Managing Salt Ponds to Increase Waterbird Nesting Habitat While Minimizing Methyl Mercury Biomagnification: Implications for the South Bay Salt Pond Restoration Project

Josh Ackerman,USGS, jackerman@usgs.gov
Collin Eagles-Smith, USGS, ceagles-smith@usgs.gov
Mark Marvin-DiPasquale, USGS, mmarvin@usgs.gov
Cheryl Strong,USFWS, Cheryl_Strong@fws.gov
Eric Mruz, USFWS, Eric_Mruz@fws.gov

The South Bay Salt Pond Restoration Project plans to convert 50-90% of salt ponds into tidal marsh. However, salt ponds are currently preferred habitat for many migrating and breeding waterbirds. Wetland managers plan to enhance the remaining salt ponds to maintain current waterbird numbers, yet it is unclear how to manage salt ponds to simultaneously increase waterbird foraging and nesting opportunities while minimizing the deleterious effects of methylmercury production. We conducted a pilot study on the Don Edwards San Francisco Bay National Wildlife Refuge and created numerous nesting islands by lowering the water level in Pond A12 and exposing submerged substrate. In response, we documented nearly 600 waterbird nests in this pond despite it having no prior nesting. Nest success was 29% for avocets and 38% for Forster's terns, which was slightly lower than some neighboring ponds, probably due to California gull depredation of eggs. This generally positive benefit of increased nesting habitat for waterbirds, however, was mediated by the potential increased production of methylmercury. We found that Forester's tern, American avocet, and black-necked stilt eggs had higher mercury concentrations in Pond A12 than in any other wetland monitored. Additionally, we found that fish mercury concentrations in Pond A12 spiked in the summer after water levels were lowered in early spring to expose nesting islands. In contrast, fish mercury concentrations in a control pond (Pond A11) actually decreased throughout the summer. We found similar differences between the manipulated and control ponds' surface water chemistry, with Pond A12 having higher phytoplankton and methylmercury concentrations compared to Pond A11. These preliminary data indicate that although we successfully created nesting habitat for waterbirds, methylmercury production may have been enhanced due to water management actions and methylmercury subsequently biomagnified up the food web. Further study is warranted to determine if these results are common among managed salt pond habitats in San Francisco Bay.

Key Words - *mercury; wetland management; bioaccumulation; birds; fish; water quality*

Theme: Salt Pond Restoration

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Rapid Changes in Small Fish Mercury Concentrations in Estuarine Wetlands: Implications for Wildlife Risk and Monitoring Programs

Collin Eagles-Smith, US Geological Survey-Davis, ceagles-smith@usgs.gov
Josh Ackerman, US Geological Survey-Davis, jackerman@usgs.gov

Small fish are commonly used to assess mercury (Hg) risk to wildlife and monitor Hg in wetlands. However, limited research has evaluated short-term Hg variability in small fish, which can have important implications for monitoring programs and risk assessment in predators. We conducted a time-series study of Hg concentrations in two small fish species representing benthic (longjaw mudsuckers [*Gillichthys mirabilis*]) and pelagic (threespine sticklebacks [*Gasterosteus aculeatus*]) food-webs within three wetland habitats in San Francisco Bay Estuary. We simultaneously monitored prey deliveries, nest initiation, and chick hatching dates of breeding Forster's terns (*Sterna forsteri*), the most abundant nesting piscivore in the region. Mudsuckers and sticklebacks were the predominant prey fish, comprising 36% and 25% of tern diet, and Hg concentrations averaged (geometric mean±SE, µg/g dw) 0.44±0.01 and 0.68±0.03, respectively. Fish Hg concentrations varied substantially over time following a quadratic form in both species, increasing 40% between March and May then decreasing 40% between May and July. Importantly, Forster's terns initiated 68% of nests and 31% of chicks hatched during the period of peak Hg concentrations in prey fish. These results illustrate the importance of short-term temporal variation in small fish Hg concentrations for both Hg monitoring programs and assessing wildlife risk.

Key Words - *mercury; biosentinel; fish; risk; salt ponds; monitoring*

Theme: Salt Pond Restoration

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Napa Plant Site Restoration – Construction Lessons Learned and Incorporation into Subsequent Engineering Design

Seth Gentzler, URS Corporation, seth_gentzler@urscorp.com
Steve Carroll, Ducks Unlimited, scarroll@ducks.org
Francesca Demgen, URS Corporatoin, francesca_demgen@urscorp.com
Susanne Von Rosenberg, GAIA Consulting, susanne@gaiainc.com
Karen Taylor, CA Department of Fish & Game, KCTAYLOR@dfg.ca.gov

Problem Statement: How to better utilize available data and modeling tools to design inter-tidal restoration projects to maximize habitat benefit, while reducing construction cost. Approach: The California State Coastal Conservancy (Conservancy), California Department of Fish and Game (CDFG), and the Army Corps of Engineers (USACE) are in the process of implementing ecological restoration of the former Cargill salt pond complex in the North Bay, which is now owned by the California Department of Fish and Game. The proposed restoration at the Napa Plant Site includes approximately 1,460 acres. Phase 1 construction has been completed or is near completion for approximately 340 acres of the site, and a large portion of this has been breached to Fagan Slough. Phase 2 restoration design of the remainder of the site will be going out to bid this coming fall and has received approximately $8.5M of ARRA funds for construction. The overall goal for the project includes the establishment of self-sustaining tidal and seasonal wetlands that provide habitat for a broad range of migratory shorebirds and waterfowl, marsh-dependent birds, mammals, fish and other aquatic organisms, and threatened and endangered species. This poster focuses on lessons learned from Phase 1 construction and breach monitoring data that can inform and improve future restoration design. Results: Lesson learned during the Phase 1 construction, in addition to monitoring data completed during and after the breach, provide interesting feedback to inform final design for the remainder of the site. This feedback is applicable to inter-tidal restoration design and construction projects throughout the bay to help balance habitat benefit versus construction cost. Conclusions Issues to be addressed include breach design and implementation, construction techniques for channel excavation, extent of channel excavation necessary to balance successful habitat evolution, incorporation of habitat refuge islands, and erosion control techniques for wind generated waves within newly implemented wetland restoration sites.

Key Words - *Salt Pond; Restoration; Construction*

Theme: Salt Pond Restoration

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Integrating Avian Datasets for Management, Modeling, and Visualization

Mark Herzog, PRBO Conservation Science, mherzog@prbo.org
Josh Ackerman, USGS, jackerman@usgs.gov
Nicole Athearn, USGS, nathearn@usgs.gov
Jill Demers, San Francisco Bay Bird Observatory, jdemers@sfbbo.org
Collin Eagles-Smith, USGS, ceagles-smith@usgs.gov
Michael Fitzgibbon, PRBO Conservation Science, mfitzgibbon@prbo.org
Cheryl Strong, Don Edwards San Francisco Bay National Wildlife Refuge, Cheryl_Strong@fws.gov
John Takekawa, USGS, john_takekawa@usgs.gov
Julian Wood, PRBO Conservation Science, jwood@prbo.org

The 2003 purchase of more than 15,000 acres of salt ponds in San Francisco Bay created North America's second largest habitat restoration project. Utilizing an adaptive management framework, the South Bay Salt Pond Restoration Project (SBSPRP) requires access to historical and current data to assess past actions and inform future management. PRBO Conservation Science, U.S. Geological Survey, and San Francisco Bay Bird Observatory have initiated a collaborative project to make all available avian data accessible to SBSPRP managers. These data represent millions of dollars in investments, and will provide the SBSPRP with accurate baseline estimates of bird numbers and a measure of progress for current activities. The Integrated South Bay Avian Database (ISBA-DB) utilizes the industry-proven infrastructure of the California Avian Data Center (http://www.prbo.org/cadc) to organize and facilitate the synthesis and visualization of avian data in the South Bay. Modeling efforts will help set restoration targets and assist the SBSPRP team to make informed management decisions. The application will provide the information required to determine data needs and prioritize future collection efforts. The new system allows new data to be instantly available for managers and restoration assessment. Linkages between ISBA-DB and the existing South Bay Salt Pond Project Database will provide managers with even more decision-support resources. The ISBA-DB project team will be working directly with the SBSPRP project leads to ensure that the metrics and data summarizations are those needed for project assessment and planning. In addition, training and support will ensure the tools are immediately used.

Key Words - *informatics; modeling; salt pond restoration; restoration assessment; adaptive management; monitoring*

Theme: Salt Pond Restoration

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Seasonal Dynamics of Surface Water Mercury Speciation and Partitioning in Two Contrasting South San Francisco Bay Salt Ponds: The Influence of Primary Production

Mark Marvin-DiPasquale, U.S. Geological Survey, mmarvin@usgs.gov
Jennifer Agee, U.S. Geological Survey, jlagee@usgs.gov
Evangelos Kakouros, U.S. Geological Survey, kakouros@usgs.gov
Le Kieu, U.S. Geological Survey, lkieu@usgs.gov
Josh Ackerman, U.S. Geological Survey, jackerman@usgs.gov
Collin Eagles-Smith, U.S. Geological Survey, ceagles-smith@usgs.gov

One goal of the South Bay Salt Pond Restoration Project is to increase wildlife habitat. To this end, and to accommodate planned changes in Pond A8 that would decrease bird nesting habitat, Pond A12 was partially drained to increase interior island habitat for nesting birds. As part of a larger study to investigate the effectiveness of this management action on bird nesting recruitment, we examined water column mercury (Hg) dynamics in Pond A12 and compared and contrasted these to a control pond (A11), which was not partially drained. The focus was to examine (a) Hg-speciation (total mercury [THg], methylmercury [MeHg] and reactive inorganic mercury [Hg(II)R]) and Hg-partitioning (dissolved vs. particulate) within these two managed ponds, and (b) the extent to which observed Hg dynamics are influenced by temporal/spatial changes in water column primary production (as chlorophyll-a) and total suspended solids (TSS). Surface water was sampled bimonthly, between January and September 2008. Key findings include: (a) the vast majority of both THg and MeHg was associated with the particulate phase (TSS); (b) whole water concentrations for all three Hg species were consistently higher in Pond A12 than in A11, which paralleled the findings for THg concentrations in bird eggs and fish; (c) the partitioning of both THg and MeHg between the filtered and dissolved phases varied more dramatically in Pond A11 than in Pond A12; (d) a significant increase in the percentage of THg that was Hg(II)R, between January and May in Pond A12; (e) this was followed by both filtered and particulate MeHg peaking in Pond A12 during July, which also corresponded to a peak in chlorophyll-a and TSS; (f) salinity, chlorophyll-a and TSS were all consistently higher in Pond A12 compared to A11; and (g) there was a significant positive correlation between surface water salinity and chlorophyll-a (all data). It is unclear if the difference in Hg dynamics between the two ponds was directly due to the partial draining of Pond A12, as no baseline data prior to the draining event was available. However, these results do suggest that pond salinity is linked to phytoplankton density, which in turn affects the concentration and speciation of Hg in the particulate phase, and ultimately Hg concentration in biota.

Key Words - *mercury; salt ponds; primary production*

Theme: Salt Pond Restoration

Poster Board Number: 81. Submission Number: 200

Assessing Differences in Food-web Mercury Associated with Restoring Salt Ponds to Tidal Marsh in South San Francisco Bay

April Robinson, San Francisco Estuary Institute, april@sfei.org
Aroon Melwani, San Francisco Estuary Institute, aroon@sfei.org
Shira Bezalel, San Francisco Estuary Institute, shira@sfei.org
Jennifer Hunt, San Francisco Estuary Institute, jhunt@sfei.org
Josh Collins, San Francisco Estuary Institute, josh@sfei.org
Letitia Grenier, San Francisco Estuary Institute, letitia@sfei.org

During 2006 – 2008, water, sediment, and resident biota (biosentinels) were sampled to address the question of how methylmercury in the food web might change if Pond A8 in the Alviso area were restored to tidal action. Biosentinel animals representative of particular sub-habitats in tidal marsh and salt ponds were selected and tested as indicators of mercury condition. Previous work has shown that some wetlands may be sites of methylmercury production, and concentrations of methylmercury in San Francisco Bay are known to be above levels of concern for some wildlife and for people who eat sport fish. Consequently, there is a concern that the planned restoration of salt ponds to tidal marsh may increase the amount of methylmercury accumulated in the local food web. The biosentinel species were used to compare different areas and management choices and to provide a pre-restoration baseline for mercury condition in these habitats. This study design aimed to give managers an idea of how methylmercury in local biota might change as Pond A8 was converted from salt pond to marsh. Results indicated that Pond A8 in its current salt pond state has some of the worst mercury conditions in the South Bay food web. Higher concentrations of methylmercury were seen in fish and flies from Pond A8 than from the surrounding marsh and pond habitats. The fringing marsh in Alviso Slough across the levee from Pond A8 is the best available indicator of what future mercury conditions might be in the restored Pond A8 marsh. Biosentinels from the fringing marsh had lower mercury than the same biosentinel species from Pond A8 and had similar mercury concentrations compared to reference marshes across South Bay. These results suggest that future restoration of Pond A8 to tidal marsh is likely to improve the mercury condition in the food web.

Key Words - *Salt Pond Restoration; Mercury; Biosentinels*

Theme: Salt Pond Restoration

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Western Snowy Plovers in the San Francisco Bay: Determining Nest Success, Predators and the Effects of Habitat Enhancements.

Caitlin Robinson, San Francisco Bay Bird Observatory, crobinson@sfbbo.org
Cheryl Strong, United States Fish and Wildlife Service, Don Edwards San Francisco Bay National Wildlife Refuge, cheryl_strong@fws.gov
Scott Demers, H.T. Harvey and Associates, sdemers@harveyecology.com

The Western Snowy Plover (*Charadrius alexandrinus nivosus*) is a threatened species that nests on dry salt ponds in the San Francisco Bay. The number of snowy plovers in the Bay area has decreased over the past 30 years. The majority of plover habitat in the Bay is within the South Bay Salt Pond Restoration Project area, which will impact the amount of nesting habitat available. We estimated nest success at Eden Landing Ecological Reserve in Hayward and the Don Edwards San Francisco Bay National Wildlife Refuge in Alviso, Fremont and Menlo Park from 2004 through 2008. Nest success for all sites combined decreased from 83.6% in 2004 and 85% in 2005 to 58% in 2006 and 67% in 2008. The decrease in nest success in 2006 through 2008 was due to high predation rates. In 2008, 41.5% of the nests were depredated (n=89), compared to 10% of the nests in 2005 (n=20) and 4.9% in 2004 (n=59). Nest predation was attributed mostly to Common Ravens (*Corvus corax*), Northern Harriers (*Circus cyaneus*) and California Gulls (*Larus californicus*). In 2009, we deployed nest cameras to determine nest predators and captured footage of California Gulls, Northern Harriers, Common Ravens and Red-Tailed Hawks (*Buteo jamaicensis*) depredating Snowy Plover nests. Additionally, we used a randomized block design to test the effectiveness of habitat enhancement projects to reduce nest predation and increase nest density. Preliminary data indicates that plots enhanced with oyster shells increase nest success and nest density.

Key Words - *Snowy Plover*

Theme: Salt Pond Restoration

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Rapid sediment accumulation in a restoring tidal salt marsh in the South Bay Salt Pond Restoration Project

Lisa Schile, University of California, Berkeley, lschile@nature.berkeley.edu
John Callaway, University of San Francisco, callaway@usfca.edu
V. Thomas Parker, San Francisco State University, parker@sfsu.edu
Ellen Herbert, San Francisco State University, herberte@sfsu.edu

Sediment accumulation is a critical factor driving the development of restored tidal marshes as elevation increases to a point suitable for vegetation establishment. This issue is particularly important for highly subsided tidal wetland restoration sites. In 2006, a large-scale restoration of industrial salt evaporation ponds was initiated in South San Francisco Bay, California, and we have monitored short and long-term sediment dynamics for the past 3 years within the first site to be restored. Prior to tidal restoration, the former salt pond lacked vegetation and was covered by a solid, dense gypsum layer up to 25 cm thick, overlying remnant marsh vegetation, sediment, and channels. We installed PVC sediments pins across the site to monitor long-term sediment dynamics and examine within-site sedimentation patterns. For short-term, mass-based accumulation rates, we used a modification of the "filter paper method", deploying sample discs over a two-week tidal period. Substantial sediment accumulation has occurred since tidal restoration in March 2006, with approximately 12-14 cm of sediment accumulating at lower elevations over the first year alone, with even greater accumulation in particular locations. Sediment depth decreased with distance from breach, which also corresponds with an underlying elevation gradient. Accumulation rates at higher elevations were variable but lower in magnitude; however, sediment accumulation was orders of magnitude higher than in most natural tidal wetlands. Short-term, mass-based measurements of accumulation reflect similar spatial variability across the pond and show that substantial sediment accumulation has occurred throughout most of the year. Three years since restoration, the sediment depth ranged from 1 to 57 cm and native vegetation is colonizing rapidly along channel edges. These results give an indication of the potential for sediment accumulation during the critical initial restoration period for subsided tidal marshes.

Key Words - *South Bay Salt Pond Restoration Project; sedimentation rates; tidal salt marsh*

Theme: Salt Pond Restoration

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Green Biomass Machines: Primary Productivity in the Former Salt Ponds of South San Francisco Bay

Tara Schraga, US Geological Survey, tschraga@usgs.gov
James Cloern, US Geological Survey, jecloern@usgs.gov
Julien Thébault, Université de Bretagne Occidentale, julien.thebault@univ-brest.fr
Eric Dunlavey, City of San Jose, Eric.Dunlavey@sanjoseca.gov

Over 6110 ha of the commercial production salt ponds surrounding South San Francisco Bay, CA have been decommissioned and reconnected to the Bay, most as part of the South Bay Salt Pond Restoration Program. The open water ponds are critical habitat for millions of birds annually and restoration program managers must determine the appropriate management of ponds that will be maintained as open water habitats. This study describes the metabolism of these new systems and their ecological value as feeding habitats for birds. We determined metabolic parameters in one pond from high resolution timeseries of dissolved oxygen concentration. Areal gross primary production (8.17 g O2 m-2 d-1) was roughly double the world's most productive estuaries. High rates of phytoplankton photosynthesis were balanced by high rates of community respiration (8.25 g O2 m-2 d-1), revealing a rapid biomass producing and consuming system. Pond metabolic equilibrium was delicately poised, sharp irradiance and temperature shifts triggered short term photosynthesis reduction resulting in oxygen depletion. The result of net primary production routed though simple food webs was high potential forage production and energy supply to waterbirds, equivalent to 11-163 million planktivorous fish or 19-78 billion small estuarine clams within the pond between May and November. The pond's beneficial food supply function is challenged by its potential to produce toxic or inedible algae, and susceptibility to hypoxia. Our study provides the first measurement of primary production in the open water ponds of San Francisco Bay and presents a novel approach for transforming primary production into forage production as a metric of an ecosystem's energetic carrying capacity.

Key Words - *salt pond, primary production,*

Theme: Salt Pond Restoration

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Sediment salinity distribution along the tidal channel networks of a restored salt pond in the San Francisco Bay-Delta Estuary system

Gregory Tseng, gregorygtseng@gmail.com

Restoration of solar salt producing ponds back into salt marsh is one ongoing Bay Area project that has recently gained focus and momentum. Following the levee breaching of salt ponds in the Don Edwards San Francisco Bay Wildlife Refuge in March 2006, tidal inundation has started to naturally restore the salt marshes. Adaptive management, a continual, iterative process of studying the restoration site, and then implementing changes and corrections from the results, is being used to manage the ponds. Research monitoring the annual progress of sedimentation concluded that two years since the breeching, tidal action has deposited considerable amounts of sediment on the surface of the salt pond. Sediment salinity is a basic indicator of favorable conditions for vegetation recruitment. Vegetation recruitment has started on the surface of the pond; however, only sporadically and in certain areas. Since tidal channels are the main conduits by which sediments enter and leave the pond, I conducted a study of the tidal channels in Pond A21, investigating sediment salinity with respect to distance to nearest levee breech and along the assumed tidal channel flow path.

Theme: Salt Pond Restoration

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