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Freshwater inputs and tidal marsh elevation in Elkhorn Slough

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Relevant publications:

García-García, A., M. Leavey, and **E. B. Watson**. 2013. High resolution seismic study of the Holocene infill of the Elkhorn Slough, Central California. *Continental Shelf Research* 55: 108-118.

Wasson, K., **A. Woolfolk**, C. Fresquez. 2013. Ecotones as indicators of changing environmental conditions: rapid migration of salt marsh–upland boundaries. Estuaries and Coasts 36:654-664

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Watson, E.B., K. Wasson, G.B. Pasternack, **A. Woolfolk**, E. Van Dyke, A.B. Gray, A. Pakenham, and R.A. Wheatcroft. 2011. Applications from paleoecology to environmental management and restoration in a dynamic coastal environment. *Restoration Ecology* 19: 765-775.

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ABOUT THE ELKHORN SLOUGH TECHNICAL REPORT SERIES

The mission of the Elkhorn Slough Foundation and the Elkhorn Slough National Estuarine Research Reserve is conservation of estuarine ecosystems and watersheds, with particular emphasis on Elkhorn Slough, a small estuary in central California. Both organizations practice science-based management, and strongly support applied conservation research as a tool for improving coastal decision-making and management. The Elkhorn Slough Technical Report Series is a means for archiving and disseminating data sets, curricula, research findings or other information that would be useful to coastal managers, educators, and researchers, yet are unlikely to be published in the primary literature.

Executive Summary

This analysis reveals that the tidal marshes in Elkhorn Slough that have proved most resilient to local sea level rise are the ones that had the greatest freshwater influence, highlighting the important role of freshwater inputs in future marsh survival. A striking example of this pattern is found in the Moss Landing area, in front of and across from Moss Landing Marine Laboratories. This is one of the healthiest marshes in the entire estuary, having undergone expansion while most Elkhorn Slough marshes are contracting. This is almost certainly due to its proximity to Tembladero Slough freshwater sources, which bring sediments and lower salinity, both of which increase marsh ability build in elevation and to track sea level rise. We also highlight other areas in the estuary that historically received freshwater inputs and that still maintain greater elevation and resilience today, emphasizing the importance of future freshwater inputs for marsh survival under future sea level rise scenarios.

Introduction

Sea level rise (SLR) is projected to rise by 20-180 cm over next century, and tidal marshes will need to build in elevation to track SLR in order to avoid drowning. In order to do this, marshes need to build vertically through sediment accretion and peat formation. Sediment accumulation that builds salt marshes come s mainly from watershed-derived mineral sediment, while peat formation relies on the production and preservation of wetland organic material like plant litter, and belowground material such as roots and rhizomes. Pickleweed dominates Elkhorn tidal marshes where salinity is marine, but California marshes include tules (sedge family), cattails and ditch grass when salinity drops below 18 ppt. As freshwater influence increases, plant productivity increases, and accretion usually is dominated by peat accumulation. This contributes to elevation gains needed to track sea level rise.

In the past, freshwater sources in Elkhorn Slough's tidal habitats included Watsonville and Carneros Creek, the Salinas River and Tembladero Slough, and springs that occurred within the tidal marsh and along the marsh-upland border. Brackish plants have been reported from historical times, when there was greater freshwater input. Today, freshwater inputs are presumably reduced relative to the past, due to river diversions, reclamation of lakes that fed Tembladero Slough, and groundwater overdraft.

This report examines the relationship between past and present freshwater inputs and tidal marsh elevations in Elkhorn Slough.

Methods

As part of a project to reconstruct past wetland distribution and character, approximately 90 sediment cores were collected from Elkhorn Slough in a grid pattern covering 400 ha. Sediment cores are a means to reconstruct past conditions in accreting environments, such as lakes, wetlands. Cores were classified by habitat (tidal flat vs. wetland), and macrofossils were used to classify marsh organic sediments into salt marsh and sedge peat. Sedge peats were found where freshwater inputs promoted brackish plant growth.

In addition, historical tidal wetland surveys, maps, and aerial photographs were collected and georeferenced using ArcGIS 10.2 (Table 1). Data for salt and brackish marshes in Elkhorn Slough were digitized and shapefiles created for both habitat types.

Table 1. Historic surveys, maps, and aerial

Date	Description	Origin
1854	Part of the Coast of Cal. from Pajaro River Southward topographic sheet (T473)	U.S. Coast Survey
1854	Field Notes of Surveys of Township and Range Lines. Southern Boundary of T.12S. R.2E.	Day, Sherman, U.S. Surveyor General
1898	Map of a survey made for Mrs. Winifred C. Tarpy et al as part of the Carneros Rancho	Herrmann, A.T.
1937	Panchromatic aerial photograph, 1:20,800 scale, 0.66 m pixel^{-1}	U.S. Department of Agriculture/Fairchild Aerial Surveys, Inc.

Elevation data used were from Light Detection and Ranging (LIDAR) elevation surveys collected in 2010 and acquired from the California Coastal Conservancy. LiDAR bare earth digital elevation models were post-processed based on plant cover datasets, and melded with a bathymetric data model to produce a high quality (~<10cm vertical accuracy) topographic-bathymetric dataset for Elkhorn Slough. In ArcGIS 10.2, brackish patches detected from sediment cores and/or historical sources were overlaid on LIDAR data, creating a series of maps. Brackish patches were identified only where at least two independent sources indicated past brackish plants, and only sites that were previously undiked were considered. Diked marshes tend to subside over time because of peat oxidation. Also mapped was the marsh elevation adjacent to Moss Landing Marine Laboratories, along the Old Salinas River Channel, site of today's main freshwater flow into the estuary.

Results

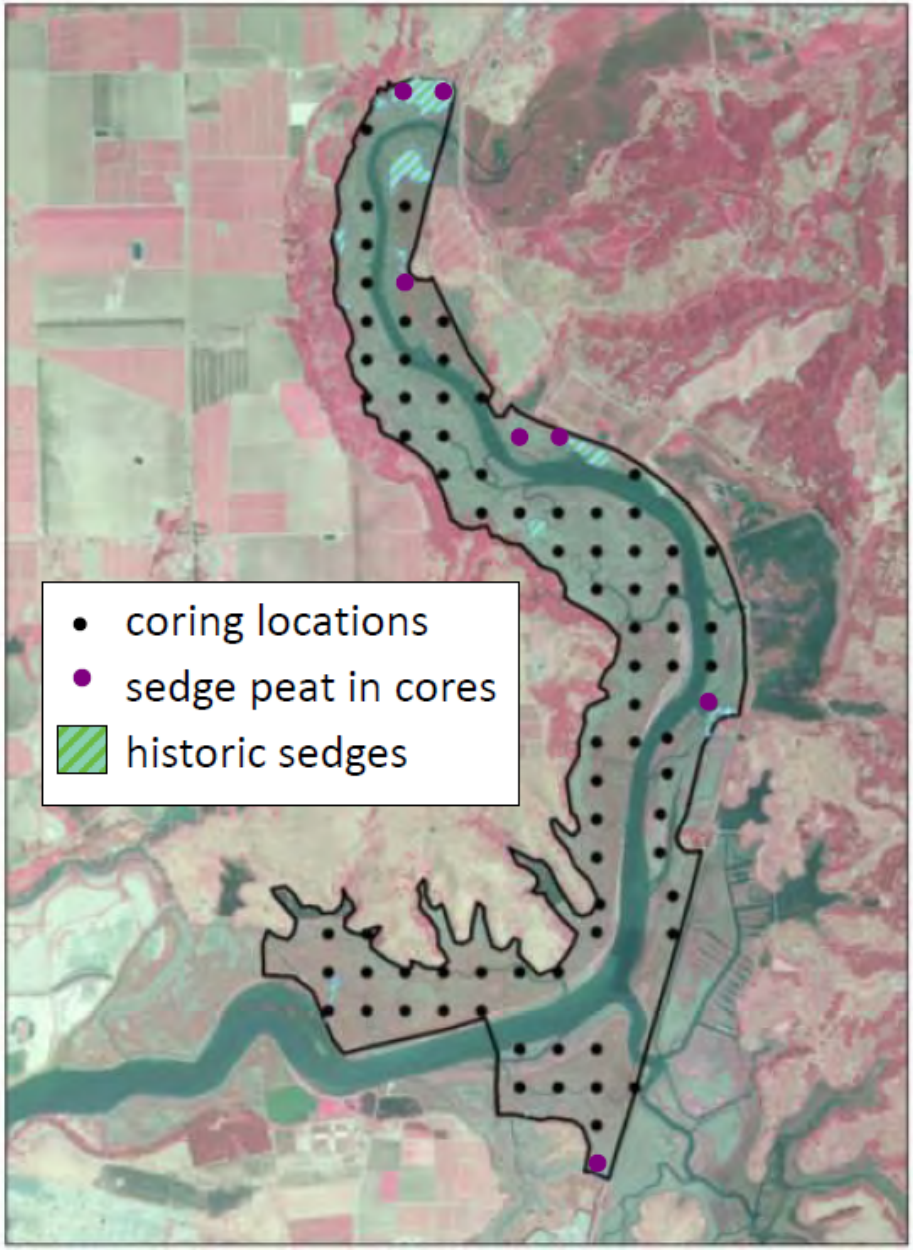
Sediment cores and historical mapping both uncovered a patchy distribution of brackish plants in Elkhorn Slough's tidal wetlands in the past (Figure 1). Areas identified as historic brackish patches are today dominated by salt marsh plants, primarily pickleweed.

The comparison between past brackish plant distribution and marsh elevations reveals a close relationship between past habitat type and high elevations, particularly relative to surrounding wetlands (Figures 2-5). The map of the Old Salinas River Channel marsh where freshwater flows enters the system today also reveals very high elevations (Figure 6).

Discussion

High elevation marsh (at or above MHHW) is rare in Elkhorn Slough (Figure 7). These uncommon higher sites represent "elevation capital" for sensitive salt marshes, providing resilience in face of sea level rise. Many of these rare high marsh sites are closely related to past or current freshwater inputs, highlighting the role of freshwater in tidal marsh sustainability in the long term.

Many of the historic freshwater inputs that promoted brackish marsh and high marsh productivity have been lost over the last 100 years. Freshwater springs that were once mapped in Elkhorn's tidal marshes are today marine. The Salinas River only occasionally contributes freshwater to the Old Salinas River Channel (OSRC) and its tributary estuaries, relative to 19th century conditions. Freshwater lakes that fed freshwater to Tembladero Slough have been reclaimed, reducing another source of freshwater flow into the OSRC, as well as Moro Cojo Slough and Elkhorn Slough. Remaining freshwater inputs appear to result in high marsh elevations where they enter just west of the Moss Landing Marine Laboratories, perhaps through mineral sediment delivery and promotion of high plant productivity. Recent marsh recolonization in formerly diked wetlands has been documented near the mouth of Elkhorn Slough. Future studies should explore the relationship of that new recruitment to freshwater inputs from Tembladero and the OSRC.



Historic sedge distribution sources

US Coast Survey T-473-8 (1854)

Township & Range survey notes (1854)

A.T. Hermann, Carneros Rancho (1898)

Aerial photographs (Nov 1937)

7 of 89 cores

=

7.9% of wetlands, at least ca. 200 CE

by 1900 < 5%

- Patchy distribution of sedges
- Suggest altered hydrology

Fig. 1. Distribution of brackish marshes (plants in sedge family) based on sediment cores and historical maps and aerials.

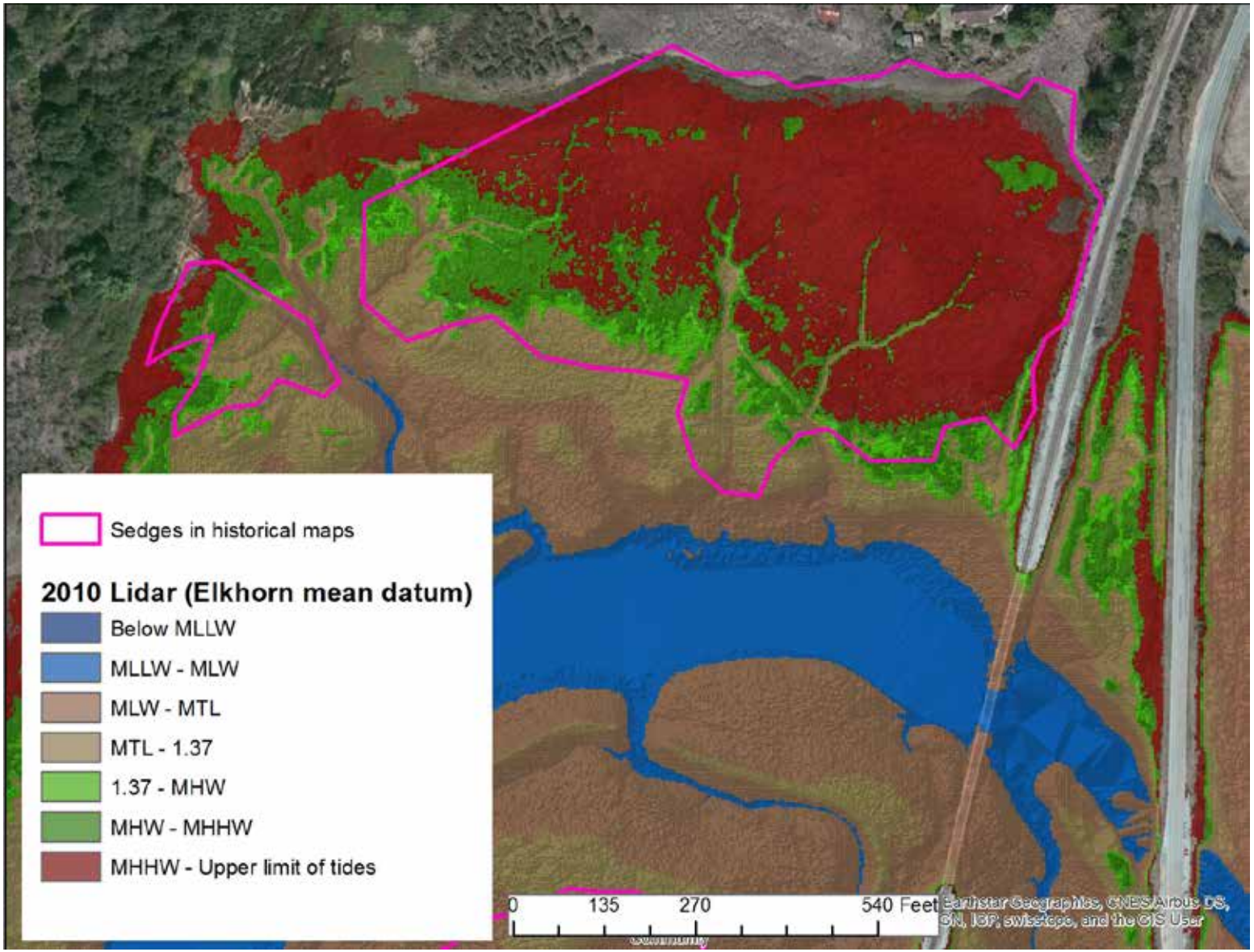


Fig 2. North end of Elkhorn Slough: Hudson's Landing. Data sources: 1) pollen from sediment cores, 2) 1937 aerial. The marsh that once existed between the main channel (blue) and historic brackish marsh (pink outline) has since drowned. The historical brackish marsh continues to be high in elevation today, mainly above MHHW (shown in red).

Fig 3. Northeast portion of Elkhorn Slough: Kirby Park area. Data sources: 1) pollen from sediment cores, 2) 1898 mapped survey. The marsh that once grew to the northwest of the historical brackish marsh has drowned since the mid-1900s, and is shown in brown (mudflat) on the left half of this map.

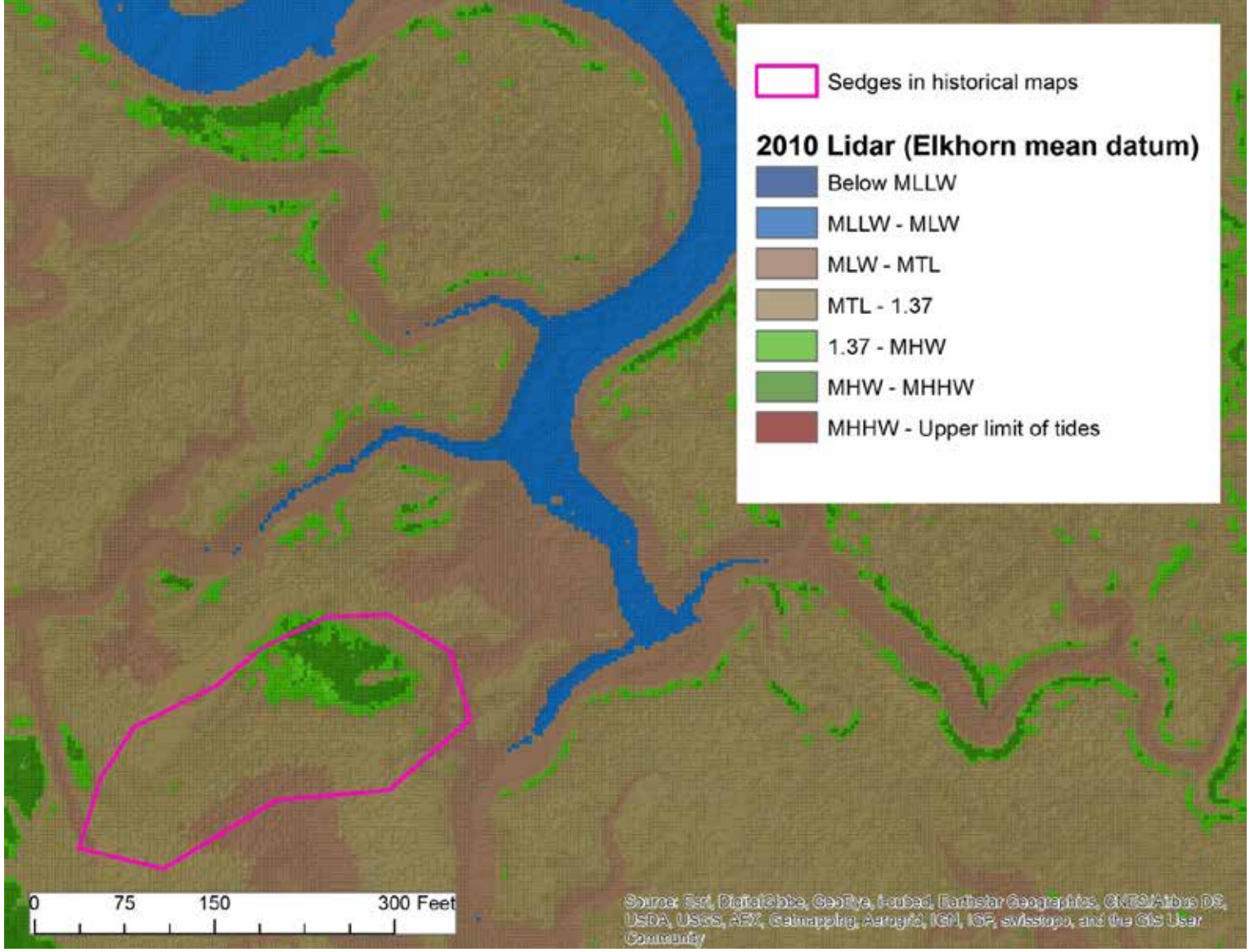


Fig 4. Northwest portion of Elkhorn Slough: Big Creek. Data sources: 1) 1854 survey, 2) 1937 aerial. This marsh has almost completely drowned, with only a few remnants left along tidal creeks and the upland edge. This former brackish patch is perhaps the only remaining marsh in the area not directly adjacent to a creek or upland, and corresponds to an old "tule patch" first described in field notes in 1854. While not as high as the marshes on previous slides, its elevation is relatively high for the area.

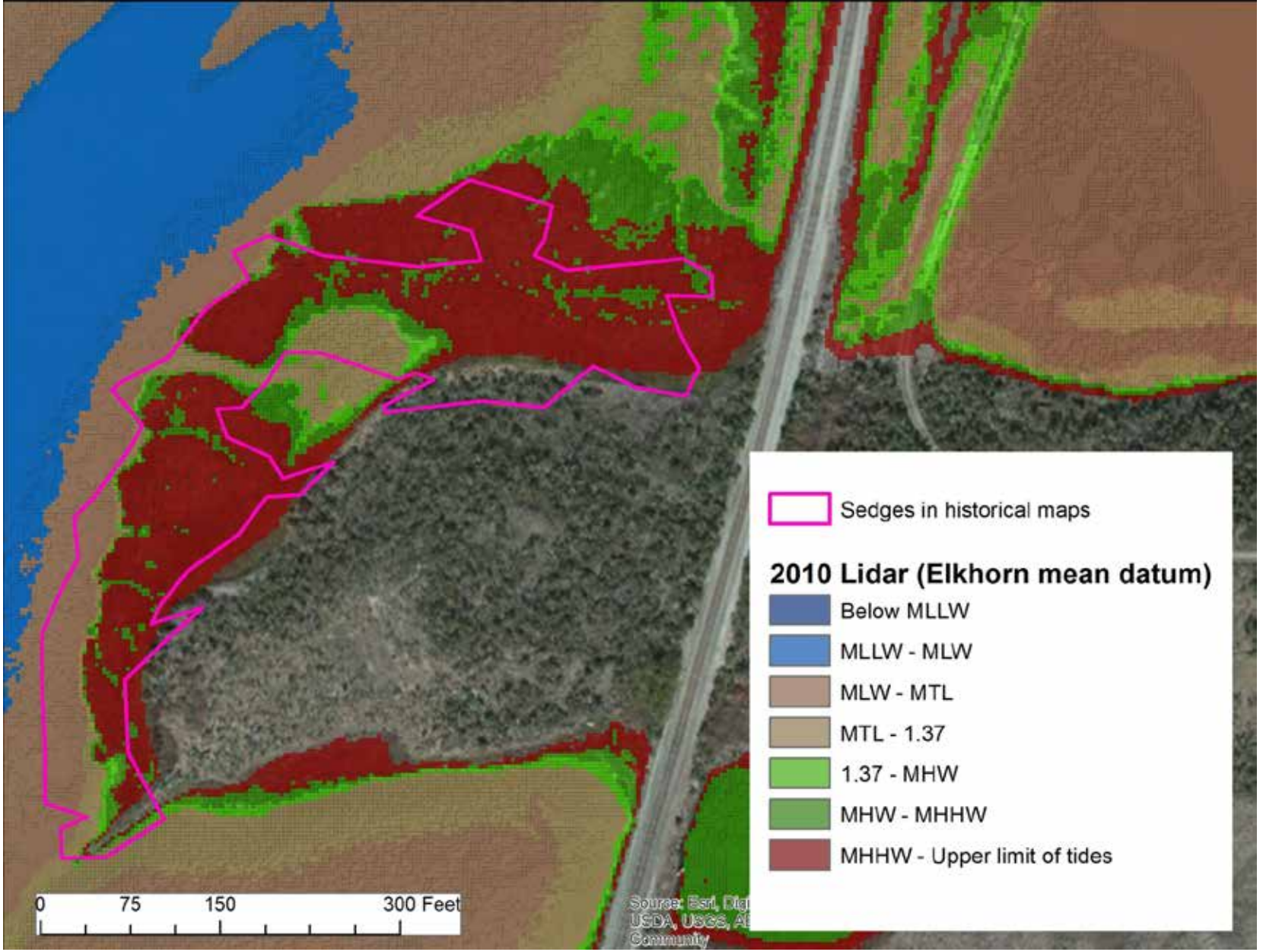


Fig 5. Mid-portion of Elkhorn Slough: Coyote Island. Data sources: 1) pollen data from sediment cores, 2) 1937 aerial. The pond feature in the middle may have been a freshwater spring. Today the historically brackish marsh remains high.

Fig 6. Old Salinas River Channel where freshwater enters from Potrero gates today. This slide does not include historical data. The marsh is very high at this location. Sediment sources may include marine sources, sand dunes, and freshwater that might increase marsh productivity.

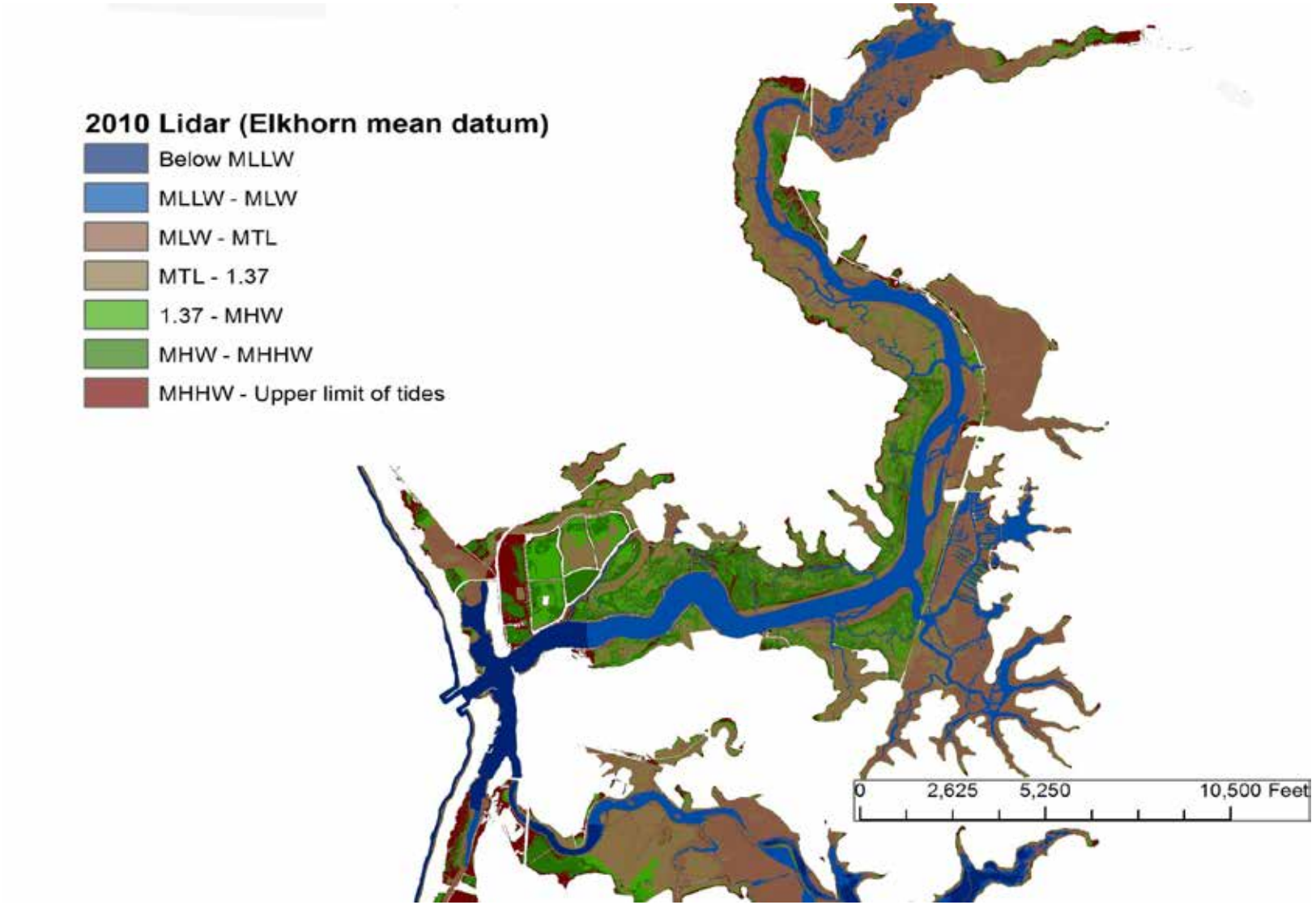


Fig. 7. Overview of Elkhorn Slough tidal elevations. Despite appearing frequently in the preceding slides, high marsh (shown in red) is rare in the estuary. About 50% of the historical marshes in Elkhorn Slough have been converted to mudflat through diking and ecological drowning due to low relative elevations. Many of the remaining marshes are relatively low and susceptible to predicted sea level rise without new sources of sediment.