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Central Coast Watershed Studies

CCoWS

Some observations of
seawater intrusion in
surface waters of the
Moro Cojo Watershed,
Monterey County,
California

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Executive Summary

This study was conducted as part of a class project by students in the Advanced Watershed Science and Policy (ENVS660) course at California State University at Monterey Bay (CSUMB).

The Moro Cojo Slough has many water quality impairments. Tide gate failure at the downstream terminus of the slough has added the threat of increasing saltwater intrusion into upstream freshwater habitats (Potter and Porter 2014). We sought to determine and monitor the extent of this intrusion. We found that saline conditions exist throughout the majority of the slough. The furthest upstream salinity site was at the Castroville Boulevard crossing near North Monterey County High School, where hypersaline conditions exist. We compared salinity conditions from measurements taken in 2005 to measurements taken in 2015. We found a significant difference in mid-depth salinity concentrations between 2005 and 2015 (Welch's t-test; $p=0.002$; $\alpha=0.05$). We compared the 2015 salinity data by depth. We found a significant difference in salinity concentrations between the bottom and mid-depth samples for the 2015 dataset (Welch's t-test; $p=0.0001$; $\alpha=0.05$). During the salinity study, we also monitored temperature and dissolved oxygen. We found a consistent trend of temperatures and dissolved oxygen values throughout the slough. Dissolved oxygen values tended to be hypoxic near the bottom of the channel, and super-saturated towards the top, which is common in this type of estuarine environment. Increased salinity could adversely affect California tiger salamanders (*Ambystoma californiense*), Santa Cruz long-toed salamanders (*Ambystoma macrodactylum croceum*), California red-legged frogs (*Rana draytonii*), and their breeding habitat. Increased salinity can also affect farming operations in the area, which contribute substantially to the local economy.

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1 Introduction

1.1 Background

Wetlands provide many valuable ecosystem services including improvement of water quality, flood protection, carbon sequestration, erosion control, and important wildlife habitat (Wall 1998). Many wetlands in the United States have been lost to commercial or agricultural conversion. California has lost 91% of its original wetlands primarily due to conversion for agricultural purposes (USGS 2007). The loss of these important wetlands and their ecosystem functions has substantial consequences on the ecological health and stability of the landscape (Turner et al. 2000).

Monterey County's economy is largely dependent on agriculture. Nearly half of the counties jobs are related to farming or food manufacturing within the \$4.4 billion agricultural sector (Monterey Farm Bureau 2015). Monterey County supplies a majority of the United States crops including strawberries, apples, broccoli, cauliflower and artichokes (City of Watsonville 2015). Given the area's agricultural importance, farmland is constantly expanding and has historically encroached upon the County's wetlands. Nearly 24% of the Elkhorn Slough Watershed has become cultivated agriculture, with the most productive farms being located in the Springfield Terrace and Moro Cojo Sloughs (Elkhorn Slough Foundation 2015).

Moro Cojo Slough was historically a freshwater source, though more recently it has become saline. Prior to salinity increases, Moro Cojo Slough provided substantial freshwater resources and supported large salmonid spawning populations (Coastal Conservation and Research, Inc. 2008). The over use of freshwater aquifers in the area has resulted in subsurface seawater intrusion. Additionally the failure of the tide gates has exacerbated the salinity problem within Moro Cojo Slough. The

intrusion of seawater in Moro Cojo Slough has damaged local habitat value and increased farmer's reliance on reclaimed water.

1.2 Salinity

Salinity is one of the largest factors limiting crop productivity across the United States, accounting for nearly \$12 billion in costs annually (Pitman and Lauchli 2002). Increases in salinity can cause a variety of issues, including significant crop yield reductions (Schwabe et al. 2006). Decline of crop yields would be extremely detrimental to the local Monterey County economy. Salinity fluctuations can also be harmful to natural systems with changes in salinity regimes resulting in shifts of plant and wildlife communities resulting in significant loss of biodiversity within wetlands (Neubauer 2013). An increase in saline water within Moro Cojo Slough may have ramifications for plants and wildlife, including impacts to federally endangered Santa Cruz long-toed salamanders (*Ambystoma macrodactylum croceum*), federally threatened California tiger salamanders (*Ambystoma californiense*), and California red-legged frogs (*Rana draytonii*): all of which are known to occur within the Moro Cojo Slough watershed (CNDDDB 2015).

1.3 Study area

The study area is located along Monterey Bay on the central California coast, encompassing a large portion of the Moro Cojo Slough watershed, which is comprised of approximately 44 km² (Figure 1; CCWG and CCR 2013). The Moro Cojo Slough drains into Moss Landing Harbor where the water can migrate into the Elkhorn Slough with the incoming tide (Dr. Fred Watson, CSU Monterey Bay, pers. comm. 3/13/2015). The Moro Cojo Slough is designated as a California State Marine Reserve (SMR), and the Elkhorn Slough has designated areas of State Marine Conservation Area (SMCA) and SMR (CDFW 2014). California SMRs and SMCAs are intended to conserve and protect marine habitat and marine life.



Study Area Moro Cojo Slough

0 0.5 1 km

Map Author: CSUMB ENVS 660 Class
Data Source: USDA NAIP 2014

Figure 1. Moro Cojo Slough on the Central Coast of California, draining into the Elkhorn Slough and the Monterey Bay.

1.4 Project goals

The project goals were to conduct a salinity assessment throughout the Moro Cojo Slough and compare it to historical data. Our documentation of current aquatic conditions within Moro Cojo may also inform any mitigation efforts related to the tide gate failure and recent drought conditions.

2 Methods

On November 19, 2015 we completed a salinity transect at 12 locations (S1 – S12) extending from Castroville Boulevard to the Highway 1 culverts (Figure 2). For each location we measured salinity and temperature, at various depths within the water column. We recorded depths and values found on the surface, below the halocline, and on the bottom at each site.

We compared these data to historic salinity values to determine the extent of seawater intrusion within the Moro Cojo Slough. Log transformed salinity measurements from 2005 were compared to measurements taken in 2015 with Welch's two-sample t-test. The two sample t-test was also used to compare salinity of the top and bottom of the water column in 2015 (Appendix).



Figure 2. Shows the locations where salinity monitoring occurred.

3 Results

We found evidence that the 2005 mid-depth salinity data were not normally distributed (Shapiro-Wilk; $p=0.001$; $\alpha=0.10$). We subsequently log-transformed the 2005 and 2015 mid-depth salinity datasets to meet normality conditions (Shapiro-Wilk; $p=0.61$; $p=0.93$). Once these data were transformed, we found a significant difference in mid-depth salinity concentrations between 2005 and 2015 (Welch's t-test; $p=0.002$; $\alpha=0.05$).

Similarly, we found evidence that the 2015 bottom salinity data were not normally distributed (Shapiro-Wilk; $p=0.096$; $\alpha=0.10$). We subsequently log-transformed the bottom and mid-depth 2015 salinity datasets to meet normality conditions (Shapiro-Wilk; $p=0.136$; $p=0.606$). Once these data were transformed, we found a significant difference in salinity concentrations between the bottom and mid-depth samples for the 2015 dataset (Welch's t-test; $p=0.0001$; $\alpha=0.05$).

In situ measurements from the November 19, 2015 salinity transect were relatively uniform throughout Moro Cojo Slough. Sites S1 through S12 have been affected by the tide gate failure, causing seawater to migrate through the entire slough (Figure 3). Each site had a thin 0.02 m to 0.05 m layer of freshwater on top of a much deeper, dense layer of saltwater (Table 1). Salinity of the saltwater layer ranged from 22.5 ppt to 37.1 ppt with the highest values being found at the upstream sampling locations. Temperature remained consistent at each site with the lowest recorded values being found on the bottom. Dissolved oxygen also followed a consistent trend throughout the slough. This trend included lower values on the bottom of the channel and supersaturation occurring in the topmost layer. Site 7 was an exception, with readings at the bottom of the channel of 2.2 mg L^{-1} and 2.64 mg L^{-1} in the topmost layer. These low values were found within a pulse of suspended sediment.



Moro Cojo Salinity Comparison

Map Author: CSUMB ENVS 660 Class
Data Source: USDA NAIP 2014

Figure 3. Salinity data taken November 19, 2015, after the tide gate failure, compared to samples taken in April 2005 (CCWG and CCR 2008).

4 Discussion

Salinity is currently a major problem affecting surface water conditions, habitats, and groundwater within the Moro Cojo Slough watershed. Results of the salinity transect show that seawater has encroached

throughout the slough, most notably seen in the 36.7 ppt salinity concentration found at the furthest upstream location. This problem stems from the tide gate failure. Without action resolving that failure, elevated salinity will likely persist. Should the extremely saline water continue to dominate the slough, Moro Cojo may undergo a habitat conversion into a salt marsh. This would adversely affect species which rely on freshwater habitats within the slough, particularly as breeding habitat. The Moro Cojo provides habitat to several endangered and threatened amphibians, including the Santa Cruz long-toed salamander, the California tiger salamander, and California red-legged frog which are known to occur within the Moro Cojo watershed (CNDDDB 2015). These habitats are also essential for a variety of upland and wetland associated species of birds. In addition, the damage resulting from elevated salinity will eventually spread beyond the slough to neighboring agricultural fields, resulting in decreased crop yields.

5 Conclusion

The Moro Cojo Slough is currently facing potential impact of increasing salinity associated with the tide gate failure (CCRWQCB 2013). This report and the associated data indicate that salinity has increased substantially throughout the Moro Cojo Slough relative to a previous study from 2005, and that the water at the furthest upstream end of the MCS is now hypersaline (CCWG and CCR 2008). This is likely due in part to the tide gate failure and the lack of substantial amounts of freshwater influence over the past 3 years during the drought. Without these freshwater inflows, the hypersaline water has not been flushed out of the system. This increased salinity will likely impact a variety of plants and wildlife, including federally threatened and endangered species present within the Moro Cojo Slough watershed. The Moro Cojo Slough is in danger of shifting into a saltmarsh habitat should saline conditions persist.

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7 Appendix

R-code

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#2005 vs 2015
SAL2005 = c(10,18,1,2,1,0.1,1,0.5)
SAL2015 = c(29.6,28.2,24.4,23.7,25.8,25.2,23.4,20.7)
shapiro.test(SAL2005)
shapiro.test(SAL2015)
LSAL2005 = log(SAL2005)
LSAL2015 = log(SAL2015)
shapiro.test(LSAL2005)
shapiro.test(LSAL2015)
t.test(LSAL2005,LSAL2015)

#Bottom of water column vs. just below the halocline (2-5cm below
surface)
SAL_BOT = c(29.5,29.5,25.6,28,28.1,28.2,32.1,26.2,35.3,36,37.1,36.7)
SAL_UP = c(29.6,28.2,22.5,24.4,24.1,23.5,23.7,25.8,25.2,24.3,23.4,20.7)
shapiro.test(SAL_BOT)
shapiro.test(SAL_UP)
LSAL_BOT = log(SAL_BOT)
LSAL_UP = log(SAL_UP)
shapiro.test(LSAL_BOT)
shapiro.test(LSAL_UP)
t.test(LSAL_BOT,LSAL_UP)
```