

Appendix C

China Camp Marsh

Site Introduction

China Camp State Park (hereafter China Camp) is a 1517 acre park owned and managed by California State Parks. China Camp is located in Marin County and the city of San Rafael. It contains a large expanse of undeveloped historic marsh, with adjacent uplands comprised of oak woodlands. China Camp is part of the NOAA National Estuarine Research Reserve (NERR) network, where it is used as a reference for healthy marsh and a living laboratory for staff and scientists.

China Camp is located adjacent to Gallinas Creek on San Pablo Bay. It is influenced by tidal flow from the San Pablo Bay as well as freshwater flow from Gallinas Creek. China Camp provides habitat for state listed species, such as the California black rail (*Laterallus jamaicensis*) and federally endangered species such as salt marsh harvest mouse (*Reithrodontomys raviventris*) and California clapper rail (*Rallus longirostris obsoleta*).

This study focused on 96.7 ha of marsh at China Camp. Elevation and vegetation surveys were conducted in 2010 using RTK GPS. To monitor tidal inundation, four water level loggers were deployed in 2010.

Results

Elevation surveys

A total of 753 elevation measurements were taken at China Camp (Fig. C-1). The elevation range was 0.87 - 2.28 m with a mean of 1.79 m (NAVD88). Over half (58%) of the survey points were

within 1.75 m - 1.85 m, with a 0.1 m range (Fig. C-2). China Camp was a relatively high marsh with the majority (67%) of survey points located at elevations above mean high water (MHW). A 3-m resolution elevation model was developed in ArcGIS 9.3 (ESRI, Redlands, CA), Spatial Analyst using the Kriging method (Fig. C-3). This baseline elevation model was used as the initial elevation in the WARMER sea-level rise (SLR) model.

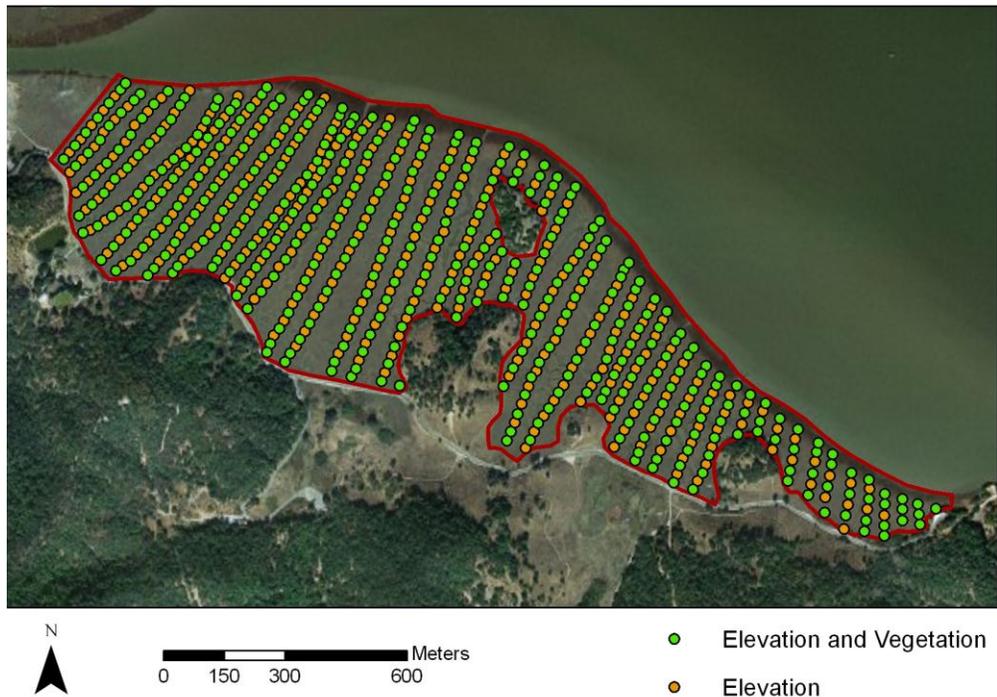


Figure C-1. China Camp with elevation and vegetation survey points taken in 2010

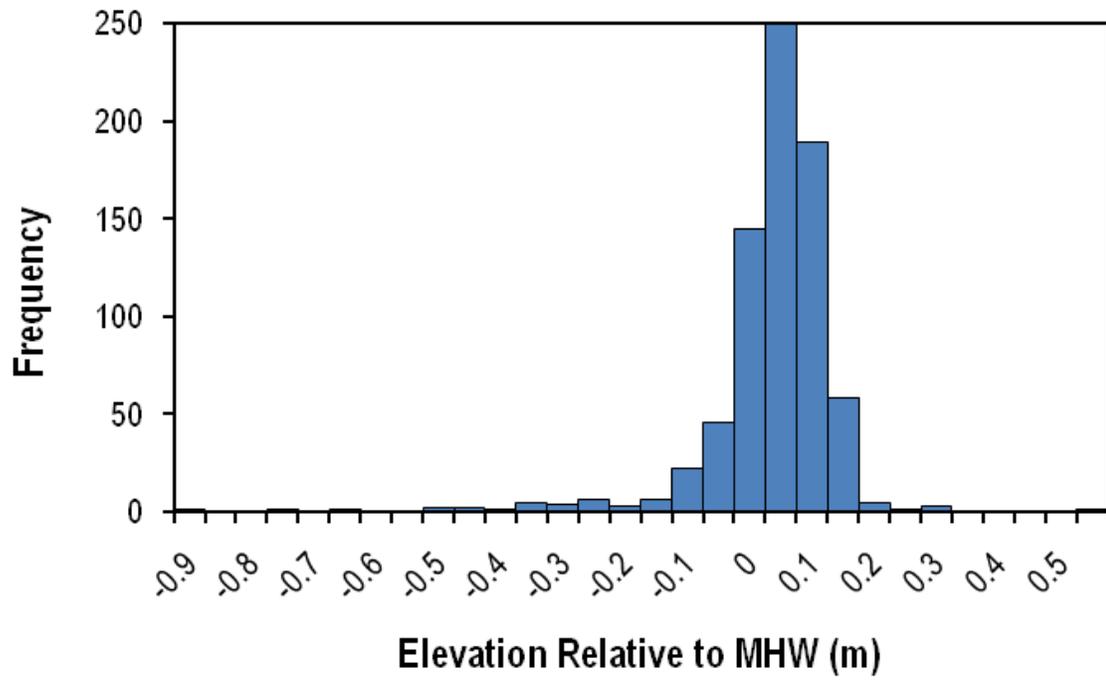


Figure C-2. Distribution of elevation relative to local mean high water (MHW) at China Camp.

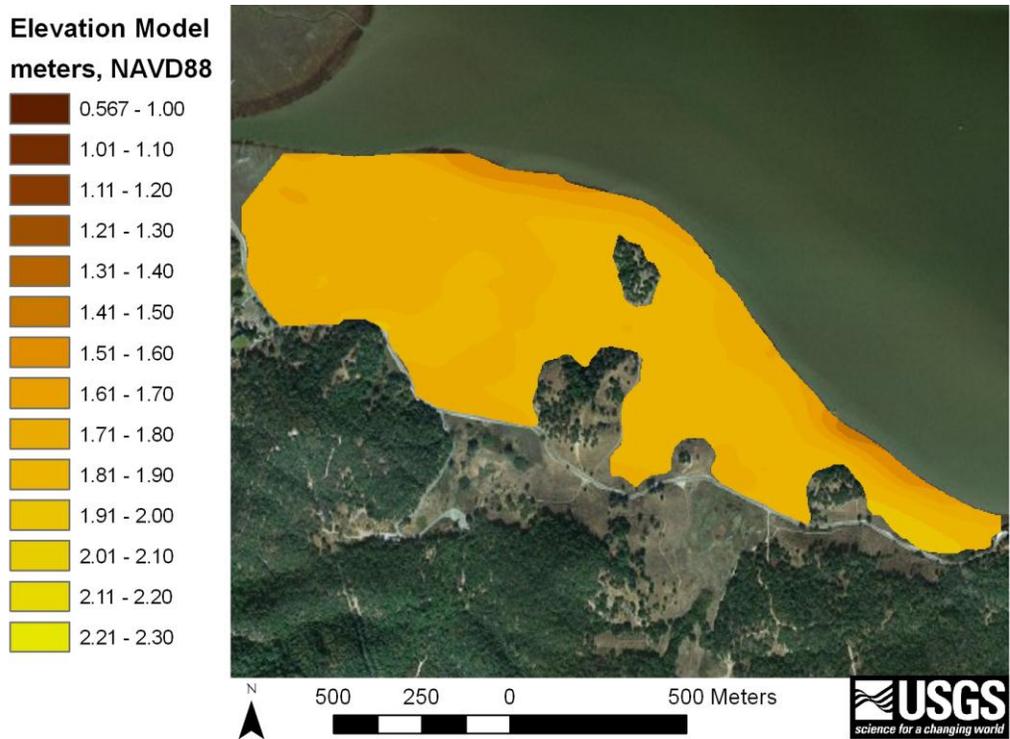


Figure C-3. ArcGIS elevation model (3-m resolution) developed from ground RTK GPS elevation data.

Vegetation surveys

Vegetation was surveyed at China Camp concurrently with elevation in February - March of 2010. A total of 423 locations (Fig. C-1) were measured for vegetation composition, height (cm), and percent cover (Table C-1). We did not distinguish between invasive and native *Spartina* or *Scirpus* in the survey. Vegetation in marshes is sensitive to soil salinity, inundation patterns and disturbance. Therefore, a stratification of vegetation species relative to MHW (Fig. C-4) was observed within this low slope marsh.

Table C-1. Mean marsh elevation, avg. and max height (cm), percent cover with standard deviations (SD), and presence by species at China Camp.

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
<i>Sarcocornia pacifica</i>	0.01	0.10	29.72	8.78	41.76	10.30	81.45	24.51	408	96.68
<i>Spartina spp.</i>	-0.46	0.21	34.25	13.92	44.08	15.51	12.75	11.33	12	2.84
<i>Scirpus spp.</i>	-0.13	0.16	18.00	21.01	23.00	27.23	16.29	25.84	7	1.66
<i>Grindelia stricta</i>	0.06	0.10	62.03	22.07	66.10	24.87	26.45	20.41	29	6.87
<i>Jaumea carnosa</i>	0.01	0.06	12.76	3.36	16.88	4.32	19.82	26.24	34	8.06
<i>Frankenia salina</i>	0.09	0.04	19.50	5.36	24.33	5.85	24.33	30.64	6	1.42
<i>Distichlis spicata</i>	0.03	0.10	17.85	8.65	22.91	9.40	19.00	26.51	54	12.80
<i>Lepidium latifolium</i>	0.11	0.08	20.40	22.43	24.40	23.29	12.20	11.95	5	1.18

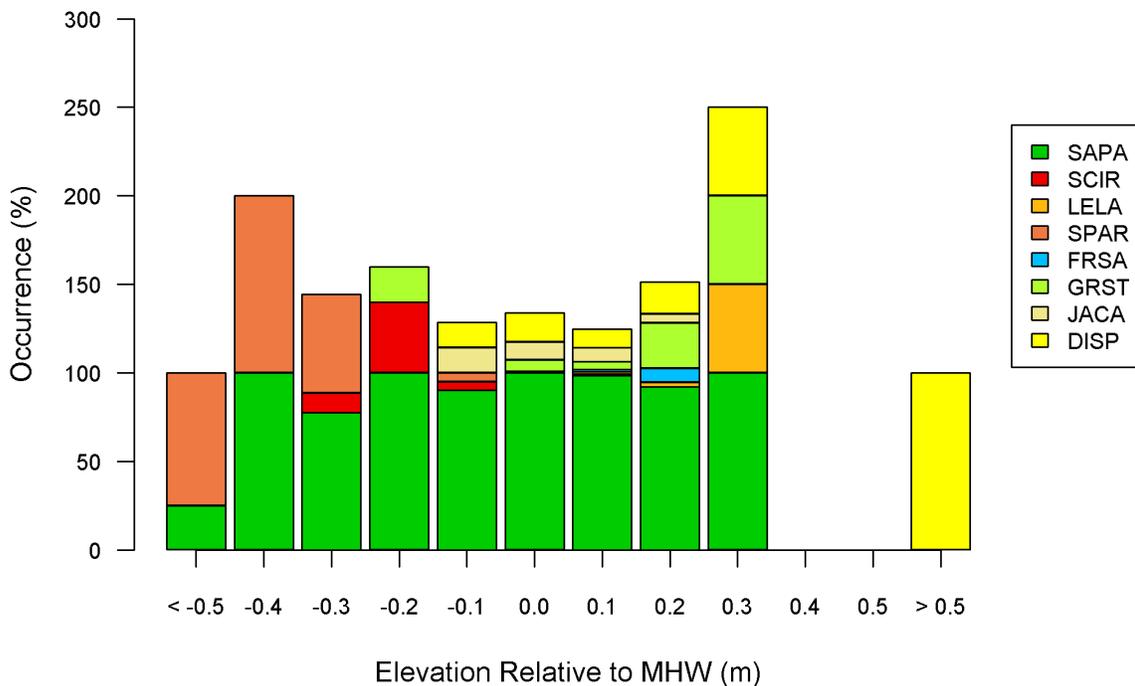


Figure C-4. Stratification of vegetation species was observed relative to MHW. Species codes: SAPA = *Salicornia pacifica*; SCIR = *Scirpus spp.*; LELA = *Lepidium latifolium*; SPAR = *Spartina spp.*; FRSA = *Frankenia salina*; GRST = *Grindelia stricta*; JACA = *Jaumea carnosa*; DISP = *Distichlis spicata*.

Water level monitoring

Site specific water level was monitored at China Camp for one year, from February 2010 to January 2011. Water level was measured using two data loggers deployed in second order channels. We found MHW was 1.77 m, and mean higher high water (MHHW) was 1.95 m for the site (NAVD88). The marsh platform (defined as mean marsh elevation) was inundated most often in February 2010 (Fig. C-5). We believe these long periods of inundation were the result of above average cumulative rainfall in January 2010 throughout the San Francisco bay area (NOAA).

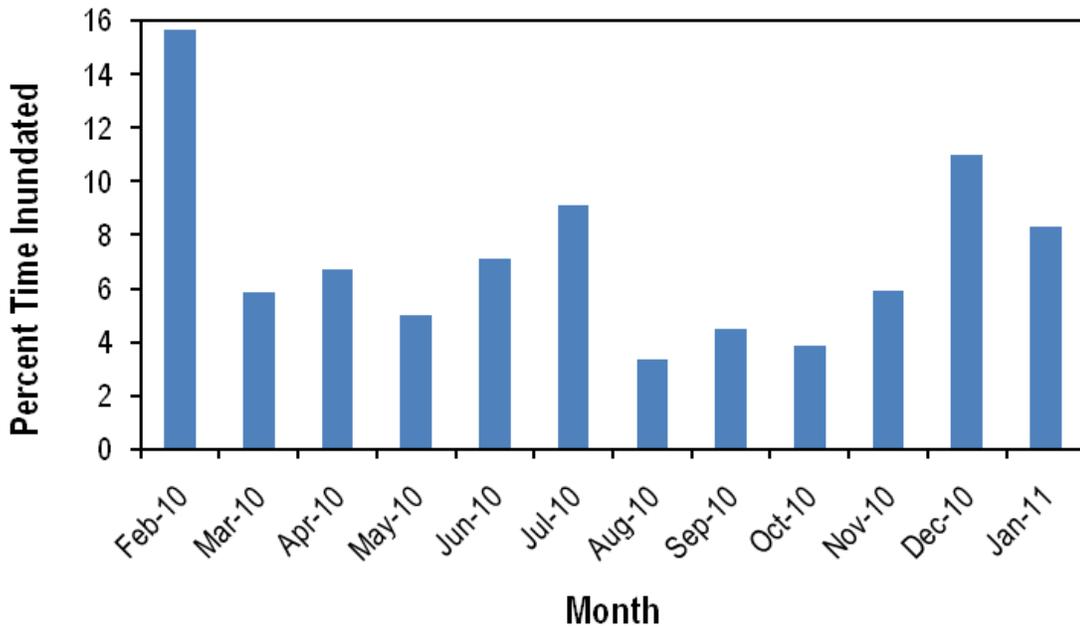


Figure C-5. Percent of time China Camp was inundated monthly, based on the mean elevation of the marsh platform.

Marsh elevation modeling

China Camp SLR response modeling showed that the marsh was able to maintain its elevations through 2030, unlike lower elevation marshes around SFB. However, WARMER projections showed a gradual reduction in elevation relative to MHW over time after 2030, with a more dramatic decline after 2060 (Fig C-6). By 2080 the marsh is projected to be under mean sea level (MSL), and functionally a mudflat (Fig. C-7). Despite its relatively high elevation, WARMER results indicate that China Camp will not keep pace with local SLR through this century.

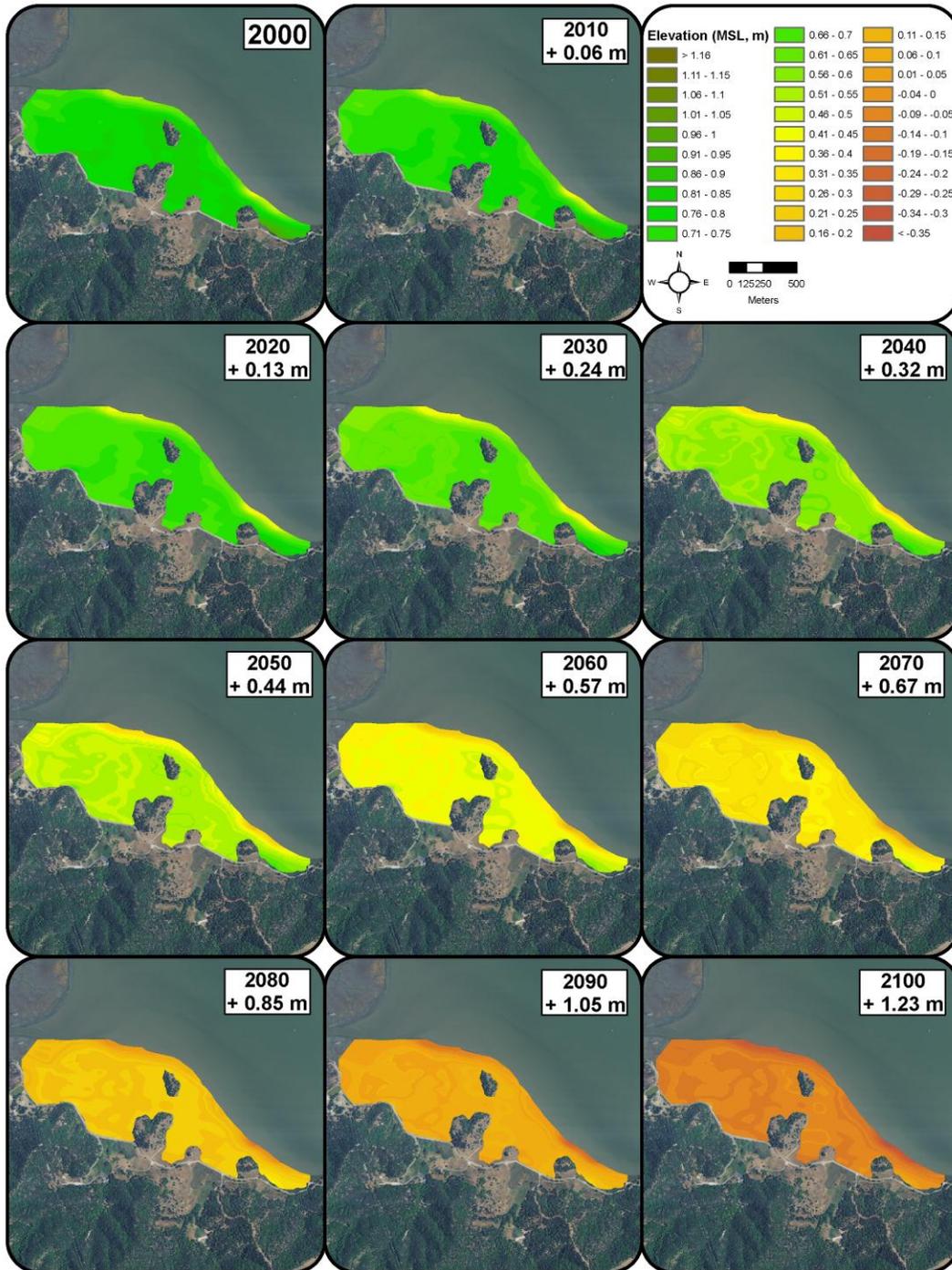


Figure C-6. WARMER results for China Camp. WARMER accounts for changes in relative sea-level, subsidence, inorganic sediment accumulation, above/below ground organic matter productivity, compaction, and decay. Non-linear sea-level rise projections for California were used (Cayan *et al.* 2009).

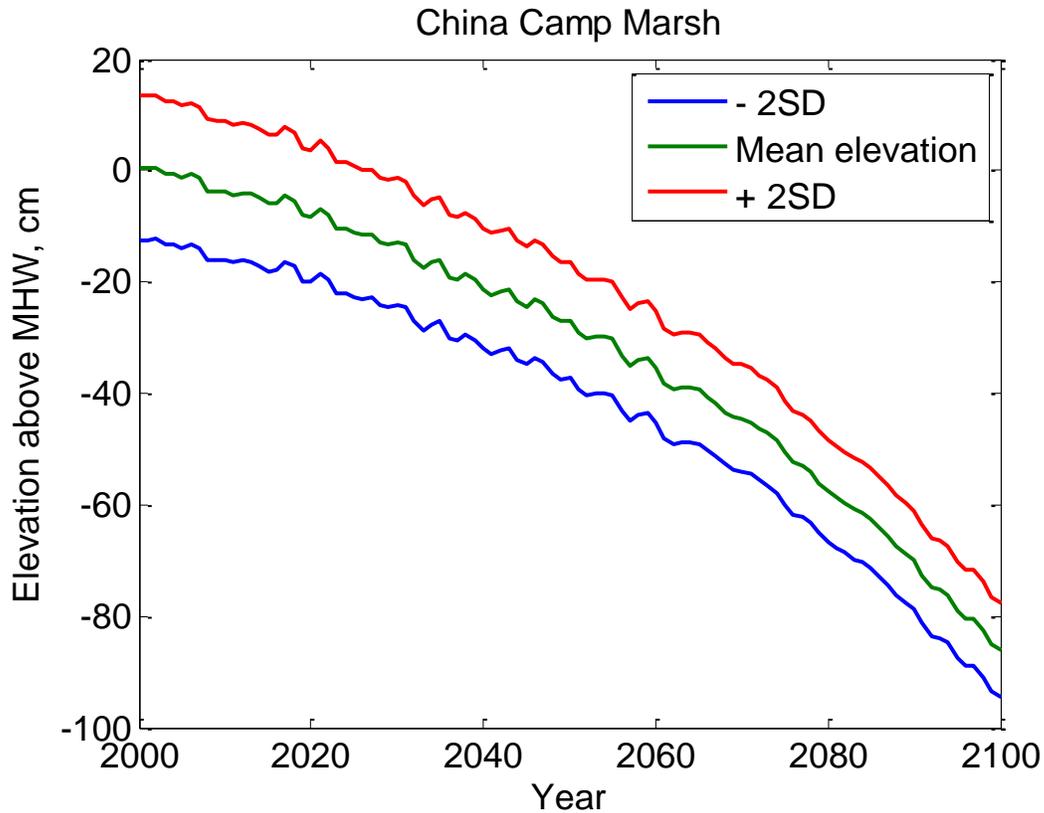


Figure C-7. Modeled WARMER scenarios of marsh elevation change at China Camp. Elevation above MHW is plotted versus model year with two standard deviations (SD).

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. C-8, C-9). 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.* China Camp is dominated by mid and high marsh plant communities dominated by *Sarcocornia pacifica*, primarily with low marsh vegetation adjacent to the bay. China Camp elevations are between high and mid marsh plant community

classifications (Table 4). Therefore, WARMER shows a brief expansion of high marsh habitat in 2020 (+ 0.13 m SLR) which is an artifact of the classification bins based on all vegetation observed in SFBE. Plant communities then return to relatively the same distribution projected in 2000 between 2030 (+ 0.13 m SLR) and 2050 (+ 0.44 m SLR). However, by 2060 (+ 0.57 SLR) most of the marsh will transition to low marsh plant communities. By 2090 (+ 1.05 m SLR) the marsh is projected to transition completely to mudflat.

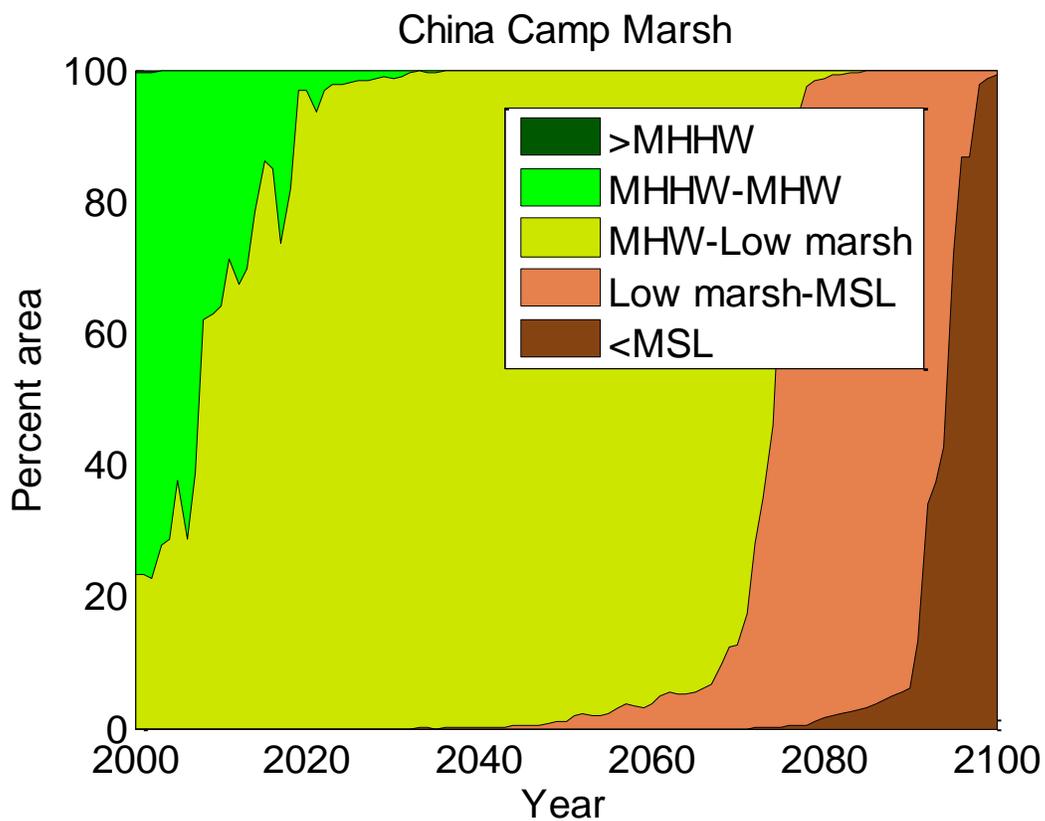


Figure C-8. Area of China Camp within a given tidal range for the duration of the simulation period.

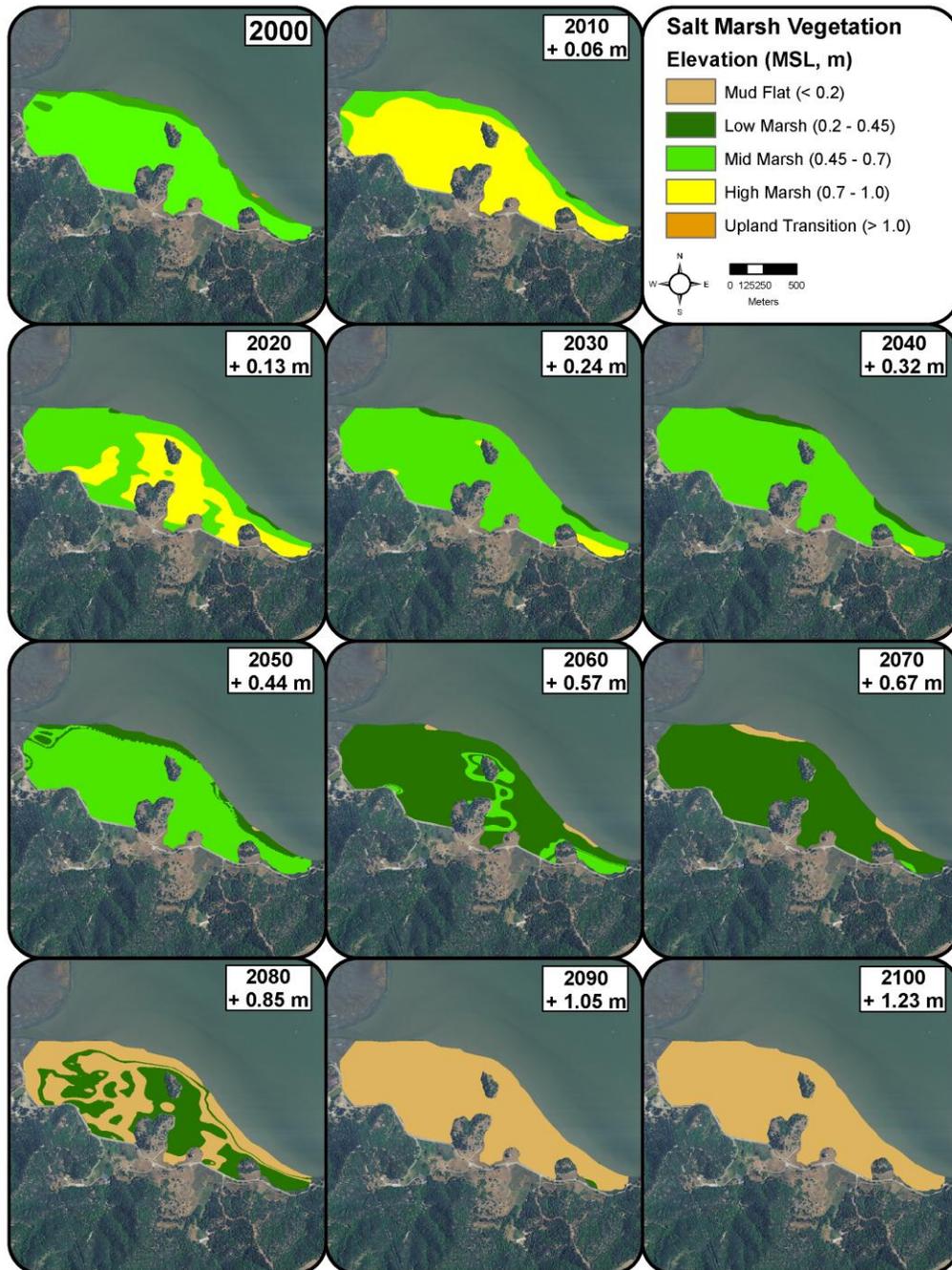


Figure C-9. China Camp WARMER results in terms of plant communities: mudflat, low, mid, or high marsh, or upland transition.