Appendix L

San Pablo Bay Marsh

Introduction

San Pablo Bay National Wildlife Refuge marsh (hereafter San Pablo) is located on the north shore of San Pablo Bay in Sonoma, Solano, and Napa Counties. It is owned and managed by the U.S. Fish and Wildlife Service with adjacent lands owned and managed by California Fish and Game and Sonoma Landtrust. It is one of the largest areas of intact marsh in the San Francisco Bay estuary. San Pablo supports federally and state-listed species, such as the salt marsh harvest mouse (*Reithrodontomys raviventris*) and the California black rail (*Laterallus jamaicensis*). San Pablo is also an important stopover on the Pacific Flyway and provides critical migratory and wintering habitat for shorebirds. San Pablo is influenced both by the tides and freshwater input from Petaluma River, Sonoma Creek, and Napa River.

Due to the extent of San Pablo, we split data analysis into two sections; 962.6 ha on the northeast side and 449.5 ha on the northwest separated by Sonoma Creek. Elevation and vegetation surveys were conducted in 2008 - 2009 using an RTK GPS. To monitor tidal inundation and salinity water level loggers were deployed in 2009.

Results

Elevation

A total of 1,396 elevation measurements were taken at San Pablo (Fig. L-1, L-2). The elevation range was 0.56 - 3.11 m with a mean of 1.94 m (NAVD88). 58% of the survey points fell within 1.7 - 2.1 m. Over half (64%) of the survey points were located at elevations above mean high water (MHW; Fig. L-3). A 3-m resolution elevation model was developed in ArcGIS 9.3 (ESRI, Redlands, CA) Spatial Analyst using the

Kriging method (Figs. L-4 – L-5). This baseline elevation model was used as the initial elevation in the WARMER sea-level rise (SLR) model.

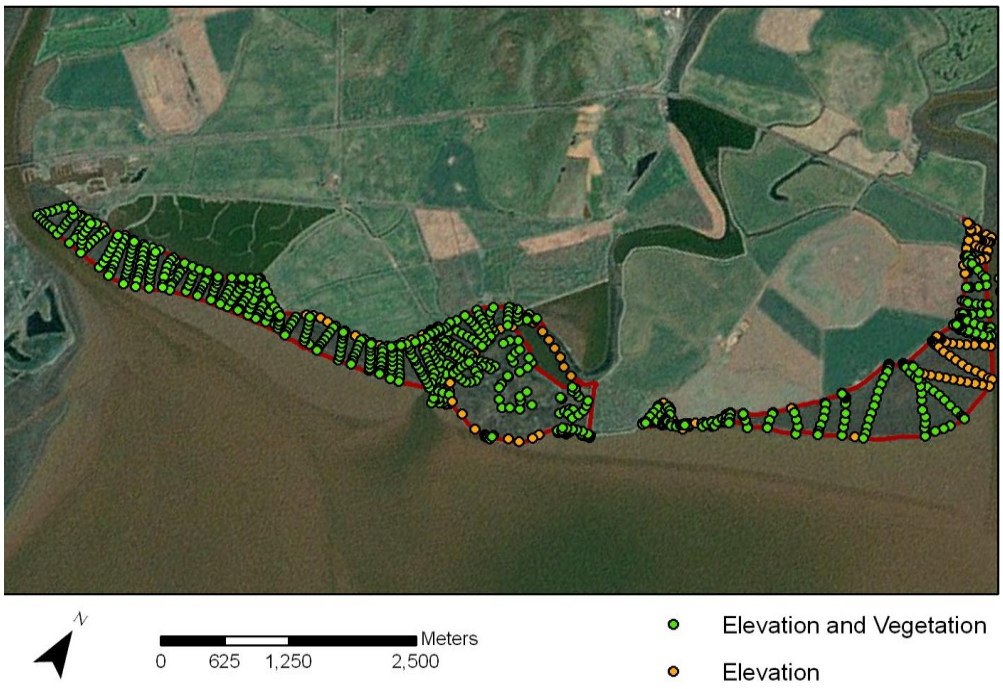

Figure L-1. Western portion of San Pablo with elevation and vegetation survey points taken in 2009.

Figure L-2. Eastern portion of San Pablo with elevation and vegetation survey points taken in 2008.

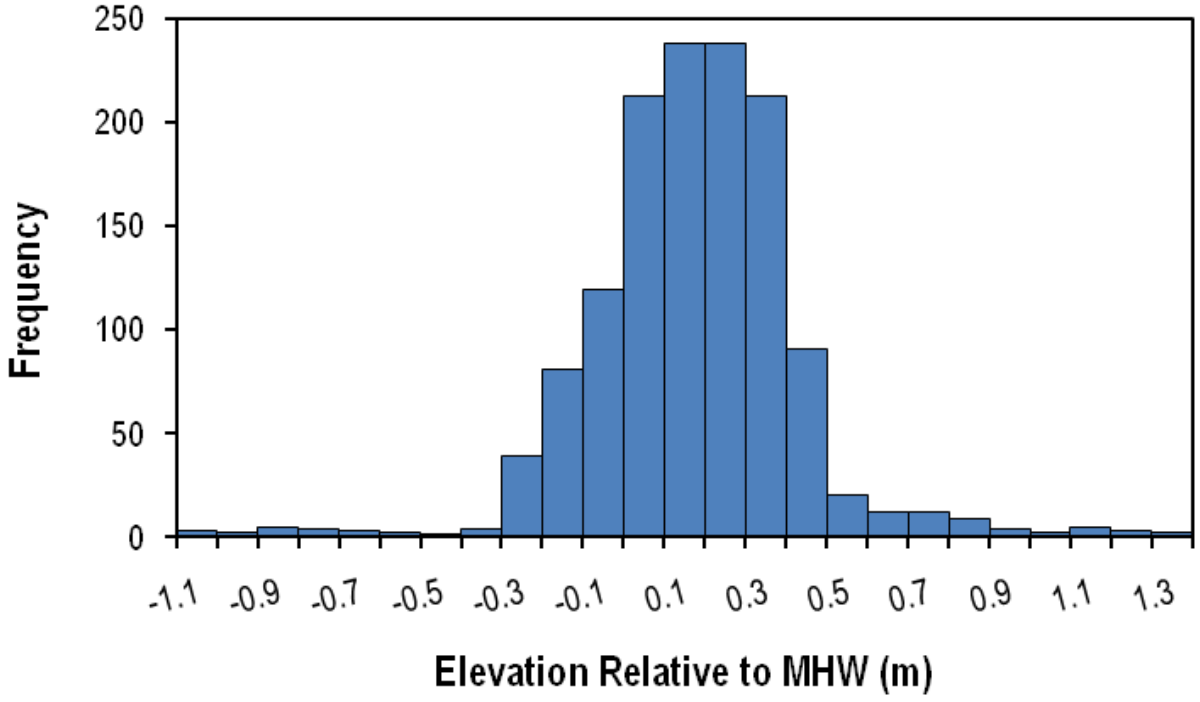

Figure L-3. Distribution of elevation relative to local mean high water (MHW) for all San Pablo data.

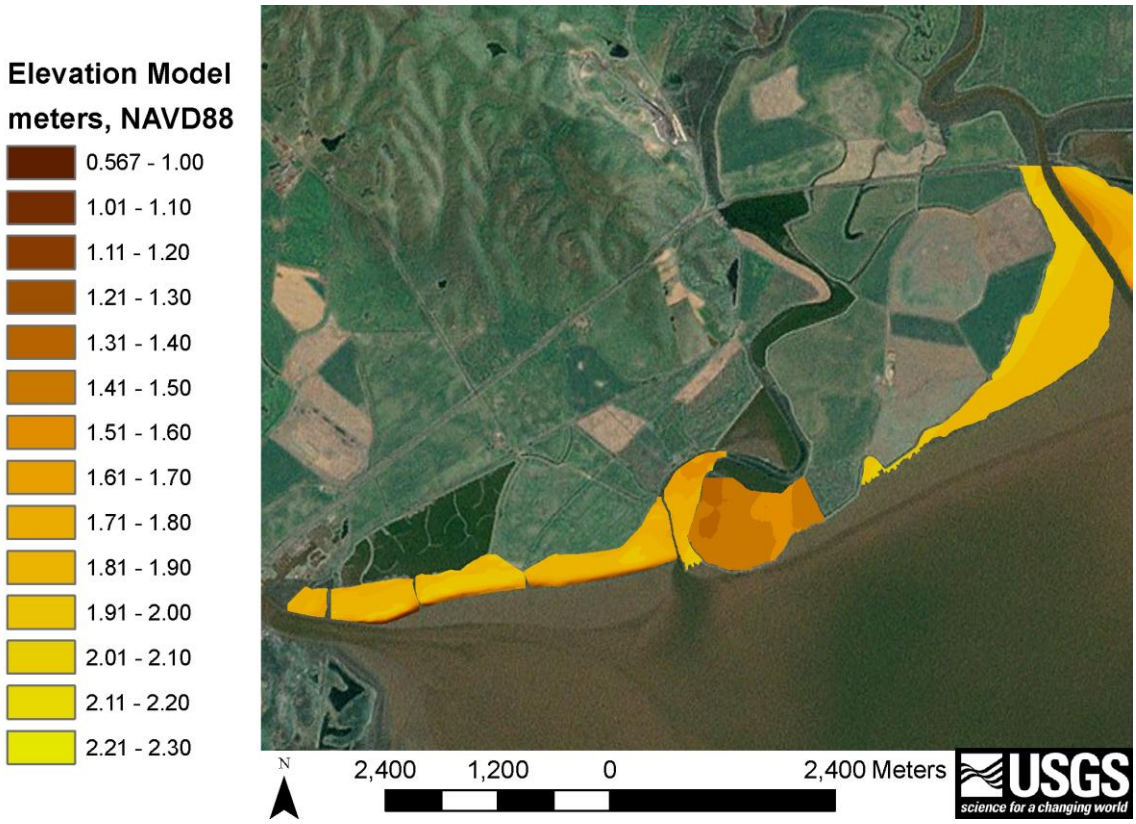

Figure L-4. Elevation model (3-m resolution) developed from ground RTK GPS elevation data for west San Pablo.

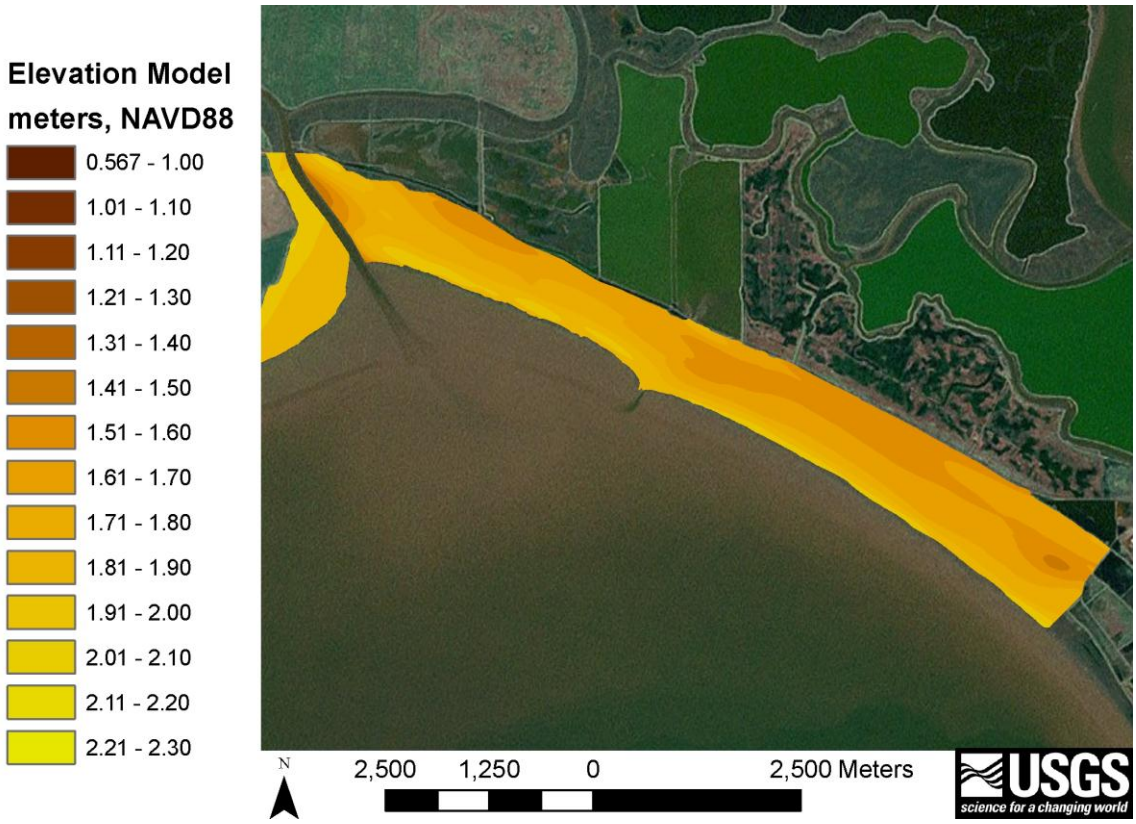

Figure L-5. Elevation model (3-m resolution) developed from ground RTK GPS elevation data for east San Pablo.

Vegetation

Vegetation was surveyed at San Pablo concurrently with elevation in the summer of 2008 and 2009. A total of 888 locations (Fig. L-1) were measured for vegetation composition, height (cm), and percent cover (Table L-1 – L-2). We did not distinguish between invasive and native *Spartina spp.* and *Scirpus spp*. in the survey. Vegetation in marshes is sensitive to soil salinity, inundation patterns and disturbance. Therefore, stratification of vegetation relative to MHW (Figs. L-6 – L-7) was observed within this low slope marsh.

Table L-1. Mean marsh elevation, avg. and max height (cm), percent cover with standard deviations (SD), and presence by species at west San Pablo.

Species	Elevation (MHW, m)	Elevation SD (MHW, m)	Avg. Height (cm)	Avg. Height SD (cm)	Max Height (cm)	Max Height SD (cm)	% Cover	% Cover SD	n	% Presence
Sarcocornia pacifica	0.08	0.19	44.41	12.49	52.82	13.56	76.43	33.73	579	84.90
Spartina spp.	-0.38	0.34	70.95	17.84	77.51	16.98	36.02	25.43	63	9.24
Scirpus spp.	-0.21	0.19	31.08	33.15	32.42	34.75	15.58	23.36	12	1.76
Grindelia stricta	0.03	0.18	67.38	16.17	73.49	17.62	34.90	29.49	71	10.41
Jaumea carnosa	-0.06	0.21	16.45	8.26	20.00	9.86	57.24	34.31	33	4.84
Frankenia salina	0.17	0.27	20.92	10.53	25.50	11.77	40.47	32.05	76	11.14
Distichlis spicata	0.09	0.28	13.83	8.57	17.11	10.90	56.49	32.87	53	7.77
Lepidium latifolium	0.18	0.24	46.67	32.31	48.33	33.54	18.11	18.81	9	1.32
Atriplex triangularis	0.07	0.41	20.00	16.96	22.00	18.23	12.60	20.98	5	0.73
Baccharis pilurais	0.37	0.30	76.50	27.02	85.90	34.91	46.00	32.35	20	2.93

Table L-2. Mean marsh elevation, avg. and max height (cm), percent cover with standard deviations (SD), and presence by species at east San Pablo.

Species	Elevation (MHW, m)	Elevation SD (MHW, m)	Avg. Height (cm)	Avg. Height SD (cm)	Max Height (cm)	Max Height SD (cm)	% Cover	% Cover SD	n	% Presence
Sarcocornia pacifica	0.05	0.16	42.64	14.26	54.40	14.75	72.07	32.27	166	80.58
Spartina spp.	-0.16	0.25	66.13	17.44	74.38	16.26	21.94	17.25	16	7.77
Scirpus spp.	0.13	0.14	90.00	14.14	107.50	10.61	15.00	7.07	2	0.97
Grindelia stricta	0.21	0.10	50.00	22.14	59.17	26.45	44.33	38.82	6	2.91
Frankenia salina	0.10	-	26.00	-	42.00	-	98.00	-	1	0.49
Lepidium latifolium	0.31	0.10	72.00	21.80	84.42	18.97	31.83	36.90	12	5.83
Baccharis pilurais	0.30	0.71	50.00	21.21	67.00	1.41	22.50	3.54	2	0.97

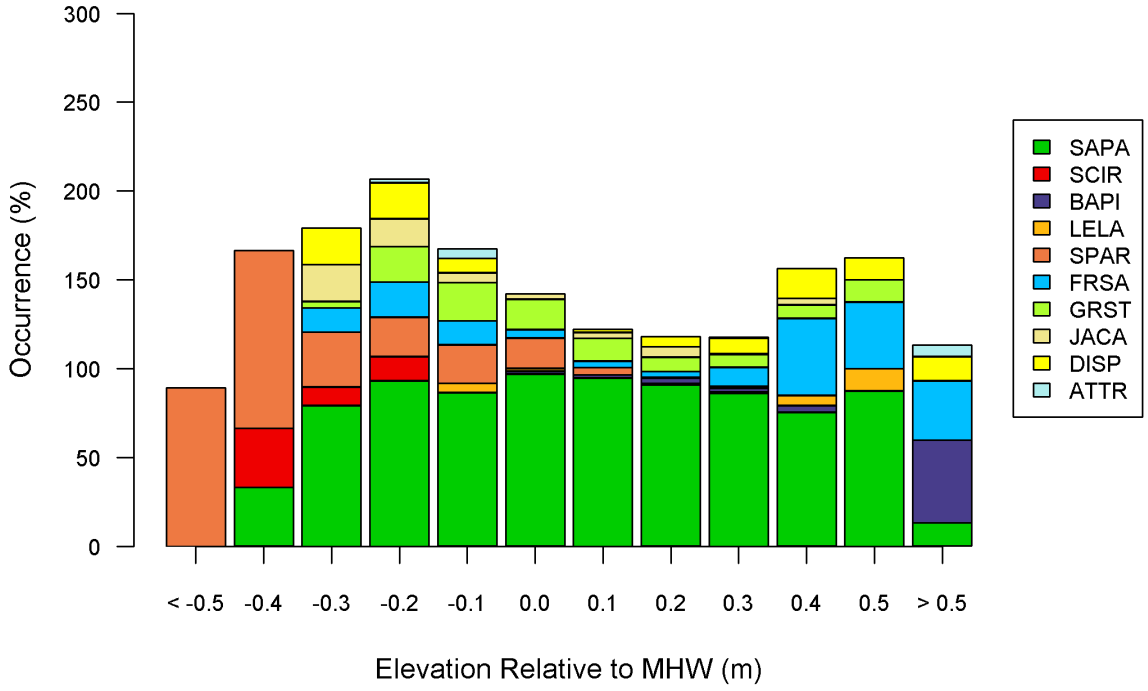

Figure L-6. Stratification of vegetation species was observed relative to MHW at west San Pablo. Species codes: SAPA = *Sarcocornia pacifica;* SCIR = *Scirpus spp.;* BAPI: *Baccaris pilularis*; LELA = *Lepidium latifolium*; SPAR = *Spartina;* FRSA = *Frankenia salina;* GRST = *Grindelia stricta;* JACA = *Jaumea carnosa*; DISP = *Distichlis spicata*; ATTR = *Atriplex triangularis.*

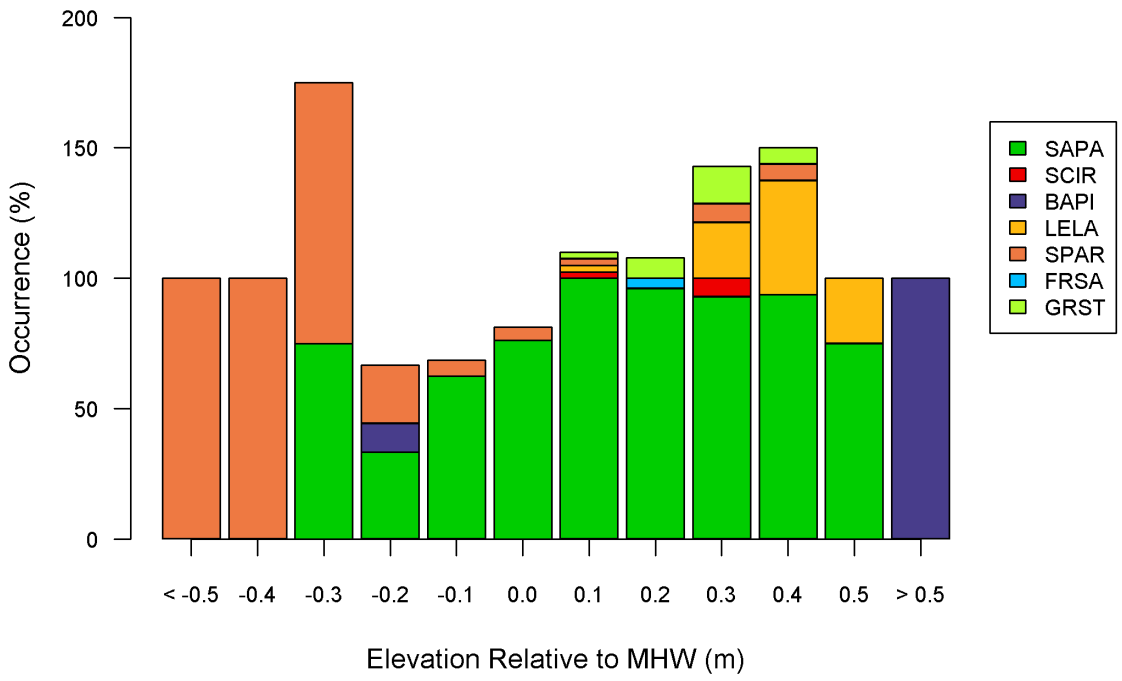

Figure L-7. Stratification of vegetation species was observed relative to MHW at east San Pablo. Species codes: SAPA = *Sarcocornia pacifica;* SCIR = *Scirpus spp.;* BAPI = *Baccaris pilularis*; LELA = *Lepidium latifolium*; SPAR = *Spartina spp.;* FRSA = *Frankenia salina;* GRST = *Grindelia stricta;* JACA = *Jaumea carnosa*; DISP = *Distichlis spicata*; ATTR = *Atriplex triangularis.*

Water level monitoring

Site-specific water level was monitored for one year from December 2009 and May 2011. Water level was measured using four data loggers deployed at the mouth of second order channels and in the marsh interior. We found mean high water (MHW) at 1.68 m and mean higher high water (MHHW) at 1.85 m for the site (NAVD88). Water levels throughout the year were recorded to evaluate seasonal patterns in tides. The marsh platform (defined as mean marsh elevation) was inundated most often in January when the diurnal high tides were highest (Fig. L-8). Mean salinity during 2010 at San Pablo was 19.0 (SD = 5.9) PSS.

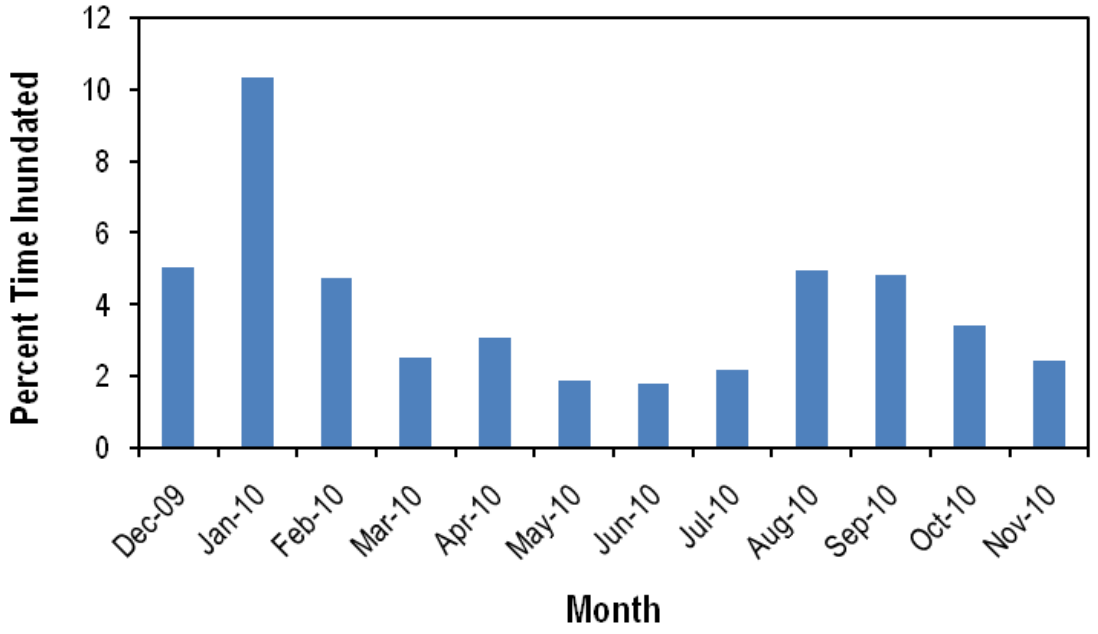

Figure L-8. Percent of time all of San Pablo was inundated monthly, based on the mean elevation of the marsh platform.

Marsh elevation modeling

WARMER results indicate that San Pablo will not keep pace with local SLR through this century. Results show a gradual reduction in elevation relative to MHW over time, with a more dramatic decline after 2060 (Figs. L-9 – L-10). By 2090 the marsh is projected to be under MSL, therefore functionally a mudflat (Fig. L-11).

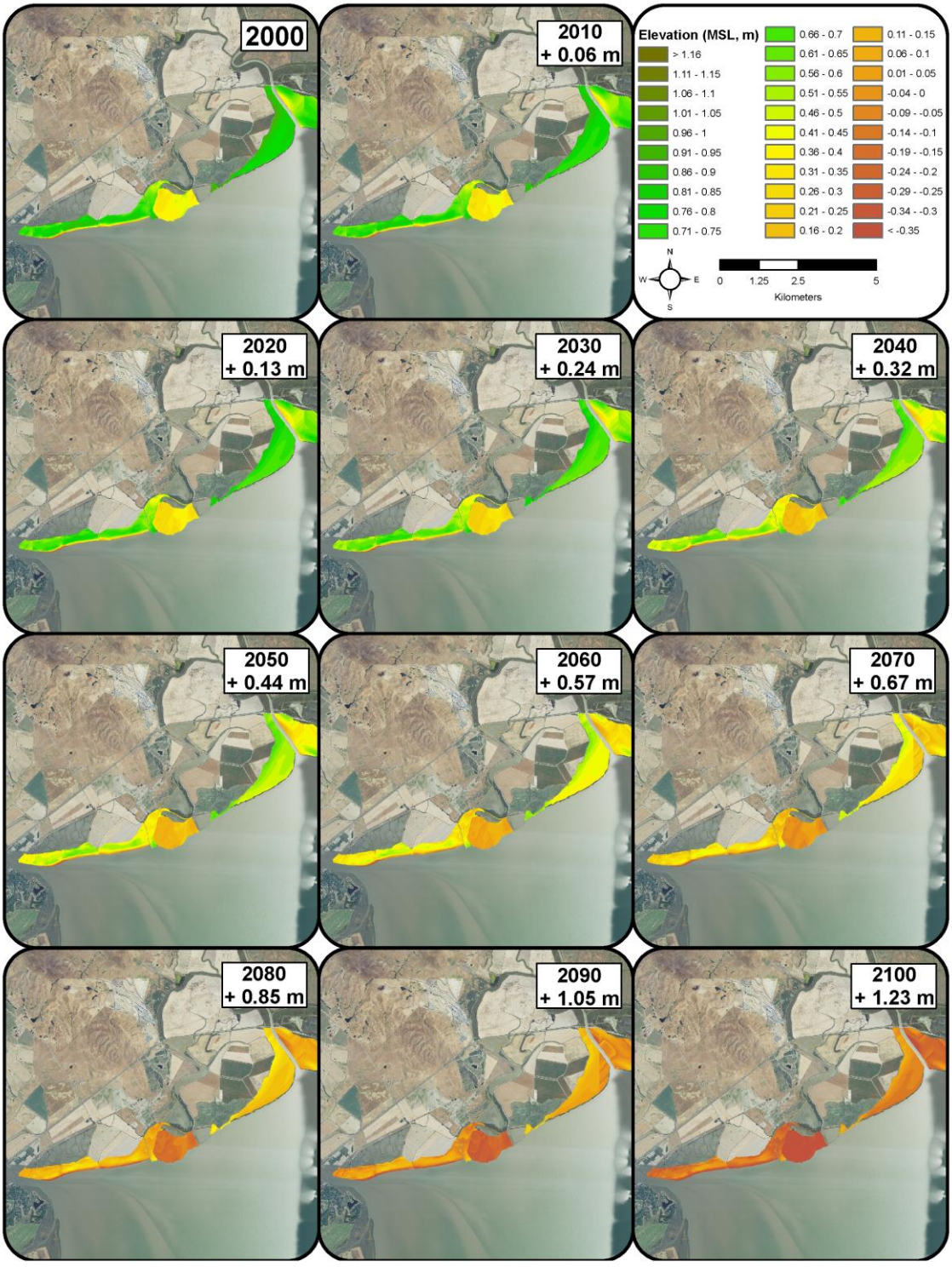

Figure L-9. WARMER results for west San Pablo. WARMER accounts for changes in relative seal-level, subsidence, inorganic sediment accumulation, above/below ground organic matter productivity, compaction, and decay. Non-linear sea-level rise projections for California were used (Cayan *et al.* 2009).

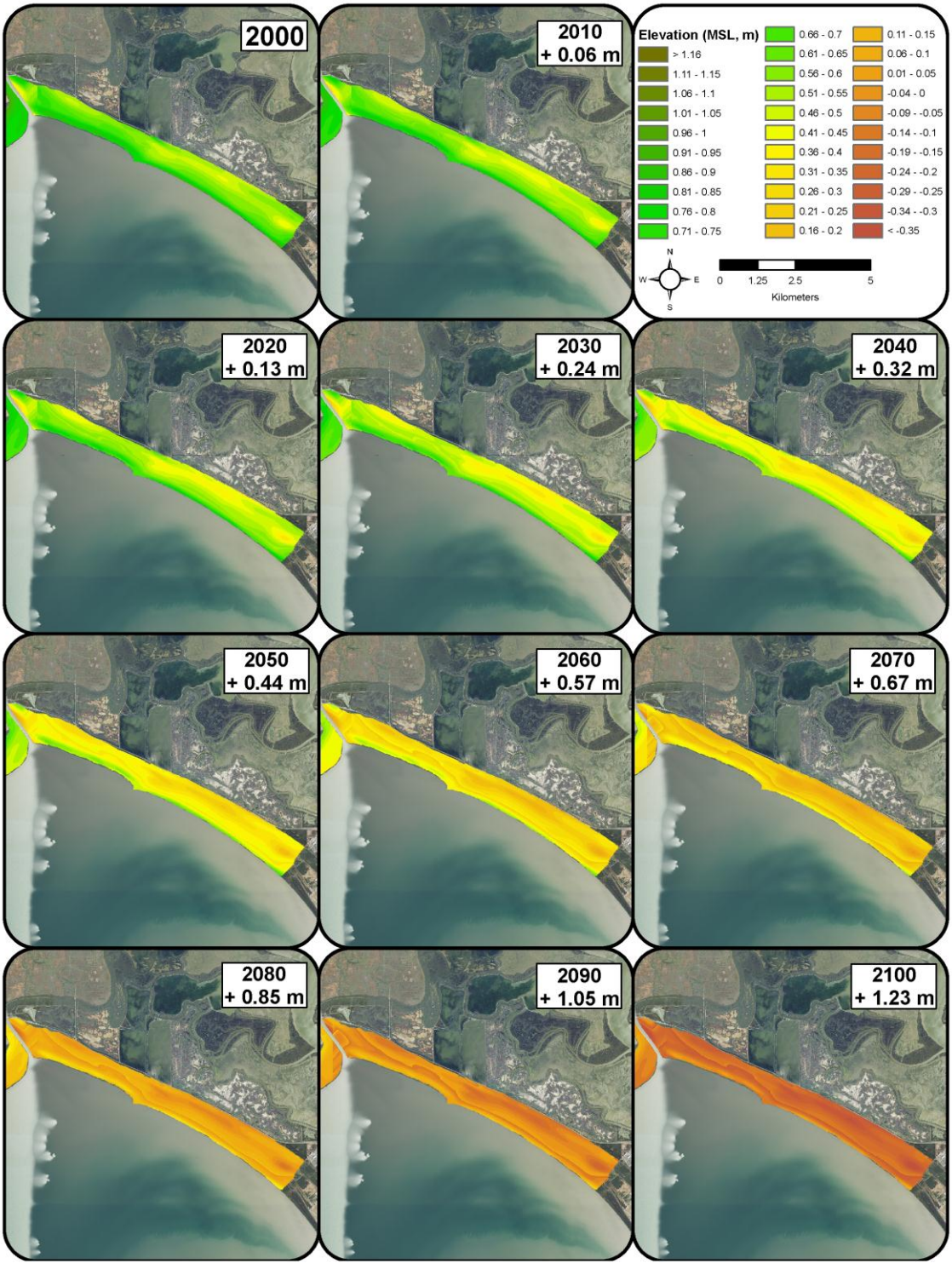

Figure L-10. WARMER results for east San Pablo. WARMER accounts for changes in relative seal-level, subsidence, inorganic sediment accumulation, above/below ground organic matter productivity, compaction, and decay. Non-linear sea-level rise projections for California were used (Cayan *et al.* 2009).

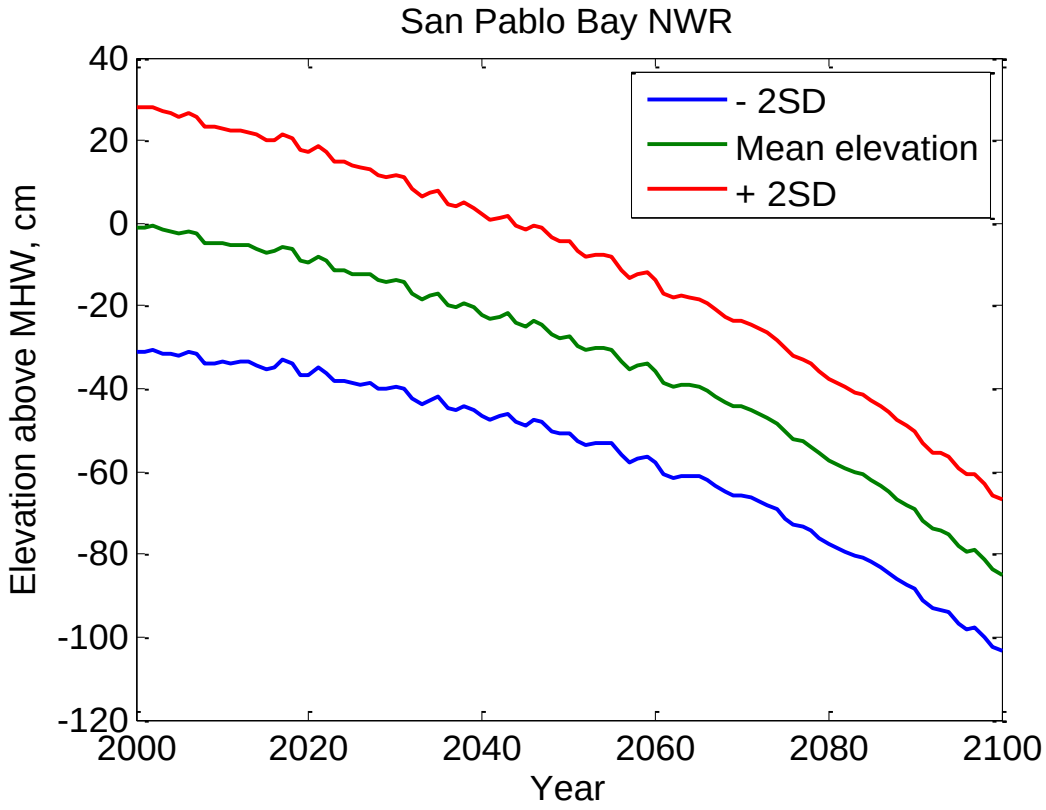

Figure L-11. WARMER scenarios for San Pablo elevation change. Elevation above MHW is plotted versus model year with two standard deviations (SD).

Elevation relative to the local tidal datum can be tied to vegetation observations (see methods). Vegetation data were categorized as mudflat, low, mid, high marsh, or upland transition plant communities (Table 4) and used to interpret the WARMER SLR results (Figs. L-12 – L-14). Upland transition (> 1.0 m MSL), is characterized by coyote bush (*Baccharis pilularis*). High marsh (0.7 – 1.0 m MSL), is characterized by *Frankenia salina* and *Jaumea carnosa*, while mid marsh (0.45 – 0.7 m MSL), is dominated by *Sarcocornia pacifica.* Low marsh (0.2 – 0.45 m MSL), is characterized by *Spartina spp.* or *Scirpus spp.* in brackish areas. Mudflat habitat (< 0.2 m MSL), is unvegetated or sparsely covered with *Spartina spp.* Currently, west San Pablo is primarily mid and high marsh. High marsh is projected to increase from 2000 through 2020 (+ 0.13 m SLR). All high marsh vegetation is projected to be gone by 2040 (+ 0.32 m SLR). Mid marsh is dominate to 2060 (+ 0.57 m SLR), at which time it transitions to low marsh. A transition to mudflat is projected by 2080 (+ 0.85 m SLR).

East San Pablo is also primarily mid marsh habitat, with some high marsh vegetation bordering San Pablo Bay. All high marsh is projected to be mostly gone by 2020 (+ 0.13 m SLR), with mid marsh projected to be gone by 2050 (+ 0.44 m SLR). Low marsh dominates till 2070 (+ 0.67 m SLR) at which time east San Pablo begins to transition below MSL to a mudflat. All vegetation is gone by 2090 (+ 1.05 m SLR)

The WARMER model parameters for San Pablo Bay were extrapolated using sediment core data from China Camp marsh, thus predictions should be interpreted with caution as local sedimentation processes may be different between these marshes. To improve results, local site-specific sediment core data should be collected, along with suspended sediment concentrations to characterize sediment deposition potential.

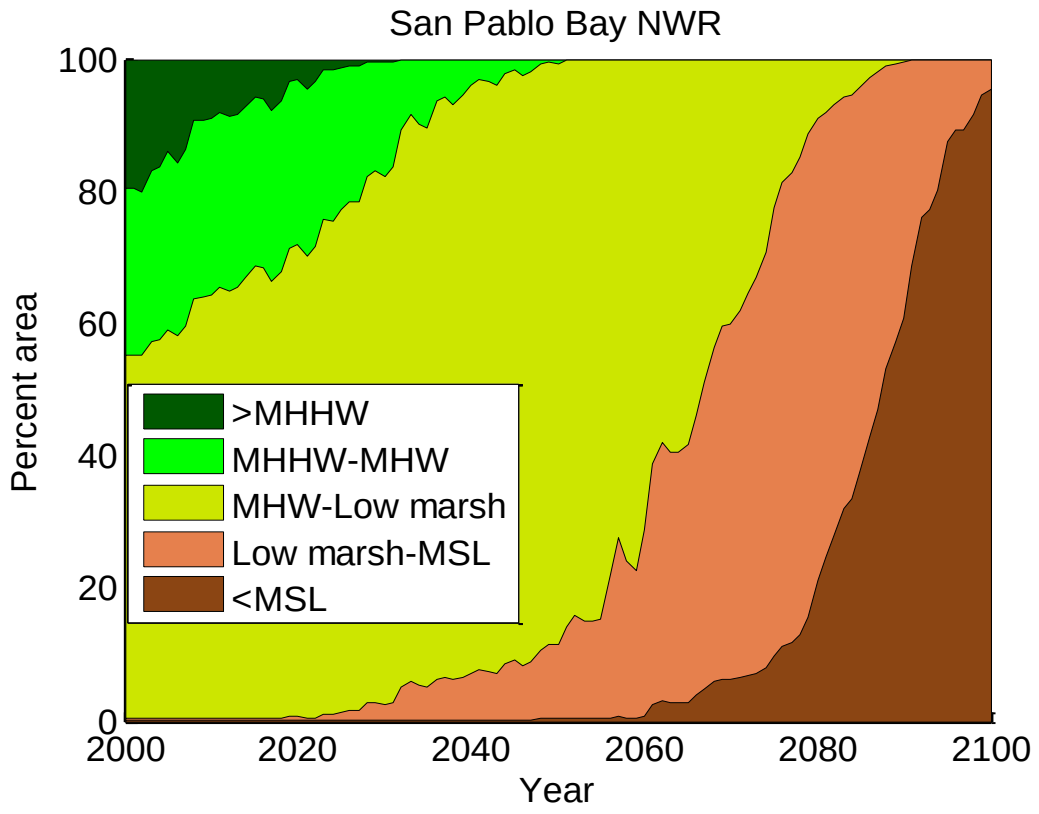

Figure L-12. Area of San Pablo within a given tidal range for the duration of the simulation period.

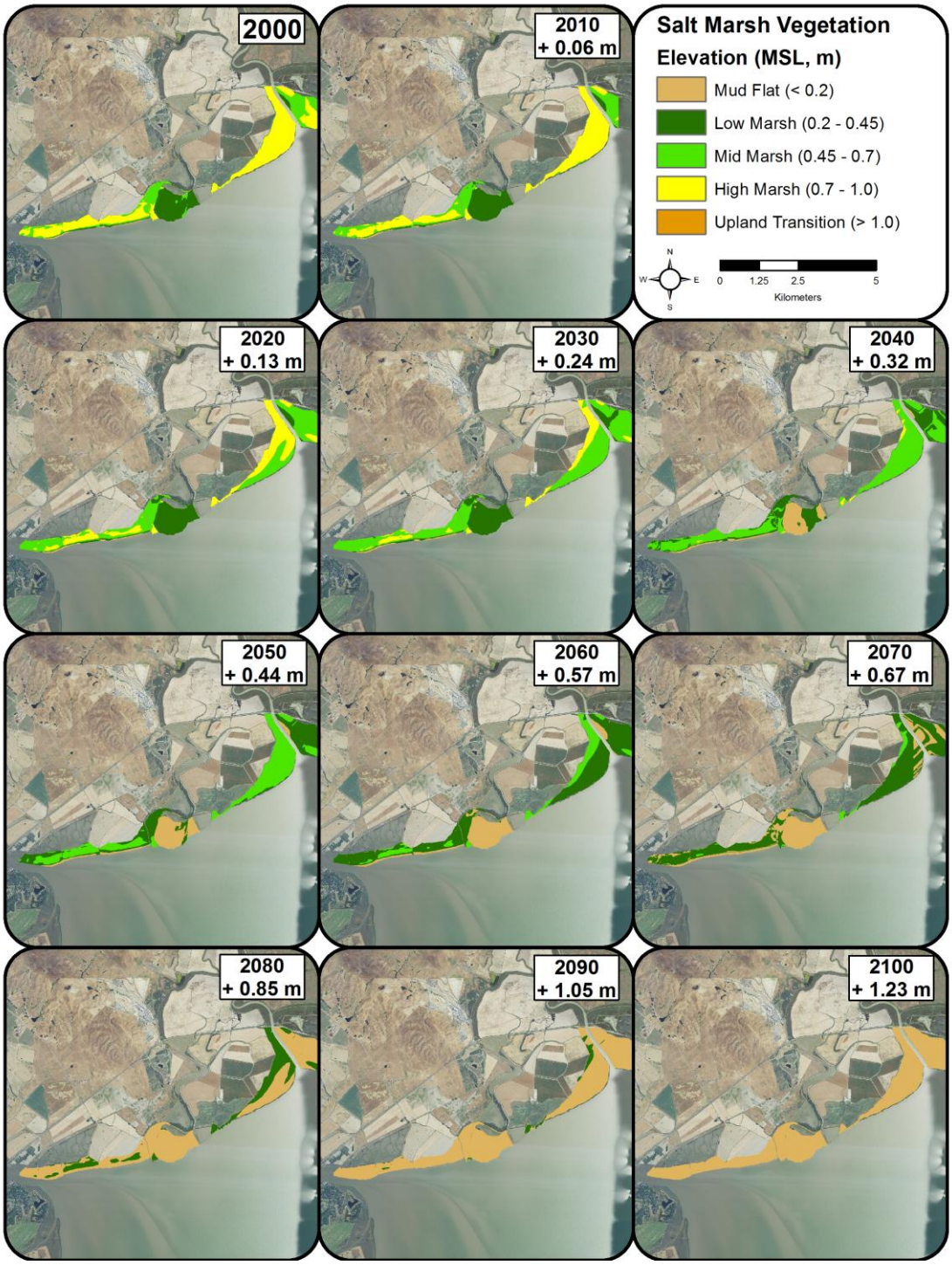

Figure L-13. West San Pablo WARMER results in terms of plant communities: mudflat, low, mid, or high marsh, or upland transition.

Figure L-14. East San Pablo WARMER results in terms of plant communities: mudflat, low, mid, or high marsh, or upland transition.