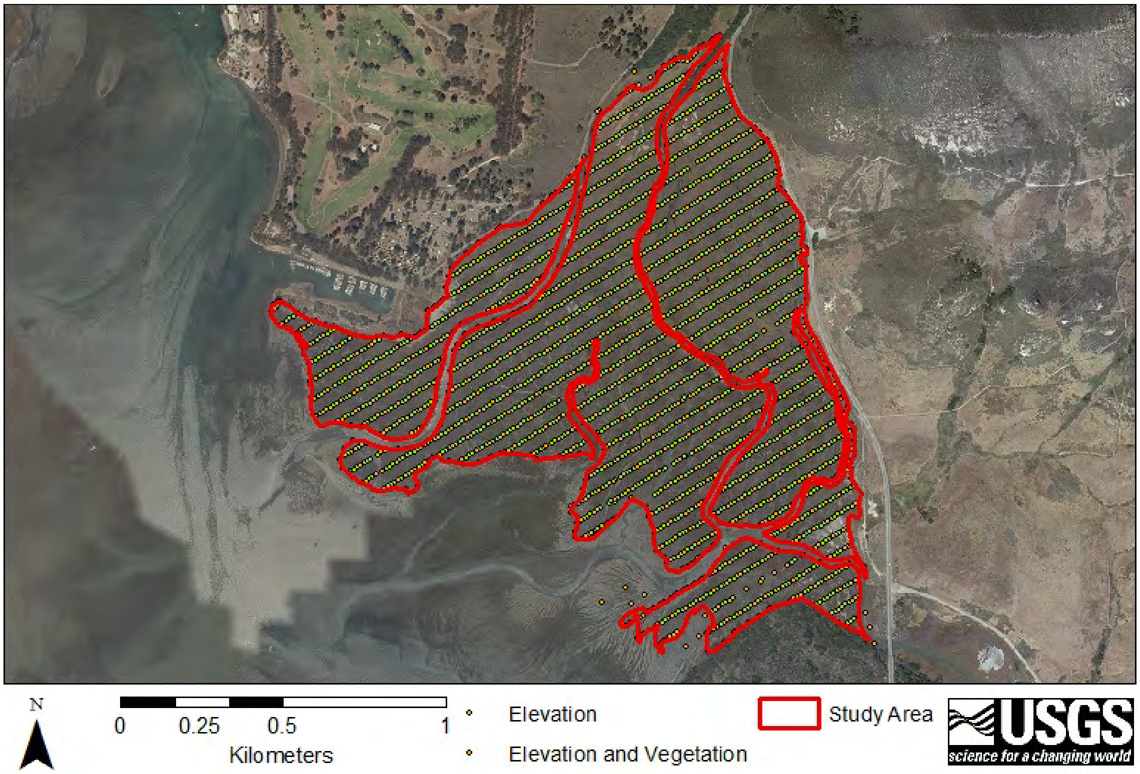

Figure D1. Distribution of elevation and vegetation survey points at Morro Bay.

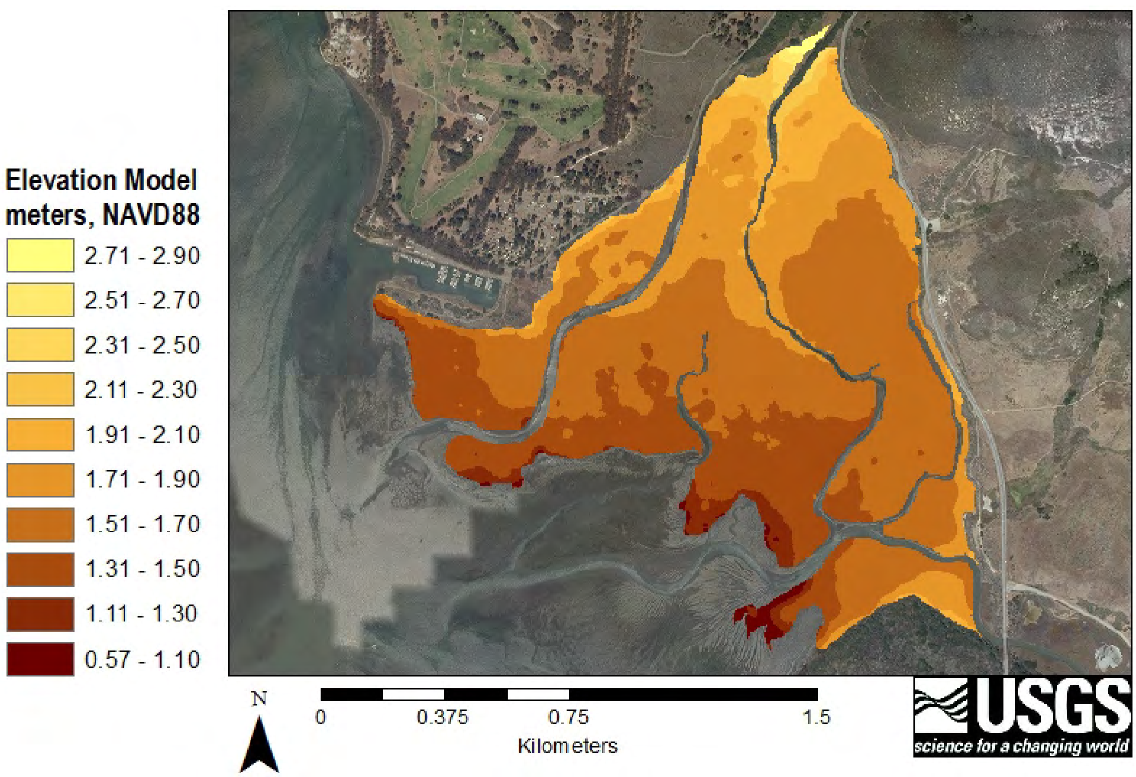

Figure D2. Elevation model (3 m resolution) of tidal marsh at Morro Bay developed from RTK GPS survey data.

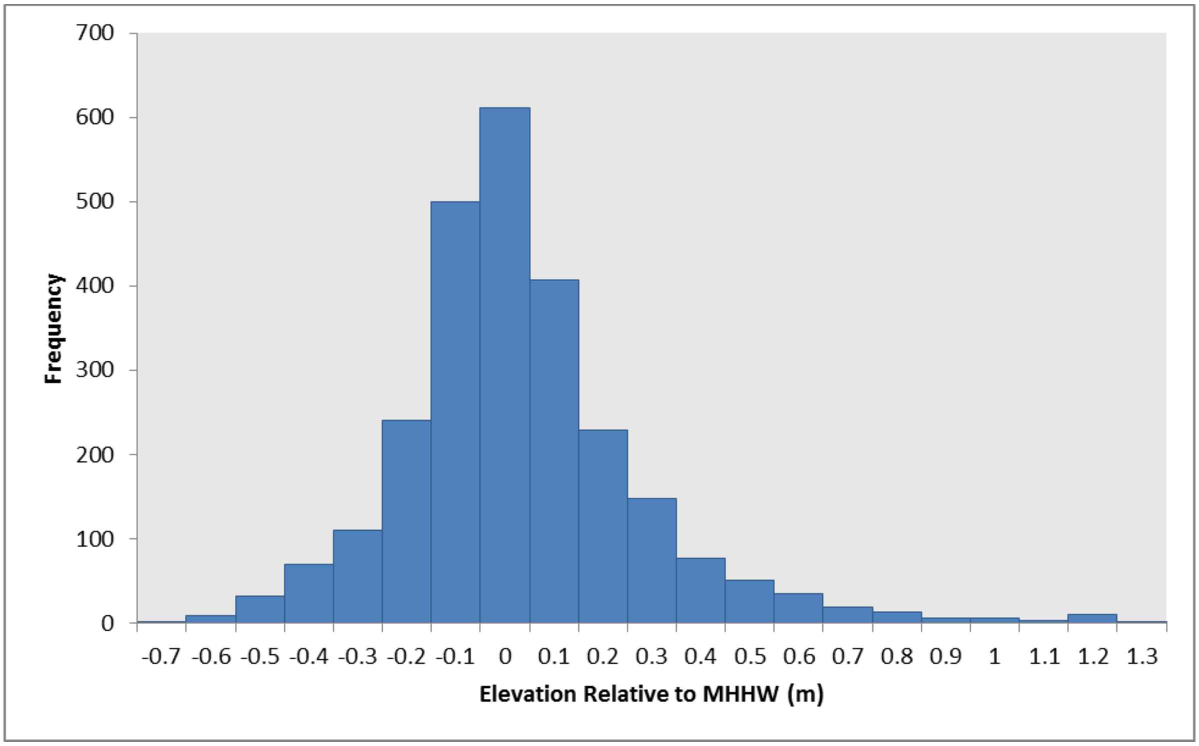

Figure D3. Frequency distribution of marsh surface elevation measurements relative to local mean higher high water (MHHW) at Morro Bay.

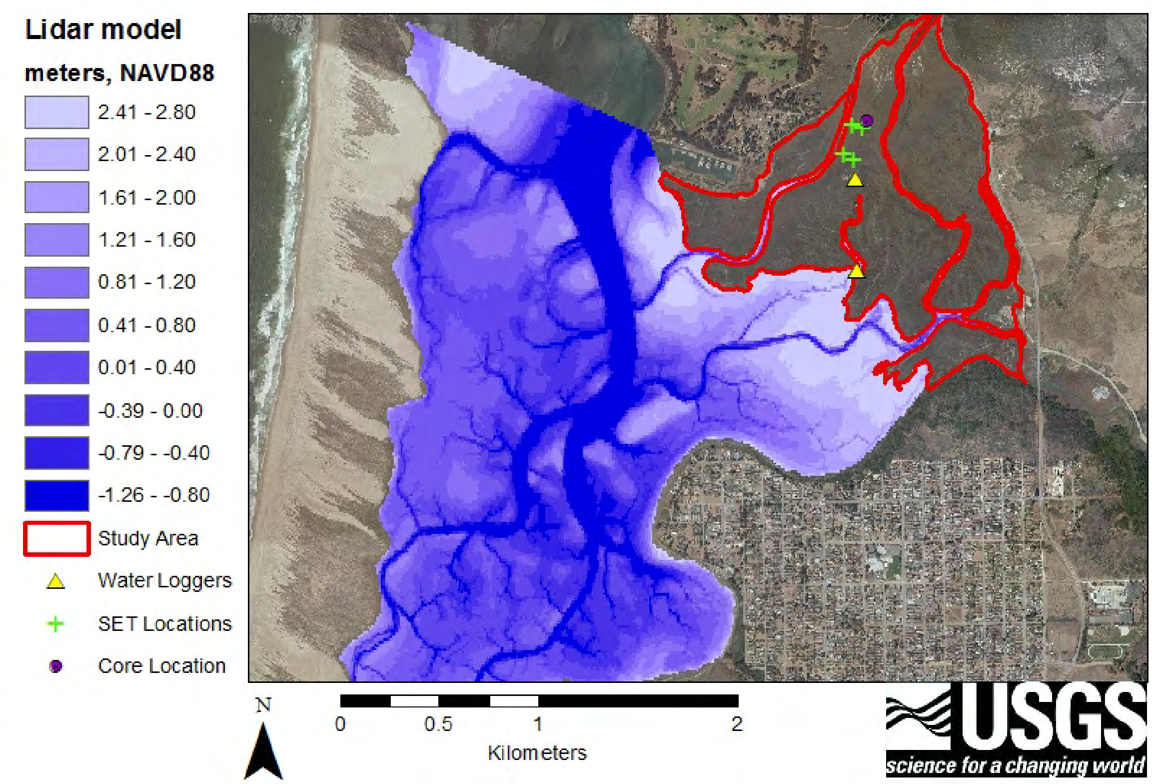

Figure D4. Near-shore bathymetry model for Morro Bay and location of water level loggers, surface elevation tables (SET), and deep sediment cores.

Table D1. Frequency of occurrence, percent cover, and height of vascular plant species encountered in sample plots at Morro Bay.

NA = not measured.

Species	Description	Frequency of occurrence	Percent cover Mean	Percent cover Max	Plant heights (cm) Mean	Plant heights (cm) Max
Sarcocornia pacifica	Perennial forb	94.4	59	100	19	71
Jaumea carnosa	Perennial forb	57.5	28	100	11	49
Triglochin concinna	Perennial forb	44.3	11	95	13	27
Frankenia salina	Perennial forb	25.3	8	100	17	56
Distichlis spicata	Perennial grass	23.4	6	100	18	37
Limonium californicum	Perennial forb	6.4	1	35	9	36
Cuscuta pacifica	Ann-perennial	3.0	NA	NA	NA	NA
Undetermined 1	NA	1.4	0	35	27	55
Schoenoplectus americanus	Perennial sedge	0.8	0	95	66	147
Hirschfeldia incana	Ann-perennial forb	0.5	0	50	77	235
Atriplex watsonii	Perennial forb	0.5	0	30	10	19
Bromus hordaceus	Annual grass	0.3	0	85	22	34
Schoenoplectus acutus	Perennial sedge	0.3	0	40	77	242
Salicornia bigelovii	Annual forb	0.3	0	40	27	39
Juncus patens	Perennial rush	0.2	0	50	75	125
Cirsium occidentale	Biennial forb	0.2	0	5	17	18

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

[SarPac = Sarcocornia pacifica; JauCar = Jaumea carnosa; FraSal = Frankenia salina; DisSpi = Distichlis spicata; TriCon = Triglochin concinna.]

Marsh zone	% high tides reaching zone	MHHW range (m)	n	Mean cover of top four dominant plants (%)
Transition	0.14-3	0.525 to 0.297	36	SarPac (59), JauCar (18), FraSal (16), DisSpi (5)
High	3-25	0.297 to 0.013	176	SarPac (57), JauCar (23), FraSal (17), TriCon (13)
Middle	25-50	0.013 to -0.198	307	SarPac (54), JauCar (37), TriCon (14), DisSpi (6)
Low	>50	-0.198 to -0.543	97	SarPac (78), JauCar (13), FraSal (3), TriCon (2)

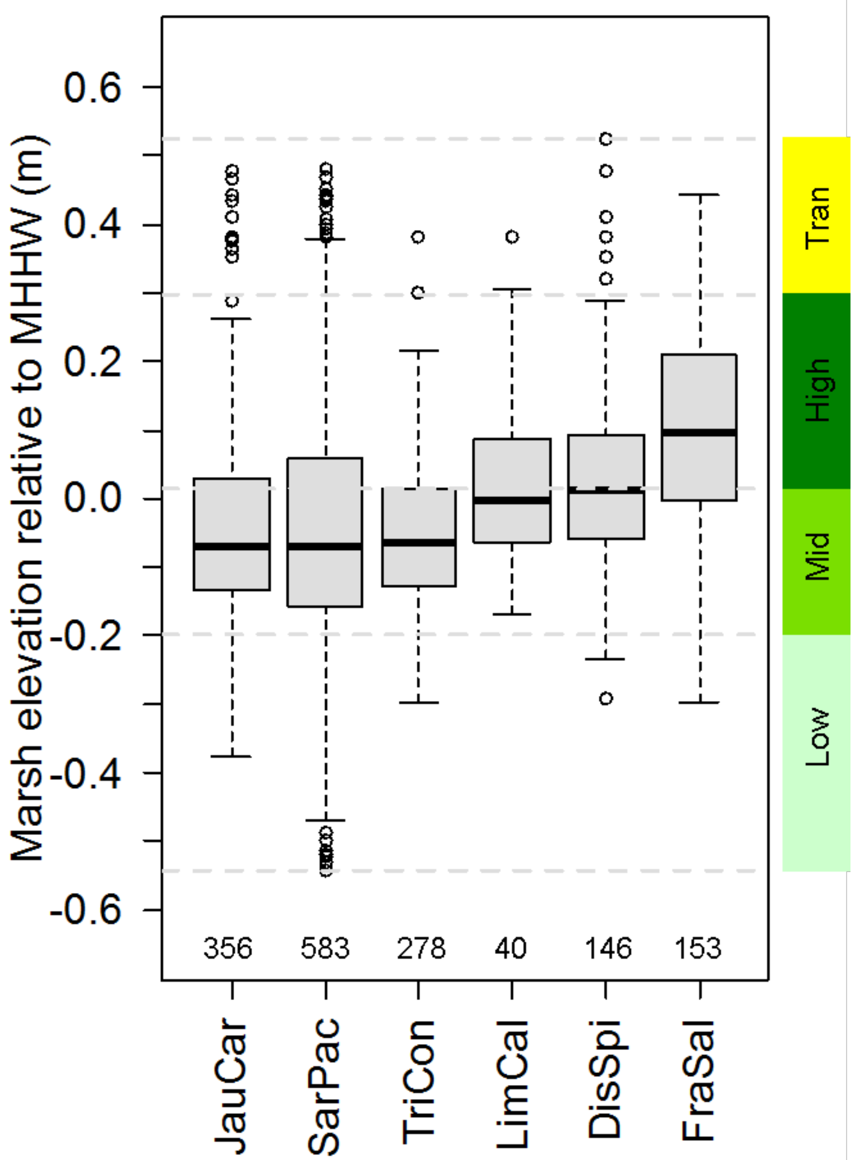

Figure D5. Elevation distribution of the six most commonly occurring vascular plant species at Morro Bay. The black horizontal bars show the median elevation at which the species occurs; shaded boxes indicate the interquartile range; upper and lower whiskers encompass points no greater than 1.5 x the 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 616 plots). Marsh elevation zones (low, middle, high and transition) are illustrated at right. JauCar = *Jaumea carnosa*; SarPac = *Sarcocornia pacifica*; TriCon = *Triglochin concinna*; LimCal = *Limonium californicum*; DisSpi = *Distichlis spicata*; FraSal = *Frankenia salina*.

Table D3. Locations of water loggers, SETs, and cores (UTM zone 10).

Location	Easting (m)	Northing (m)
water logger	696940	3912999
SET	696904	3913502
	696852	3913531
	696897	3913675
	696942	3913660
core samples	696598	3913007

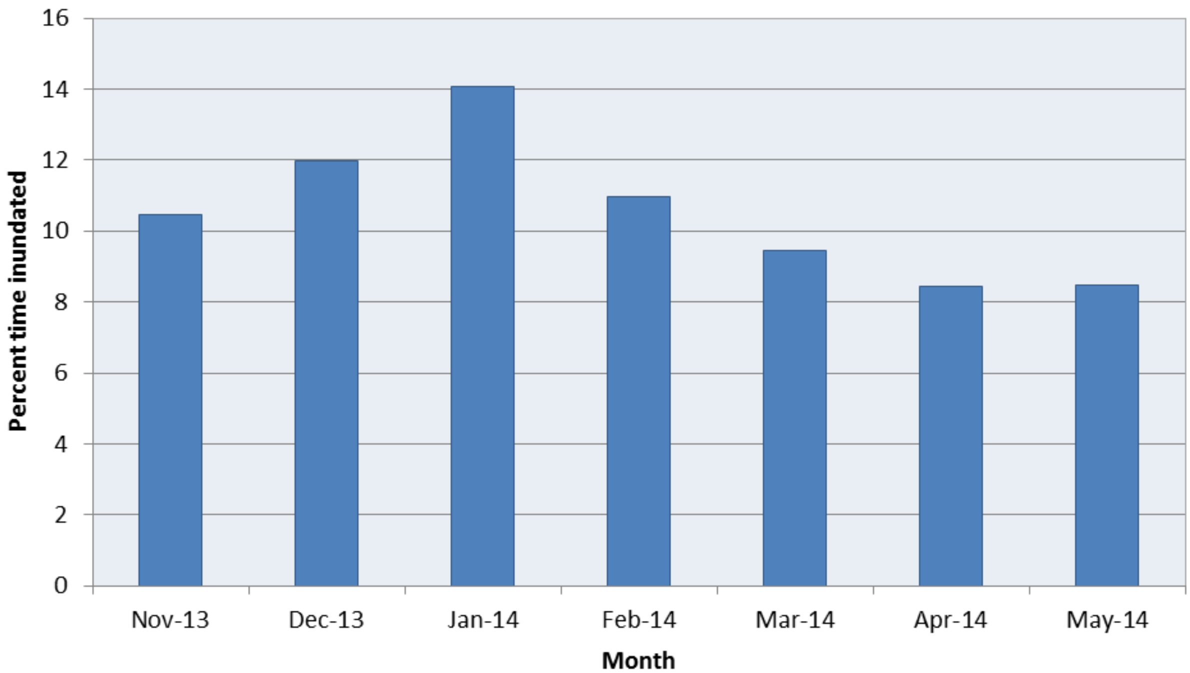

Figure D6. Average monthly inundation of the study site based on an average marsh elevation. Water levels were determined with a Hobo water logger deployed at 0.78 m above NAVD88.

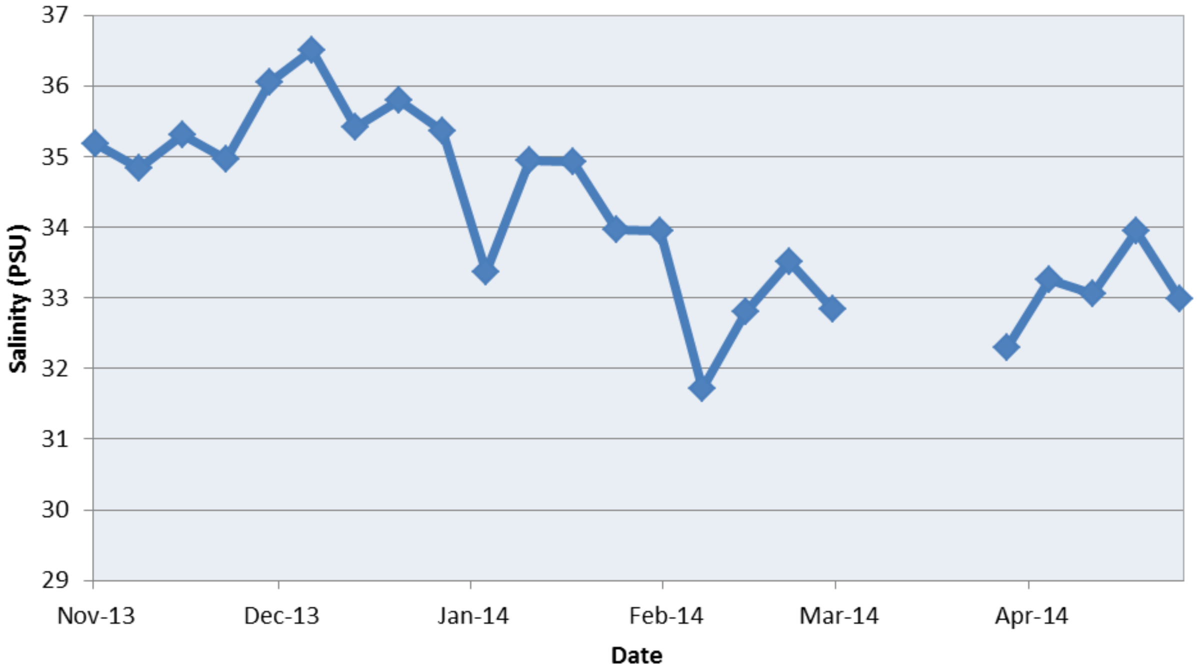

Figure D7. Average weekly maximum salinity from November 2013–April 2014 at Morro Bay.

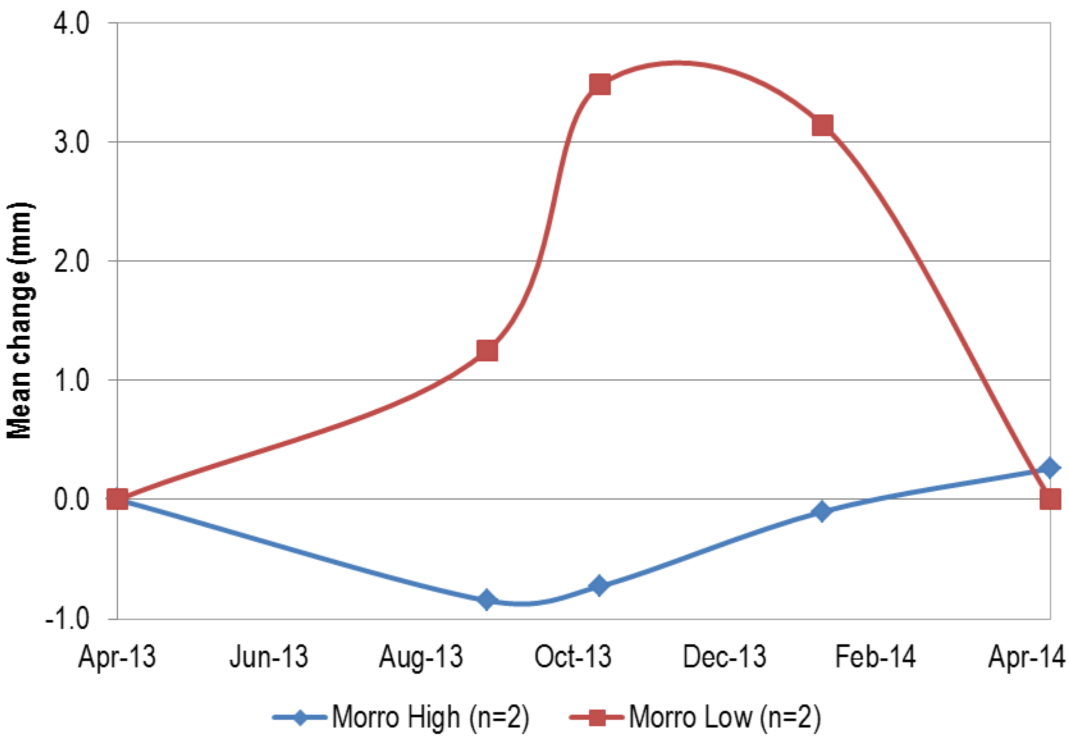

Figure D8. Baseline measurements of net marsh surface elevation change at surface elevation tables (SET) at Morro Bay.

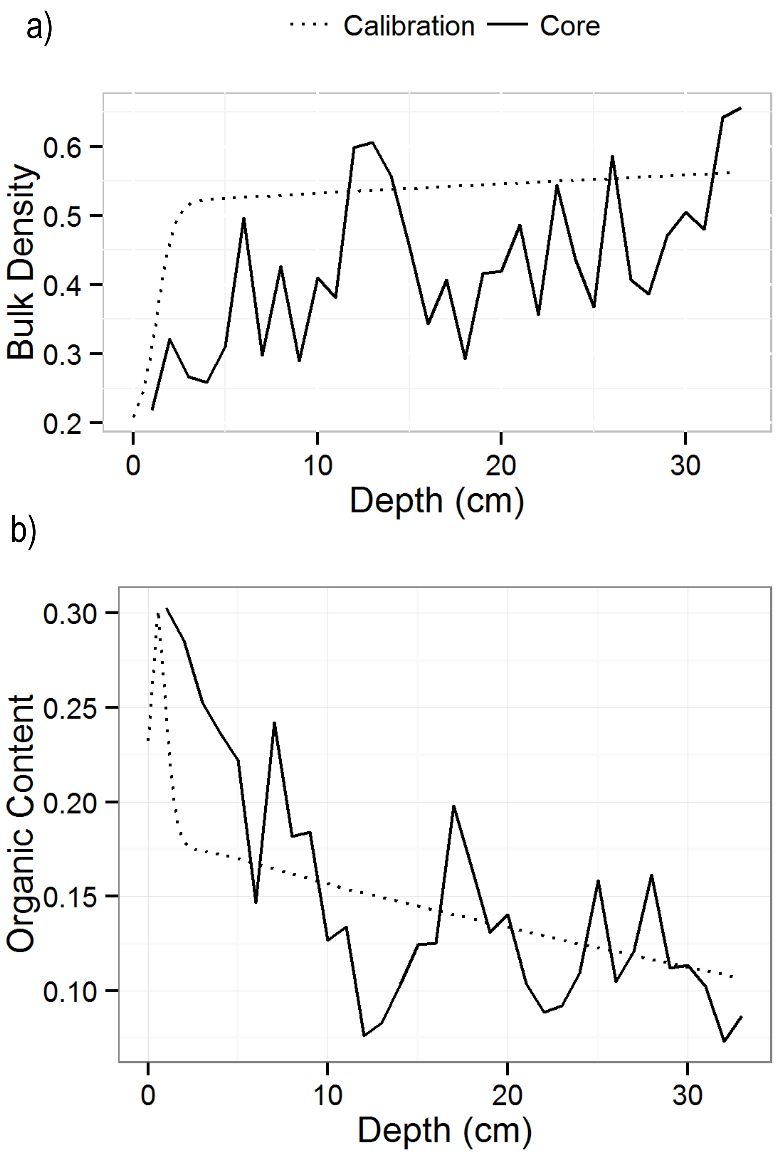

Figure D9. Deep sediment core calibration of the WARMER model using depth profiles of (a) bulk density (g cm^{-3}) and (b) organic matter content (%).

Table D4. WARMER parameters and soil core characteristics used for SLR model calibration at Morro Bay

NDVI = Normalized Difference Vegetation Index; NAIP = National Agriculture Inventory Program.

Model parameter	Value	Source
Sediment accumulation rate (g cm^{-2} yr^{-1})	0.15	Core Calibration
Elevation of peak biomass (cm, MSL)	93	NDVI from NAIP
Minimum elevation of vegetation (cm, MSL)	16.2	Field surveys
Max. aboveground organic accumulation (g cm^{-2} yr^{-1})	0.0550	Core calibration
Root-to-shoot ratio	0.458	C. Janousek, unpub data
Porosity at sediment surface (%)	90	Core
Porosity at depth (%)	75	Core
Refractory carbon (%)	16.7	Core
Maximum astronomical tide (cm, MSL)	133	Port San Luis tide gauge (NOAA,9412110)
Historic sea-level rise (mm yr^{-1})	0.79	Port San Luis tide gauge (NOAA,9412110)
Organic matter density (g cm^{-3})	1.14	DeLaune 1983
Mineral density (g cm^{-3})	2.61	DeLaune 1983

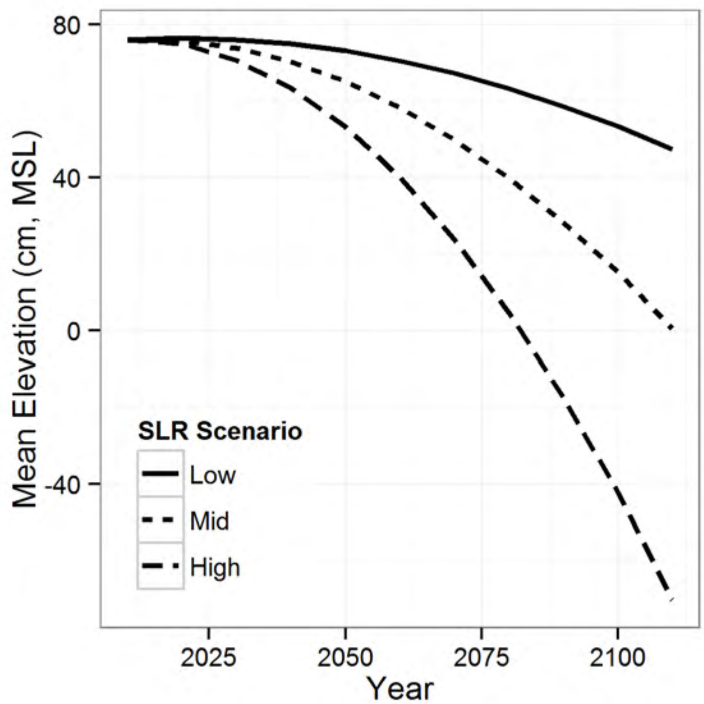

Figure D10. WARMER model projections for the change in average marsh elevation (relative to MHHW) at Morro Bay from 2010 to 2110 under low, mid, and high NRC sea-level rise scenarios.

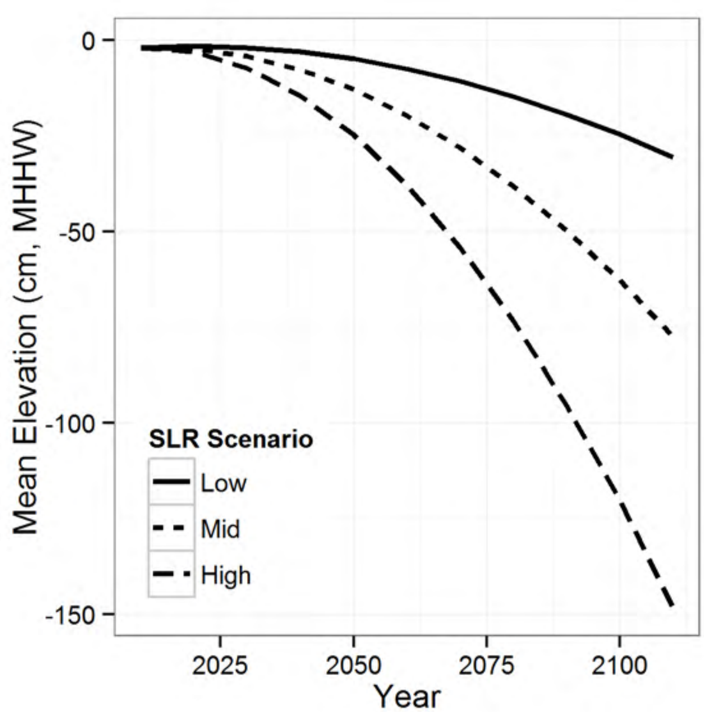

Figure D11. WARMER model projections for the change in average marsh elevation (relative to MSL) at Morro Bay from 2010 to 2110 under low, mid, and high NRC sea-level rise scenarios.

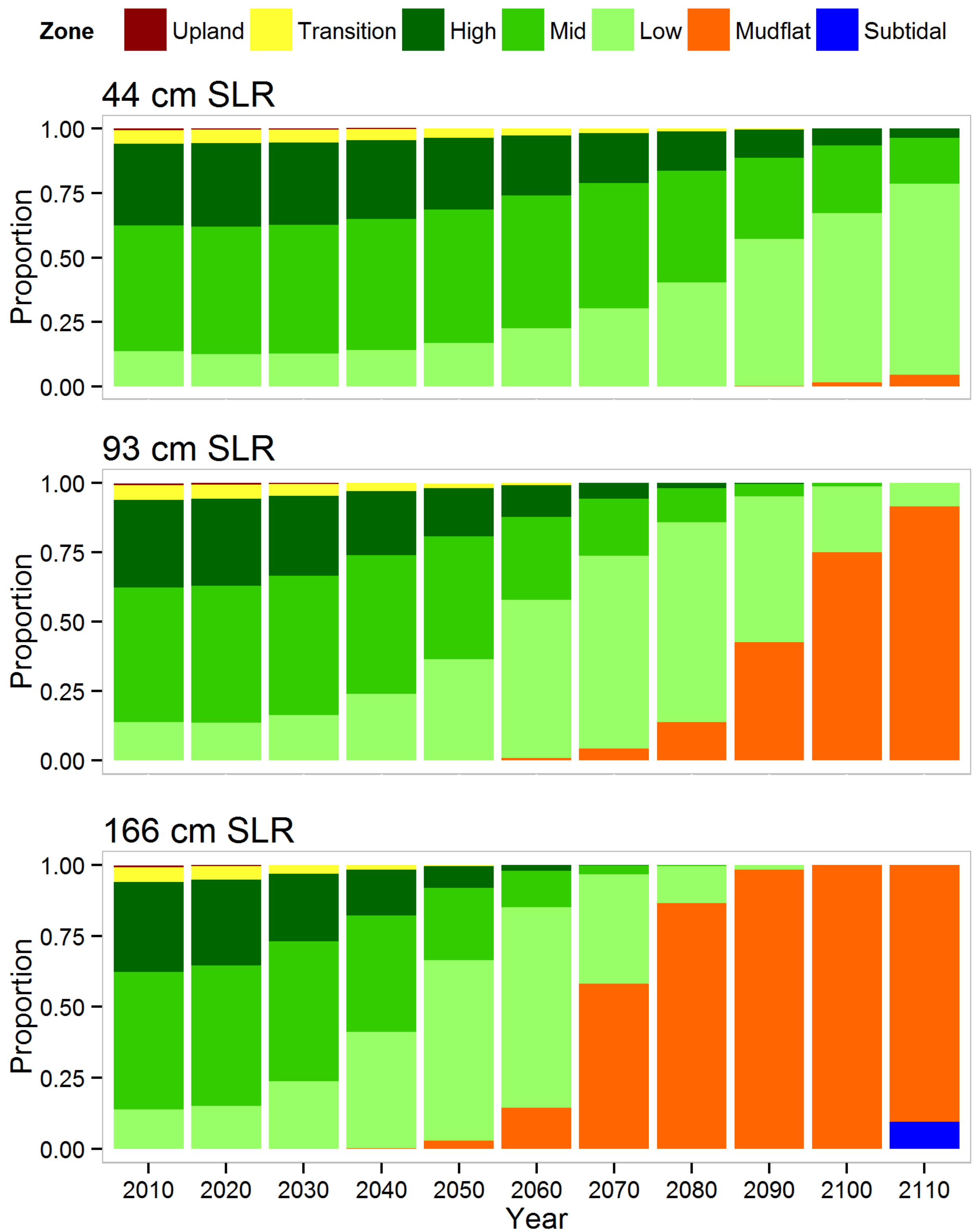

Figure D12. Model projections for change in the relative proportion of upland; transitional, high, mid and low marsh; and mudflat habitat at Morro Bay under the NRC's low (43 cm), mid (93 cm), and high (166 cm) sea-level rise scenarios from 2010 to 2110.

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 (44 cm)			Mid SLR (93 cm)			High SLR (166 cm)		
	2010	**2050**	**2110**	**2010**	**2050**	**2110**	**2010**	**2050**	**2110**
Upland	1	0	0	1	0	0	1	0	0
Transition	5	3	0	5	2	0	5	0	0
High	32	28	3	32	18	0	32	8	0
Mid	49	52	18	49	44	0	49	25	0
Low	14	17	74	14	36	8	14	64	0
Mudflat	0	0	5	0	0	92	0	3	91
Subtidal	0	0	0	0	0	0	0	0	9

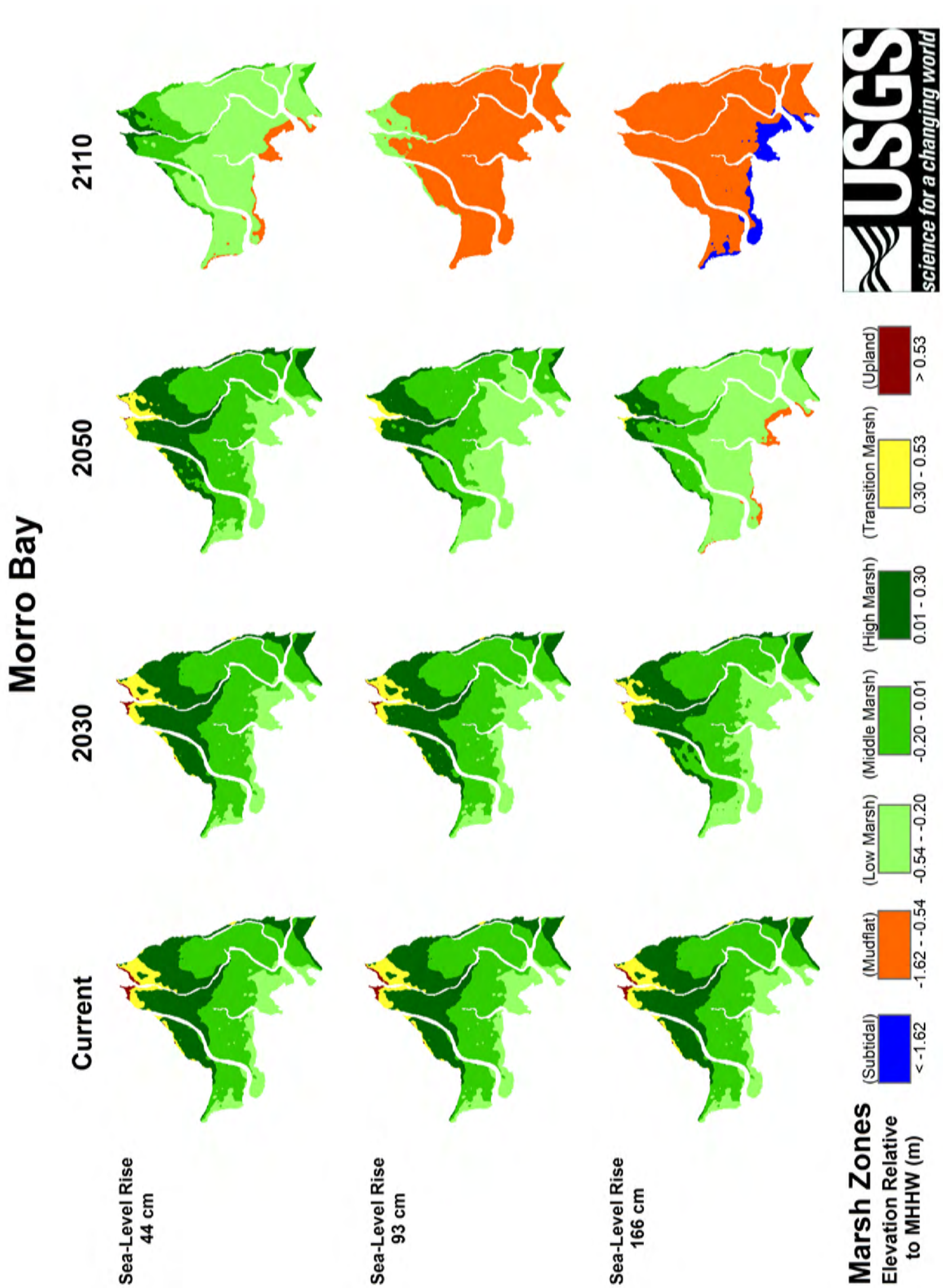

Figure D13. Projected habitat distribution at Morro Bay for 2030, 2050 and 2110 with the WARMER model under three NRC sea-level rise scenarios.

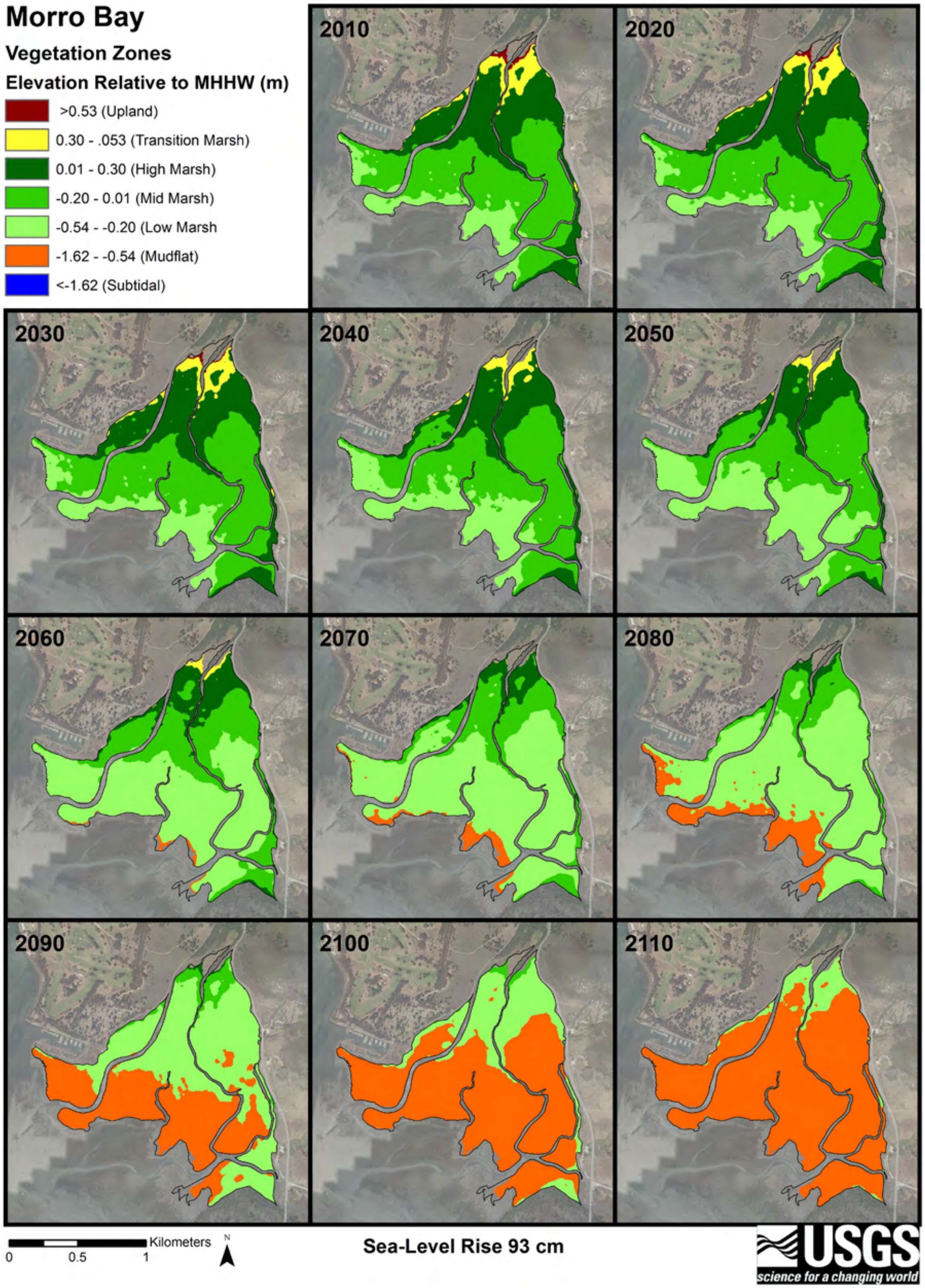

Figure D14. Projected changes in Morro Bay habitat zones under the mid NRC sea-level rise scenario (93 cm).

Appendix E. Site Specific Details for Pt. Mugu, Naval Base Ventura County, California

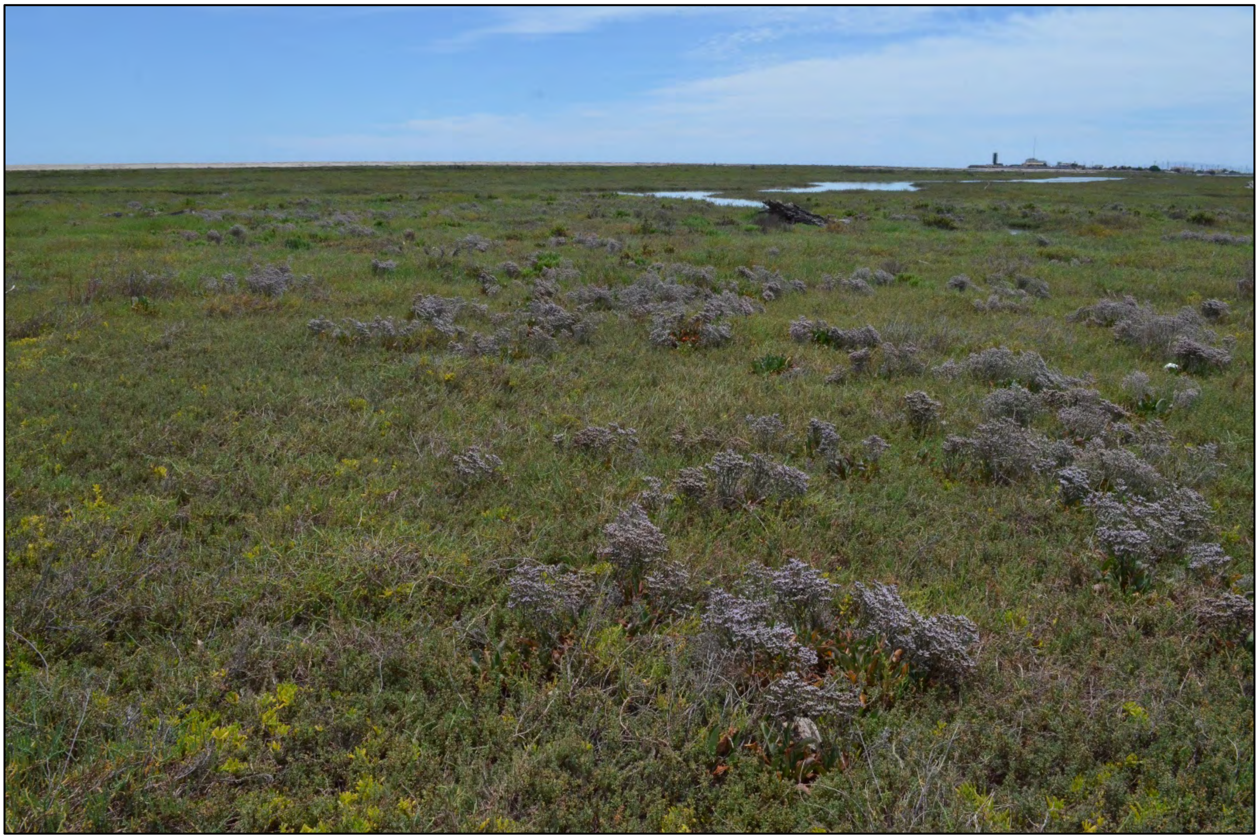

Photo: C. Janousek, OSU/USGS

Summary:

- *Study site*: 109.0 ha
- *Location*: 34° 6'3.46"N latitude, 119° 5'11.82"W longitude
- *Site management*: Naval Base Ventura County
- *Site vegetation and elevation survey:* December 6, 2012–January 10, 2013
- *Sample size*: 1,720 elevation points, 373 vegetation plots
- *Marsh elevation model*: 56% of elevation points were above MHHW
- *Plant community composition*: Succulent chenopods (mostly *Sarcocornia pacifica*) dominated vegetation across the site. *Frankenia salina* was also relatively common.
- *Bathymetric surveys*: 54.6 ha of nearshore habitat were mapped adjacent to the study area.
- *Soil characteristics*: The accumulation rates used in WARMER were: mineral accumulation rate = 0.807 g cm^{-2} yr^{-1}; organic matter accumulation rate = 0.089 g cm^{-2} yr^{-1}; net accretion = 0.96 cm yr^{-1}.

- *Water monitoring data collection:* water level (January 2013 - February 2014). Water level and conductivity monitoring is ongoing.
- *Calculated tidal datums: MHHW* is at 1.60 m NAVD88; MHW is at 1.39 m NAVD88.
- *Marsh inundation pattern:* Maximum inundation occurred during July 2013; minimum inundation during November 2014.
- *SETs:* Two high marsh SETs and two low marsh SETs were installed on April 19, 2013. During the first year of monitoring, cumulative elevation change was +0.01 mm in high marsh and +2.88 mm in low marsh.
- *Sea-level rise marsh response modeling:* Under the NRC's low SLR scenario, there is a modest expansion of mid marsh from 2030 to 2100, but all 4 intertidal marsh zones remain present through the end of the century. Under mid SLR, there is expansion of low marsh at the expense of other habitat types from 2050 to 2090 followed by a large increase in mudflat habitat by 2110. Finally, under the NRC's high SLR scenario, there is loss of transitional marsh by 2070, and loss of high marsh by 2090. All vegetated marsh is projected to be lost by 2110.

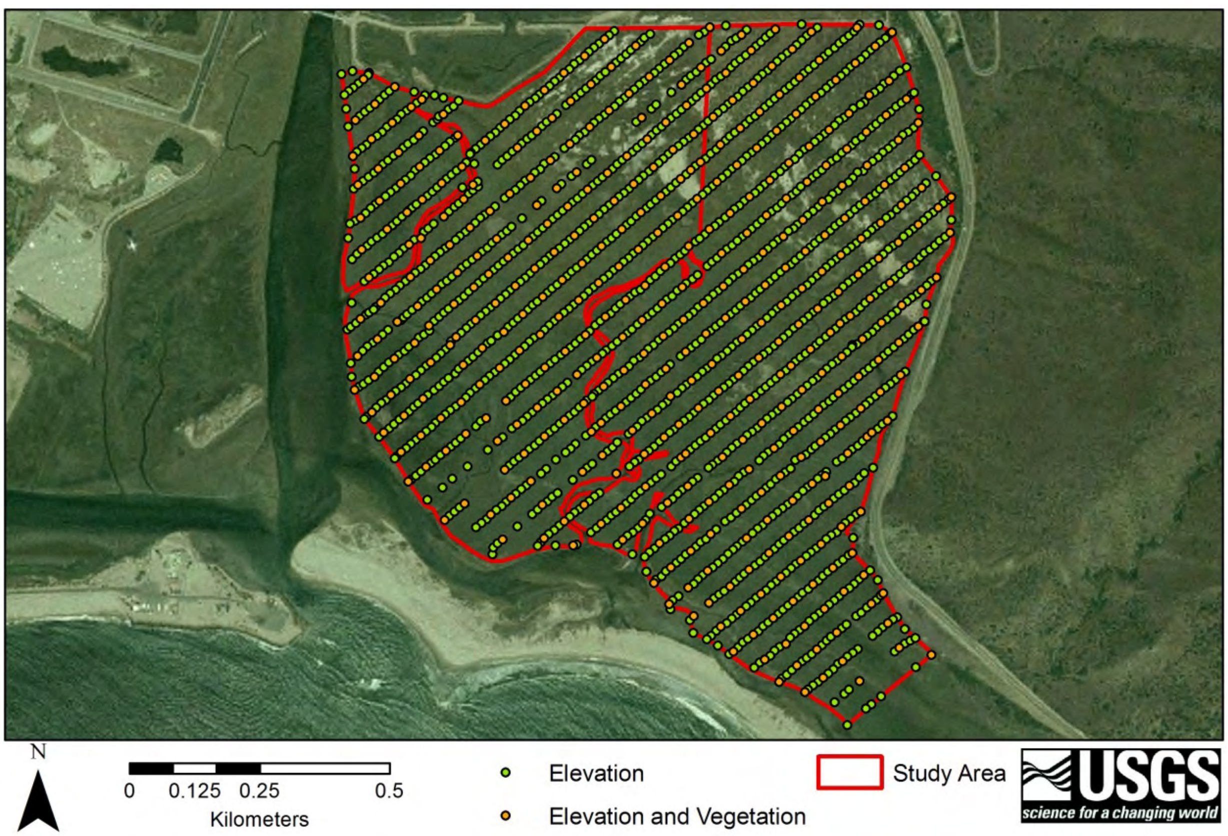

Figure E1. Distribution of elevation and vegetation survey points at Pt. Mugu.

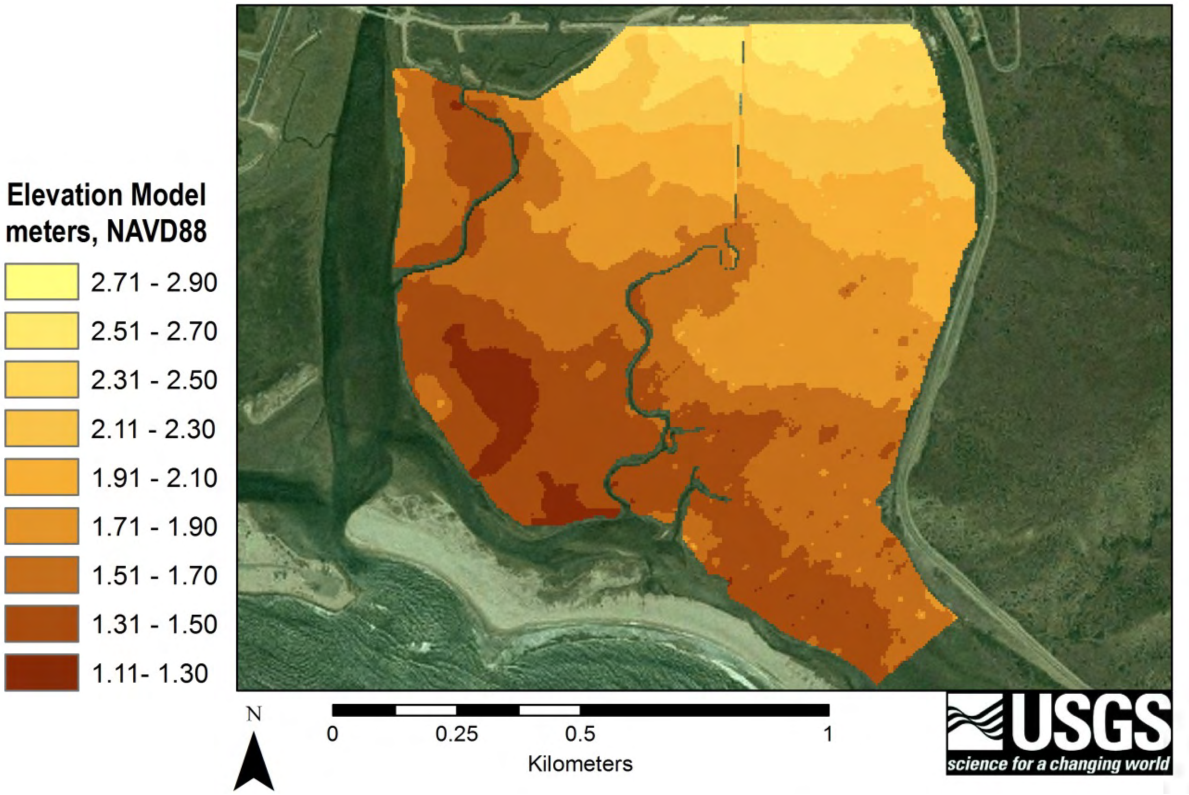

Figure E2. Elevation model (3 m resolution) of tidal marsh at Pt. Mugu developed from RTK GPS survey data.

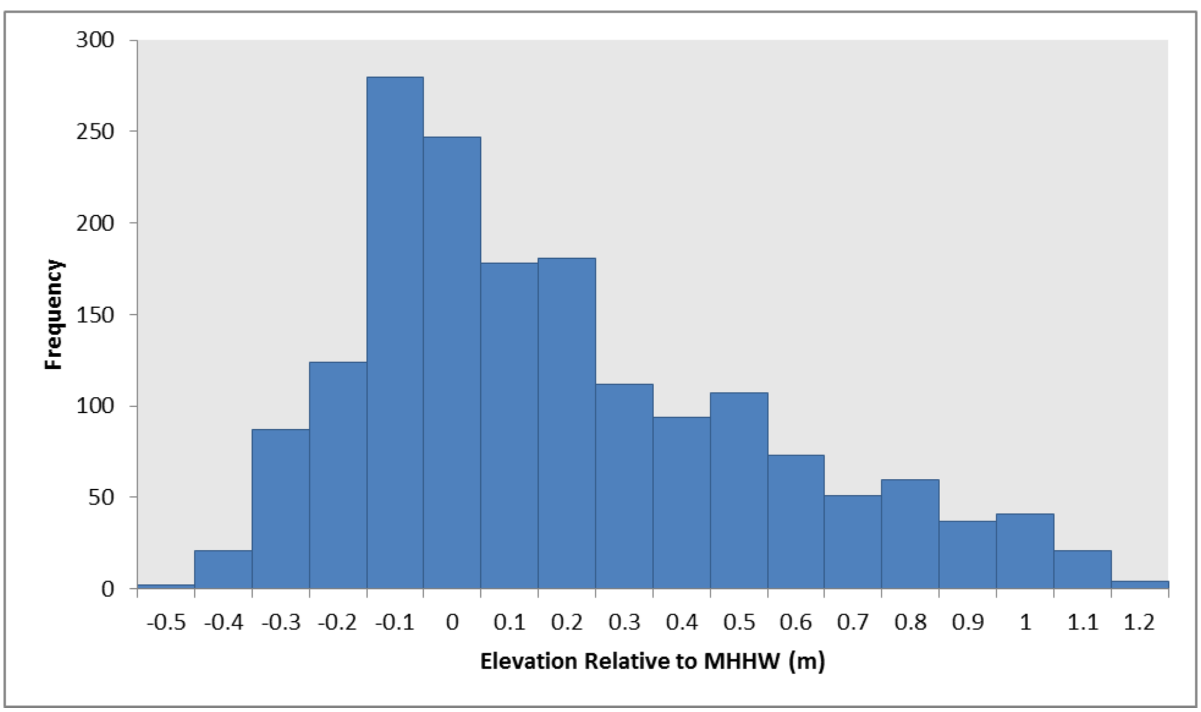

Figure E3. Frequency distribution of marsh surface elevation measurements relative to local mean higher high water (MHHW) at Pt. Mugu.

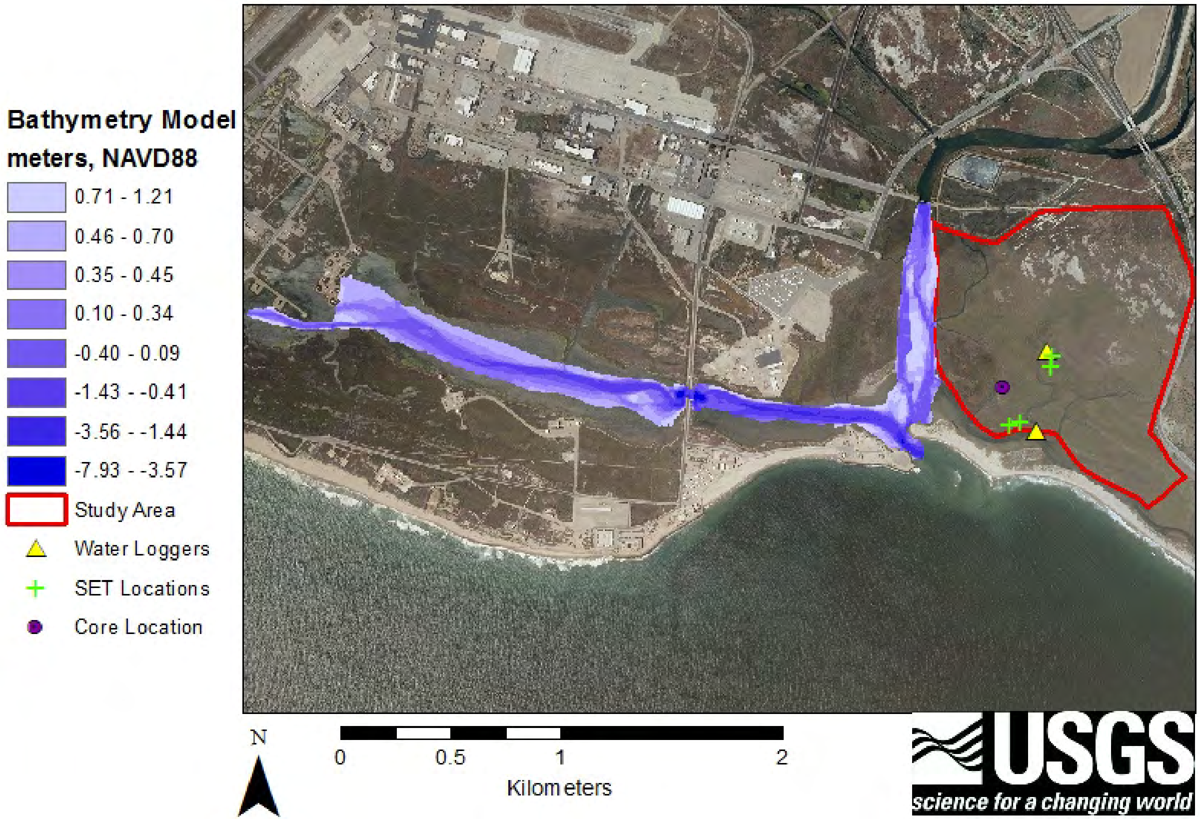

Figure E4. Near-shore bathymetry model for Pt. Mugu and location of water level loggers, surface elevation tables (SET), and deep sediment cores.

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

[NA = not measured]

Species	Description	Frequency of occurrence (%)	Percent cover Mean	Percent cover Max	Plant heights (cm) Mean	Plant heights (cm) Max
*Chenopodiaceae**	Perennial forb	87.8	63	100	31	108
Frankenia salina	Perennial forb	39.5	13	100	19	57
Jaumea carnosa	Perennial forb	21.5	10	100	14	42
Distichlis littoralis	Perennial grass	16.5	7	100	19	64
Distichlis spicata	Perennial grass	15.4	3	100	25	62
Batis maritima	Perennial forb	12.9	3	95	15	43
Undetermined 1	NA	5.1	3	100	61	142
Cuscuta pacifica	Ann-perennial parasite	4.8	NA	NA	NA	NA
Cressa truxillensis	Perennial subshrub	3.3	1	95	14	26
Limonium californicum	Perennial forb	3.3	1	50	19	38
Suaeda esteroa	Ann-perennial forb	2.5	1	65	23	43
Undetermined 2	NA	1.5	0	100	52	131
Triglochin maritima	Perennial forb	1.5	0	5	13	20
Baccharis pilularis	Perennial shrub	0.5	1	100	97	152
Spartina foliosa	Perennial grass	0.5	0	20	51	68
Cakile edentata	Ann-perennial forb	0.3	0	90	13	19

* Mostly *Sarcocornia pacifica*, but also probably including *Arthrocnemum subterminale*.

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

[Cheno = *Chenopodiaceae* (mostly *Sarcocornia pacifica*); Undet = undetermined species; BatMar = *Batis maritima*; DisLit = *Distichlis littoralis*; FraSal = *Frankenia salina*; JauCar = *Jaumea carnosa*; DisSpi = *Distichlis spicata*; SpaFol = *Spartina foliosa*.]

Marsh zone	% high tides reaching zone	MHHW range (m)	n	Mean cover of top four dominant plants (%)
Transition	0.14-3	0.570 to 0.394	37	Cheno (50), Undet (15), BatMar (13), DisLit (9)
High	3-25	0.394 to 0.041	113	Cheno (48), FraSal (25), DisLit (20), JauCar (4)
Middle	25-50	0.041 to -0.211	162	Cheno (68), JauCar (21), FraSal (10), DisSpi (4)
Low	>50	-0.211 to -0.474	61	Cheno (84), FraSal (1), BatMar (1), SpaFol (1)

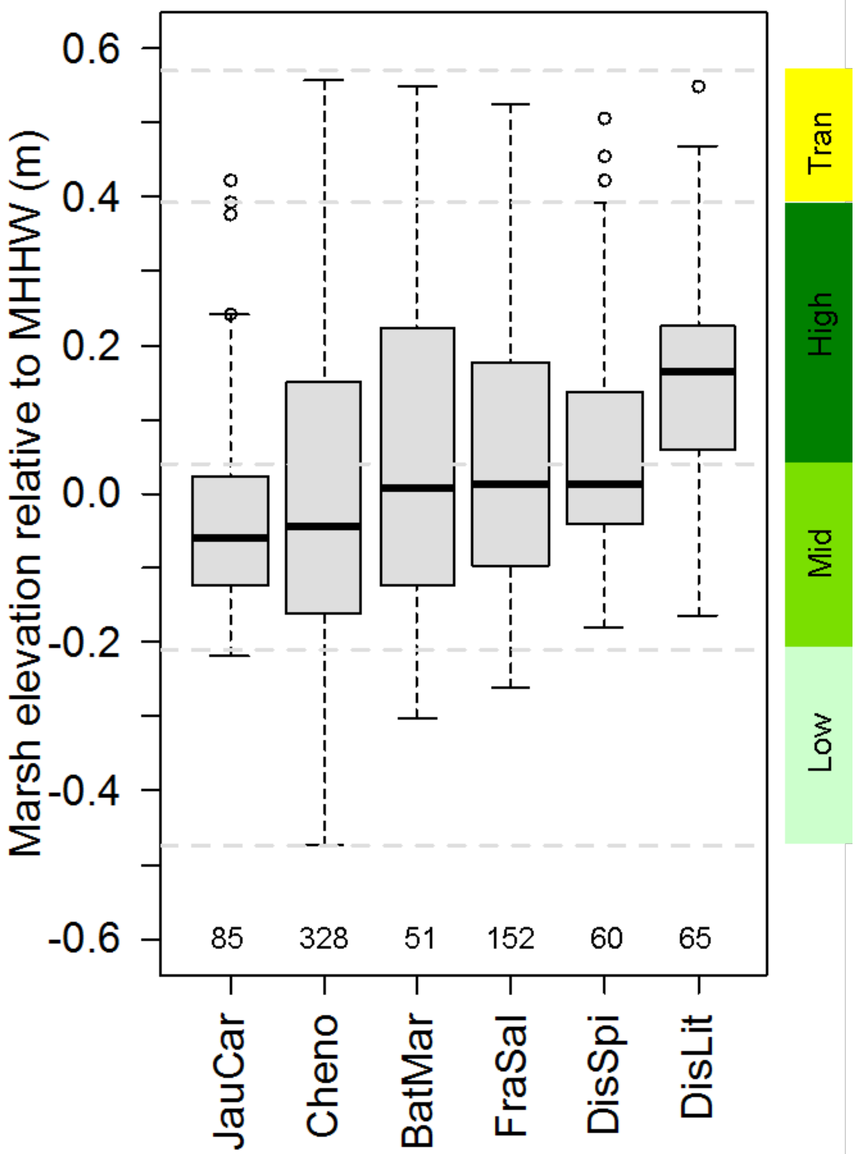

Figure E5. Elevation distribution of six most commonly-occurring vascular plant species at Pt. Mugu. The black horizontal bars show the median elevation at which the species occurs; shaded boxes indicate the interquartile range; upper and lower whiskers encompass points no greater than 1.5 x the length 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 373 plots). Marsh elevation zones (low, middle, high and transition) are illustrated at right. JauCar = *Jaumea carnosa*; Cheno = *Chenopodiaceae* (mostly *Sarcocornia pacifica*); BatMar = *Batis maritima*; FraSal = *Frankenia salina*; DisSpi = *Distichlis spicata*; DisLit = *Distichlis littoralis*.

Table E3. Locations of water level loggers, surface elevation tables (SET), and deep sediment cores at Pt. Mugu (UTM zone 11).

Location	Easting (m)	Northing (m)
water logger	307473	3775329
SETs	307356	3775360
	307408	3775371
	307547	3775672
	307546	3775619
core sample	307328	3775531

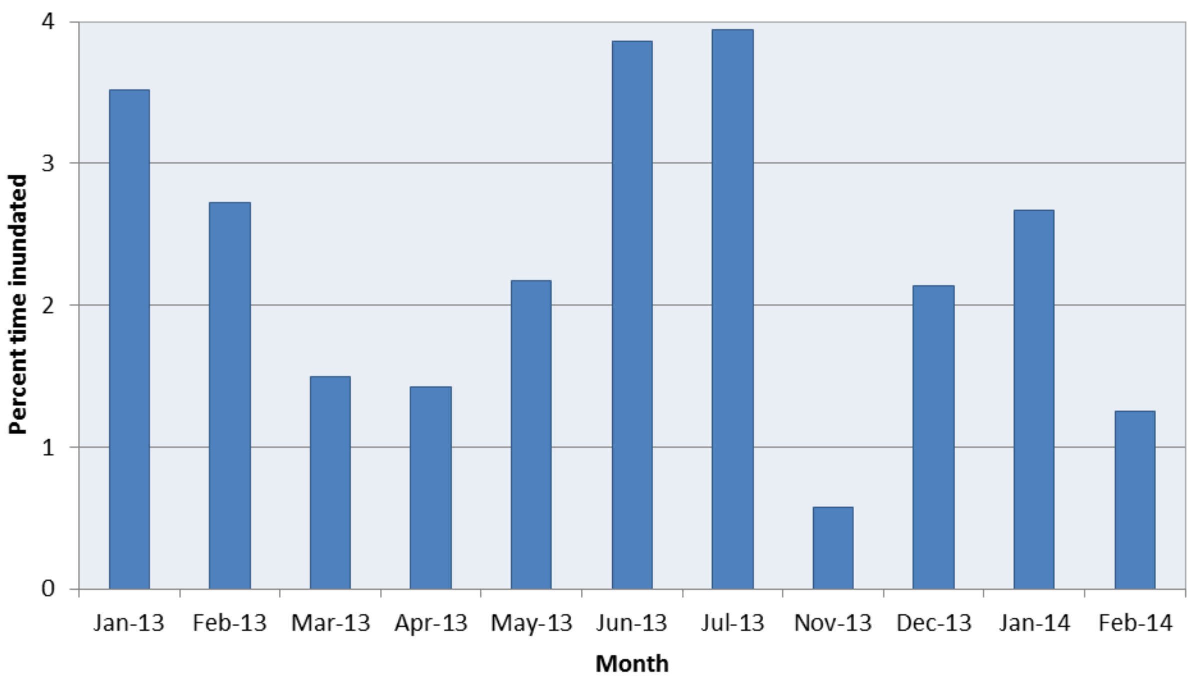

Figure E6. Average monthly inundation of the study site based on an average marsh elevation. Water levels were determined with a Hobo water logger deployed at 0.01 m above NAVD88.

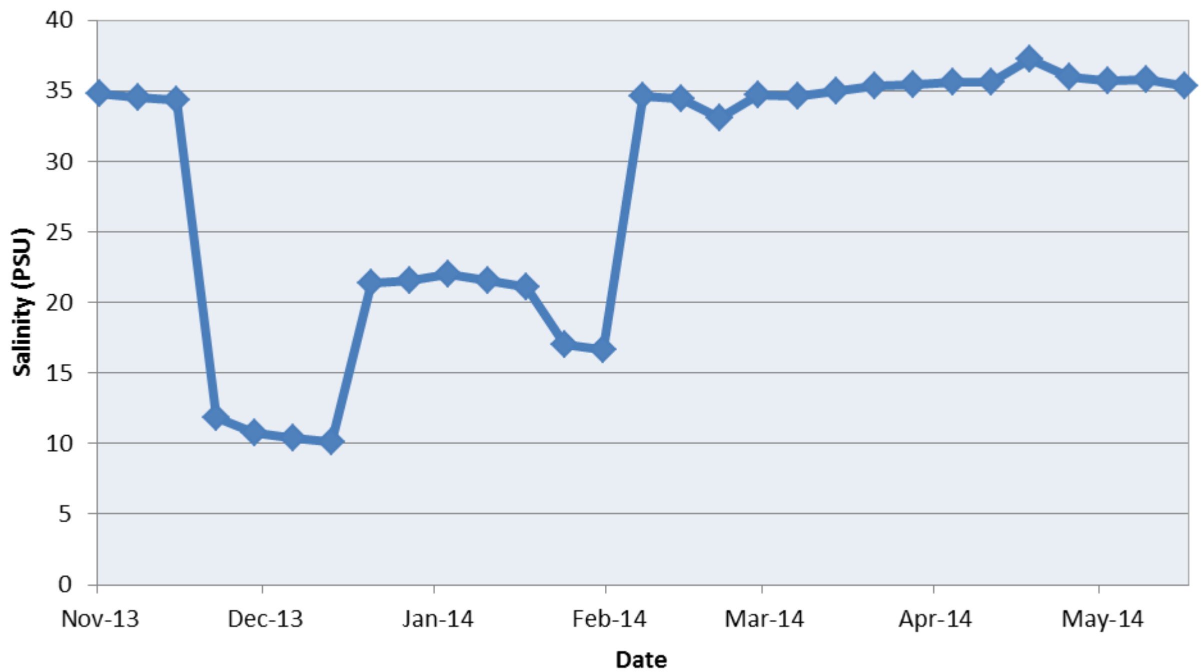

Figure E7. Average weekly maximum salinity from November 2013–May 2014 at Pt. Mugu.

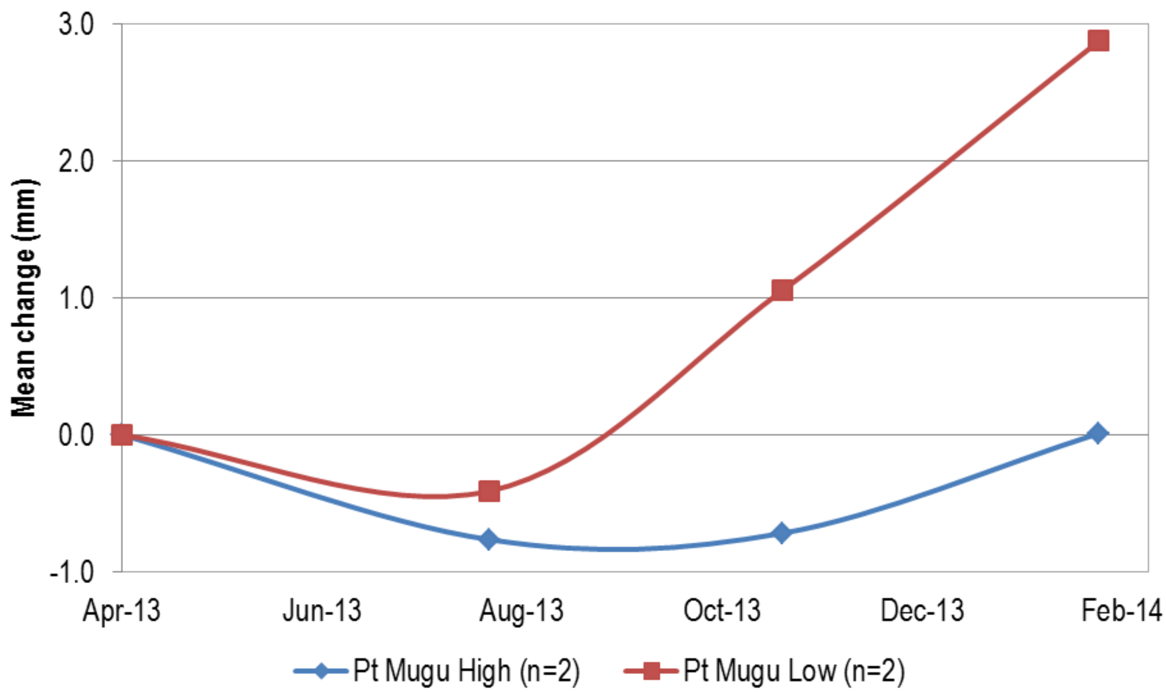

Figure E8. Baseline measurements of elevation change at Pt. Mugu using surface elevation tables (SET).

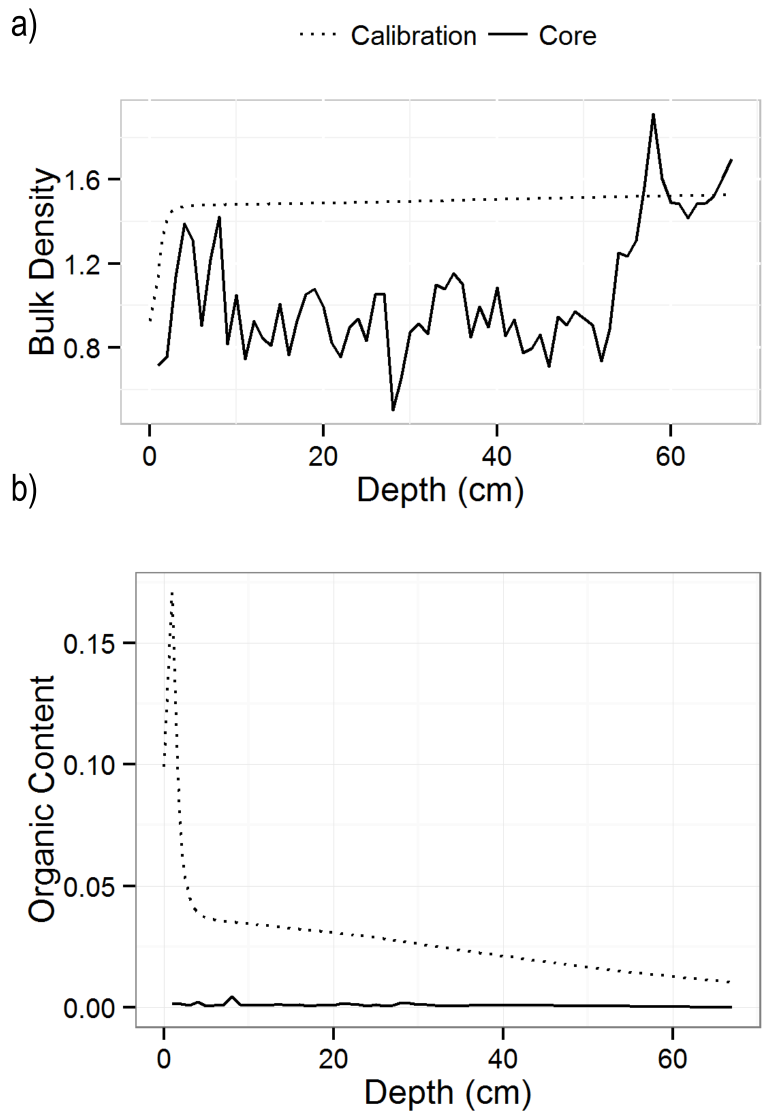

Figure E9. Deep sediment core calibration of the WARMER model using depth profiles of (a) bulk density (g cm^{-3}) and (b) organic matter content (%).

Table E4. WARMER parameters and soil core characteristics used for SLR model calibration at Pt. Mugu

[NDVI = Normalized Difference Vegetation Index; NAIP = National Agriculture Inventory Program]

Model parameter	Value	Source
Sediment accumulation rate (g cm^{-2} yr^{-1})	1.44	Core Calibration
Elevation of peak biomass (cm, MSL)	87.9	NDVI from NAIP
Minimum elevation of vegetation (cm, MSL)	30.9	Field Surveys
Max. aboveground organic accumulation (g cm^{-2} yr^{-1})	0.1656	Core calibration
Root-to-shoot ratio	0.458	C. Janousek, unpub. data
Porosity at sediment surface (%)	60	Core
Porosity at depth (%)	41	Core
Refractory carbon (%)	5.9	Core
Maximum astronomical tide (cm, MSL)	118	Santa Monica tide gauge (NOAA,9410840)
Historic sea-level rise (mm yr^{-1})	2.33	Santa Monica tide gauge (NOAA,9410840)
Organic matter density (g cm^{-3})	1.14	DeLaune 1983
Mineral density (g cm^{-3})	2.61	DeLaune 1983

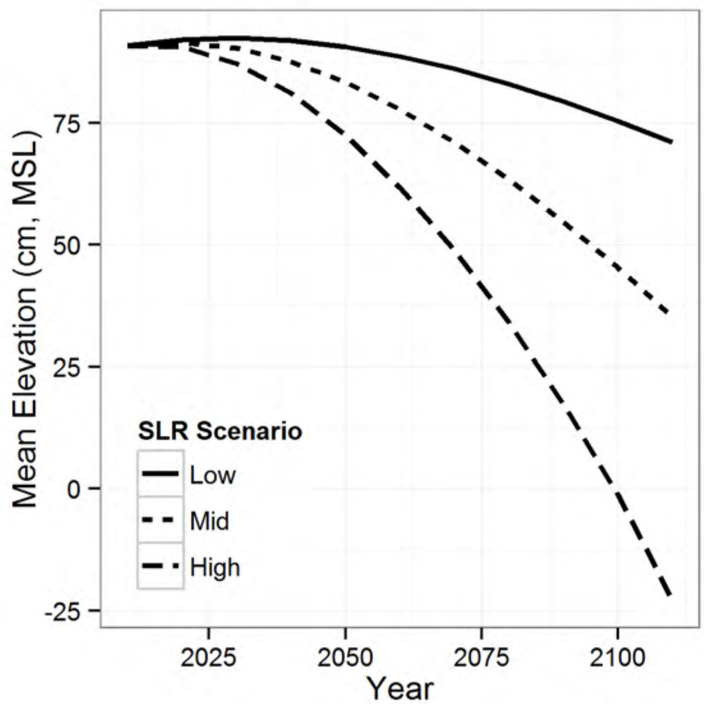

Figure E10. WARMER model projections for the change in average marsh elevation (relative to MHHW) at Pt. Mugu from 2010 to 2110 under low, mid, and high NRC sea-level rise scenarios.

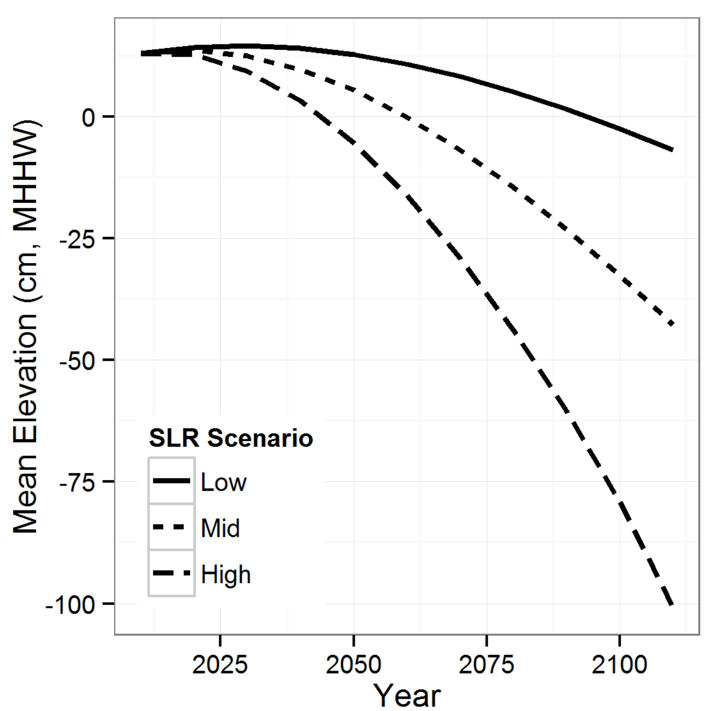

Figure E11. WARMER model projections for the change in average marsh elevation (relative to MSL) at Pt. Mugu from 2010 to 2110 under low, mid, and high NRC sea-level rise scenarios.

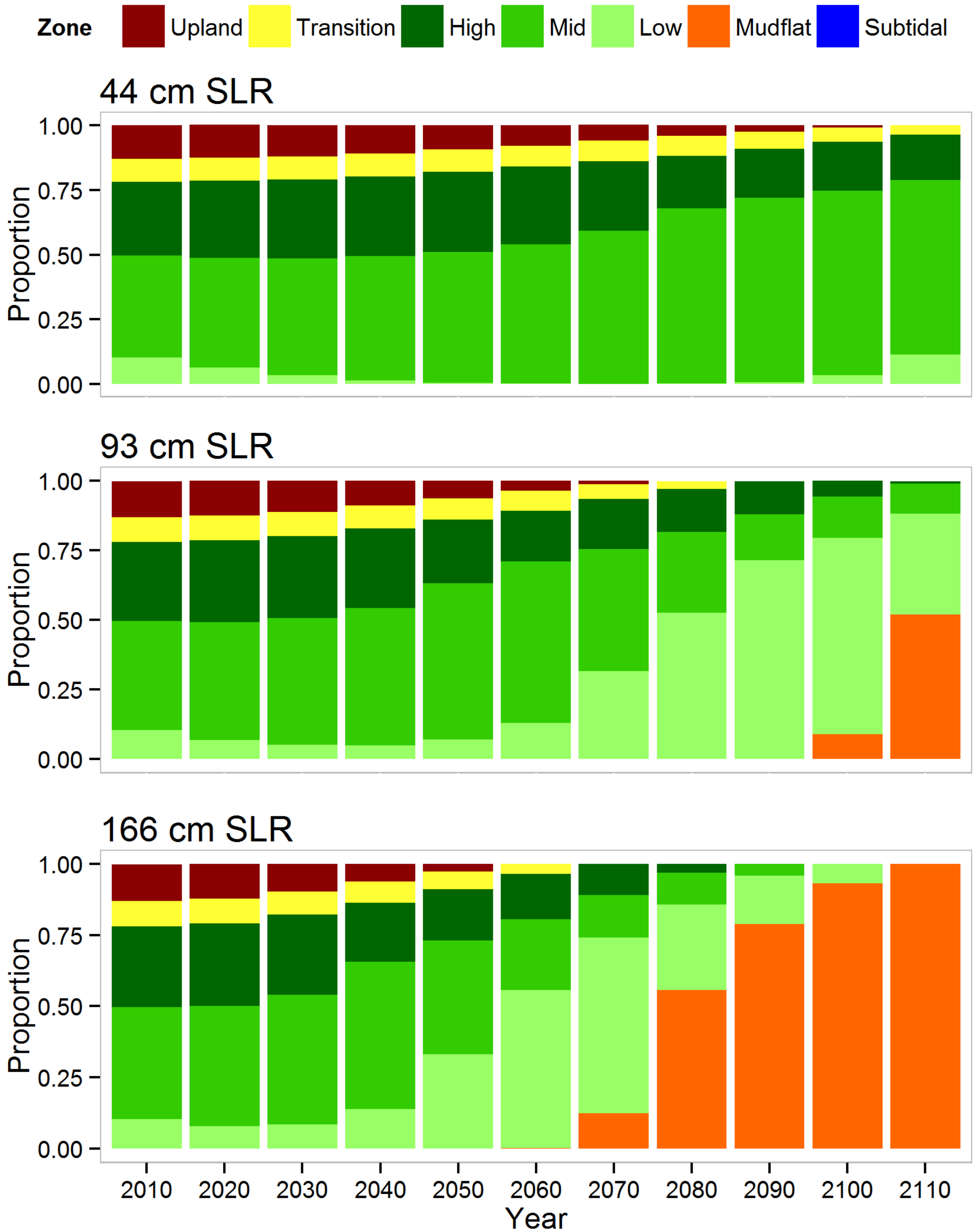

Figure E12. Model projections for change in the relative proportion of upland; transitional, high, mid and low marsh; and mudflat habitat under the NRC's low (44 cm), mid (93 cm), and high (166 cm) sea-level rise scenarios from 2010 to 2110.

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 (44 cm)			Mid SLR (93 cm)			High SLR (166 cm)		
	2010	**2050**	**2110**	**2010**	**2050**	**2110**	**2010**	**2050**	**2110**
Upland	13	9	0	13	6	0	13	3	0
Transition	9	9	4	9	8	0	9	6	0
High	29	31	18	29	23	1	29	18	0
Mid	39	50	67	39	56	11	39	40	0
Low	10	1	11	10	7	36	10	33	0
Mudflat	0	0	0	0	0	52	0	0	100

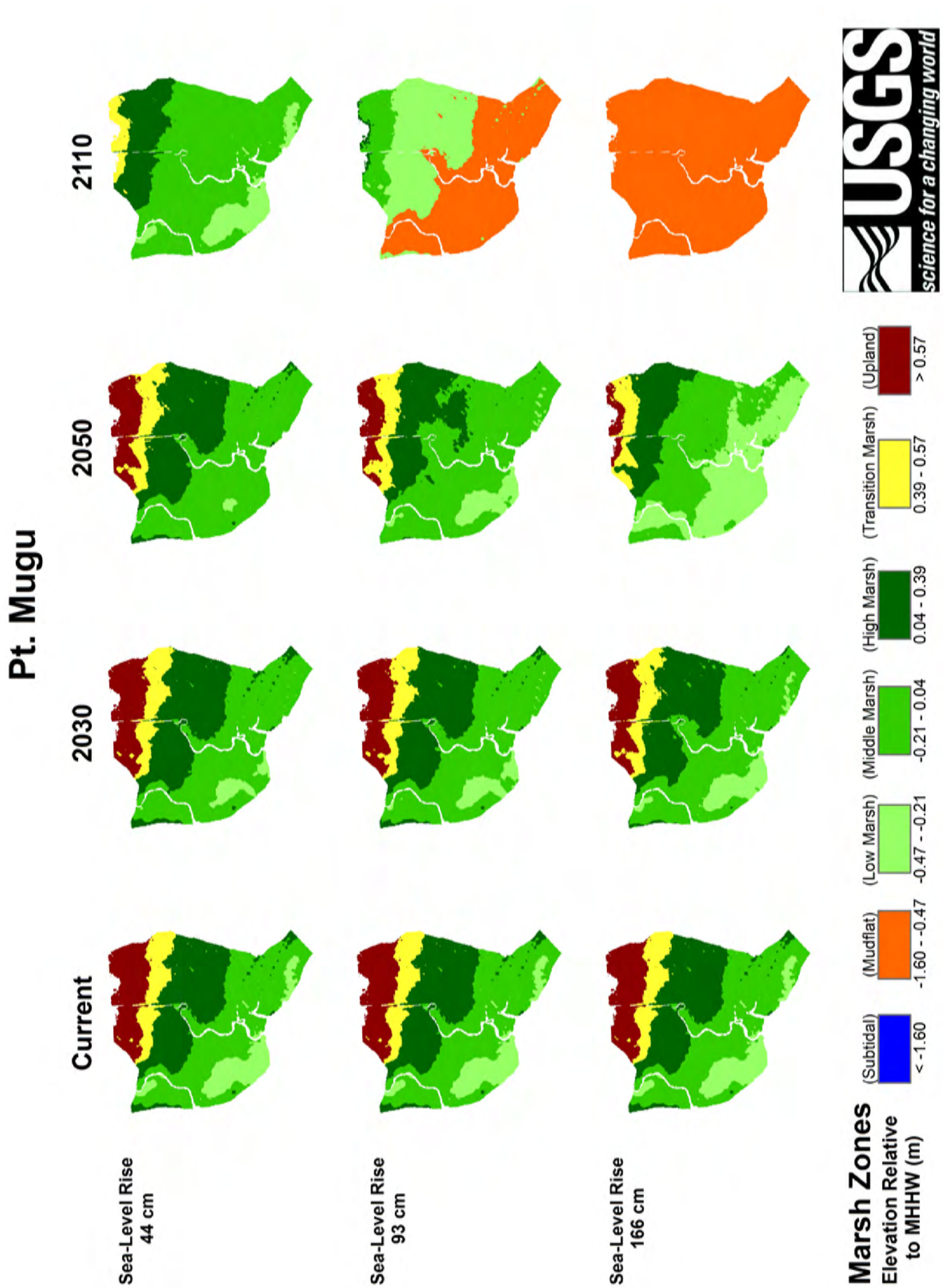

Figure E13. Projected habitat distribution at Pt. Mugu for 2030, 2050 and 2110 with the WARMER model under three NRC sea-level rise scenarios.

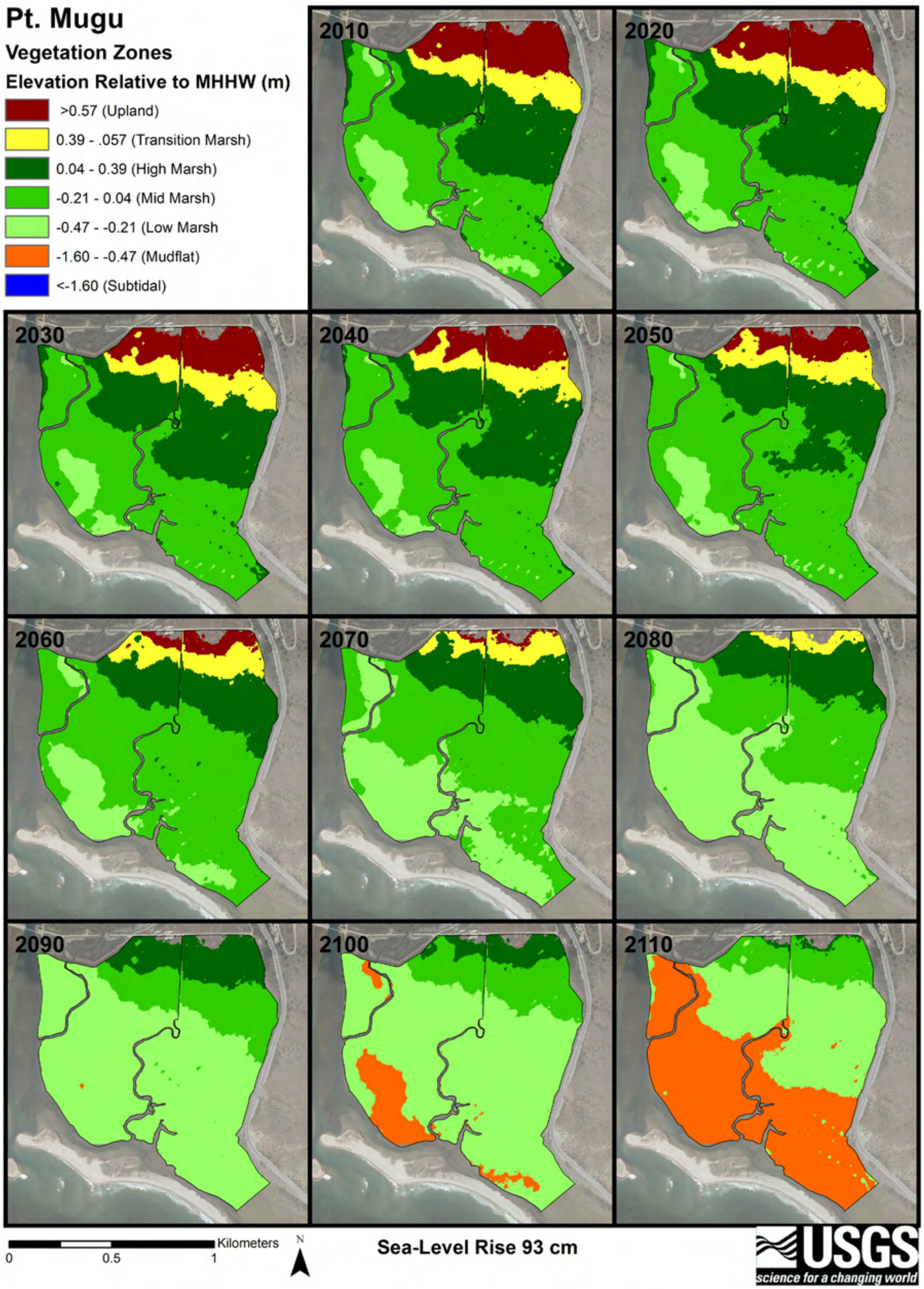

Figure E14. Projected changes in Pt. Mugu habitat zones under the mid NRC sea-level rise scenario (93 cm).

Appendix F. Site Specific Details for Upper Newport Bay, Newport Bay, Orange County, California

Photo: C. Freeman, USGS

Summary:

- *Study site size*: 59.8 ha
- *Location*: 33°38'59.31"N latitude, 117°53'12.83"W longitude
- *Site management*: California Department of Fish and Wildlife and Orange County Parks
- *Site vegetation and elevation survey*: November 26–December 3, 2012
- *Sample size*: 1,037 elevation points, 248 vegetation plots
- *Marsh elevation model*: 36% of elevation data points were above MHHW
- *Plant community composition*: The most commonly-occurring species was *Sarcocornia pacifica*, occurring from low marsh to the marsh-upland transition zone. *Spartina foliosa* (usually in low or mid marsh) and *Batis maritima* (typically mid marsh) were also common.
- *Bathymetric surveys*: 80.0 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 = 0.095 g cm^{-2} yr^{-1}; organic matter accumulation rate = 0.013 g cm^{-2} yr^{-1}; net accretion = 0.26 cm yr^{-1}.
- *Water monitoring data collection*: water level (December 2012–February 2014); conductivity (July 2013-January 2014). Water level monitoring is and conductivity ongoing.
- *Calculated tidal datums*: MHHW is at 1.60 m NAVD88; MHW is at 1.38 m NAVD88.
- *Marsh inundation pattern*: Maximum monthly inundation occurred during January 2014; minimum monthly inundation during November 2013.
- *SETs*: Two high marsh SETs and two low marsh SETs were installed on November 17, 2013. During the first year of monitoring, cumulative elevation change was -1.00 mm in high marsh and +1.59 mm in low marsh.
- *Sea-level rise marsh response modeling*: Under the NRC's low SLR scenario, there is little change in habitat composition at the site between 2010 and 2030. Thereafter, there is a gradual expansion of low marsh through the end of the century. At 2110, most of the site consists of low marsh. Under the mid SLR scenario, there is a more rapid expansion of low marsh projected between 2030 and 2090. Thereafter mudflat increases at the site. Under the high SLR scenario, there is loss of transition zone marsh and most high and mid marsh by 2060. Between 2060 and 2090, there is a rapid increase in mudflat habitat over former tidal marsh. At 2110, most of the site consists of either intertidal mudflat or subtidal habitat.

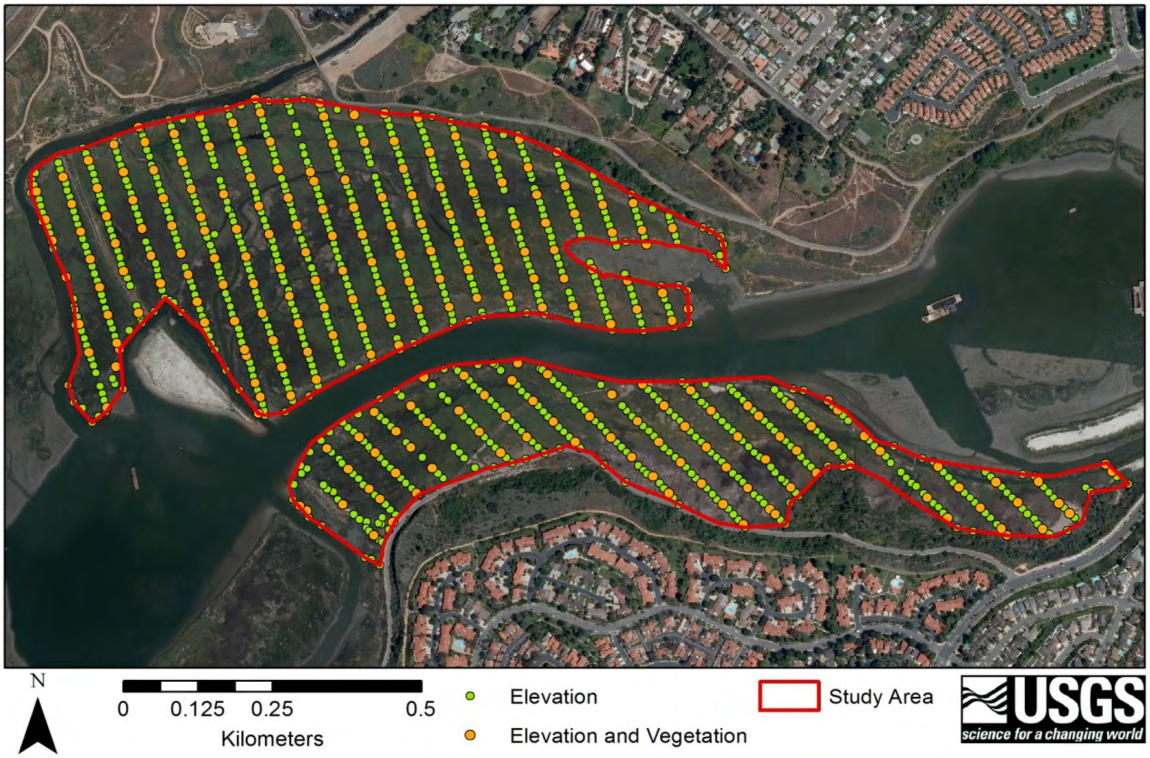

Figure F1. Distribution of elevation and vegetation survey points at Upper Newport Bay.

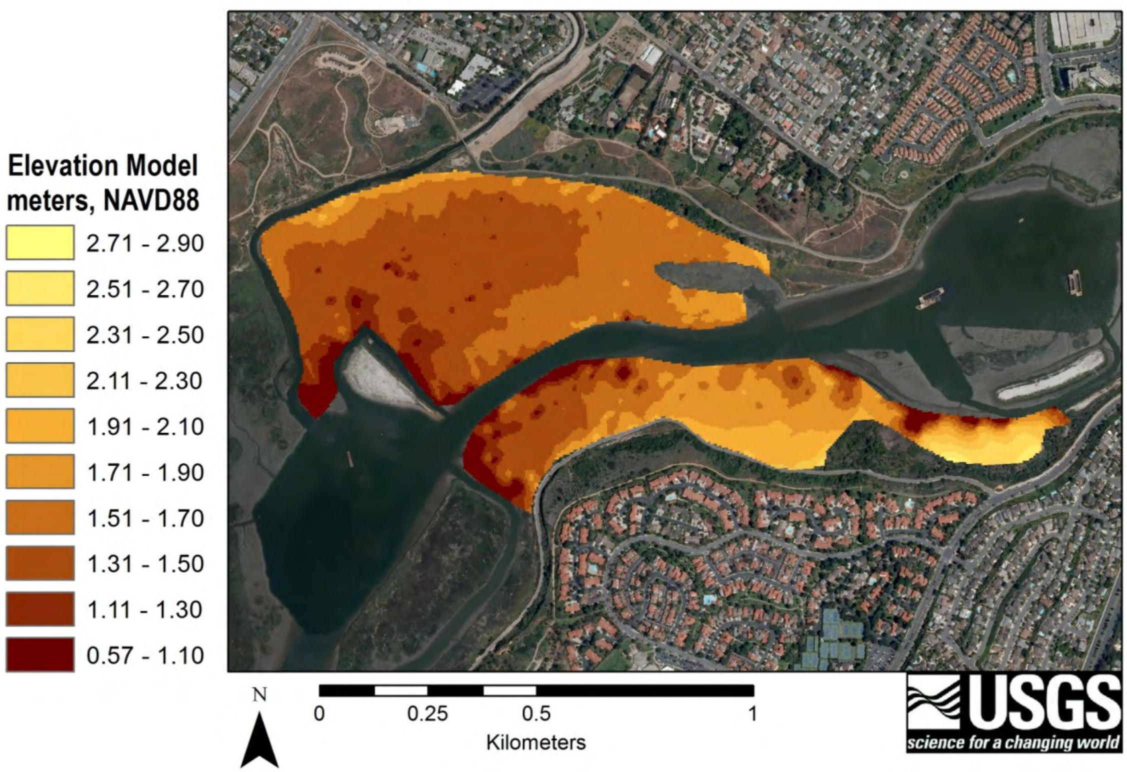

Figure F2. Elevation model (3 m resolution) of tidal marsh at Upper Newport Bay developed from RTK GPS survey data.

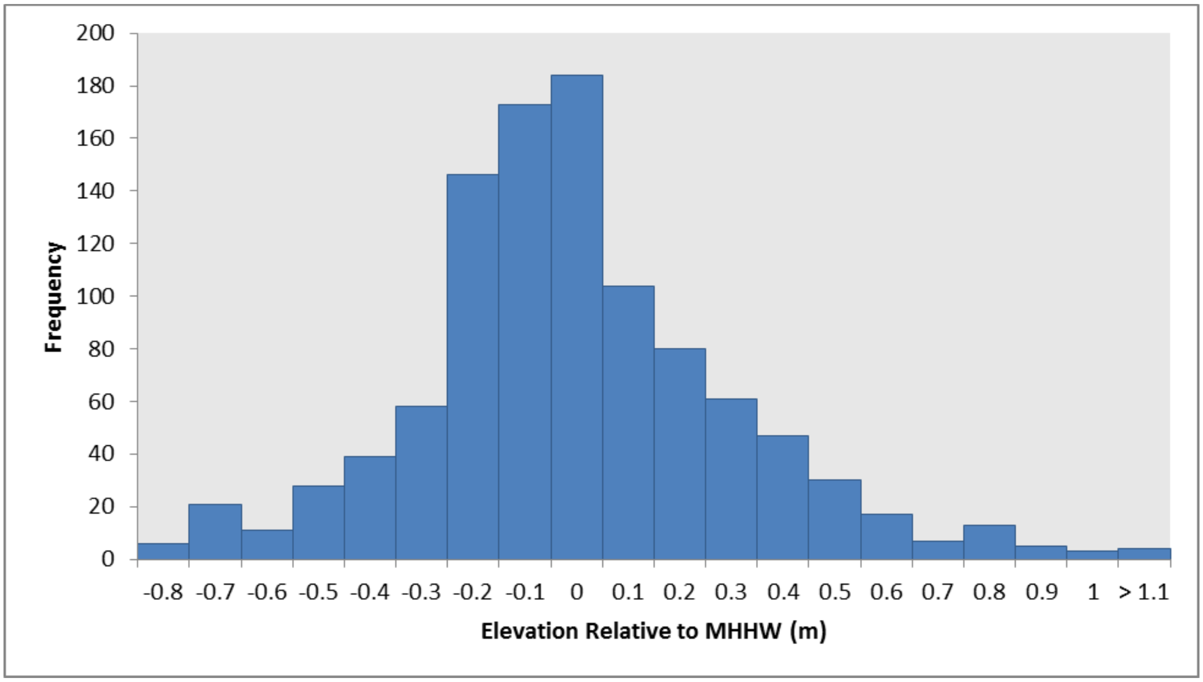

Figure F3. Frequency distribution of marsh surface elevation measurements relative to local mean higher high water (MHHW) at Upper Newport Bay

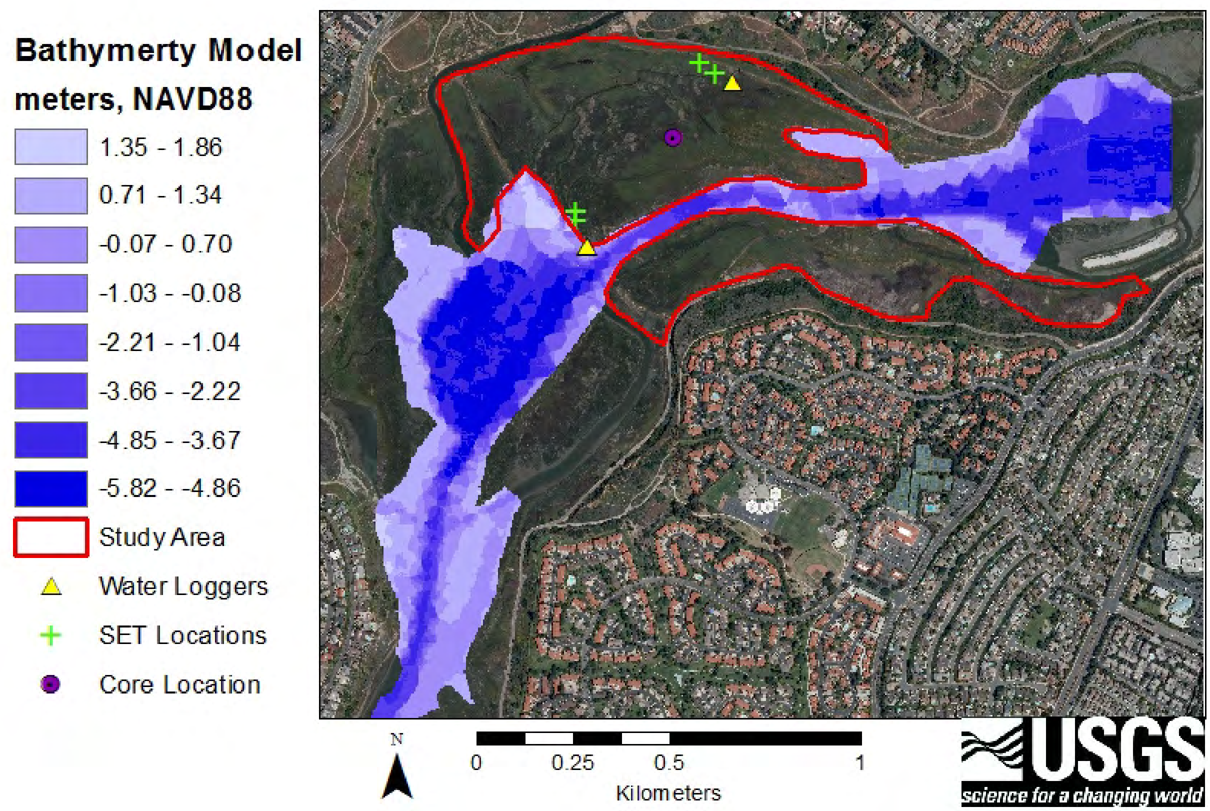

Figure F4. Near-shore bathymetry model for Upper Newport Bay and location of water level loggers, surface elevation tables (SET), and deep sediment cores.

Table F1. Frequency of occurrence, percent cover, and height of vascular plant species encountered in sample plots at Upper Newport Bay.

[NA = not measured]

Species	Description	Frequency of occurrence (%)	Percent cover Mean	Percent cover Max	Plant heights (cm) Mean	Plant heights (cm) Max
Sarcocornia pacifica	Perennial forb	64.6	25	100	30	84
Spartina foliosa	Perennial grass	56.5	27	100	65	153
Batis maritima	Perennial forb	53.3	13	100	19	50
Jaumea carnosa	Perennial forb	38.2	24	100	15	43
Distichlis spicata	Perennial grass	14.2	4	100	20	56
Cuscuta pacifica	Ann-perennial parasite	13.4	NA	NA	NA	NA
Frankenia salina	Perennial forb	12.6	4	100	17	41
Limonium californicum	Perennial forb	5.3	1	65	11	64
Suaeda esteroa	Ann-perennial forb	4.5	1	90	18	36
Typha sp.	Perennial forb	3.7	3	100	180	320
Schenoplectus americanus	Perennial sedge	3.3	2	100	88	174
Distichlis littoralis	Perennial grass	2.0	1	100	19	41
Cressa truxillensis	Perennial subshrub	1.6	0	30	20	35
Bolboschoenus robustus	Perennial sedge	1.2	1	100	152	187
Juncus acutus	Perennial rush	0.4	0	100	101	146
Isocoma menziesii	Perennial subshrub	0.4	0	70	111	135
Atriplex semibaccata	Perennial forb	0.4	0	60	14	17
Schoenoplectus californicus	Perennial sedge	0.4	0	10	112	136
Triglochin maritima	Perennial forb	0.4	0	5	4	5
Undetermined	NA	0.4	0	5	5	6

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

[SarPac = *Sarcocornia pacifica*; JauCar = *Jaumea carnosa*; BatMar = *Batis maritima*; FraSal = *Frankenia salina*; SpaFol = *Spartina foliosa*.]

Marsh zone	% high tides reaching zone	MHHW range (m)	n	Mean cover of top four dominant plants (%)
Transition	0.14-3	0.600 to 0.414	8	SarPac (24), JauCar (17), BatMar (17), FraSal (16)
High	3-25	0.414 to 0.043	62	SarPac (34), BatMar (23), JauCar (12), FraSal (11)
Middle	25-50	0.043 to -0.222	123	JauCar (38), SpaFol (28), SarPac (24), BatMar (14)
Low	>50	-0.222 to -0.953	55	SpaFol (66), SarPac (18), JauCar (5), BatMar (2)

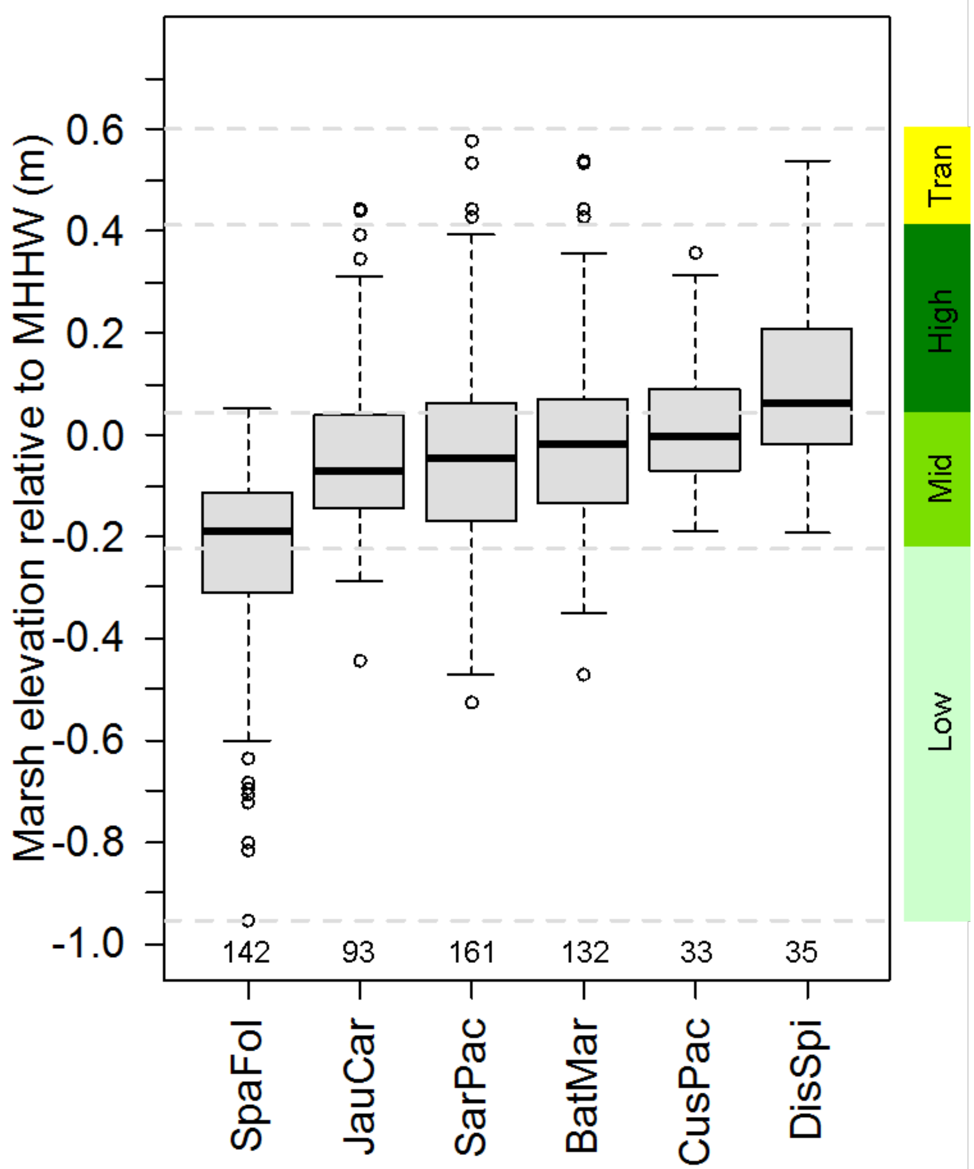

Figure F5. Elevation distribution of six most commonly occurring vascular plant species at Upper Newport Bay. The black horizontal bars show the median elevation at which the species occurs; shaded boxes indicate the interquartile range; upper and lower whiskers encompass points no greater than 1.5 x 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 248 plots). Marsh elevation zones (low, middle, high and transition) are illustrated at right. SpaFol = *Spartina foliosa*; JauCar = *Jaumea carnosa*; SarPac = *Sarcocornia pacifica*; BatMar = *Batis maritima*; CusPac = *Cuscuta pacifica*; DisSpi = *Distichlis spicata*.

Table F3. Locations of water level loggers, surface elevation tables (SET), and deep sediment cores at Upper Newport Bay (UTM zone 11).

Location	Easting (m)	Northing (m)
water logger	417972	3723416
SET	417945	3723482
	417945	3723507
	418264	3723891
	418303	3723866
core sample	418300	3723831

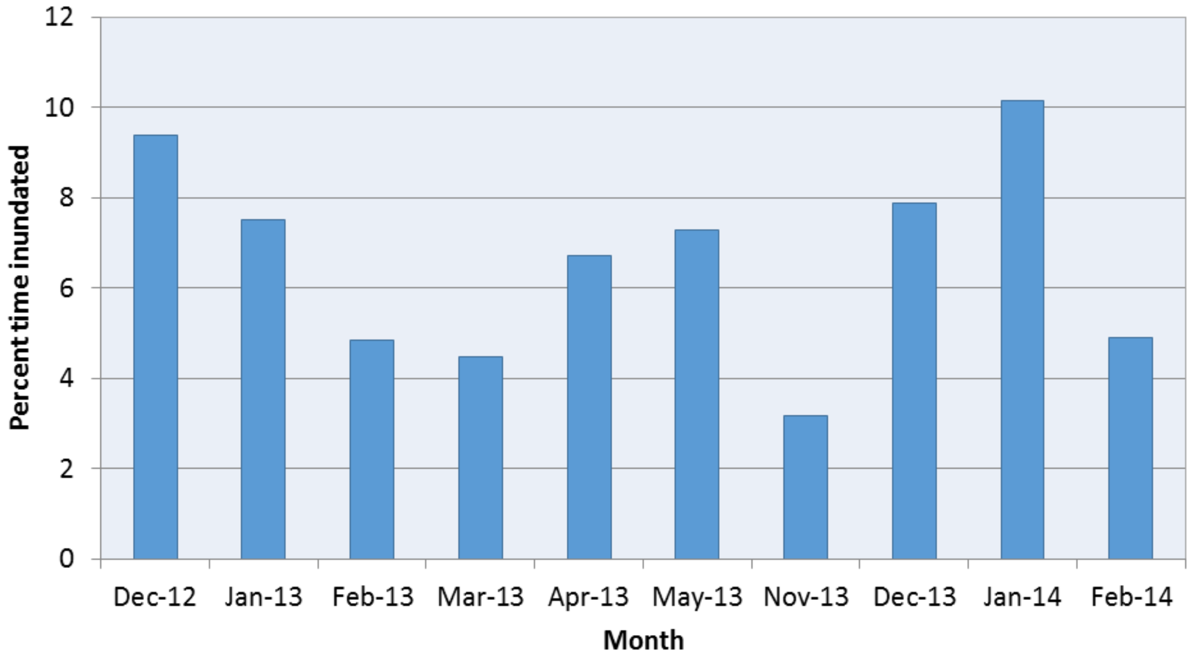

Figure F6. Average monthly inundation of the study site based on an average marsh elevation. Water levels were determined with a Hobo water logger deployed at 0.08 m above NAVD88.

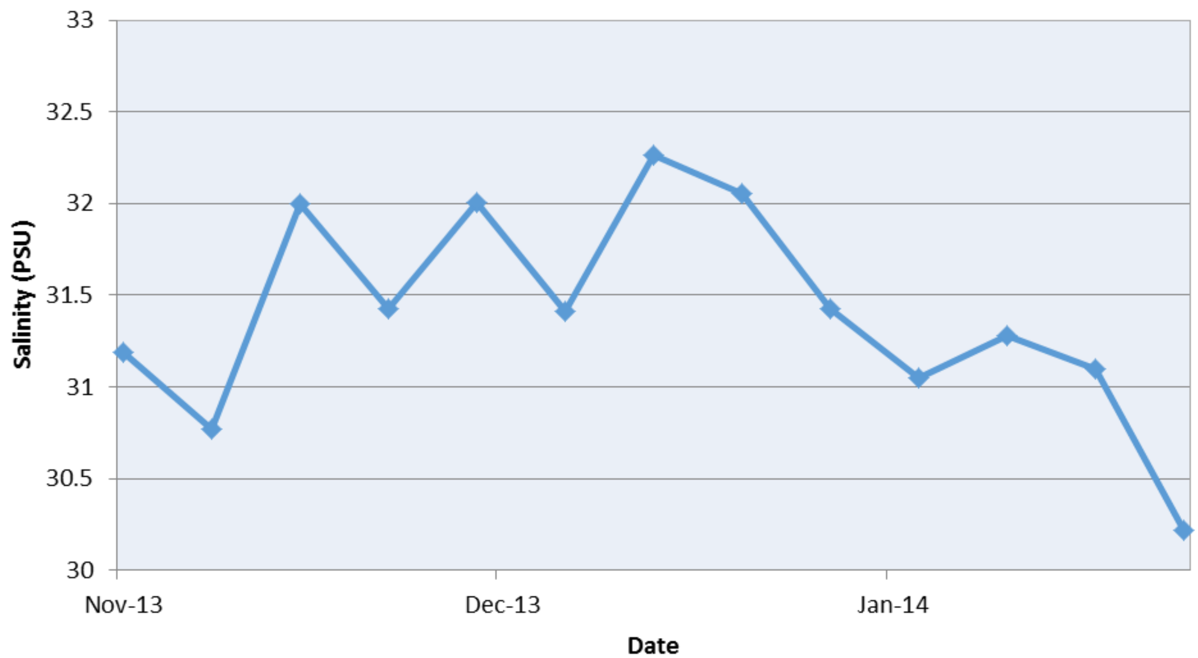

Figure F7. Average weekly maximum salinity from November 2013–February 2014 at Upper Newport Bay.

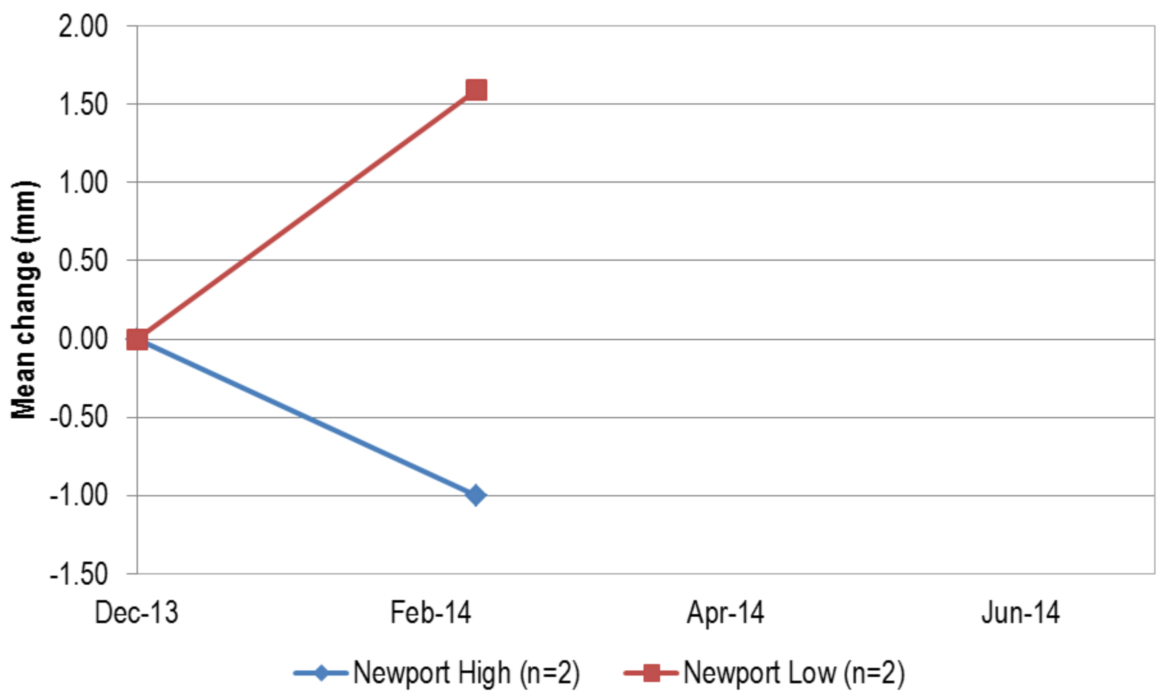

Figure F8. Baseline measurements of net marsh surface elevation change at surface elevation tables (SET) in Upper Newport Bay.

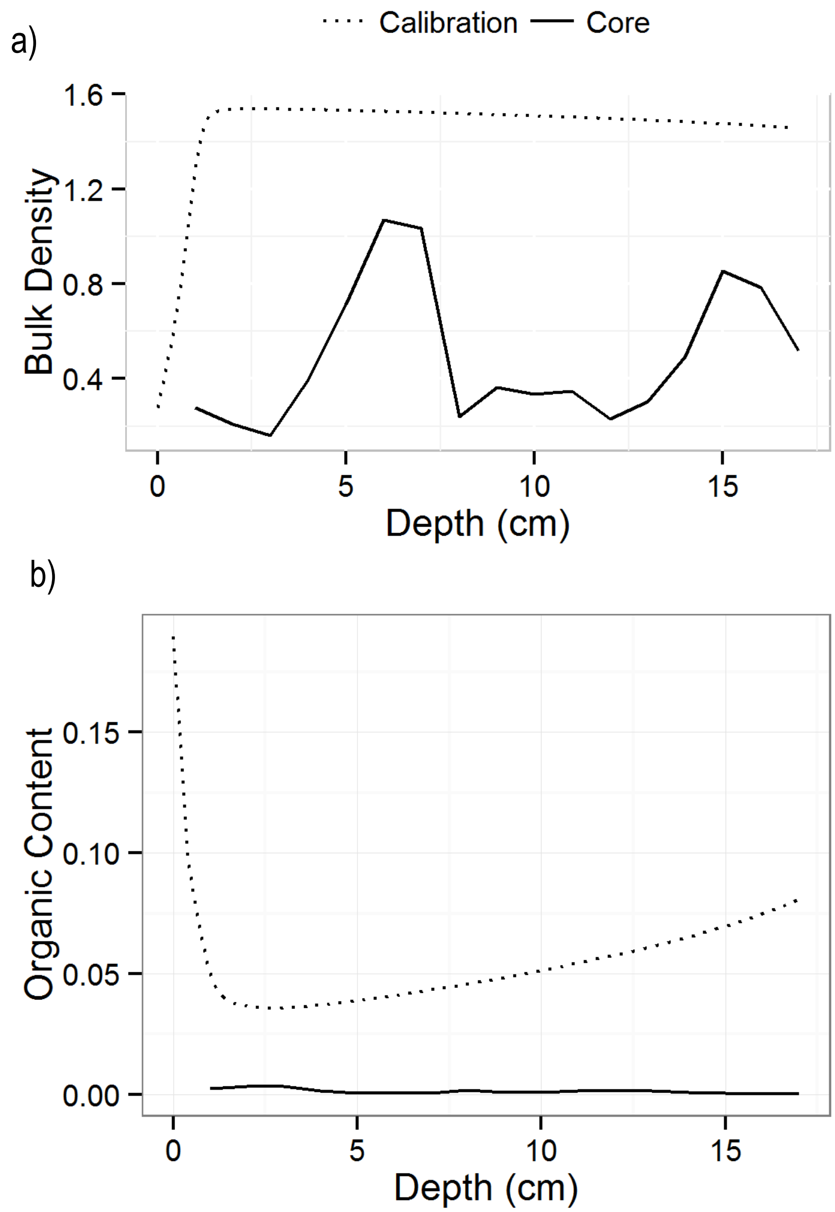

Figure F9. Deep sediment core calibration of the WARMER model using depth profiles of (a) bulk density (g cm^{-3}) and (b) organic matter content (%).

Table F4. WARMER parameters and soil core characteristics used for SLR model calibration at Upper Newport Bay.

[NDVI = Normalized Difference Vegetation Index; NAIP = National Agriculture Inventory Program]

Model parameter	Value	Source
Sediment accumulation rate (g cm^{-2} yr^{-1})	0.253	Core calibration
Elevation of peak biomass (cm, MSL)	92	NDVI from NAIP
Minimum elevation of vegetation (cm, MSL)	2	Field surveys
Max. aboveground organic accumulation (g cm^{-2} yr^{-1})	0.0338	Core calibration
Root-to-shoot ratio	0.458	C. Janousek, unpub data
Porosity at sediment surface (%)	87	Core
Porosity at depth (%)	38	Core
Refractory carbon (%)	8.9	Core
Maximum astronomical tide (cm, MSL)	157	Los Angeles tide gauge (NOAA,9410660)
Historic sea-level rise (mm yr^{-1})	2.22	Los Angeles tide gauge (NOAA,9410660)
Organic matter density (g cm^{-3})	1.14	DeLaune 1983
Mineral density (g cm^{-3})	2.61	DeLaune 1983

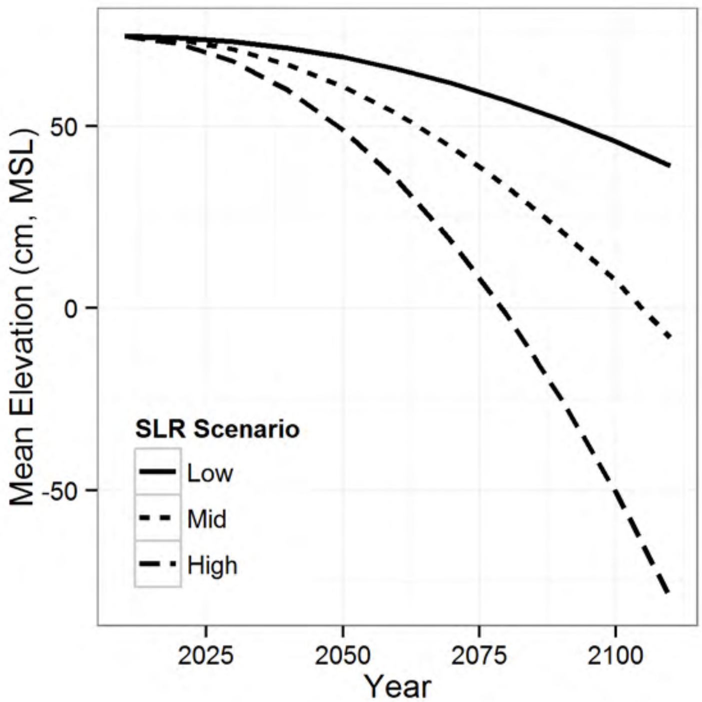

Figure F10. WARMER model projections for the change in average marsh elevation (relative to MHHW) at Upper Newport Bay from 2010 to 2110 under low, mid, and high NRC sea-level rise scenarios.

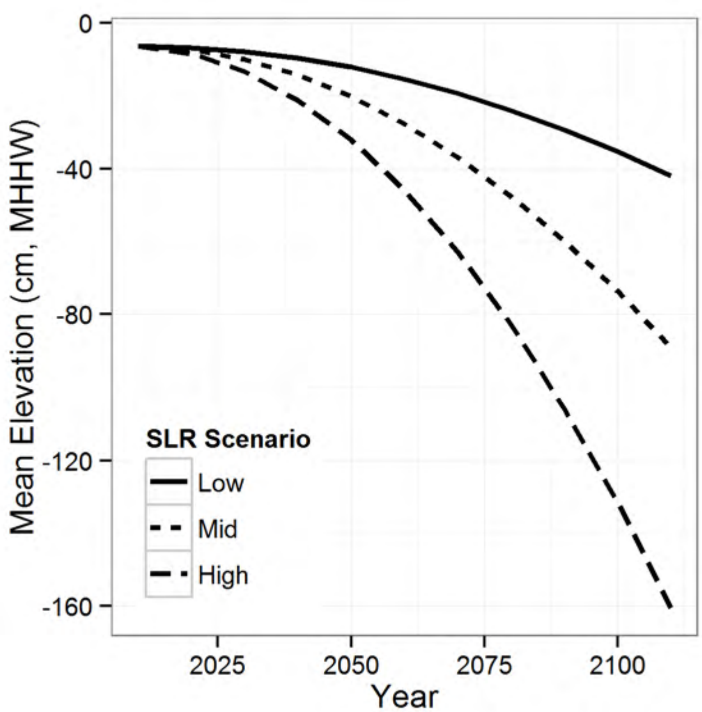

Figure F11. WARMER model projections for the change in average marsh elevation (relative to MSL) at Upper Newport Bay from 2010 to 2110 under low, mid, and high NRC sea-level rise scenarios.

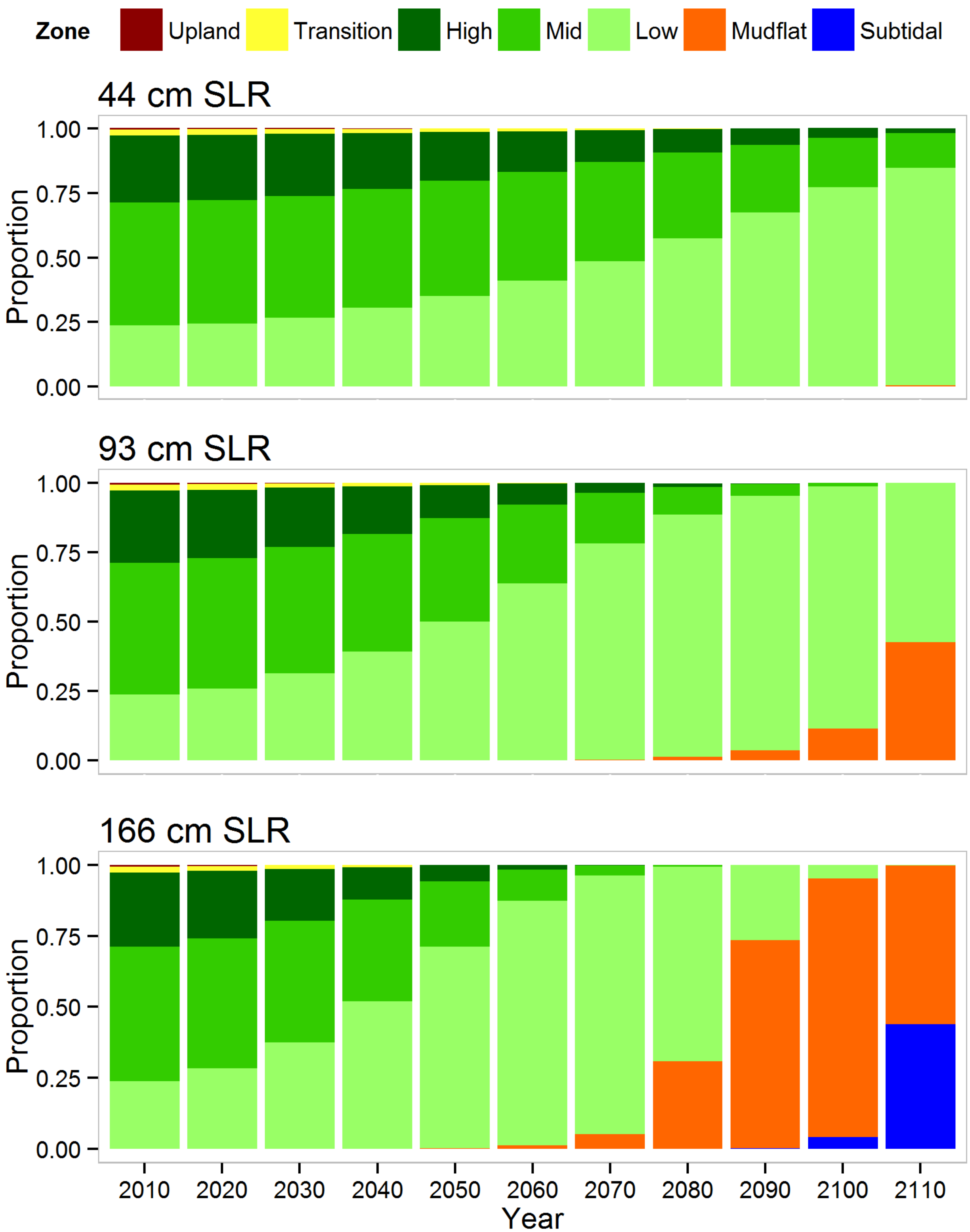

Figure F12. Model projections for change in the relative proportion of upland; transitional, high, mid and low marsh; and mudflat habitat under the NRC's low (44 cm), mid (93 cm), and high (166 cm) sea-level rise scenarios from 2010 to 2110.

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 (44 cm)			Mid SLR (93 cm)			High SLR (166 cm)		
	2010	2050	2110	2010	2050	2110	2010	2050	2110
Upland	1	0	0	1	0	0	1	0	0
Transition	2	1	0	2	1	0	2	0	0
High	26	19	2	26	12	0	26	6	0
Mid	47	45	13	47	37	0	47	23	0
Low	24	35	84	24	50	57	24	71	0
Mudflat	0	0	0	0	0	43	0	0	56
Subtidal	0	0	0	0	0	0	0	0	44

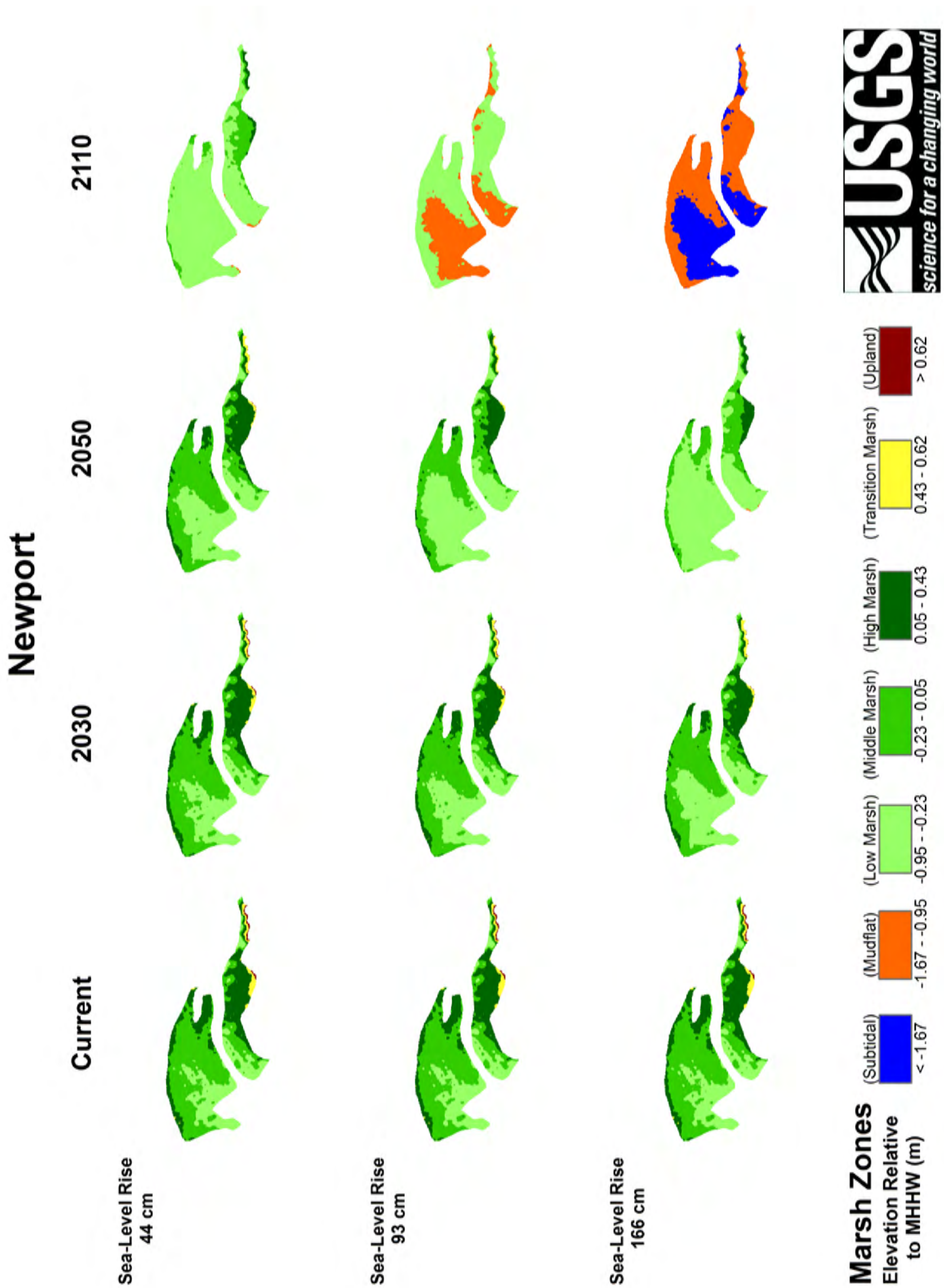

Figure F13. Projected habitat distribution at Upper Newport Bay for 2030, 2050 and 2110 with the WARMER model under three NRC sea-level rise scenarios.

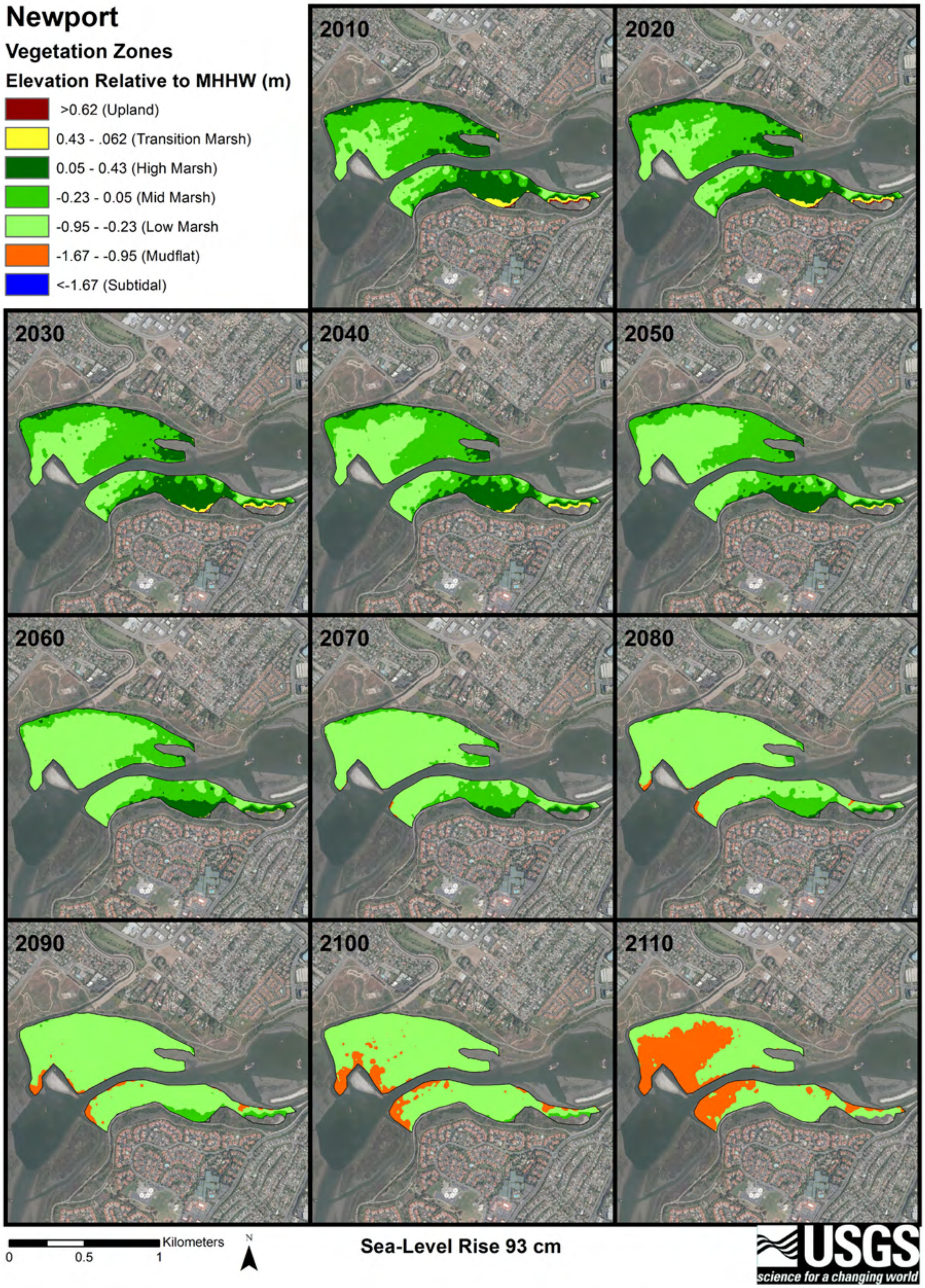

Figure F14. Projected changes in Upper Newport Bay habitat zones under the mid NRC sea-level rise scenario (93 cm).

Appendix G. Site Specific Details for Tijuana Estuary, San Diego County, California

Photo: k. Powelson, USGS

Summary

- *Study site size:* 61.7 ha
- *Location*: 32°33'8.81"N latitude, 117° 6'38.07"W longitude
- *Site management*: U.S. Fish and Wildlife Service
- *Site vegetation and elevation survey*: November 8–December 9, 2011
- *Sample size:* 989 elevation points, 309 vegetation plots
- *Marsh elevation model*: 35% of elevation data points were above MHHW
- *Plant community composition*: The dominant species was *Sarcocornia pacifica*, occurring from low marsh to the marsh-upland transition zone. *Spartina foliosa* tended to occur lowest in the marsh while *Distichlis littoralis* was typically distributed in high marsh.
- *Soil characteristics*: The accumulation rates used in WARMER were: mineral accumulation rate = 0.134 g cm^{-2} yr^{-1}; organic matter accumulation rate = 0.022 g cm^{-2} yr^{-1}; net accretion = 0.26 cm/yr^{-1}.
- *Water monitoring data collection*: water level (June 2012–February 2014); conductivity (November 2013–May 2014). Water level and conductivity monitoring is ongoing.
- *Calculated tidal datums*: MHHW is at 1.56 m NAVD88; MHW is at 1.37 m NAVD88.

- *Marsh inundation pattern*: Maximum monthly inundation occurred between August 2012; minimum monthly inundation during February 2014.
- *SETs*: Two high marsh SETs and two low marsh SETs were installed on September 6, 2012. During the first year of monitoring, cumulative elevation change was -0.20 mm in high marsh and +5.54 mm in low marsh.
- *SLR marsh modeling*: Using the NRC's low SLR scenario, the site is projected to have little habitat change between 2010 and 2040, but an increases in low marsh and decline in mid marsh between 2050 and 2110. Under the mid SLR scenario, there is a rapid conversion of mid marsh habitat to low marsh between 2030 and 2070. Mudflat expands considerably between 2080 and 2100. Under the high SLR scenario, there is a very rapid transition of habitat types between 2030 and 2080. By 2100, the site is composed completely of mudflat.

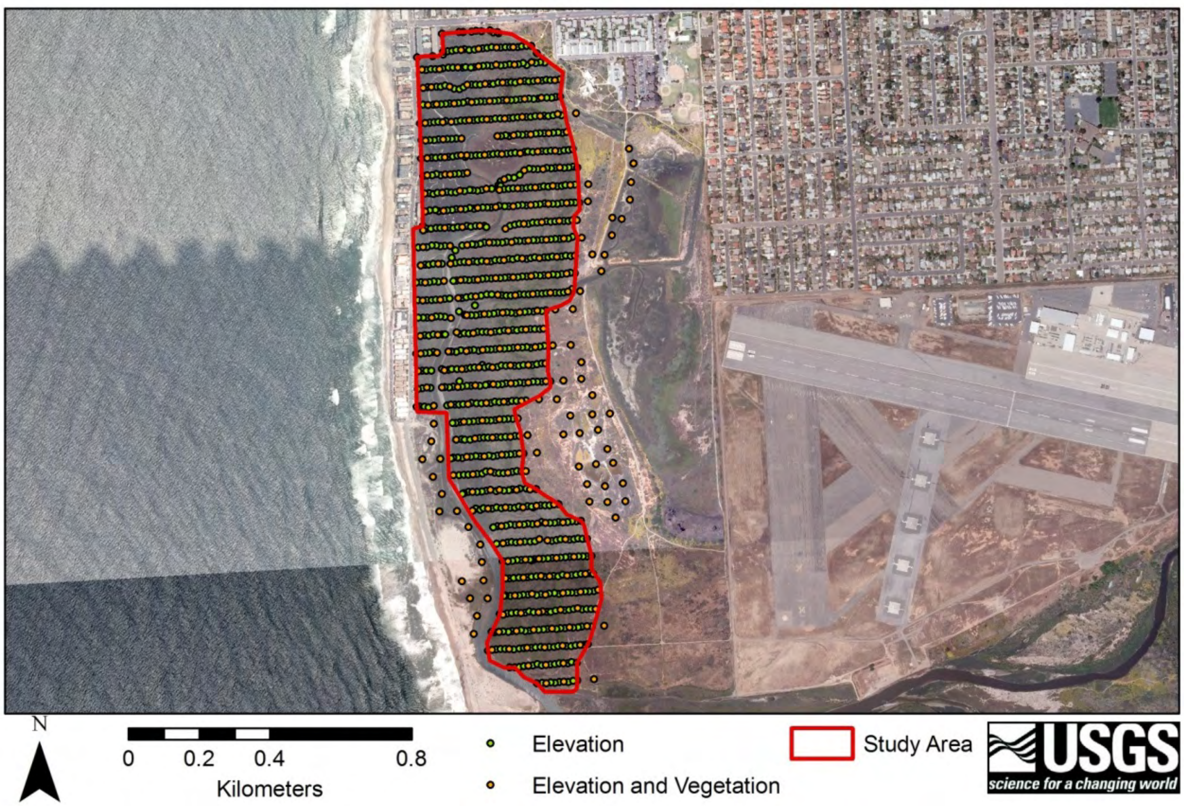

Figure G1. Distribution of elevation and vegetation survey points at Tijuana Estuary.

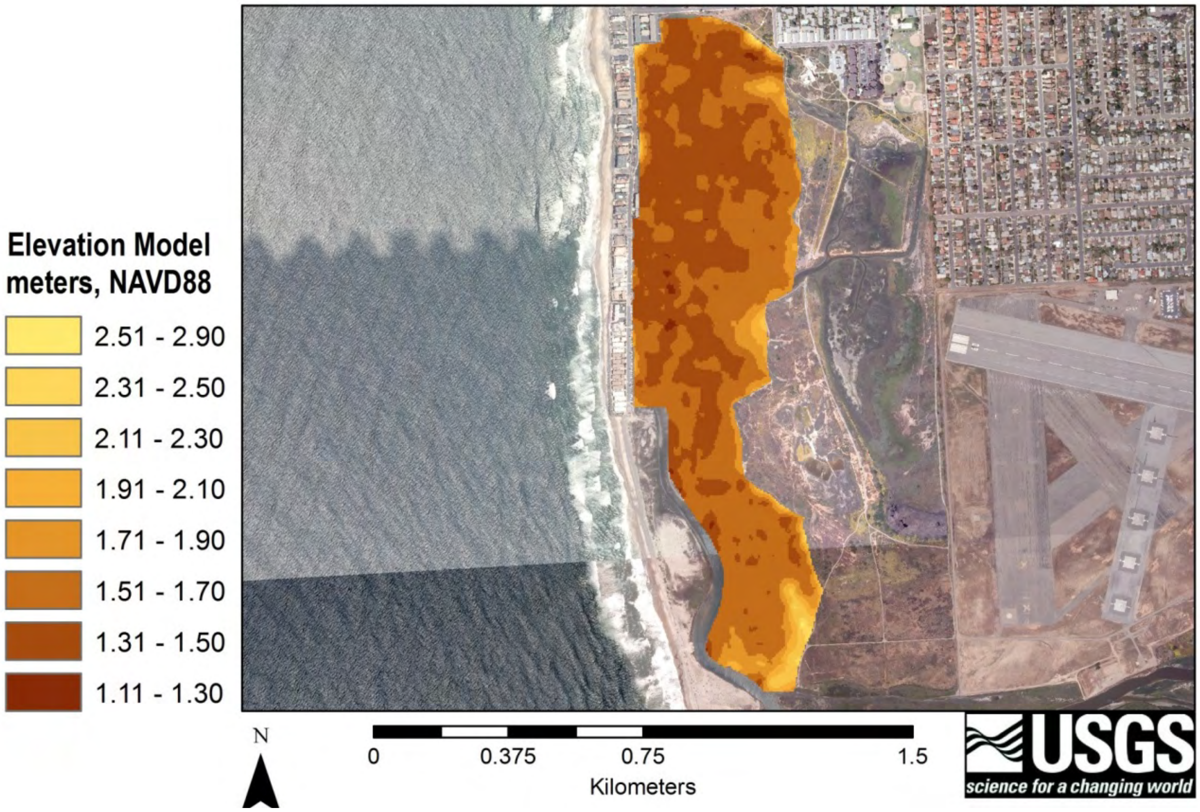

Figure G2. Elevation model (3 m resolution) of tidal marsh at Tijuana Estuary developed from RTK GPS survey data.

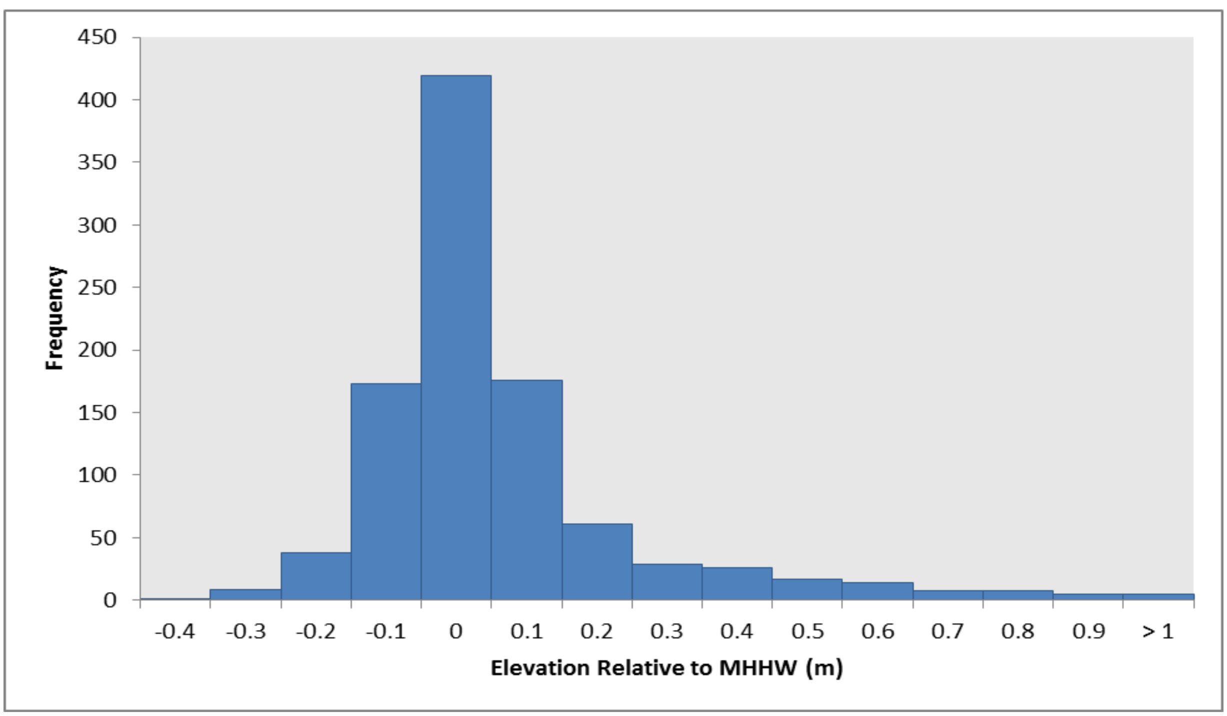

Figure G3. Frequency distribution of elevation relative to local mean higher high water (MHHW) at Tijuana Estuary.

Figure G4. Water level, SET (surface elevation table), and sediment core locations at Tijuana Estuary.

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

Species	Description	Frequency occurrence (%)	Percent cover		Plant heights (cm)	
			Mean	Max	Mean	Max
Sarcocornia pacifica	Perennial forb	80.7	60	100	33	75
Jaumea carnosa	Perennial forb	44.3	29	100	14	40
Frankenia salina	Perennial forb	43.4	15	100	20	45
Spartina foliosa	Perennial grass	30.6	14	100	66	130
Batis maritima	Perennial forb	26.6	5	80	20	50
Distichlis littoralis	Perennial grass	15.3	9	100	14	35
Distichlis spicata	Perennial grass	15.0	7	100	24	45
Arthrocnemum subterminale	Perennial forb	9.5	6	100	20	55
Limonium californicum	Perennial forb	7.6	1	40	22	60
Undetermined	NA	4.6	2	100	27	170
Suaeda esteroa	Ann-perennial forb	2.4	1	50	29	45
Triglochin maritima	Perennial forb	1.5	0	15	11	15
Juncus acutus	Perennial rush	0.6	0	90	58	105
Atriplex spinifera	Perennial forb	0.6	0	25	15	20
Cuscuta pacifica	Ann-perennial parasite	0.3	NA	NA	NA	NA
Mesembryanthemum crystallinum	Ann-biennial forb	0.3	0	90	5	10
Salicornia bigelovii	Annual forb	0.3	0	35	25	35
Atriplex watsonii	Perennial forb	0.3	0	25	10	15

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

[ArtSub = *Arthrocnemum subterminale*; DisLit = *Distichlis littoralis*; DisSpi = *Distichlis spicata*; Undet = undetermined; SarPac = *Sarcocornia pacifica*; FraSal = *Frankenia salina*; JauCar = *Jaumea carnosa*; SpaFol = *Spartina foliosa*; JunAcu = *Juncus acutus*.]

Marsh zone	% high tides reaching zone	MHHW range (m)	n	Mean cover of top four dominant plants (%)
Transition	0.14-3	0.653 to 0.451	23	ArtSub (42), DisLit (27), DisSpi (13), Undet (13)
High	3-25	0.451 to 0.047	67	SarPac (49), FraSal (36), DisLit (31), JauCar (22)
Middle	25-50	0.047 to -0.241	195	SarPac (77), JauCar (40), SpaFol (19), FraSal (10)
Low	>50	-0.241 to -0.534	26	SarPac (49), SpaFol (35), DisSpi (17), JunAcu (5), Undet (5)

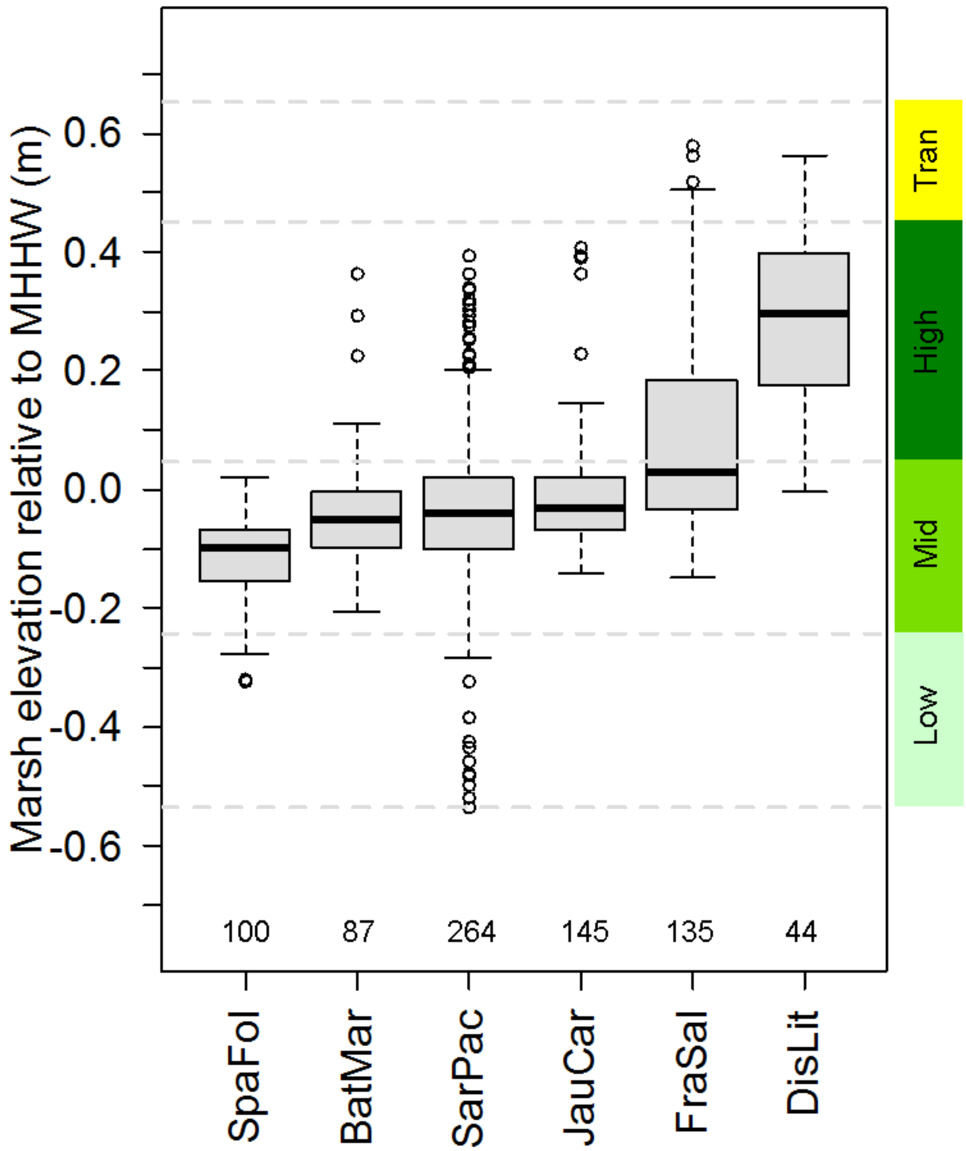

Figure G5. Elevation distribution of six most commonly-occurring vascular plant species at Tijuana Estuary. The black horizontal bars show the median elevation at which the species occurs; shaded boxes indicate the interquartile range; upper and lower whiskers encompass points no greater than 1.5 x the 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 309 plots). Marsh elevation zones (low, middle, high and transition) are illustrated at right. SpaFol = *Spartina foliosa*; BatMar = *Batis maritima*; SarPac = *Sarcocornia pacifica*; JauCar = *Jaumea carnosa*; FraSal = *Frankenia salina*; DisLit = *Distichlis littoralis*.

Table G3. Locations of water level loggers, surface elevation tables (SET), and deep sediment cores at Tijuana Estuary (UTM zone 11).

Location	Easting (m)	Northing (m)
water logger	487883	3602479
SET	487954	3604180
	487981	3604211
	487954	3604119
	487928	3604150
core sample	487955	3604211

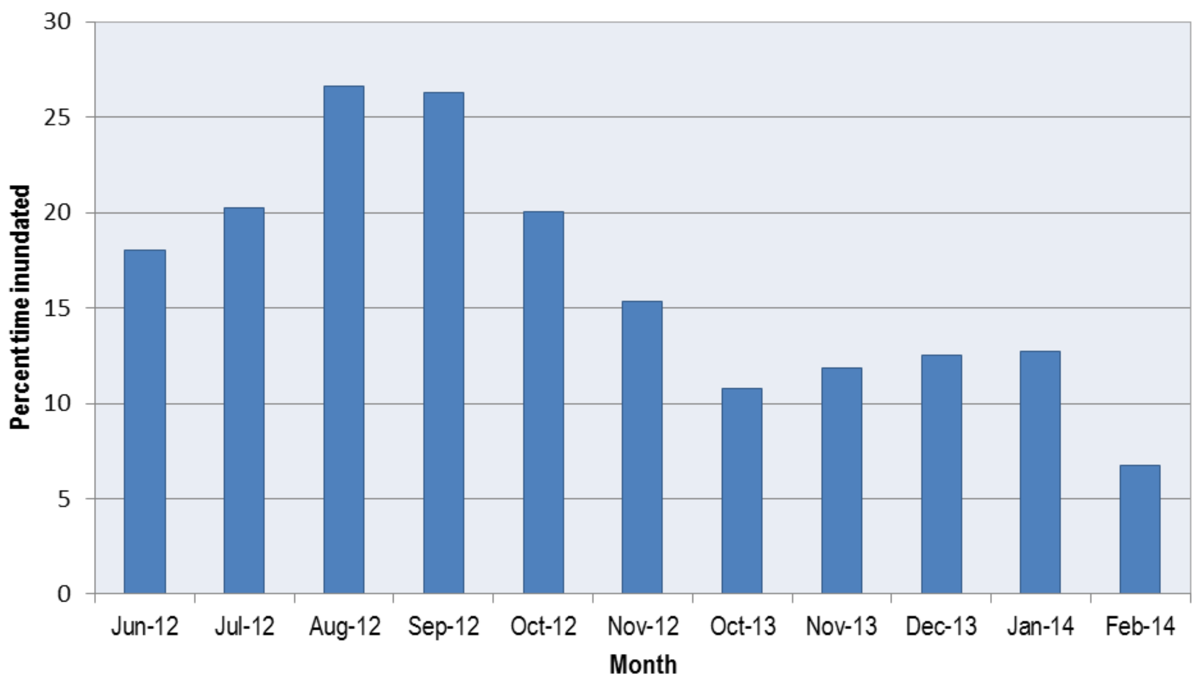

Figure G6. Average monthly inundation of the study site based on an average marsh elevation. Water levels were determined with a Hobo water logger deployed at 1.03 m above NAVD88.

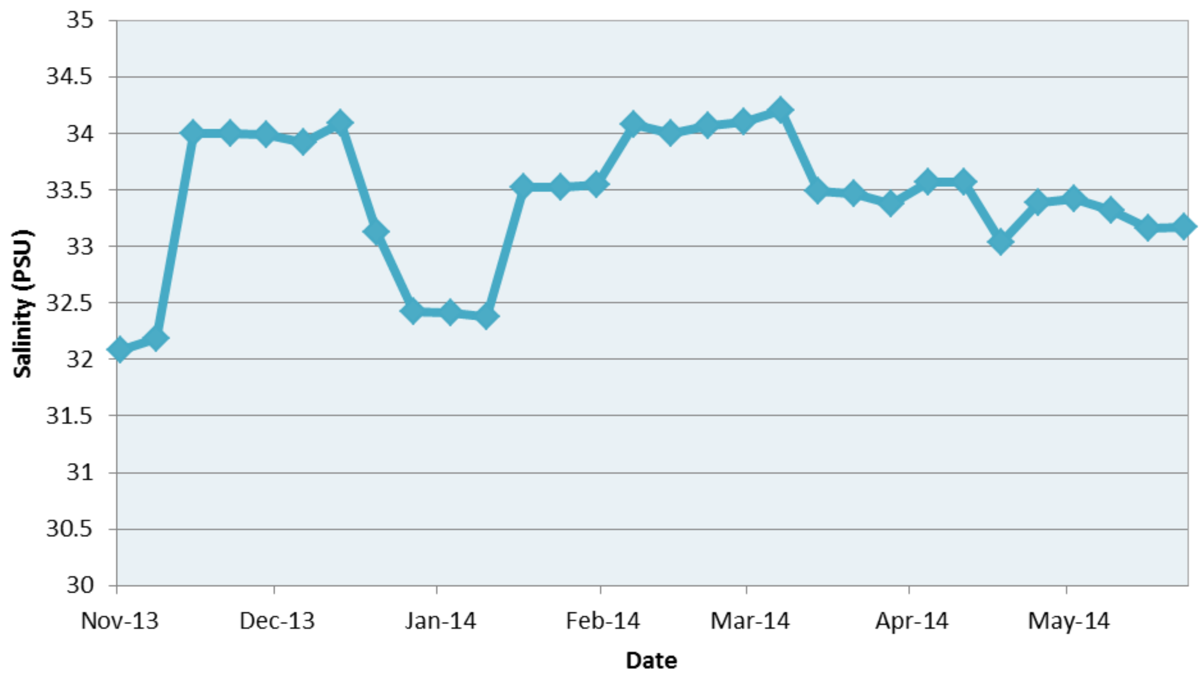

Figure G7. Average weekly maximum salinity from November 2012–May 2013 at Tijuana.

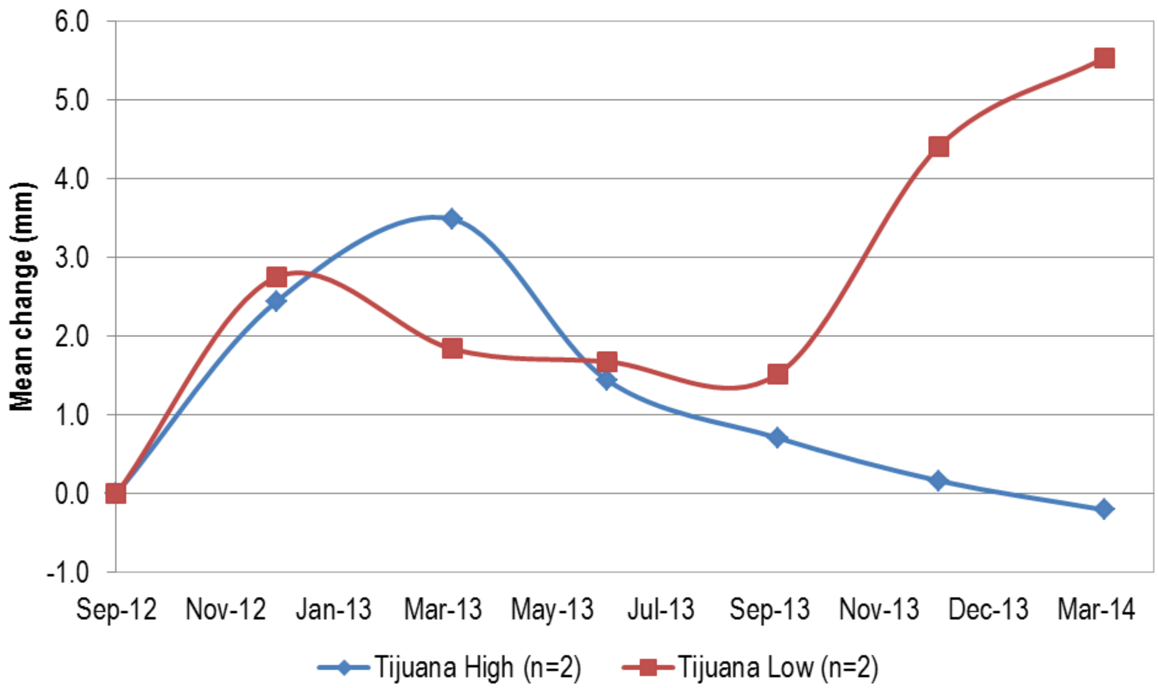

Figure G8. Baseline measurements of elevation change at Tijuana Estuary using surface elevation table (SET).

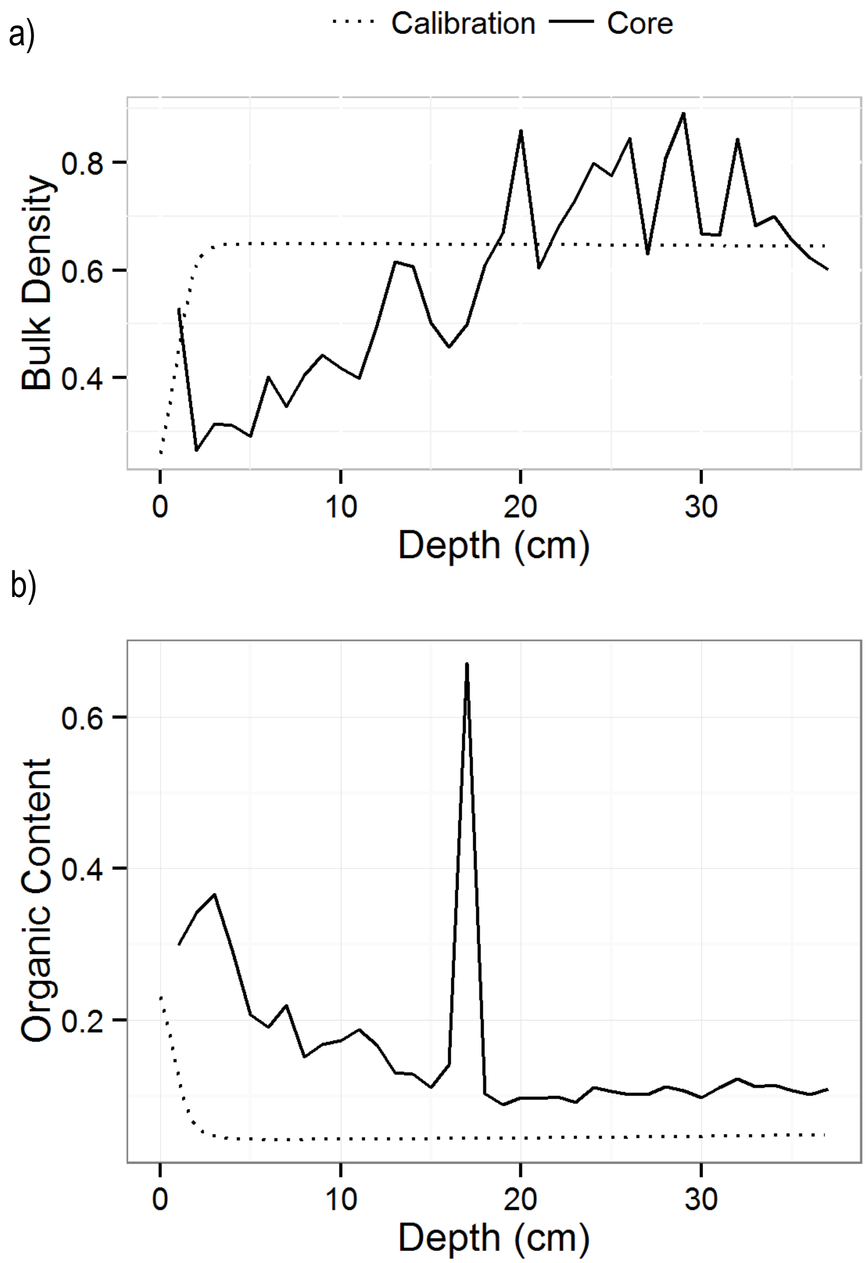

Figure G9. Deep sediment core calibration of the WARMER model using depth profiles of (a) bulk density (g cm^{-3}) and (b) organic matter content (%).

Table G4. WARMER parameters and soil core characteristics used for SLR model calibration at Tijuana Estuary.

[NDVI = Normalized Difference Vegetation Index; NAIP = National Agriculture Inventory Program]

Model parameter	Value	Source
Sediment accumulation rate (g cm^{-2} yr^{-1})	0.193	Core calibration
Elevation of peak biomass (cm, MSL)	73.2	NDVI from NAIP
Minimum elevation of vegetation (cm, MSL)	11.2	Field surveys
Max. aboveground organic accumulation (g cm^{-2} yr^{-1})	0.0502	Core calibration
Root-to-shoot ratio	0.458	C. Janousek, unpub data
Porosity at sediment surface (%)	87	Core
Porosity at depth (%)	74	Core
Refractory carbon (%)	7.00	Core
Maximum astronomical tide (cm, MSL)	136.2	San Diego tide gauge (NOAA,9410170)
Historic sea-level rise (mm yr^{-1})	2.06	San Diego tide gauge (NOAA,9410170)
Organic matter density (g cm^{-3})	1.14	DeLaune 1983
Mineral density (g cm^{-3})	2.61	DeLaune 1983

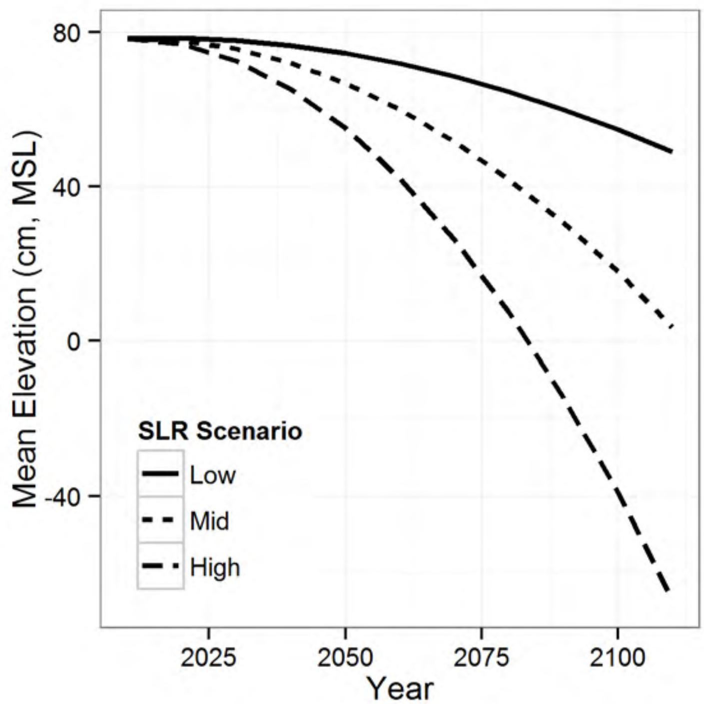

Figure G10. WARMER model projections for the change in average marsh elevation (relative to MHHW) at Tijuana Estuary from 2010 to 2110 under low, mid, and high NRC sea-level rise scenarios.

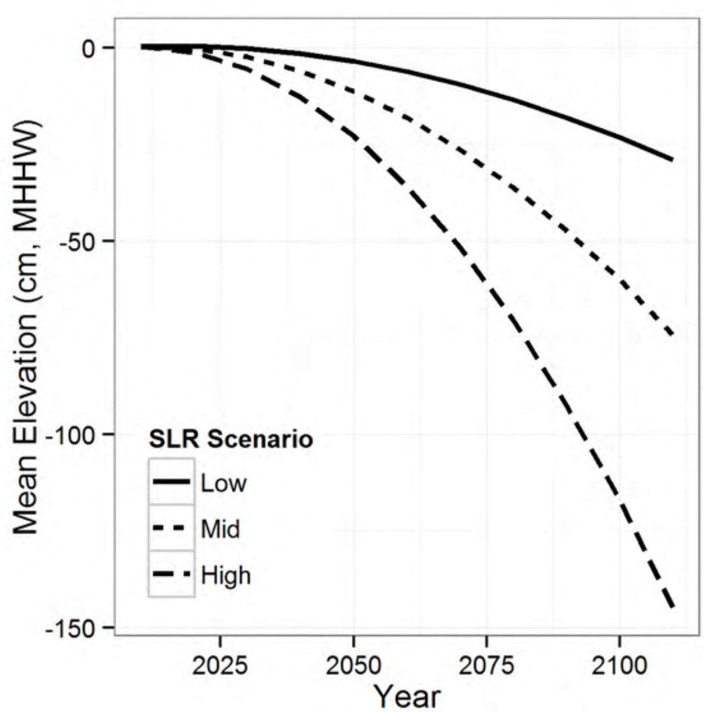

Figure G11. WARMER model projections for the change in average marsh elevation (relative to MSL) at Tijuana Estuary from 2010 to 2110 under low, mid, and high NRC sea-level rise scenarios.

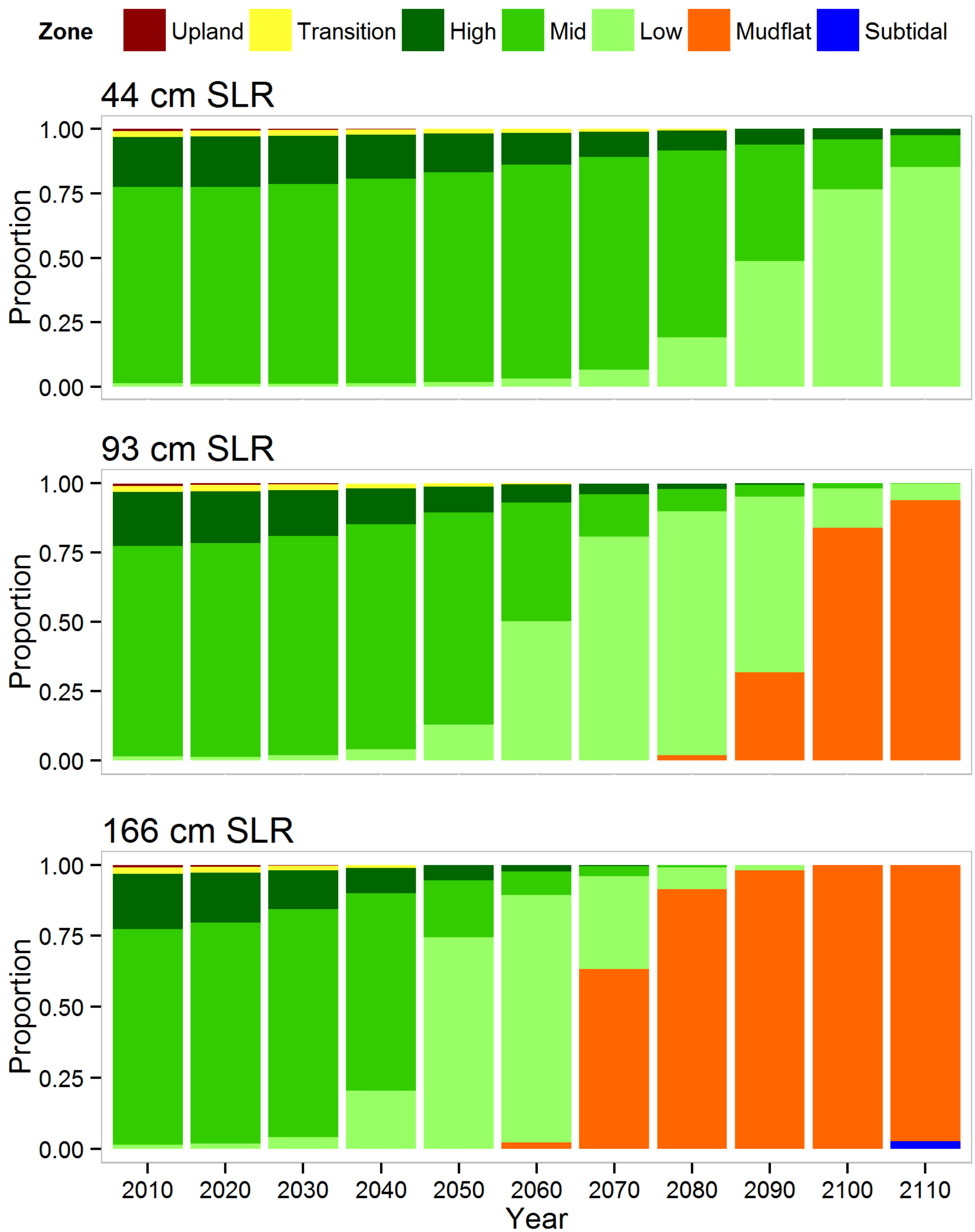

Figure G12. Model projections for change in the relative proportion of upland; transitional, high, mid and low marsh; and mudflat habitat under the NRC's low (43 cm), mid (93 cm), and high (166 cm) sea-level rise scenarios from 2010 to 2110.

Table G5. 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 (43 cm)			Mid SLR (93 cm)			High SLR (166 cm)		
	2010	**2050**	**2110**	**2010**	**2050**	**2110**	**2010**	**2050**	**2110**
Upland	1	0	0	1	0	0	1	0	0
Transition	2	2	0	2	1	0	2	0	0
High	19	15	3	19	10	0	19	5	0
Mid	76	81	12	76	76	0	76	20	0
Low	2	2	85	2	13	6	2	75	0
Mudflat	0	0	0	0	0	94	0	0	97
Subtidal	0	0	0	0	0	0	0	0	3

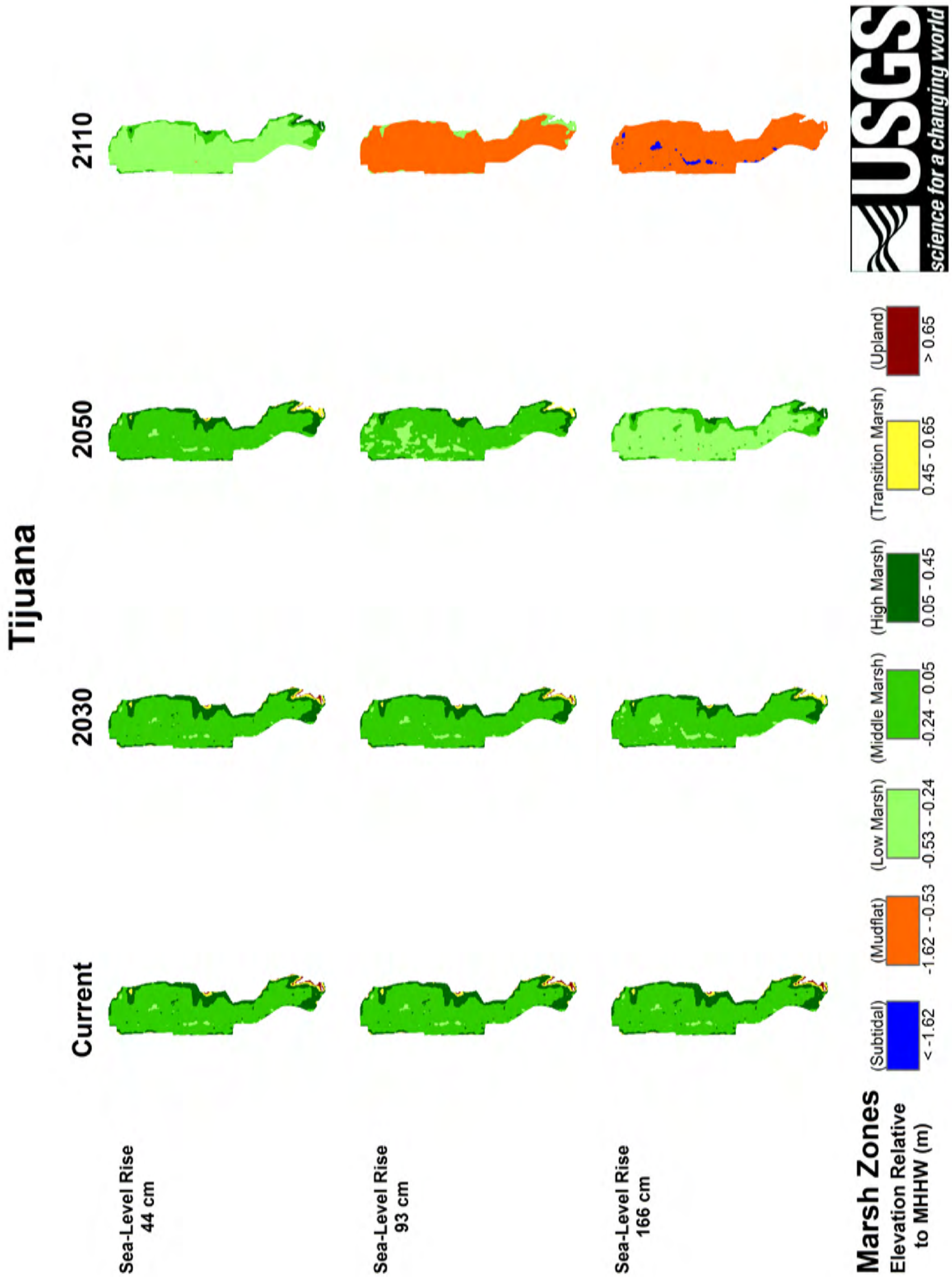

Figure G13. Projected habitat distribution at Tijuana Estuary for 2030, 2050 and 2110 with the WARMER model under three NRC sea-level rise scenarios.

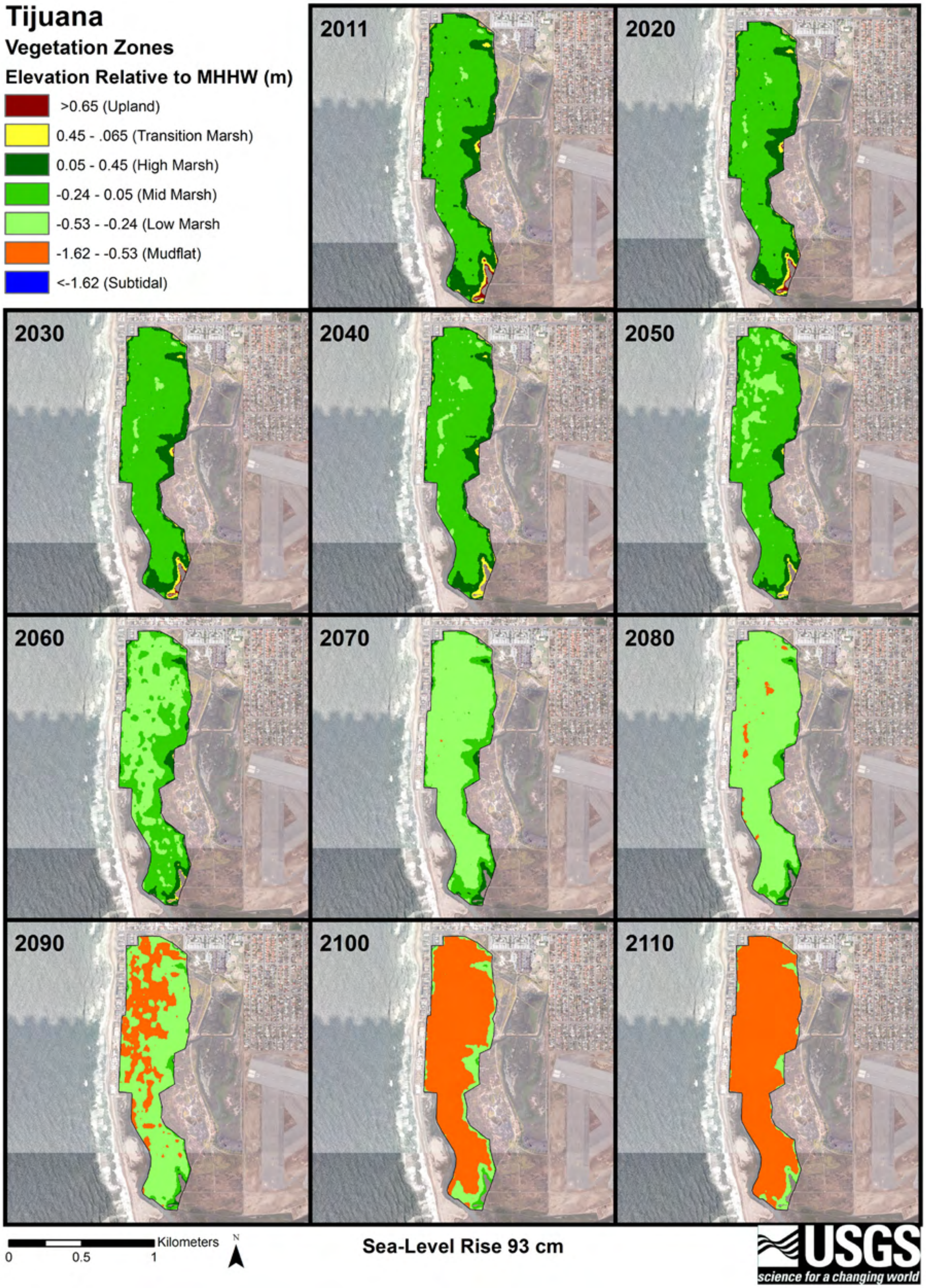

Figure G14. Projected changes in Tijuana Estuary habitat zones under the mid NRC sea-level rise scenario (93 cm).