ELKHORN SLOUGH NATIONAL ESTUARINE RESEARCH RESERVE

Parsons Slough Management Plan

Tidal Wetland Project
2014

A summary of the rationale and process for implementing and managing a water control structure at the mouth of a major arm of the Elkhorn Slough Estuary -- Parsons Slough. This document describes the decision-making process leading up to the implementation of the structure, and details how monitoring and targeted studies will allow ESNERR to manage the structure adaptively.

Table of Contents

Management Plan: Parsons Slough Project

Executive Summary

In 2011, the Elkhorn Slough National Estuarine Research Reserve placed a sill across the mouth of a major arm of the Elkhorn Slough Estuary, Parsons Slough. The sill was put in place to reduce the erosive force of tides in and out of Parsons Slough.

The team of scientists and resource agencies that planned, designed and implemented the sill set project objectives in two categories: positive outcomes that were desired consequences of the sill and areas where no change was desired. Desired consequences of the sill included a 10% decrease in the peak velocities of the tidal currents in the main channel and an increased proportion of estuarine endemics vs. marine generalists in Elkhorn Slough. Changes the project hoped to avoid included worsening of water quality and eutrophication, any significant decreases in native fauna throughout Parsons Slough and any significant increases in invasive species in the slough.

The sill resulted in significant reduction in peak velocities, particularly during ebb tide and in bed shear stress in the channel just upstream of the sill. In the reaches of Elkhorn Slough downstream of the structure, critical shear stress (the level at which sediments begin to erode) is now exceeded less frequently than it was prior to the placement of the sill. Overall, with less fine sediment exported from Parsons, there is more opportunity for deposition of sediments on marshes and in slow-moving shallow regions within the Parsons complex. After four years of post-sill monitoring, it appears that the sill has not altered water quality, or species distribution patterns significantly.

Context

The Elkhorn Slough ecosystem faces a number of threats, from tidal scour and bank erosion, to invasive species, agrochemical and disease contamination and many others. In recognition of these multiple threats, the Tidal Wetland Project, in collaboration with numerous local experts, has developed long-term goals for the management and conservation of Elkhorn Slough. The foundation of these goals is the Elkhorn Slough National Estuarine Research Reserve's (ESNERR) Management Plan. These goals are integral to the ecosystem function and biodiversity of the estuary as a whole and will be used to evaluate overall estuarine ecosystem "health" and biological or physical trends over long time periods. Explicit consideration of these long-term, estuary-wide goals as a part of the Parsons project is important to ensure that no part of the estuary is heavily compromised by the pursuit of any one goal and that ESNERR contributes towards this whole-system vision of ecosystem health.

Long-term Goals for Elkhorn Slough

1. Hydrodynamics and Geomorphology: Restore more natural hydrodynamic and geomorphic conditions and processes to Elkhorn Slough in order to better sustain key habitats and their associated species

2. Water quality: Improve water quality in the estuary and maintain chief hydrological parameters important for the sustainability of aquatic life in Elkhorn Slough within the range of historical values.
3. Habitats: Extensive and healthy intertidal and shallow subtidal habitats at Elkhorn Slough.
4. Fish: Stable and diverse fish populations throughout Elkhorn Slough.
5. Invertebrates: Rich and diverse estuarine invertebrate communities --invertebrate abundance and richness patterns that fall within the natural range of variation for similar regional estuaries and/or within the historical range of variation of the past millennia at Elkhorn Slough.
6. Waterbirds: Maintain rich and diverse waterbird assemblages of estuarine habitats at Elkhorn Slough (mudflat, salt marsh, and aquatic)–waterbird abundance and richness patterns that fall within the natural range of variation for similar regional estuaries and/or within the historical range of variation of the past millennia at Elkhorn Slough.
7. Marine Mammals: Maintain healthy marine mammal populations in the Elkhorn Slough, with mammal habitat-use patterns that fall within the natural range of variation for similar regional estuaries and/or within the historical range of variation of the past millennia at Elkhorn Slough

The Parsons Slough Project directly addressed one of these long-term goals for the management of Elkhorn Slough (Goal 5 Hydrodynamics) by decreasing velocities in the lower main channel, and potentially tidal scour. By doing so, more fine sediments should be retained in the lower estuary, which may support additional goals.

Rationale for the installation of a sill at Parsons Slough

Parsons Slough is a 450-acre complex of mudflats and other tidal wetlands that is entirely owned and managed by ESNERR. This area historically supported 400 acres of tidal marsh, but now only 35 acres remain. In the first half of the twentieth century, Parsons Slough was diked off from the tides and drained for farming and cattle grazing. The marsh soils dried and shrunk and thereby lowered the land surface elevation in a process termed subsidence.

In late 1982, shortly after the land was acquired by the California Department of Fish and Game (DFG), the dikes around Parsons Slough broke. When the tides returned, currents and tidal scour increased measurably throughout Elkhorn Slough.

This acceleration of currents throughout lower Elkhorn Slough occurred because while Parsons Slough makes up 15 percent of Elkhorn Slough by land area, due to subsidence it accounts for 35 percent of the daily exchange of tidal waters by volume. This increase in tidal volume and currents has resulted in loss of soft sediments from the lower main channel, and may contribute to salt marsh loss because less sediment is available to help marshes gain elevation and track sea

level rise. Reducing tidal exchange at Parsons Slough with construction of a submerged sill slowed peak currents in lower Elkhorn Slough, potentially increasing the retention of more fine sediments in the lower estuary and thereby enhancing sediment available to marshes. This was achieved through the implementation of a sill at the mouth of Parsons Slough. Salt marsh can be restored in the future in Parsons Slough by adding sediment to raise the elevation of subsided former marshes, but sediment addition was not part of the initial sill project plan.

Originally, the sill design was an adjustable structure which allowed for manipulation of sill height. Sill height directly influences the volume of water entering and exiting the Parson's Slough Complex. Concern was raised by Union Pacific Railroad that an adjustable sill above the fixed portion would increase the water differential between the Parson's Complex and the main channel. Such a differential in water level would likely destabilize the levee currently supporting the rail road tracks. Consequently, installing an adjustable sill was not feasible until this differential could be addressed. The completed sill is therefore lower and non-adjustable, so the expected impacts are less than originally anticipated.

The Parsons Slough Adaptive Management Plan focuses on how a sill at the mouth of Parsons Slough was implemented to enhance soft mud habitats and sediment availability for marshes while protecting the high quality existing habitat in Parsons Slough for sharks and rays, sea otters, seals and shorebirds. The sill at Parsons Slough was also thought to be a good test for evaluating the potential impacts of a sill at the Highway 1 Bridge, which would impact the entire Elkhorn Slough ecosystem. Careful monitoring by the researchers at ESNERR and their collaborators supports the management plan.

Key Monitored Parameters

ESNERR monitors a suite of parameters in order to determine how to assess progress toward long-term, estuary-wide goals and manage Parsons Slough in both the short-term and the long-term.

Definition of Management Objectives

ESNERR and local estuarine experts formulated objectives at two temporal and spatial scales.

Estuary-wide Objectives provide specific detail on long-term, estuary-wide goals. For each key biological or physical category (water quality, invertebrates, etc.), broad goals are subdivided into more these detailed estuary-wide objectives; both are stated in qualitative terms.

Project Objectives are measurable, quantitative conditions, perceived as beneficial to ecosystem health, that the project aims to achieve within Parsons Slough and in the rest of the estuary. Project objectives may be measurable on immediate or considerably longer time scales and progress towards these objectives will be evaluated at intervals > two years.

Not meeting project or estuary-wide objectives would be cause to carefully evaluate three management options: 1) add height to the structure in order to enhance the ability to reach objectives, 2) add sediments to Parsons Slough to reduce tidal prism and restore salt marsh while maintaining the structure at the current height to balance positive and negative effects of the structure or most drastically, 3) removing the structure because of unintended and unforeseen negative impacts.

Process for designating Project Management Objectives

In order to designate management objectives, the Tidal Wetland Project reviewed existing information on the effects of tidal restriction throughout the estuary, created predictions of the likely effects of a sill at Parsons Slough, identified the key species, habitats and physical processes.

Identification of key species, habitats and physical processes

Through a collaborative process between the ESNERR Research Team, the Strategic Planning Team (SPT) and the Science Panel (SP), TWP identified a subset of key species, habitats and physical processes that required specific management consideration and, in many cases, focused additional monitoring to document the effect of the structure. Each of these categories was assigned as the focus of a designated Working Group, comprised of ESNERR researchers, local experts and regulatory agency representatives.

Identification of key players and roles:

Six groups, hierarchical in size, are critical to the development of the Adaptive Management Plan and the effective operation of the structure. These groups are: the Strategic Planning Team, the Science Panel, the Internal TWP Team, the Steering Committee, the Working Group Leads, and the Working Groups.

The Strategic Planning Team

The Strategic Planning Team (SPT) advises the entire Tidal Wetland Project and therefore they provide expertise beyond the Parson's Slough Project. This group is composed of principal investigators of the various grants funding this work, jurisdictional/regulatory entities, representatives of key regional conservation organizations, and scientists with experience in strategic planning for wetland resources.

Role

- Primary decision-making body for the entire TWP planning process

- Oversees the strategic planning process and development of a Tidal Wetland Plan
- Develops the criteria for selecting habitat goals for tidal habitats
- May attend or hold joint meetings with the Science Panel during each phase of the project
- Provides input on background materials for the Tidal Wetland Plan
- Evaluates and prioritizes strategies to address hydrological management issues

The Science Panel

The Science Panel is dedicated to providing scientific expertise to the Tidal Wetland Project as a whole, beyond the Parsons Slough Project. The group is composed of regional scientists or resource managers with local or regional expertise in estuarine ecology, hydrology, or geology.

Role

- Compiles background research
- Identifies key habitats and hydrological problems
- Recommends large to small scale alternatives for restoration
- Develops and recommends strategies
- Identifies adaptive management and monitoring activities

The Internal TWP Team (ITT)

The ITT is the group of ESNERR staff that regularly participates in TWP meetings and plays a role in the decision-making for the Parsons Project.

Role

- Review monitoring data and determine whether objectives are being met
- Provide feedback on design criteria

The Steering Committee

The ITT debated the merits of having a large decision-making group that incorporated representatives from outside of ESNERR, vs. a relatively small, internal group. It was decided by unanimous vote that while the Steering Committee would receive a recommendation from the ITT and consult with outside experts as needed, the actual decision of whether to change management of Parsons Slough should be an ESNERR/CDFW decision. Due to the ITT's desire to have a group small enough to meet frequently and that would represent the

fact that ESNERR is solely responsible for Parsons Slough, the ITT decided unanimously that the Steering Committee would be comprised of:

The ESNERR Reserve Manager -- currently Dave Feliz, and Becky Suarez at the beginning of the project. The ESNERR Reserve Manager is the person with ultimate responsibility for the effects of the sill. As the reserve is managed by the California Department of Fish and Wildlife (CDFW), the Reserve Manager will be in close communication with the relevant personnel at CDFW throughout the management process.

The Stewardship Coordinator -- currently Andrea Woolfolk. The Stewardship Coordinator will be the person responsible for ensuring proper maintenance and operational capability.

The Research Coordinator -- currently Kerstin Wasson. The Research Coordinator will be responsible for data collection in support of the Adaptive Management process. This person will be the most qualified person to speak to the ecological impacts of the structure.

The Tidal Wetland Project Director -- currently Monique Fountain and Bryan Largay at the beginning of the project. The TWP Director will be responsible for having the most current information on the effect that the structure has had on physical processes and how the structure at Parsons Slough complements other restoration actions throughout the slough.

Role

- Decision-making body
- Receives recommendation from the ITT and then weighs supporting evidence in order to determine whether to implement further management actions
- Represents ESNERR and TWP regionally

Working Group Lead (WGL)

An ESNERR staff member was assigned the role of Working Group Lead (WGL) for each Working Group.

Role During Development of Monitoring Plan

- Write key parameters summary for monitoring plan in coordination with the working group members
- Hold 1-2 working group meetings and/or seek expert review as needed to set key parameters

Role After Construction of Sill

- Oversee collection of relevant monitoring data for key parameters used as management triggers and objectives.
- Process existing data to improve accuracy, exercise quality control as needed, conduct statistical analyses, interpret findings with regard to whether significant changes have occurred after sill was implemented and whether causality can be assigned to sill.
- Give presentations on monitoring plans and results to science panel and perhaps other audiences, about once a year for the first two years post-construction.

Working Groups

Waterbirds: The Waterbird Working Group developed recommendations for management objectives and management triggers for shorebirds, wading birds and waterfowl for Parsons Slough and Elkhorn Slough as a whole. The WGL for this group was Susie Fork, an ESNERR Research Biologist.

Fish: The Fish Working Group developed recommendations for bony fish and elasmobranchs that use Parsons Slough and Elkhorn Slough as a whole. The WGL for this group was Monique Fountain, who at the time was the Tidal Wetland Project's Project Manager.

Marine Mammals: The Marine Mammal Working Group developed recommendations for harbor seals and sea otters. The WGL for this group was Quinn Labadie, the Tidal Wetland Project's Communications Assistant.

Habitat change: The Habitat Change Working Group developed guidelines for habitat conversion, with particular focus on salt marsh, mud flat and subtidal habitat. The Working Group for this group was Beth Watson, an ESNERR estuarine ecologist.

Invertebrates: The Invertebrate Working Group developed recommendations for invertebrates, including benthic invertebrates such as fat inn-keeper worms and nekton such as crab species. The WGL for this group was Kerstin Wasson, ESNERR Research Coordinator.

Eelgrass: The Eelgrass Working Group developed guidelines for changes in the distribution and abundance of eelgrass, plausibly attributable to the Parsons project. The WGL for this group was Kerstin Wasson, ESNERR Research Coordinator.

Geomorphology and Hydrodynamics: The Geomorphology and Hydrodynamics Working Group focuses on guidelines for tidal scour, current velocities and other physical properties within Parsons Slough and throughout the estuary. The WGL for this group was Gui Lessa, an ESNERR Estuarine Ecologist; Gui was replaced by Beth Watson in October 2010.

Water Quality and Eutrophication: The Water Quality Working Group delineates management objectives and management triggers for water quality in Parsons Slough. The WGL for this group was Gui Lessa, an ESNERR Estuarine Ecologist. In October of 2010, John Haskins, ESNERR Researcher replaced him.

Working Group Role (Creation of management plan)

- Compile and review the existing monitoring data pertinent to the specific group,
- Reviewing the 'straw man' document
- Reach "no veto consensus" on whether to accept or modify the straw man.
- Determine whether additional monitoring was needed and/or submit a short proposal requesting funding for additional monitoring or restoration work.
- Relay pertinent information to the Internal TWP Team (ITT) for approval.

Working Group Role (Evaluation of sill effects)

- Serve as a technical resource for ESNERR researchers if needed
- Serve as a reviewer for summary analyses or reports of sill effects as needed

Management Guidelines

Hydrodynamics and Geomorphology

<u>Long-term goal</u>: Restore more natural hydrodynamic and geomorphic conditions and processes to Elkhorn Slough in order to better sustain key habitats and their associated species

<u>Estuary-wide objective 1</u>: Decrease tidal velocities and tidal scouring in Elkhorn Slough

Justification: The volume of salt water exchanged between Elkhorn Slough and Monterey bay was dramatically increased after the opening of Moss Landing Harbor and the return of large expanses of diked land to the estuarine realm. This extra exchange of water increased the tidal current magnitudes and promoted erosion and tidal scour, which may decrease sediment availability to salt marshes and thus their sustainability.

Project objective 1a: A 10% decrease in the peak velocities of the tidal currents in the main channel.

Past monitoring: As a proxy for peak velocities, we monitored mudbank erosion on four separate occasions between April 2011 and January 2013. We surveyed mudbanks on the west side of the main channel, across from the sill, using a Terrestrial Laser Scanner

(TLS) and found that the bank is eroding. However, the east bank directly across from the survey area has had the highest erosion rates in the main channel before the sill was constructed.

Current monitoring: None. (Experts in hydrodynamics indicated that there is substantial interannual variability in tidal currents, as well as high spatial variability, so a simple monitoring approach such as deploying an ADCP to measure velocity pre vs. post sill construction at a single site would be unlikely to detect the magnitude of effects anticipated. Instead, they recommended a numerical simulation approach, which was completed and revealed that peak bed shear stress is likely to have been reduced by up to 8% by the sill construction at a modeled location in the lower estuary, but increased by up to 11% at a modeled location in the upper estuary.)

Project objective 1b: A 30% decrease in the peak velocities of the tidal currents in the Parsons Complex.

Past monitoring:

1) Same as 1a. Hydrodynamic modeling calibrated with field data obtained after the sill was in place revealed that peak bed shear stress is likely to have been reduced by up to 40%.
2) One year of repeat total station scanning of a spatially discrete area of intertidal mudflats near the mouth of Parson's to determine mudflat accretion/erosion including temporal variability (spring-neap tidal cycles, inter-seasonal, inter-annual), conducted in 2010-2011 by MLML team.
3) Ground-based LIDAR scanning (at low tide) conducted in 2011 by CSUMB team to produce a high-resolution elevation dataset for Parsons. This provided baseline data against which future changes may be measured, and furthermore provided an accurate surface for applying water level data to measure habitat changes pre- and post- tidal restriction.
4) Bathymetric profiles of selected cross sections, obtained with conventional echo sounder in 2011 by CSUMB team, to identify sub-tidal morphological changes both in Parsons and in the main channel.

Current monitoring: On-going ESNERR monitoring of estuarine habitat change with GIS analysis of aerial photographs; digital terrain modeling and tidal gauging.

Monitoring thus far has yielded results consistent with the project objective.

Water Quality

<u>Long-term goal</u>: Improve water quality in the estuary and maintain chief hydrological parameters important for the sustainability of aquatic life in Elkhorn Slough within the range of historical values.

<u>Estuary-wide objective 2</u>: Decrease frequency of acute and chronic toxic conditions in the estuary.

Justification: Numerous studies have demonstrated the degradation of water quality in Elkhorn Slough, clearly highlighting the need for improvement. Some of these changes in water quality, such as longer and more frequent hypoxia events, as well as the formation of free ammonia can compromise the abundance and richness of estuarine species.

<u>Project objective 2a</u>:

i. OXYGEN: The percent of a monthly deployment with hypoxia conditions (defined by a dissolved oxygen concentration <2.3 mg/L) in any given month should not exceed the maximum pre-sill (2000-2010) percent hypoxia for that month by more than 20%. (From 2000 to 2010, the month of July is consistently the month where the most severe hypoxia is observed. Maximum percent of deployment with hypoxia for the month of July from 2000 to 2010 was 9%. A 20% increase in hypoxia for July, relative to pre-sill data would mean that dissolved oxygen concentration would be less than 2.3 mg/L for 10.8% of the time.)

ii. pH: The annual percentage of data collected where pH is outside the range of 7.0 to 8.5 should not increase more than 20% relative to the average pre-sill percentage. (From 1995 to 2010, the annual average percent time where pH was outside the range of 7.0-8.5 at South Marsh was 1.1%. A 20% increase in the percent time outside the range of pH = 7.0 to 8.5 would be 1.3% of the time.)

iii. CHLOROPHYLL: The annual percentage of samples where Chlorophyll *a* concentrations > 15ug/L should not increase more than 20% relative to the average pre-sill percentage. (From 2002 to 2010, the annual percentage of samples in which chlorophyll *a* concentration exceeded 15ug/L was 4.0%. A 20% increase in the percentage of samples where chlorophyll *a* concentration exceeded 15ug/L would be 4.8% of all samples in a year.)

iv. FREE AMMONIA: The annual percentage of samples in which free ammonia concentration > 0.025 ppm should not increase more than 20% relative to the average pre-sill percentage. (From 2002-2010 free ammonia concentrations averaged < 0.005 ppm per year and < 1 % of the samples contain free ammonia concentrations > 0.025 ppm. A 20% increase in free ammonia samples exceeding 0.025 ppm, relative to pre-sill data would be 1.2% of the samples in one year).

Current monitoring: Water quality in Parsons Slough has been monitored continuously since 1995. Chlorophyll *a* monitoring began in August of 2002. Physical data from the South Marsh station (Parsons Slough) are accessible online with hourly updates from the website: <u>http://www.nws.noaa.gov/oh/hads/</u> . A second station in the Parsons Slough complex was monitored for 9 months but was discontinued because data were very similar to data from the existing South Marsh station. Ammonium levels from water

samples collected monthly at South Marsh throughout a tidal cycle have be continuously monitored since June 2003.

Thus far, this monitoring has revealed that project objective 2a has been met.

Project objective 2b: Stratification of the water column should not increase relative to past conditions in the Parsons complex.

Past monitoring: Stratification monitoring was conducted for one year prior to and two years following completion of the construction of the sill. Since no stratification was observed, the monitoring stopped after two years (as per a priori agreement with the permitting agencies). Project objective 2b is considered to have been met. The stratification monitoring consisted of two parts as described below:

i. Continuous monitoring of multiple factors
From August 2010-February 2013 water quality parameters such as temperature, pH, turbidity, salinity, Chlorophyll *a* and dissolved oxygen have been continuously monitored at a temporary monitoring station, just east of the Railroad Bridge in the deepest part of the channel. In addition to the subtidally deployed sonde, a depth and temperature logger (a level-logger) was deployed at the surface at this monitoring station in order to identify potential stratification in temperature. This station had been identified as having the highest potential for stratification but there was no indication of stratification in temperature from any of our collected data.

ii. Periodic vertical profiling of a few key parameters
In addition to the subtidally deployed sonde and the level-logger at the surface described in section i. above we characterized the water column through high resolution vertical profiling at the time of year, and the time of day where vertical stratification is most likely to occur. Two pre-sill surveys were conducted in September and October 2010, and six post-sill surveys were conducted in order to comply with permits. The post-sill surveys were conducted in August, September, and October 2011 and August, September, and October 2012. We characterized the water column through high resolution vertical profiling of the water column close to the mooring site by lowering a water quality sonde sampling at a frequency of once per second. We lowered the sonde starting at the water surface and ending at the bottom of the slough at a rate of about 0.5 m per second. The profiles thus had depth intervals of 0.5 meters and were carried out every half hour during a period of 3-6 hours at the smallest neap tide in August, September, and October. At least half of the profiles were collected during the pre-dawn hours. After analyzing the data no evidence of stratification in temperature, salinity or dissolved oxygen in pre-sill or post-sill data was found.

All results indicate that project objective 2b has been met.

Current monitoring: None

Estuary-wide objective 3: Reduce the causes and symptoms of eutrophication throughout the estuary.

Justification: Eutrophication and extensive algal mats can severely limit available oxygen in both the water column and the benthos, causing the associated fauna to die off.

Project objective 3: Avoid widespread expansion of macroalgae (*Ulva*) area. Floating algal cover should not exceed 10% of open water area at high tide in the Parsons complex.

Current monitoring: 1) Visual assessment of floating algal cover at six permanent sites, three inside Parson's and three outside the Parson's complex. Floating algal cover will be visually estimated monthly relatively close to the time of the high tide. 2) Analysis of photographic record of the percentage of floating algal cover at permanent sites located inside and outside Parsons. These data are collected once a month during the monthly water quality sampling.

In Spring 2014, floating algal cover in the Parsons complex exceeded 10%, counter to the project objective.

Habitats

Long-term goal: Extensive and healthy intertidal and shallow subtidal habitats at Elkhorn Slough.

Estuary-wide Objective 4: Appropriate conditions for marsh function and sustainability; no net loss of current aerial extent of salt marshes at Elkhorn Slough

Justification: Over the past 150 years, about 50% of Elkhorn Slough's salt marshes have been lost (Van Dyke & Wasson 2005). Ideally, it would be desirable to restore some of this acreage, but given the constraints of limited sediment sources due to diversion of the Salinas River and predicted sea level rise, the objective is to prevent any further loss of total salt marsh acreage in the estuary (by conducting marsh restoration projects in some areas to offset continuing losses in others). However, given the reduction in current speeds and potential increase in sediment retention within the Parsons complex resulting from the sill, it is possible that marsh expansion will occur.

Project objective 4: Increase aerial extent of salt marsh within Parsons complex

Current monitoring: On-going ESNERR monitoring of estuarine habitat change with GIS analysis of aerial photographs. Permanent field transects by ESNERR staff to measure changes in marsh width and elevational distribution in the Parsons complex.

Thus far, no significant change in marsh acreage within the Parsons complex has been observed, but such changes would be anticipated to occur gradually.

Estuary-wide Objective 5: Continued representation of historical diversity of native estuarine endemic plants in the high marsh and marsh-upland ecotone.

Justification: High marsh diversity is important for wetland function (Zedler et al. 2001) and estuarine endemics in the high marsh at Elkhorn Slough have been shown to be sensitive to cattle grazing and tidal restriction (Wasson & Woolfolk 2011).

Project objective 5: Continued representation of native high marsh species in Parsons Complex at similar cover and richness as observed in nine years prior to sill construction.

Current monitoring: ESNERR monitoring program of permanent ecotone-high marsh transects both inside and outside Parsons complex since 2001, which can be analyzed using BACI design to test for effects attributed to sill.

Thus far monitoring suggests this project objective is being met.

Estuary-wide Objective 6. Continued expansion of eelgrass beds in Elkhorn Slough.

Justification: Eelgrass beds were abundant in the lower estuary in the 1930s-40s, but then underwent a sharp decline. In the past decades, substantial recovery of these beds has occurred (data in State of the Estuary report available at http://www.elkhornslough.org/research.htm). This recovery is desirable not only as a return to historical conditions but also because eelgrass has been shown to support fish and crab species at Elkhorn Slough (Grant 2009) and has been documented to provide important ecosystem services in other estuaries.

Project objective 6: Continued expansion of eelgrass beds in the lower main channel.

Current monitoring: On-going ESNERR monitoring of estuarine habitat change with GIS analysis of aerial photographs. Field transects of eelgrass beds to assess shoot density, canopy height, sediment characteristics, and other parameters using standard NERR vegetation monitoring protocols. Conducted in 2010-2011 by MLML researchers with NERR vegetation monitoring funds and to be repeated when funds are next available.

Monitoring thus far indicates the project objective is being met.

Invertebrates

Long-term goal: Rich and diverse estuarine invertebrate communities --invertebrate abundance and richness patterns that fall within the natural range of variation for similar regional estuaries and/or within the historical range of variation of the past millennia at Elkhorn Slough.

Estuary-wide Objective 7: Increased representation of estuarine endemics and brackish-tolerant species.

Justification: Comparison of benthic infaunal cores from the 1970s and 2000s reveals that estuarine endemics and brackish-tolerant species have decreased and marine species have increased over this period in the lower main channel, and this change is attributed to the artificial estuary mouth subsequent strong marine influence in the lower estuary (Oliver et al. 2007).

Project objective 7: Increased proportion of estuarine endemics vs. marine generalists in Parsons complex benthic infauna due to decreased velocities and increased retention of fine sediments.

Current monitoring: None currently sufficient to determine whether this objective is met. However, the Benthic Lab from the Moss Landing Marine Labs was funded to collect cores in the Parsons complex directly after installation of the sill. Future funding will be required for processing the cores.

Estuary-wide Objective 8: Decreased rate of invasion by non-native species, and decreased abundance of existing non-natives.

Justification: Non-native species account for about half the cover on hard substrates, and a quarter of the biomass in soft sediments in Elkhorn Slough, and have displaced native species (Wasson et al. 2001); new marine invasions continue to be documented on this coast and threaten Elkhorn Slough.

Project Objective 8: No major increase (i.e. >50%) in the abundance of non-native invertebrate species within the Parsons complex.

Current monitoring: ESNERR monitoring of a) crabs (annually), and b) large clams, shrimp, and epifauna with rapid assessments (every 2 years), on-going since 2002 and continuing indefinitely. This dataset can be used for a BACI-design to test for changes attributed to the Parsons Sill project.

Thus far, the project objective has been met; there have been no significant increases in abundance of non-native species.

Estuary-wide Objective 9. No major decline in benthic infaunal invertebrate biomass, since this provides key food web support for migratory shorebirds, flatfish and sharks using Slough as nursery, and sea otters.

Justification: Benthic infaunal invertebrates provide key food web support for many estuarine consumers, including migratory shorebirds, flatfish and sharks that use the estuary as a nursery, and sea otters. Different predators use different prey items and vary in their diet specificity, but as a general rule, it is desirable to maintain abundant total infauna for these predators.

Project Objective 9: No major decrease (i.e., to less than 50% of current average) in total abundance of benthic infauna (in cores) within the Parsons complex.

Current monitoring: None.

Estuary-wide Objective 10: Increased abundance of native oysters.

Justification: Native Olympia oysters have declined dramatically at most estuaries on this coast, including at Elkhorn Slough. The Elkhorn population provides connectivity between southern and northern California populations, but is low enough in total size (about 5000-10,000 individuals in estuary) to be in danger of local extinction.

Project Objective 10: No significant (i.e. >50%) decline in recruitment and survival of native oysters within the Parsons complex.

Current monitoring: ESNERR monitoring of recruitment rate and survival of recruits on standard recruitment collectors used since 2007 will be continued indefinitely, inside and

outside of the Parsons complex, allowing for a BACI design to examine changes attributed to the sill project.

Thus far the project objective has been met, with no significant change in recruitment observed.

Fish

Long-term goal: Stable and diverse fish populations throughout Elkhorn Slough.

Estuary-wide Objective 11: Maintain fish population abundances and current levels of fish diversity at Elkhorn Slough.

Justification: The fish fauna in Elkhorn slough is abundant, diverse, and dominated by marine and estuarine species (Cailliet et al. 1977; Yoklavich et al. 1991; Yoklavich, Stevenson, and Cailliet 1992). The slough provides critical habitat not only for year-round residents, but also for marine species from nearshore waters that enter the estuary to feed, mate and spawn.

Project objective 11: No significant population decrease (no measurable, statistically significant decrease) of fish or nekton diversity in the Parsons complex.

Past monitoring: Intensive surveys (by ESNERR staff and volunteers) were conducted to characterize fish species distribution and abundance in Parsons Slough. No significant changes were observed pre vs. post sill construction within Parsons Slough.

This project objective was met.

Waterbirds

Long-term goal: Maintain rich and diverse waterbird assemblages of estuarine habitats at Elkhorn Slough (mudflat, salt marsh, and aquatic)–waterbird abundance and richness patterns that fall within the natural range of variation for similar regional estuaries and/or within the historical range of variation of the past millennia at Elkhorn Slough.

Estuary-wide Objective 12: Maintain or increase the abundance of any of the major groups of water birds (shorebirds, waterfowl, waders).

Justification: Over the last several decades, many species of migratory birds have experienced precipitous population declines (Terborgh 1989, Askins 1990, Finch 1993);

shorebirds depend upon Pacific coastal estuaries and wetlands for feeding, resting and breeding and the loss of this habitat may result in further population declines in some species (Moore 1993). Additionally, shorebirds are higher level predators in estuarine ecological communities, and significant changes in shorebird population size may have cascading effects on organisms at lower trophic levels (Daborn et al. 1993). Lastly, migratory shorebirds are a high profile group of species that generate considerable public interest as well as ecotourism dollars (Manion et al. 2000, Sekercioglu 2002). Given the public interest, decline in shorebird abundance and diversity may have substantial social and economic impacts on coastal communities.

Project Objective 12: Maintain (counts remain within 20% of previous 5 year average) or increase abundance in major groups of waterbirds (waterfowl, waders, large or small shorebirds) in Parsons Slough in years following sill placement.

Current monitoring: Monthly surveys of South Marsh; slough-wide quarterly surveys (main channel, Parsons Slough, South Marsh, North Marsh, North Harbor). There have been no significant changes in abundance of any group of shorebirds pre vs. post sill construction, within or outside of Parsons.

Thus far the project objective has been met.

Marine Mammals

Long-term goal: Maintain healthy marine mammal populations in the Elkhorn Slough, with mammal habitat-use patterns that fall within the natural range of variation for similar regional estuaries and/or within the historical range of variation of the past millennia at Elkhorn Slough.

Estuary-wide Objective 13: Continue to provide quality habitat for a variety of important functions (reproduction, resting, foraging) for marine mammal species that occupy Elkhorn Slough.

Justification: The California sea otter population is well below its estimated carrying capacity and is considered a threatened species; the Elkhorn Slough may provide a protected habitat that could encourage these mammals to thrive (Maldini, Eby and Scoles 2009). Harbor seals used five haul out areas within the Parson's Slough Complex and one haul-out site at the Parson's Slough entrance (Maldini, Eby and Scoles 2009). It is also illegal to take a marine mammal (Marine Mammal Protection Act 1976).

Project objective 13a: Do not maim, injure or kill any marine mammals during construction of the sill.

Parsons Sill Construction Trigger 1: Impending death or dismemberment of any marine mammal would immediately halt construction activities.

Past monitoring: Intensive monitoring during and after construction of sill. Post construction monitoring included a month of intense monitoring to ensure the sill was not injuring marine mammals followed by a year of monthly censuses to ensure that they aren't being excluded from Parsons.

All results were consistent with the project objective.

Project objective 13b: Do not inflict undue stress on marine mammals during construction of the sill.

Parsons Sill Construction Trigger 2a: Prolonged flushing of marine mammals during sill construction.

Parsons Sill Construction Trigger 2b: Pup abandonment during sill construction.

Past monitoring: Biological monitoring during construction and at least monthly census in the months leading up to project construction as well as the year after completion of construction.

The project objective was met.