SCOPE OF WORK

TITLE: A Carbon Sequestration Research and Demonstration Project in the Brackish Coastal Wetlands of Suisun Marsh

BACKGROUND AND JUSTIFICATION

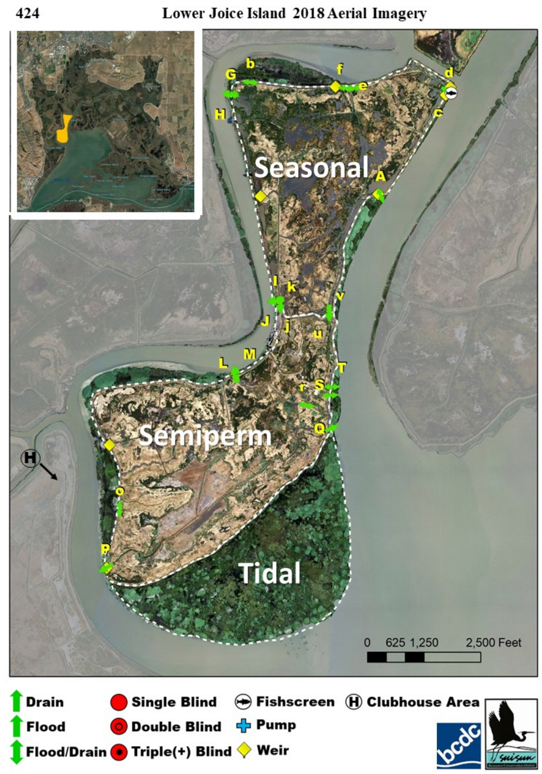
Coastal wetlands have the potential to play a significant role in mitigating climate change by pulling carbon from the atmosphere and storing it long-term in soils (Taillardat et al. 2020). By many estimates, coastal wetlands and associated estuary complexes are substantially more effective and efficient at capturing and storing carbon than terrestrial forests (Chmura et al. 2003; McLeod et al. 2011). Coastal wetlands contain more total ecosystem carbon than terrestrial ecosystems, primarily due to carbon-rich soils that are resistant to decomposition processes, which can be several meters in depth (Kauffman et al. 2020). Lands that support wetland functions are strong carbon sinks compared to lands used for agriculture (Knox et al. 2015), and if fully drained, former tidal wetlands can become greenhouse gas sources (Kroeger et al. 2017). Coastal wetlands can also increase carbon storage over time by building elevation, as long as inundation thresholds are not surpassed (Thorne et al. 2018).

While coastal wetlands store and accumulate carbon in soils, the impact that wetlands have on global climate depends on the eventual fate of stored soil carbon. Soil carbon can be stored for millennia in anoxic soils but may leave wetlands both vertically as greenhouse gases and horizontally as dissolved carbon. Lateral fluxes of carbon dissolved in tidal waters likely represent a major portion of coastal wetland carbon budgets which can affect their contribution to climate change mitigation (Wang et al. 2016; Bogard et al. 2020; Schutte et al. 2020). Vertical fluxes of carbon as greenhouse gases also represent a major portion of coastal wetland carbon budgets, but whether emissions have a net cooling effect on climate depends on the type of greenhouse gases emitted (Rosentreter et al. 2021). Methane has ~25-times higher warming potential than carbon dioxide (Bridgham et al. 2013) and may reduce net climate mitigation. Climate mitigation by coastal wetlands is therefore dependent on conditions affecting fluxes of soil carbon, including plant composition, hydrology, and soil characteristics such as salinity.

We are in the early stages of understanding the role brackish wetlands can play in climate mitigation including which management practices may maximize carbon sequestration. Permanently flooded, impounded wetlands can sequester impressive amounts of carbon influenced by water depth and flow patterns (Miller 2011; Knox et al. 2018; Windham-Myers et al. 2018). For example, carbon burial rates in SF Bay tidal salt marshes indicate that they may sequester 0.87-1.2 metric tons of C/ha/yr (Callaway et al. 2012). However, the climate mitigation value of semi-permanent or seasonally impounded wetlands is less known, especially in a brackish setting where net mitigation values are higher since soil salinity may suppress methane emission (Poffenbarger et al. 2011). Pond features in tidal and especially seasonally-impounded brackish wetlands provide robust habitat for wildlife (Casazza et al. 2021), but the impact of specific hydrologic management practices on their climate mitigation potential remains unstudied.

The 116,000-acre Suisun Marsh region supports the largest brackish marsh on the west coast and serves as the resting and feeding ground for resident waterbirds and thousands of migrants on the Pacific Flyway. Its 52,000 acres of wetlands supports more than 221 bird species, 45 mammalian species, 16 herptile species, and more than 40 fish species, and the wetlands have been managed for wildlife values since the late 1800s. If carbon sequestration is similar to the SF Bay tidal salt marshes (Callaway et al. 2012), the region has the potential to sequester 18,000 metric tons of carbon per year. Thus, we propose to undertake a demonstration project to examine the climate mitigation value of Suisun Marsh brackish wetlands and to determine best management practices (BMPs) for maximizing carbon sequestration while maintaining its substantial fish and wildlife habitat values and biodiversity.

Our project team of nongovernmental, state, and federal agency partners includes the California Waterfowl Association (CWA), Suisun Resource Conservation District (SRCD), and U. S. Geological Survey Western Ecological Research Center (USGS). CWA, one of California's largest and oldest wetlands restoration preservation organizations, and its project partners are uniquely positioned to conduct this innovative research and demonstration project to broaden understanding of how wetlands can be leveraged to contribute to climate mitigation. The demonstration project will be conducted on the 1330-acre Lower Joice Island (Fig. 1), located between Suisun and Montezuma Sloughs along Suisun Bay and owned and managed by SRCD since 2001 for the purpose of advancing conservation management. The demonstration project will identify, develop, and test management practices that optimize carbon sequestration while achieving wildlife habitat objectives. Findings from the project will be applicable to coastal wetland restoration and management practices across the state and will be informative for wetland owners and managers throughout California and the west coast. This work also will support national efforts to inform how management impacts the carbon balance of wetlands (Crooks et al. 2018).



OBJECTIVES

The goal of this project will be to examine the potential for maximizing carbon sequestration in managed seasonal, semi-permanent, and tidal wetlands of brackish Suisun Marsh. The demonstration project will be conducted at Lower Joice Island (Fig. 1) owned and managed by the Suisun Resource Conservation District, a special district of the state of California.

1. Install resilient water control structures to improve wetland management at Lower Joice Island.
2. Test best management practices for sequestering carbon in brackish wetlands of Suisun Marsh..
3. Assess effectiveness of different BMPs and suggest an approach to maximize carbon sequestration in brackish wetland management.

PROCEDURES

Obj 1. Install resilient water control structures to improve wetland management at Lower Joice Island.

Lower Joice Island is a large (1330 acres) wetland that includes seasonal, semi-permanent, and tidal units as water flows from north to south along an elevation gradient (Buffington et al. 2019). Each of these wetlands have distinct hydrological cycles that result in development of different vegetation communities, carbon sequestration potential, and varying carrying capacity for waterbird species (Livolsi et al. 2021). For this project, we propose to install resilient water control infrastructure to improve water control management, especially for future drought conditions (Dettinger and Cayan 2014, Dettinger et al. 2016; Diffenbaugh et al. 2015). We will upgrade 2 cast-iron intake gates along Suisun Slough in the north unit with recently developed, high efficiency HDPE or stainless-steel combination screw-flap gates for improved flows. At the 4 interior risers dividing the north and south units, we will add weir gates (north side) and canal gates (south side) to isolate the seasonal and semi-permanent wetlands. These water control structures will be more durable and provide better flow management to allow for adjustments for different water schedules that influence vegetative growth and associated carbon sequestration.

Obj. 2. Test best management practices for sequestering carbon in brackish wetlands.

We will examine differences in carbon sequestration and methane production at two different levels. On the first level, we will compare differences in sequestering carbon among the seasonal, semi-permanent, and tidal wetlands (*see* Jones et al. 2021). This will include examining large plot samples (n=3-5) of areas within these 3 wetlands for each major different vegetation functional type (n=3-5 plots x 3 wetlands x #types) to look at above- and belowground biomass. On the second level, we will look at plots within the seasonal wetlands to examine treatment effects of mowing, discing, burning, and adding nutrients. This will include treated (n>5) and untreated reference (n>5) plots. The frequency or timing of mowing may result in increased growth of some wetland plants, so we will establish a number of treatment and reference plots to examine this practice. Similarly, discing may cause oxidation of wetland soils, but integrating plant biomass into the soils at different levels may enhance carbon capture. We would use a series of treatment and reference plots to examine this practice.

Marsh burning has long been used as a valuable wildlife management tool in wetlands to decrease unproductive areas of dead vegetation, but burning aboveground plant biomass releases carbon to the atmosphere. However, the benefit of the resulting vegetative growth for carbon sequestration may greatly exceed the loss of carbon from burning but has never been studied. We will use fire curtains to isolate burn treatment plots (n=3-5) for comparison with reference sites (n≥5) to test that practice. Finally, adding nutrients such as nitrogen or phosphorus may increase plant growth and sequestration, but recent studies in the northeastern U. S. have examined nutrient additions and found that respiration increased more than primary production (Geoghegan et al. 2018; Mozdzer et al. 2021). However, similar studies have not been conducted in the arid western U. S. in brackish wetlands, so we propose to see if the response to nutrient additions is similar in this region.

With the prospects of increasing droughts and diversions in the upper estuary, SRCD and USGS have submitted a Department of Fish and Wildlife Proposition 1 proposal to examine effects of soil salinities on wetland plants. Increasing soil salinities and timing of inundation are expected to have negative effects on plant growth used for cover and food by wildlife (Buffington et al. 2020; Janousek et al. 2020). If these complementary mesocosm experiments are funded, we could integrate the experiments with the effort to examine how conditions affect wetland carbon sequestration. Also, we will pursue other collaborative opportunities with existing USGS studies (East Bay Regional Park's Brown's Island, Department of Water Resource's Dutch Slough, Solano Land Trust's Rush Ranch), agencies, universities (including graduate students and interns), and NGOs.

Obj. 3. Assess the effectiveness of different BMPs and suggest an approach to maximize carbon sequestration in brackish wetland management.

We will use several methods to assess wetland carbon and climate mitigation under the treatments described in Obj. 2. Total ecosystem carbon stock will be measured using soil cores and plant biomass samples. Soil samples will be collected with a gouge auger and subsampled to depth (to 3 m across inundation types, and to 15 cm across treatments). Each core section will be analyzed for percent moisture, bulk density, and total carbon. Cores will be collected 3 times during the growing season in the seasonal wetland and once in the semi-permanent and tidal wetlands. Plant carbon stocks will be estimated by harvesting standing biomass at the end of the growing season and drying to get dry weight per area. Plant carbon stocks will be collected 3 times during the growing season in the seasonal wetland and once in the semi-permanent and tidal wetlands.

Carbon accumulation rates will be measured using Surface Elevation Tables (SETs) with feldspar marker horizons. SETs and accretion from feldspar horizons will be measured several times per year over the course of the study providing total material accumulated per area. Subsamples will be analyzed for bulk density and total carbon content to determine carbon accumulation rates at each wetland type. Additional feldspar markers will be deployed to measure accretion response to treatments, and will be measured 3 times during the growing season across all treatments. Dissolved carbon concentrations will be measured with 15-min measurements of fluorescent dissolved organic matter in overlying water at each site (EXO2 fDOM sensor, YSI), and discrete water samples of dissolved organic carbon (DOC) and dissolved inorganic carbon (DIC) will be processed at the UC Davis Analytical Laboratory. Water samples will be measured 3 times during the growing season in the seasonal wetland and twice in the semi-permanent and tidal wetlands. Greenhouse gas fluxes will be measured in mylar chambers with an Ultraportable Greenhouse Gas Analyzer (Los Gatos Research). Carbon dioxide uptake and methane emission will be quantified seasonally at each wetland type and will be measured in the seasonal wetland after initiating treatments.

TIMELINE: 3 years including 3 growing seasons

DELIVERABLES: 1-3 scientific publications showing results of the assessments including estimated tons of carbon sequestered, presentations at local landowner, regional management, and national science meetings, results updates on websites, newsletters, and magazines, and a final report describing best management practices for carbon sequestration.

INVESTIGATORS

Jake Messerli, Chief Operating Officer, California Waterfowl Association
Steve Chappell, Executive Director, Suisun Resource Conservation District
Robert Eddings, Regional Manager, California Waterfowl Association
John Takekawa, PhD, Operations Manager, Suisun Resource Conservation District
Karen Thorne, PhD, Research Ecologist, U. S. Geological Survey Western Ecological Research Center
Scott F. Jones, PhD, Ecologist, U. S. Geological Survey Western Ecological Research Center

LITERATURE CITED

Bogard, M. J., B. A. Bergamaschi, D. E. Butman, F. Anderson, S. H. Knox, and L. Windham-Myers. 2020. Hydrologic Export Is a Major Component of Coastal Wetland Carbon Budgets. Global Biogeochemical Cycles 34.

Bridgham, S. D., H. Cadillo-Quiroz, J. K. Keller, and Q. Zhuang. 2013. Methane emissions from wetlands: biogeochemical, microbial, and modeling perspectives from local to global scales. Global Change Biology 19:1325-1346.

Buffington, K.J., Goodman, A.C., Freeman, C.M. and Thorne, K.M., 2020. Testing the interactive effects of flooding and salinity on tidal marsh plant productivity. Aquatic Botany, 164, p.103231.

Buffington, K.J., Thorne, K.M., Takekawa, J.Y., Chappell, S., Swift, T., Feldheim, C., Squellati, A., & Mardock, D.K. 2019. LEAN-Corrected DEM for Suisun Marsh: U.S. Geological Survey data release. DOI:10.5066/P97R4ES3.

Callaway, J. C., E. L. Borgnis, R. E. Turner, and C. S. Milan. 2012. Carbon Sequestration and Sediment Accretion in San Francisco Bay Tidal Wetlands. Estuaries and Coasts 35:1163–1181.

Casazza, M. L., F. McDuie, S. Jones, A. A. Lorenz, C. T. Overton, J. Yee, C. L. Feldheim, J. T. Ackerman, and K. M. Thorne. 2021. Waterfowl use of wetland habitats informs wetland restoration designs for multi-species benefits. Journal of Applied Ecology:1365-2664.13845.

Chmura, G.L., Anisfeld, S.C., Cahoon, D.R. and Lynch, J.C., 2003. Global carbon sequestration in tidal, saline wetland soils. Global biogeochemical cycles, 17(4).

Crooks, S., A. E. Sutton-Grier, T. G. Troxler, N. Herold, B. Bernal, L. Schile-Beers, and T. Wirth. 2018. Coastal wetland management as a contribution to the US National Greenhouse Gas Inventory. Nature Climate Change 8:1109–1112.

Dettinger, M, and D. Cayan. 2014. Drought and the California Delta-a matter of extremes. San Francisco Estuary and Watershed Science.

Dettinger, M., Anderson, J., Anderson M., Brown, L.R., Cayan, D., Maurer, E. 2016. Climate Change and the Delta. San Francisco Estuary and Watershed Science, 14(3), Article 5.
Diffenbaugh, N.S., Swain, D.L., and D. Touma. 2015. Anthropogenic warming has increased drought risk in California. Proceedings of the National Academy of Science, 112(13): 3931-3936.
Geoghegan, E. K., J. S. Caplan, F. N. Leech, P. E. Weber, C. E. Bauer, and T. J. Mozdzer. 2018. Nitrogen enrichment alters carbon fluxes in a New England salt marsh. Ecosystem Health and Sustainability 4. DOI: 10.1016/j.scitotenv.2020.140927.
Janousek, C.N., Dugger, B.D., Drucker, B.M. and Thorne, K.M., 2020. Salinity and inundation effects on productivity of brackish tidal marsh plants in the San Francisco Bay-Delta Estuary. Hydrobiologia, 847(20), pp.4311-4323.
Jones, S.F., Janousek, C.N., Casazza, M.L., Takekawa, J.Y. and Thorne, K.M., 2021. Seasonal impoundment alters patterns of tidal wetland plant diversity across spatial scales. Ecosphere, 12(2), p.e03366.
Knox, S. H., C. Sturtevant, J. H. Matthes, L. Koteen, J. Verfaillie, and D. Baldocchi. 2015. Agricultural peatland restoration: effects of land-use change on greenhouse gas (CO 2 and CH 4) fluxes in the Sacramento-San Joaquin Delta. Global Change Biology 21:750–765.
Knox, S.H., Windham-Myers, L., Anderson, F., Sturtevant, C. and Bergamaschi, B., 2018. Direct and indirect effects of tides on ecosystem-scale CO2 exchange in a brackish tidal marsh in Northern California. Journal of Geophysical Research: Biogeosciences, 123(3), pp.787-806.
Kroeger, K. D., S. Crooks, S. Moseman-Valtierra, and J. Tang. 2017. Restoring tides to reduce methane emissions in impounded wetlands: A new and potent Blue Carbon climate change intervention. Scientific Reports 7:11914.
Livolsi, M. C., C. K. Williams, J. M. Coluccy, and M. T. Dibona. 2021. The effect of sea level rise on dabbling duck energetic carrying capacity. Journal of Wildlife Management. DOI: 10.1002/jwmg.22031.
Mcleod, E., Chmura, G.L., Bouillon, S., Salm, R., Björk, M., Duarte, C.M., Lovelock, C.E., Schlesinger, W.H. and Silliman, B.R., 2011. A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2. Frontiers in Ecology and the Environment, 9(10), pp.552-560.
Miller, R. L. 2011. Carbon Gas Fluxes in Re-Established Wetlands on Organic Soils Differ Relative to Plant Community and Hydrology. Wetlands 31:1055–1066.
Mozdzer, T. J., S. E. Drew, J. S. Caplan, P. E. Weber, and L. A. Deegan. 2021. Rapid recovery of carbon cycle processes after the cessation of chronic nutrient enrichment. Science of the Total Environment 750:
Poffenbarger, H.J., Needelman, B.A. and Megonigal, J.P., 2011. Salinity influence on methane emissions from tidal marshes. Wetlands, 31(5), pp.831-842.
Rosentreter, J.A., Al-Haj, A.N., Fulweiler, R.W. and Williamson, P., 2021. Methane and nitrous oxide emissions complicate coastal blue carbon assessments. Global Biogeochemical Cycles, 35(2), p.e2020GB006858.
Schutte, C. A., W. S. Moore, A. M. Wilson, and S. B. Joye. 2020. Groundwater-Driven Methane Export Reduces Salt Marsh Blue Carbon Potential. Global Biogeochemical Cycles 34.
Taillardat, P., B. S. Thompson, M. Garneau, K. Trottier, and D. A. Friess. 2020. Climate change mitigation potential of wetlands and the cost-effectiveness of their restoration. Interface Focus 10:20190129.
Thorne, K., G. MacDonald, G. Guntenspergen, R. Ambrose, K. Buffington, B. Dugger, C.Freeman, C. Janousek, L. Brown, J. Rosencranz, J. Holmquist, J. Smol, K. Hargan, and J. Takekawa. 2018. U. S. Pacific coastal wetland resilience and vulnerability to sea-level rise. Science Advances 4, eaao3270 (2018).
Wang, Z. A., K. D. Kroeger, N. K. Ganju, M. E. Gonneea, and S. N. Chu. 2016. Intertidal salt marshes as an important source of inorganic carbon to the coastal ocean. Limnology and Oceanography 61:1916–1931.
Windham-Myers, L., B. Bergamaschi, F. Anderson, S. Knox, R. Miller, and R. Fujii. 2018. Potential for negative emissions of greenhouse gases (CO 2 , CH 4 and N 2 O) through coastal peatland re-establishment: Novel insights from high frequency flux data at meter and kilometer scales. Environmental Research Letters 13:045005.