South Bay Salt Pond
Restoration Project
Restoring the Wild Heart of the South Bay

Restoration Funding Application
Cover Sheet

APPLICANT INFORMATION

Name of Organization(s) Requesting Funding: **US Geological Survey, San Francisco Estuary Institute, and UC Davis**

Mailing Address: **USGS UC-Davis Field Station, University of California**
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PROJECT INFORMATION

RFP Study Topic # **2**

Project Title: **The Effects of Wetland Restoration on Mercury Bioaccumulation in the South Bay Salt Pond Restoration Project: Using the Biosentinel Toolbox to Monitor Change across Multiple Habitats and Spatial Scales**

Funding Request per year **$201,730 and $218,956** Number of years: **2**

Confirmed in-kind or matching contributions: **$ 69,974**

Source of in-kind or matching contributions: **USGS, UC Davis, RMP**

Purpose and Objectives: **The objectives of this proposal are to evaluate the effects of wetland restoration on methylmercury bioaccumulation in a suite of biosentinels.**

Proposed starting date: **Apr. 2009 or 2010** Estimated completion date: **Apr. 2011 or 2012 depending on contract approval date**

Signature : ______________ Date: 12/4/08
Principal Investigator

Signature : ______________ Date: 12/4/08
Grant Administrator

The Effects of Wetland Restoration on Mercury Bioaccumulation in the South Bay Salt Pond Restoration Project: Using the Biosentinel Toolbox to Monitor Changes Across Multiple Habitats and Spatial Scales

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ABSTRACT:
The South Bay Salt Pond Restoration Project's plans to convert salt ponds into tidal marsh habitat may result in changes to the distribution, availability, and bioaccumulation of methylmercury (MeHg) within the region, which is known to already have MeHg levels that exceed wildlife toxicity thresholds. Implementation of a robust monitoring network will allow restoration managers to document these changes simultaneously across multiple habitats, and may guide actions that compensate for unintended outcomes. The planned construction of a tidal breach in Pond A8 provides a unique opportunity to examine this approach. This proposal links changes in water column Hg concentration and speciation, and ultimately to MeHg bioaccumulation in five key biosentinel species. Each biosentinel represents an important component of the local food web in the habitat mosaic, and each will provide direct evidence of Hg bioaccumulation across the landscape. A particular strength of this proposal is the collaboration of researchers involved, all of whom have been leading extensive mercury projects in the South Bay, and their ability to leverage baseline data to clearly demonstrate any changes in MeHg exposure as a result of the A8 management action. This study will provide critical information to ecosystem managers in guiding their future decisions regarding former salt pond management and wetland restoration activities.

BACKGROUND AND JUSTIFICATION:

A. Background: Work to Date

Two of the most significant anthropogenic changes in the San Francisco Bay (SFB) Estuary over the past 150 years are the loss of over 85% of fringing tidal wetlands (Goals Project 1999) and the contamination of the estuarine food web with mercury (Hg) (Greenfield *et al*. 2005). These impacts are particularly pronounced in the South Bay, which was historically fringed with extensive tidal marshes and which receives drainage from New Almaden, the largest historic Hg mining area in North America. Extensive restoration in the South Bay region aims to return much of the important ecosystem function these wetlands provided. However, high rates of methylmercury (MeHg; the most toxic form of Hg) production, export, and bioaccumulation have been associated with wetlands relative to other water bodies (Hurley *et al.* 1995, Krabbenhoft *et al.* 1999, Waldron *et al.* 2000, Yee *et al.* 2008). Thus, the potential exists to increase Hg bioavailability in the South Bay as former salt ponds are restored to tidal marsh. This is a particularly important concern, because Hg concentrations in tissues and eggs of waterbirds in the South Bay currently exceed toxicological thresholds (Figure 1; Eagles-Smith *et al.* 2009, Eagles-Smith and Ackerman 2008), and there is evidence that Hg may be impairing egg hatchability and chick survival (Figure 2; Ackerman and Eagles-Smith 2008, Ackerman *et al.* 2008a). Thus, any increase in MeHg production and subsequent bioaccumulation in waterbirds may have a substantial impact to their reproduction.

One of the first major changes in the restoration process is the planned breach of Pond A8, to return it to muted tidal action. This breach will be in the form of an adjustable 20 ft to 40 ft wide weir-like notch that reconnects hydrologic flow between Pond A8 and Alviso Slough. Construction of the A8 notch is scheduled to begin in the spring of 2009 (C. Strong, pers. comm.). The concern surrounding breaching Pond A8 encompasses both the scour (due to increased tidal prism) and redistribution of sedimentary Hg in adjacent Alviso Slough (which has sediment total mercury (THg) concentrations 3-times higher than in the greater South Bay), and changes to MeHg dynamics within Pond A8 (Marvin-DiPasquale and Cox 2007, Grenier *et al*. 2007).

It is estimated that sediment scour in Alviso Slough with either of the notch scenarios will result in a substantial amount of Hg being remobilized to the surrounding environment (approximately 66 to 125 kg of THg, 0.05 to 0.10 kg of reactive inorganic mercury ($Hg(II)_R$), and 0.08 to 0.14 kg of MeHg; Marvin-DiPasquale and Cox 2007). It is not known how much of each Hg fraction will be transported to the larger South Bay, into Pond A8, or upstream of Pond A8. However, exposure of the buried (reduced) sediment to oxygenated overlying slough water may result in significant changes in the speciation of remobilized Hg, potentially enhancing MeHg production. Specifically, concentrations of $Hg(II)_R$ increased 40-60X within 7 days when anoxic Alviso Slough sediment collected from a depth of 150 cm was mixed with oxygenated slough water (Figure 3). Since $Hg(II)_R$ is a surrogate measure of the fraction of total inorganic Hg(II) that is available for microbial conversion to MeHg, this finding has major implications about the potential for enhanced MeHg production in Pond A8 and the surrounding region.

Within Pond A8 itself, MeHg concentrations in the sediments and biota are among the highest of any measured in the entire South Bay (Miles and Ricca in review, Ackerman *et al.* 2007a,b, Ackerman and Eagles-Smith 2008, Grenier *et al.* 2007). Although, it is unclear how Hg cycling within the pond will change post-breach, other recently breached salt ponds in the region (A19 and A20) showed more than 5-fold increases in sediment MeHg concentrations post-breach

(Miles and Ricca, in review). Thus, there is the potential that MeHg concentrations within the pond may increase above the currently high levels.

Conversely, related studies (Grenier *et al.* 2007) suggested that the elevated microbial activity in Pond A8 relative to Alviso Slough is driven by high loading of readily degraded phytoplankton (Figure 4). This coupled with the high $Hg(II)_R$ concentrations associated with Pond A8 flats, may be responsible for significantly higher %MeHg in Pond A8 than in Alviso Slough (Figure 5).

In a more recent study comparing Pond A11 (low in phytoplankton) with Pond A12 (high in phytoplankton), dissolved and particulate MeHg concentrations were significantly elevated in Pond A12 water, as was the %MeHg associated with the particulate fraction (Figure 6). Biosentinel fish further indicated that bioaccumulation of MeHg was significantly higher in Pond A12 (Figure 7). These data support the hypothesis that more organic production in the form of phytoplankton leads to more MeHg formation and bioaccumulation. Thus, for breached ponds such as A8, resulting changes in hydrology and primary productivity within the ponds may substantially alter MeHg bioaccumulation in biota that forage there. Therefore, if the notch causes less phytoplankton production and deposition in Pond A8, by allowing more regular flushing, there may be a net decrease in MeHg production over time.

Although the Alviso Pond/Slough Complex contains more THg than other areas of the South Bay (SFEI 2005, Marvin-DiPasquale and Cox 2007), wetland restoration may not necessarily increase MeHg in the local food web because MeHg production depends on many environmental factors in addition to THg concentration. Recent studies indicate significant spatial variation in Hg bioaccumulation are related to differences in habitat type (Eagles-Smith *et al.* 2008, Stewart *et al.* 2008). Even within a single type of wetland, Hg bioaccumulation within the same biosentinel species can vary greatly among wetlands with different characteristics (Grenier *et al.* 2007). Further, Hg concentrations in several waterbird species vary greatly even among adjacent wetlands (Figure 8, Ackerman *et al.* 2007a,b, 2008a,b,c), indicating the importance of processes governing MeHg production, transport and partitioning (among solid and dissolved phases) that occur within wetlands. In order to understand how management actions influence MeHg production and bioaccumulation into the food web, an integrated monitoring program that incorporates abiotic and process studies with biological indicators of exposure is recommended (Evers *et al.* in press). No single biosentinel species can provide the information needed across all habitats, spatial scales, and components of the food web. Thus, a multiple biosentinel approach is proposed to determine how management actions will affect MeHg in the food web, and ultimately risk to sensitive wildlife.

B. The Biosentinel Toolbox

The biosentinel approach is based on developing appropriate biological indicators of Hg contamination that are indicative of local conditions over a relatively discrete spatial area and time frame, and that incorporate potential effects to at-risk species. However, most species do not occur widely across different habitats, and Hg availability can differ substantially among habitats within the same geographic area (Eagles-Smith *et al.* 2008, Ackerman *et al.* 2007a, b, Grenier *et al.* 2007, Stewart *et al.* 2008). Thus, no single biosentinel can provide managers with the information they need about where and when their management actions are impacting Hg in the food web. An integrated monitoring program that incorporates multiple biosentinels is needed. Our approach in this proposal builds on a compilation of several years of research in the South Bay Restoration Project Area, as well in the greater Estuary, and has focused on biosentinel development and appropriate scales of implementation. In addition, recent research on toxicological thresholds of Hg impairment to avian reproduction for waterbirds in the region (Ackerman and Eagles-Smith 2008, Eagles-Smith and Ackerman 2008) will provide benchmark values to assess potential risk and effects of restoration on sensitive wildlife.

STUDY OBJECTIVES:

Wetland restoration and management practices that would minimize MeHg bioaccumulation are not well known. Therefore, this proposal aims to monitor changes in Hg bioaccumulation that may occur after the planned breach of Pond A8, which will return it to muted tidal action. Biosentinel monitoring will be coupled with water chemistry to understand the processes that cause changes in Hg bioaccumulation and to determine if and how the operation of the A8 Notch causes a direct change in MeHg production in Pond A8 or in Alviso Slough. An increase in the bioavailability of MeHg could negatively impact breeding waterbirds, a result opposite to the management goal of restoring waterbird habitat for the Don Edwards San Francisco Bay National Wildlife Refuge and the SBSP Restoration Project. An increase in MeHg export to surrounding waters, habitats, and the wider Bay also could have important regulatory ramifications. By monitoring across multiple habitats and spatial scales, we will increase the information that managers can draw upon as they attempt to minimize Hg risk while moving forward with restoration. As such, the primary objectives of this proposal are to:

- Assess the impact of the A8 notch on Hg cycling within Pond A8 and Alviso Slough main-channel and adjacent marshes using an integrated biosentinel approach coupled with process-level water-column studies.
- Determine the extent of the effect of the A8 notch implementation over time and with distance from the restoration site, and the relative effect among the different habitats and biosentinel species.
- Use water column mercury concentration and speciation data to link the underlying processes of MeHg production to bioaccumulation, and to investigate whether MeHg production changes as a function of changes in a) phytoplankton production, and/or b) Hg remobilization associated with Alviso Slough sediment scour.

STUDY AREA:

The primary study area will be within the Don Edwards San Francisco Bay National Wildlife Refuge and focused on Pond A8, Alviso Slough, and adjacent salt ponds, sloughs and marshes (Figure 9). We also will monitor appropriate control sites, including one pond and one slough habitat. While final control sites are yet to be determined, they will likely include Pond A16 and Mallard Slough. Control sites will be critical to assess baseline Hg bioaccumulation that is not associated with the opening of Pond A8 for three reasons. First, Pond A16 and Mallard Slough are configured similarly to Pond A8 and Alviso Slough in that Pond A16 was recently opened to Mallard Slough. Second, Pond A16 and Mallard Slough are hydrologically separated from Pond A8 and Alviso Slough, so there will be no carryover effects. Finally, data collected in Pond A16 will provide useful baseline data for when Pond A16 is enhanced by creating additional waterbird nesting islands, currently scheduled for construction in 2010 at the earliest.

APPROACH:

To monitor the effect of the Pond A8 notch on MeHg bioaccumulation within the pond and the surrounding environment, we have identified five key biosentinels that fall into three groups: waterbird eggs, small fish, and marsh songbirds. These biosentinels will provide important information on Hg bioaccumulation within specific habitats and locations, as well as allow managers to evaluate overall changes in Hg-related wildlife risk. The waterbird group provides pond-specific information on Hg bioaccumulation from both invertebrate (avocets) and fish-based (terns) prey, and is a precise indicator of potential risk to wildlife reproductive impairment (Figure 10). The fish are localized populations that provide comparative information on Hg availability within the same matrix over time and across habitats. Similarly, marsh songbirds provide a localized index of Hg bioaccumulation in tidal marsh. Below are the five individual biosentinels that comprise these groupings.

1. **Forster's Terns (*Sterna forsteri*)** are fish-eating birds that nest in high densities at multiple sites within the South Bay Salt Ponds (Strong *et al.* 2004) and forage in salt ponds and adjacent marshes (Ackerman *et al.* 2008a). As top predators, changes in MeHg bioavailability in the system are amplified in their tissues relative to lower trophic level species. Previous research has shown that terns have substantially higher Hg levels than any of the 13 bird species sampled in the Bay to date (Figure 11), and nearly half of all tern eggs sampled in the South Bay exceed known toxicological thresholds (Ackerman and Eagles-Smith 2008). Moreover, once Forster's terns arrive in the South Bay to breed, they have relatively small space use (Ackerman *et al.* 2008b, Bluso-Demers *et al.* 2008). Any changes in MeHg production associated with A8 habitat restoration will likely occur within the A8 complex and the adjacent wetlands where terns forage (Ackerman *et al.* 2008b). Therefore, monitoring tern eggs provides important information on how wetland management practices may alter overall risk of Hg exposure to wildlife.

2. **American Avocets (*Recurvirostra americana*)** are invertebrate-foraging shorebirds that are abundant in the region year-round and are the most abundant breeding shorebird in San Francisco Bay (Stenzel *et al.* 2002, Rintoul *et al.* 2003). Recent radio telemetry studies (Ackerman *et al.* 2007a, Demers *et al.* 2008) have shown that during the eight weeks approaching egg laying, avocet space use is highly localized and occurs predominantly within the ponds where nesting occurs. Thus, avocets are excellent indicators of Hg concentrations in the invertebrate food web at the "individual-pond" spatial scale. Avocets nest at high densities across a wide range of habitats, including salt pond islands, dried salt pond pannes, and vegetated marshes, highlighting their utility across the entire SBSP Restoration Project area (Ackerman *et al.* 2006). Hg concentrations in avocet eggs (which are reflective of diet only a few weeks prior to laying) differ widely among colonies. In fact, differences between nearby colonies can differ by up to a factor of 5, indicating their utility as Hg biosentinels at a small spatial scale (Figure 8).

3. **Tidal marsh Song Sparrows (*Melospiza melodia pusillula*)** are year-round marsh residents with extremely small home ranges (Marshall 1948, Grenier 2004). During the breeding season, tidal marsh sparrows forage almost exclusively on invertebrates, largely from the marsh plain (Grenier 2004), which is the part of the marsh related to high MeHg production in previous studies (Yee *et al.* 2008). Marsh sparrows have been useful to assess Hg bioaccumulation in marshes across South Bay (ambient) relative to marshes along Alviso Slough (project area), and

to highlight the variation among marshes (Figure 12). To monitor the effect of a localized action, such as the notch in the Pond A8 levee, sparrows will provide information in marshes along the slough at various distances from the action (e.g., Figure 13) to gauge both local and more distant impacts.

4. **Threespine stickleback (*Gasterosteus aculeatus*)** are a small fish species with well-studied behavior and ecology that occurs widely throughout the restoration area, is strongly linked with water column prey, and which represents an extremely important conduit for Hg transfer through the food web (Authors' unpublished data). These fish are short-lived (1-yr) and are found in loosely aggregated shoals. Additionally, USGS BRD has an extensive stickleback database (2005-2008) with Hg concentrations throughout the SBSP Restoration Project area ponds which will provide baseline conditions before extensive restoration occurs in the Alviso Salt Pond Complex (Figures 14, 15). This biosentinel will be used to assess changes in Hg bioaccumulation within ponds and adjacent sloughs, thus allowing for comparisons of changes in Hg bioaccumulation with time and between habitats.

5. **Mississippi silverside (*Menidia audens*)** is a small fish species that provides a food-web linkage from the sloughs to the wider South Bay. This species has been developed as a highly effective spatial and temporal biosentinel of MeHg exposure throughout the Bay-Delta, particularly in relation to TMDL regulatory considerations (Figure 16, Slotton *et al.* 2002, 2007). Silversides are an abundant and important prey species in the sloughs and Bay margins, with a wealth of comparative data (Greenfield *et al.* 2006, Slotton et al 2008, Figure 17). Moreover, silversides are relatively localized, and show rapid response to changes in Hg availability.

METHODS:

<u>Methods: Waterbird egg sampling (USGS-BRD):</u> We will monitor Hg concentrations in randomly collected avocet and Forster's terns eggs at 4 colonies per species located in the South Bay. Colony locations will depend on breeding conditions, however stable breeding colonies have occurred in Ponds A1, AB1, A7, A8, A16, R1, N4, New Chicago Marsh, and Eden Landing. These colonies represent a gradient of distances from the A8 (including A5/A7) wetland restoration complex and will be used to assess any changes in waterbird Hg bioaccumulation associated with restoration actions, and in relation to regional changes. To assess Hg concentrations in waterbird eggs, we will randomly sample one egg from up to 15 nests per colony for each species during 2009 and 2010 breeding seasons. We will refrigerate collected eggs until processing (<2 weeks), measure egg size and volume, then open each egg, remove all egg contents into a polypropylene jar, evaluate embryos for gross abnormalities and malpositions that can be caused by contaminants, and freeze the egg until THg analysis at the USGS Davis Field Station Hg Lab with Milestone DMA 80 Hg analyzer following EPA method 7473 (US EPA 2000). To test for changes in egg THg concentrations associated with restoration actions in the Pond A8 complex, we will use a residual-based analysis incorporating the data collected by USGS over the past 5 years (Ackerman *et al.* 2007b, Ackerman and Eagles-Smith 2008). More specifically, we will standardize relative egg Hg concentrations for each colony across years, and compare relative Hg levels in eggs sampled from colonies within or directly adjacent to A8 with concentrations in other colonies in the region that are not influenced by the A8 Hg signal. We will then test whether standardized egg Hg concentrations at each colony increase or decrease after the A8 management action.

Methods: Pond fish sampling (USGS-BRD): To assess the degree to which MeHg cycling is altered post-notch within Pond A8, we will use a resident, localized fish, the threespine stickleback, as our fish biosentinel. We will sample stickleback (*N*=10 per location and sampling event) at three locations in the Pond A8 complex (1 near the A8 notch and 2 elsewhere in the pond) at least three times per year, bounding the breaching of the pond to Alviso Slough. We will also sample in a reference pond for control for changes in ambient concentrations. Pond A16 is a strong candidate for a reference pond because USGS has been monitoring Hg in stickleback from the pond every year since 2005, it was a former salt pond that has been subsequently linked to Mallard Slough, and is scheduled to undergo future pond restoration and enhancement as part of the SBSPRP. We will sample fish using standard methods such as beach seines and minnow traps. Fish will be cleaned and stored frozen at -20°C until THg analysis at the USGS Davis Field Station Hg Lab.

Methods: Slough fish sampling (UC Davis): This component of the project provides a linkage between the restoration activities at Pond A8 and the potential export of altered MeHg exposure conditions to surrounding waters. For this project, two small fish species will be used in the slough environment. Threespine stickleback will be taken in groups of 10 replicate individuals, each to be analyzed separately, from a control slough (likely Mallard) and 4 strategically located sites along Alviso Slough: upstream of the notch, at the notch, midway down the slough, and near its base. A second species, Mississippi silverside, will be used as a more widely integrative biosentinel, providing a linkage to the Bay and to a large amount of comparative data from locations throughout the Bay-Delta watershed. Silversides are targeted for collection at all of the sites listed above, except the uppermost site on Alviso Slough, which is normally above their range. Composite samples will be used, with 6 replicate composites of up to 10 fish per composite, to reduce budget costs and provide data comparable to other regionally collected fish data (RMP). Three seasonal collections will be made in each of two years, plus two additional samplings bracketing the main notch-opening event. We will use well-established protocols to sample slough fish with seines (Slotton et al 2007), and preserve fish frozen prior to analysis. Analyses will be performed using a Perkin-Elmer FIMS cold vapor atomic absorption system outfitted with an auto sampler unit.

Methods: Marsh bird sampling (SFEI): Marsh sparrows will be sampled at four sites along a gradient of expected impact from the Pond A8 notch. The sites will be located near the notch, halfway down Alviso Slough toward the Bay, near the mouth of Alviso Slough, and at a "control" location in a slough with similar characteristics to Alviso Slough and far from other levee breaches. The exact site locations will be determined partially by where previous sparrow data are available from the South Baylands Hg Project. Sparrows will be sampled once per year during the breeding season for two consecutive years. The sample size goal for each site is 10 sparrows. Previous studies have not found significant differences in Hg bioaccumulation based on sex or age. Nevertheless, we will target adult males. Song Sparrows will be captured by mist net, weighed, measured, sexed, and aged. Small blood samples of 10−60 µl will be collected by brachial veinipuncture in heparinized microcapillary tubes. Capillary tubes will capped with plastic plugs to prevent moisture loss and then placed in larger tubes for transport and storage. Blood samples will be kept on ice in the field, then transferred to a freezer (-4 ^{o}C) until shipment (on dry ice) to the analytical lab. Birds will be marked with USFWS metal bands and unique color band combinations for field identification. All birds will be released following sample collection. THg will be determined in blood samples with a Milestone DMA 80 Hg analyzer following EPA method 7473 (US EPA 2000).

Methods: Water Column Mercury Dynamics (USGS-WRD): Biosentinel data are important for answering if, when, and where MeHg bioaccumulation is impacted by the hydrological changes from the construction and operation of the Pond A8 Notch (or similar management actions). However, biosentinel data alone do not offer an explanation as to why and how the observed changes in biota Hg concentrations occurred. Thus, process-level information regarding changes in Hg concentration and speciation in abiotic matrices (i.e. water) is essential to fully understand what the impact of a given management action was. This information also enables prediction of how MeHg concentrations in biota might be affected in the future, given similar or modified changes to the hydrology of managed ponds.

Spatial and temporal trends in water column Hg concentration and speciation will be assessed for both dissolved and particulate phases over the study period, and will be related to changes in the quality and quantity of suspended particulate material (i.e. phytoplankton and inorganic particles), dissolved nutrients (nitrate and phosphate), and dissolved organic carbon (DOC) and specific ultra-violet absorption (SUVA, and measure of organic matter quality and origin). Water samples will be collected using trace metal clean sampling techniques (USEPA, 1996), at eight locations per sampling event, on ten occasions (at approximately 2.5 month intervals) to capture the complete seasonal trends before, during and after the construction of the Pond A8 Notch (See Table 1). The distribution of sampling sites will match the biosentinel sampling and will include: Alviso Slough (3 sites), Pond A8 (3 sites), Mallard Slough (reference, 1 site), and Pond A16 (reference, 1 site). Whole water samples will be held on ice, in the dark in acid cleaned glass bottles until further processing at the laboratory (within 24 hrs of field collection). Field measurements will include water column dissolved oxygen, temperature, pH and conductivity.

Further processing and sub-sampling in the laboratory will include the collection of the particulate phase on pre-combusted / pre-weighed glass fiber filters. Non-filter passing particulates will be collected for each of the following analytes: THg, MeHg, total suspended solids (TSS), particulate carbon and nitrogen (PC/PN), and chlorophyll. The filtrate will be sub-sampled for the following dissolved analytes: THg, MeHg, DOC and nutrients. All particulate samples will be preserved at -80 ^{o}C. Dissolved THg and MeHg samples will be analyzed on an Automated Hg Analyzer (Tekran Model 2600), according to EPA Method 1631 (USEPA, 2002). Particulate MeHg samples will be analyzed on a Brooks Rand automated MeHg analyzer, following Bloom (1989). Dissolved THg will be quantified on the Tekran Model 2600 Automated Hg Analyzer (USEPA, 2002). TSS filters will be oven dried to a constant weight at 80 ^{o}C, then reweighed to calculate the mass per volume filtered. PC/PN filters will be first acid fumed in a dessicator to remove any carbonate minerals, and then will be analyzed on a Carla Erba 2500 elemental analyzer connected to an Elementar Isoprime mass spectrometer (Kendall *et al.* 2001).

Within 24 hours of collecting the filtrate the UV absorption of an aqueous sub-sample will be assessed spectrophotometrically at 254 nm wavelength using a Shimadzu Model UV-1601 spectrophotometer (Shimadzu Scientific Instruments). DOC samples will be preserved with 0.1% HCl and subsequently quantified via high temperature combustion and IR detection (Qian and Mopper, 1996) on a Total Organic Carbon Analyzer (Model TOC-VCPH, Shimadzu Scientific Instruments). SUVA will subsequently be calculated from the UV absorption and the

DOC concentration (USEPA 2005). Dissolved nutrient samples will be stored frozen and will be subsequently analyzed on an automated Aquakem 250 nutrient analyzer, according to manufactures recommendations.

Methods - QA/QC: We will follow rigorous QA/QC protocols which include analysis of appropriate method blanks, certified reference materials, duplicates, and matrix spikes with each analytical batch.

Statistical analysis: We will use Generalized Linear Models (such as ANCOVA) to test whether Hg concentrations in biosentinels differed pre- and post-notch and relative to ambient changes over the same time period. We will develop a statistical model for each biosentinel that will include independent variables of site and year for all species and date, standard length, age and sex as appropriate. We will also include site × year interactions when possible to assess whether notch construction influenced Hg concentrations relative to any ambient change.

SYNERGIES WITH OTHER PRIORITY RESEARCH STUDY TOPICS:

Whereas this proposal addresses the entire Topic 2 “Assessment of Mercury Bioavailability Utilizing Sentinel Species,” it will also provide information relating directly to these other priority topics: Topic 5 “Pond, Slough, and Bay Water Quality Interactions”, Topic 3 “Waterbird Nesting and Foraging in Managed Ponds,” and Topic 7 “Effects of Restoration on Fish Assemblages.”

The localized data from marsh birds and small slough fish are designed to dovetail with the detailed mapping of Alviso Slough mudflat and marsh habitats proposed by H.T. Harvey and SFEI (Topic 1). Together, these projects will provide a picture of where mudflat scour is occurring relative to where any effects of scour can be detected in biosentinels.

DATA ARCHIVING:

Data handling and storage will follow Federal Geographic Data Committee (FGDC) metadatastandards. Primary data (field and laboratory) will be recorded in lab notebooks and on standardized data collection forms or directly into a standardized data base using an Access form on a laptop computer. Field data will be referenced in GIS coverages, data projected in UTM in NAD83 horizontal and NAVD88 vertical datum. Data will be subsequently transferred into electronic workbooks (e.g. MS Excel, Access) for the purposes of calculation and database management. All data will be compiled, QA/QC checked, and archived on a data server with mirrored drives, tape backup, and redundant copies offsite. Both primary and electronic data will be preserved for a minimum of five years after the completion of the project. Datasets will be made available with permission for use specified in the metadata, and made accessible through the SBSPRP website. Biosentinel data will be integrated with the CALFED Bird Mercury Project, South Baylands Mercury Project, and UC Davis Mercury Biosentinel Program databases to provide standardization for comparisons over time and to facilitate future conversion to State formats (e.g. SWAMP).

WORK SCHEDULE:

Work will commence from final signature of the agreement for a period of two years (spanning parts of 3 calendar years) with an annual report delivered at the end of year one and a final report delivered at the end of year two. Most fieldwork will occur in Spring through Fall (see table below), but will bound the A8 Breach construction. Water sampling will occur at approximately 2.5 month intervals (see table below). Data analyses and report writing will occur during fall and winter of the second year, with a draft report due in March of the final year, and a final report delivered in May of the final year. Planning, field collections, data reduction, and write-up will all be coordinated among the collaborators.

Timeline by quarter	Year 1				Year 2				Year 3			
	1	2	3	4	1	2	3	4	1	2	3	4
Pre-project Planning												
Logistics/Coordination		x	x	x	x	x	x	x	x			
Field Collections												
Pond Birds (2×)		x	x			x	x					
Pond Fish (6×)		x	x	x		x	x	x				
Slough Fish (8×)		x	x	x		x	x	x				
Marsh Birds (2×)		x	x			x	x					
Water (10×)		x	x	x	x	x	x	x				
Laboratory/Analytical			x	x	x	x	x	x	x			
Data Reduction/Archiving			x	x	x	x	x	x	x			
Report writing and review									x			

EXPECTED PRODUCTS:

Annual briefings and presentations will be provided to the Science Program and given at the South Bay Science Symposium. Annual progress reports and a final report will be delivered to the SBSP Restoration Project's Lead Scientist and Project Team. Additional presentations and scientific papers will be prepared for appropriate outlets. Expected journal paper topics include: The effect of levee breaching on Hg cycling and bioaccumulation in the estuarine food web; How does returning former salt ponds to tidal action affect Hg in the surrounding ecosystems and their wildlife?

LITERATURE CITED:

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QUALIFICATIONS (CVs FOLLOW FIGURES):

This proposal is a collaborative effort among five Principle Investigators (PIs), each of whom has been conducting extensive research and directing mercury monitoring programs throughout the San Francisco Estuary, and elsewhere. Each PI has a strong track record of successfully managing large projects that integrate mercury studies across multiple disciplines, and bringing together researchers from different agencies and institutions. Additionally, a particular strength of this proposal is the ability to leverage baseline data from each of the PIs to clearly demonstrate any changes in MeHg exposure as a result of the A8 management action.

The organizational structure of the research team will be designed such that each PI is responsible for all aspects of a particular component of the study, but that the entire team together will integrate their work into a cohesive body of knowledge. As such, each PI will also be responsible for the administrative aspects of their particular component, but a single PI will coordinate all groups together. Dr. Eagles-Smith (USGS-BRD) will serve as the primary PI and administrative lead for this project, and will manage the administrative responsibilities. Please see CVs for further details and project participation.

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BUDGET AND STAFF ALLOCATIONS:
The total cost of this project is $593,509 over a two year period, and we are requesting $420,627 to complete all tasks. Thus we are providing a roughly 30% cost-share, with in-kind contributions totaling more than $170,000. Our request includes funds for <6% time for overall project PIs. We are requesting approximately $64,000 total per year for technician time to conduct field work and data entry, approximately $70,000 per year in laboratory analytical costs (e.g. mercury), and about $31,000 per year for PI salaries for coordination, field work, data analysis, and reporting. Funds for supplies include fish sampling gear, egg collection and processing supplies, lab consumables, and office supplies. Detailed budgets for the overall project and by individual team follow.

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TOTAL PROJECT BUDGET (combining all 4 collaborating groups)

Timeframe: April 2009-April 2011, or April 2010-April 2012 depending on contract approval

Budget Categories	**Total Project Budget**			**Total Grant Request**			**Total Proposed From Other Sources** *(please specify the source, if known)*
	Year 1	**Year 2**	**TOTAL**	**Year 1**	**Year 2**	**TOTAL**	
Labor *(Includes the large majority of associated project analytical work)*	$196,619	$203,796	**$400,415**	$156,578	$173,863	**$330,441**	*App. $170,000 in matching Labor funding; see individual sub-budgets for details.*
Consultant fees/ Contractual Services	$3,150	$3,339	**$6,489**	$3,150	$3,339	**$6,489**	
Travel	$6,200	$6,245	**$12,445**	$6,200	$6,245	**$12,445**	
Project specific equipment, supplies/materials	$7,318	$6,098	**$13,416**	$7,318	$6,098	**$13,416**	*Not including >$35,000 in available equipment from USGS and UC Davis.*
Overhead	$34,909	$35,836	**$70,744**	$28,455	$29,382	**$57,836**	*App. $13,000 in matching Overhead funding from USGS Menlo Park.*
Other: *Related RMP small fish biosentinel Hg work in the South Bay*	$45,000	$45,000	**$90,000**	$0	$0	**$0**	*The related SFEI RMP Small Fish Biosentinel Program includes app. $45,000/yr monitoring at other comparable South Bay sites.*
TOTAL	$293,196	$300,314	**$593,509**	$201,701	$218,927	**$420,627**	

* See sub-budgets for details of each project component.
* Budget justification text included in main proposal document.

Sub-Budget 1
US Geological Survey-BRD; Waterbird and pond fish biosentinels; Project lead

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Sub-Budget 1 of 4 - USGS WERC Davis Field Station (waterbird and fish biosentinels)

Timeframe: April 2009-April 2011, or April 2010-April 2012 depending on contract approval

Budget Categories	Total Project Budget			Total Grant Request			Total Proposed From Other Sources (please specify the source, if known)
	Year 1	Year 2	TOTAL	Year 1	Year 2	TOTAL	
Labor-Salaries and Benefits (agency: annual %FTE							
Eagles-Smith (USGS: 6%)	*$5,852*	*$6,040*	*$11,892*	*$2,926*	*$3,020*	*$5,946*	*$5,946 USGS contribution*
Ackerman (USGS: 4%)	*$7,182*	*$7,408*	*$14,590*	*$3,591*	*$3,704*	*$7,295*	*$7,295 USGS contribution*
Field Technician (USGS: 45%)	*$44,510*	*$44,510*	*$89,020*	*$38,020*	*$44,510*	*$82,530*	*$6,490 USGS contr. from RMP grant*
Analytical (480 Hg samples)	*$20,400*	*$20,400*	*$40,800*	*$16,575*	*$20,400*	*$36,975*	*$3,825 USGS contr. from RMP grant*
Labor (total)	$77,944	$78,358	**$156,302**	$61,112	$71,634	**$132,746**	
Consultant fees/ Contractual Services	$0	$0	**$0**	$0	$0	**$0**	
Travel	$3,500	$3,500	**$7,000**	$3,500	$3,500	**$7,000**	
Project specific equipment, supplies/materials	$2,500	$1,250	**$3,750**	$2,500	$1,250	**$3,750**	*>$15,000 in equipment and on-site facilities by USGS*
Overhead	$6,711	$7,638	**$14,350**	$6,711	$7,638	**$14,350**	
Other:	$0	$0	**$0**	$0	$0	**$0**	
TOTAL	$90,655	$90,746	**$181,402**	$73,823	$84,022	**$157,846**	

* Budget justification text included in main proposal document.

Budget Justification: USGS BRD is tasked with monitoring mercury bioaccumulation in 3 of the 5 biosentinels, and is the overall administrative project lead that will be coordinating the project. We are requesting funds for ~5% time for Project PIs. Additional PI time will be included as matching funds totaling $13,241. Additionally, we are offsetting the cost of the waterbird egg sampling by approximately $10,000 in year 1 by using funds under our tern monitoring project. Thus, we are requesting funds for only 40% of the tern biosentinel sampling in year 1. We are requesting funds for a technician's salary at 45% per year to conduct field work, sample processing, and data entry. Funds for supplies include consumables such as fish sampling gear, egg collection and processing supplies, lab consumables, and office supplies. USGS will provide equipment such as computers, boats, motors, and analytical equipment. All salaries include benefits and administrative costs.

Sub-Budget 2
San Francisco Estuary Institute; Marsh bird biosentinels

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Sub-Budget 2 of 4 - SFEI (tidal marsh bird biosentinels)

Timeframe: April 2009-April 2011, or April 2010-April 2012 depending on contract approval

Budget Categories	**Total Project Budget**			**Total Grant Request**			**Total Proposed From Other Sources** *(please specify the source, if known)*
	Year 1	**Year 2**	**TOTAL**	**Year 1**	**Year 2**	**TOTAL**	
Labor-Salaries and Benefits (agency: Yr1 hrs, Yr2 hrs)							
Grenier (SFEI: 130, 144)	*$13,268*	*$15,719*	*$28,987*	*$13,268*	*$15,719*	*$28,987*	
Analyst 1 (SFEI: 296, 296)	*$15,310*	*$16,229*	*$31,539*	*$15,310*	*$16,229*	*$31,539*	
Analyst 2 (SFEI: 54, 94)	*$3,646*	*$6,819*	*$10,465*	*$3,646*	*$6,819*	*$10,465*	
Project Mgr. (SFEI: 5, 5)	*$420*	*$445*	*$865*	*$420*	*$445*	*$865*	
Admin. (SFEI: 36, 36)	*$2,406*	*$2,601*	*$5,007*	*$2,406*	*$2,601*	*$5,007*	
Labor (total)	$35,050	$41,813	**$76,863**	$35,050	$41,813	**$76,863**	
Consultant fees/ Contractual Services	$3,150	$3,339	**$6,489**	$3,150	$3,339	**$6,489**	
Travel	$750	$795	**$1,545**	$750	$795	**$1,545**	
Project specific equipment, supplies/materials	$500	$530	**$1,030**	$500	$530	**$1,030**	
Overhead (0%)	$0	$0	**$0**	$0	$0	**$0**	
Other:	$0	$0	**$0**	$0	$0	**$0**	
TOTAL	$39,450	$46,477	**$85,927**	$39,450	$46,477	**$85,927**	

* The RMP at SFEI is providing contributions for both the small fish and waterbird parts of this proposal. See resepective sub-budgets for details.
Budget justification text included in main proposal document.
Rates increase at 6% per calendar year.

Budget Justification: SFEI costs include labor and direct costs for the marsh biosentinel work, with laboratory analysis provided by the Trace Element Research Laboratory in the College of Veterinary Medicine at Texas A&M University run by Dr. Robert Taylor. Travel and supply costs are for field work to sample marsh birds. Approximately 5K of the SFEI budget is administrative costs for managing a subcontract to UC Davis. This arrangement enables a lower overhead rate from UCD.

Sub-Budget 3
UC Davis; Slough fish biosentinels

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Sub-Budget 3 of 4 - UC Davis (slough fish biosentinels)

Timeframe: April 2009-April 2011, or April 2010-April 2012 depending on contract approval

Budget Categories	**Total Project Budget**			**Total Grant Request**			**Total Proposed From Other Sources** *(please specify the source, if known)*
	Year 1	**Year 2**	**TOTAL**	**Year 1**	**Year 2**	**TOTAL**	
Labor-Salaries and Benefits (agency: annual %FTE							
Slotton (UCD: 12%)	*$17,324*	*$17,324*	*$34,648*	*$10,269*	*$10,269*	*$20,538*	*Est. $14,110 UC Davis contribution*
Research Assoc. 1 (UCD: 16%)	*$12,685*	*$12,685*	*$25,370*	*$11,276*	*$11,276*	*$22,552*	*Est. $2,818 UC Davis contribution*
Research Assoc. 2 (UCD: 15%)	*$12,214*	*$12,214*	*$24,428*	*$9,178*	*$9,178*	*$18,356*	*Est. $6,072 UC Davis contribution*
Labor (total) *(includes Hg analyses and sample prep. for an estimated 592 samples)*	$42,223	$42,223	**$84,446**	$30,723	$30,723	**$61,446**	
Consultant fees/ Contractual Services	$0	$0	**$0**	$0	$0	**$0**	
Travel	$1,200	$1,200	**$2,400**	$1,200	$1,200	**$2,400**	
Project specific equipment, supplies/materials	$1,350	$1,350	**$2,700**	$1,350	$1,350	**$2,700**	*>$20,000 in equipment from UC Davis.*
Overhead (10%)	$3,327	$3,327	**$6,655**	$3,327	$3,327	**$6,655**	
Other: *Related RMP small fish biosentinel Hg work in the South Bay*	*$45,000*	*$45,000*	***$90,000***	$0	$0	**$0**	*The related SFEI RMP Small Fish Biosentinel Program includes app. $45,000/yr monitoring at other comparable South Bay sites.*
TOTAL	$93,100	$93,100	**$186,201**	$36,600	$36,600	**$73,201**	

* Budget justification text included in main proposal document.

Budget Justification: UC Davis labor and supply costs include mercury analytical and sample processing for an estimated 592 slough fish biosentinel samples. It is estimated that app. $23,000 will be contributed from other University funding toward planning, interpretation and writeup tasks not covered by the submitted budget. The small fish slough biosentinels will be comparable to and complemented by an extensive small fish data set from the Regional Monitoring Program (SFEI) at a cost of 150K/yr in total and app. 45K/yr specifically for the South Bay. This data set provides a regional context and ambient comparison for the project slough fish samples. The RMP small fish project thus represents and in-kind contribution of approximately $90,000.

Sub-Budget 4
U.S. Geological Survey – WRD Menlo Park; Water process studies

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Sub-Budget 4 of 4 - USGS Menlo Park (water process studies)

Timeframe: April 2009-April 2011, or April 2010-April 2012 depending on contract approval

Budget Categories	Total Project Budget			Total Grant Request			Total Proposed From Other Sources *(please specify the source, if known)*
	Year 1	Year 2	TOTAL	Year 1	Year 2	TOTAL	
Labor-Salaries and Benefits (Pay grade, Hourly Rate; planned hrs/yr)							
J. Agee (GS-11; $45.90/hr; 175 hrs/yr)	*$8,002*	*$8,002*	*$16,004*	*$8,002*	*$8,002*	*$16,004*	
E. Kakouros (GS-11; $45.18/hr; 250 hrs/yr)	*$11,291*	*$11,291*	*$22,582*	*$11,291*	*$11,291*	*$22,582*	
L.H. Kieu (GS-9; $35.94/hr; 248 hrs/yr)	*$8,914*	*$8,914*	*$17,828*	*$8,914*	*$8,914*	*$17,828*	
Technician (GS-2; $11.65/hr; 128 hrs/yr)	*$1,486*	*$1,486*	*$2,972*	*$1,486*	*$1,486*	*$2,972*	
M. Marvin-DiPasquale (GS-14; $78.06/hr; 150 hrs/yr)	*$11,709*	*$11,709*	*$23,418*	*$0*	*$0*	*$0*	*Dr. Marvin-DiPasquale's time provided by USGS as a cost-share*
Labor (total) *(includes aqueous analytical work)*	$41,402	$41,402	**$82,804**	$29,693	$29,693	**$59,386**	
Consultant fees/ Contractual Services	$0	$0	**$0**	$0	$0	**$0**	
Travel	$750	$750	**$1,500**	$750	$750	**$1,500**	
Project specific equipment, supplies/materials	$2,968	$2,968	**$5,936**	$2,968	$2,968	**$5,936**	
Overhead (55.12% of NET)	$24,870	$24,870	**$49,740**	$18,416	$18,416	**$36,832**	
Other:	$0	$0	**$0**	$0	$0	**$0**	
TOTAL	$69,990	$69,990	**$139,980**	$51,827	$51,827	**$103,654**	

* Budget justification text included in main proposal document.

Budget Justification: Analytical costs for water column mercury speciation and SPM geochemical analyses, conducted by USGS (Menlo Park, CA), are reflected in staff salary plus benefits (90% of analytical costs) plus supplies (10% of analytical costs). Staff costs also includes those for data synthesis, interpretation, and report writing. All dollar amounts are given as gross costs using the current Federal government overhead rate of 55.12% of net costs, which includes both Bureau and Facilities (rent, operation and maintenance) costs. The budget for the work preformed by the USGS Menlo Park research group does not include any salary for Dr. Mark Marvin-DiPasquale, which is projected at 300 hours over the course of the whole project, and equals an in-kind cost-share contribution of $23,418 net costs or $36,326 gross costs, which is more than 1/3 of the requested budget.

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Mark Stephenson, California Dept. of Fish and Game, Moss Landing, CA;
email: mstephenson@mlml.calstate.edu

David Evers, Biodiversity Research Institute, Gorham, ME; email:
david.evers@briloon.org

Chad Hammerschmidt, Wright State University; Dayton, OH;
email: chad.hammerschmidt@wright.edu

NECESSARY PERMITS:
Biosentinels will be monitored and handled under existing California Department of Fish and Game Scientific Collection (SC000009, SC801083-01, SC002545 and SC000084), Federal U.S. Fish and Wildlife Service (MB102896, TE-042630-3), and U.S. Geological Survey Bird Banding Laboratory (22911, 23446) permits, and Don Edwards San Francisco Bay National Wildlife Refuge Special Use Permit (11640-2006-006, 11640-2008-022, 81640-2008-060).

ANIMAL CARE AND USE:
All research will be conducted under approved study plans and guidelines of the U.S. Geological Survey, Western Ecological Research Center, Animal Care and Use Committee. This study proposes limited handling and disturbance of birds and is mainly observational in nature. Weekly nest monitoring activities have been extensively developed in cooperation with the Don Edwards SFBNWR staff over the past 5 breeding seasons and causes minimal disruption to nesting birds as indicated by low nest abandonment rates. Slough fish work by UC Davis will be conducted using UCD Animal Care and Use Protocol 13464, which was developed in conjunction with the UCD Wildlife Veterinary Unit to minimize any discomfort to sampled individuals, or disruption to sampled populations. As a private non-profit organization, SFEI does not have an ACUC. Nevertheless, marsh bird studies will be conducted as per procedures previously approved by the University of California, Berkeley, ACUC. Impact on birds will be minimized by sampling only once per year without repeated visits to the same territories.

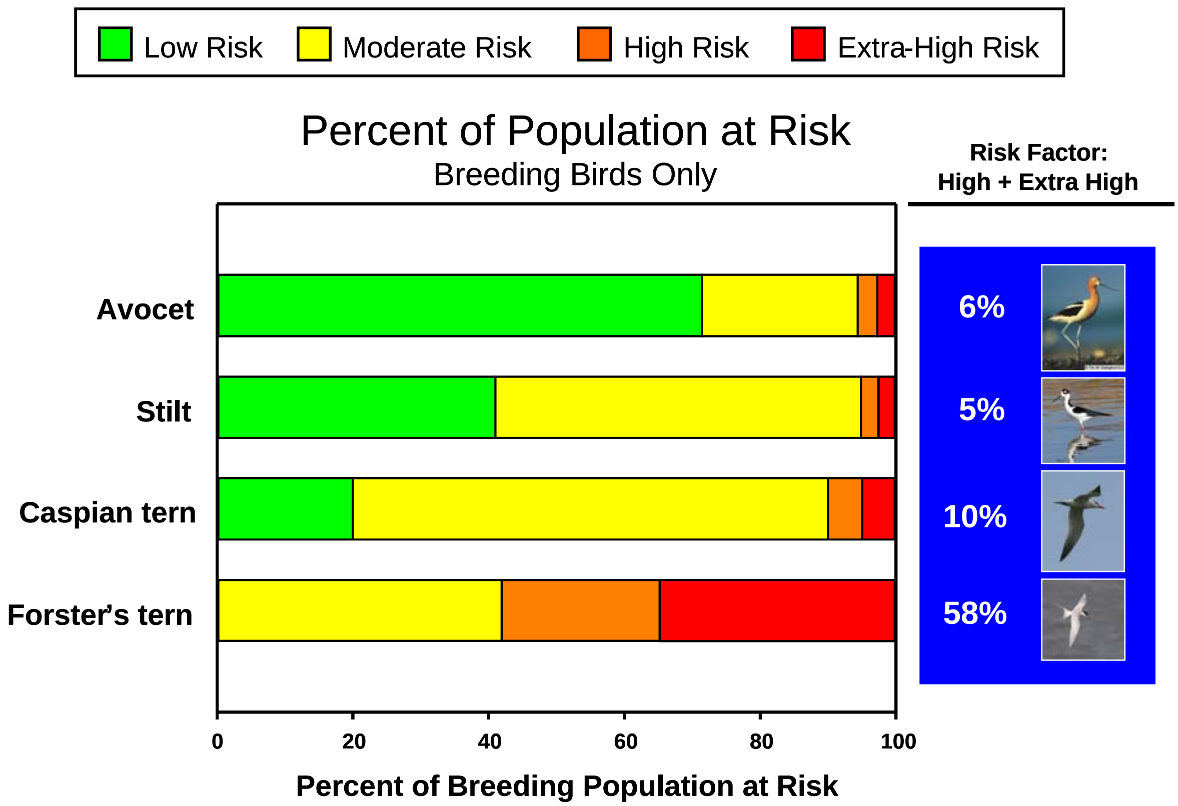

Figure 1. Percentage of waterbird breeding populations that are at risk to reduced reproductive success and declining populations due to mercury contamination in the South San Francisco Bay. Data are from birds captured on nests while incubating; blood was used as the sample matrix (Ackerman et al. 2007b). Risk levels were derived from Evers et al. 2008.

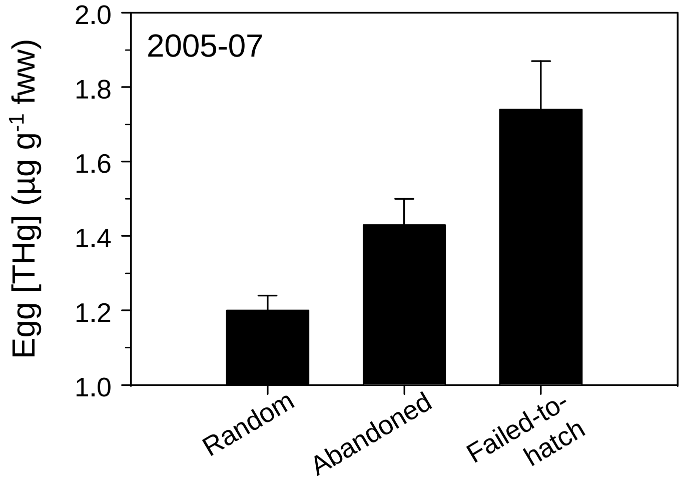

Figure 2. Mercury concentrations in failed-to-hatch Forster's Tern eggs were higher than randomly sampled eggs from successful nests during 2005-2007. Ackerman and Eagles-Smith 2008b.

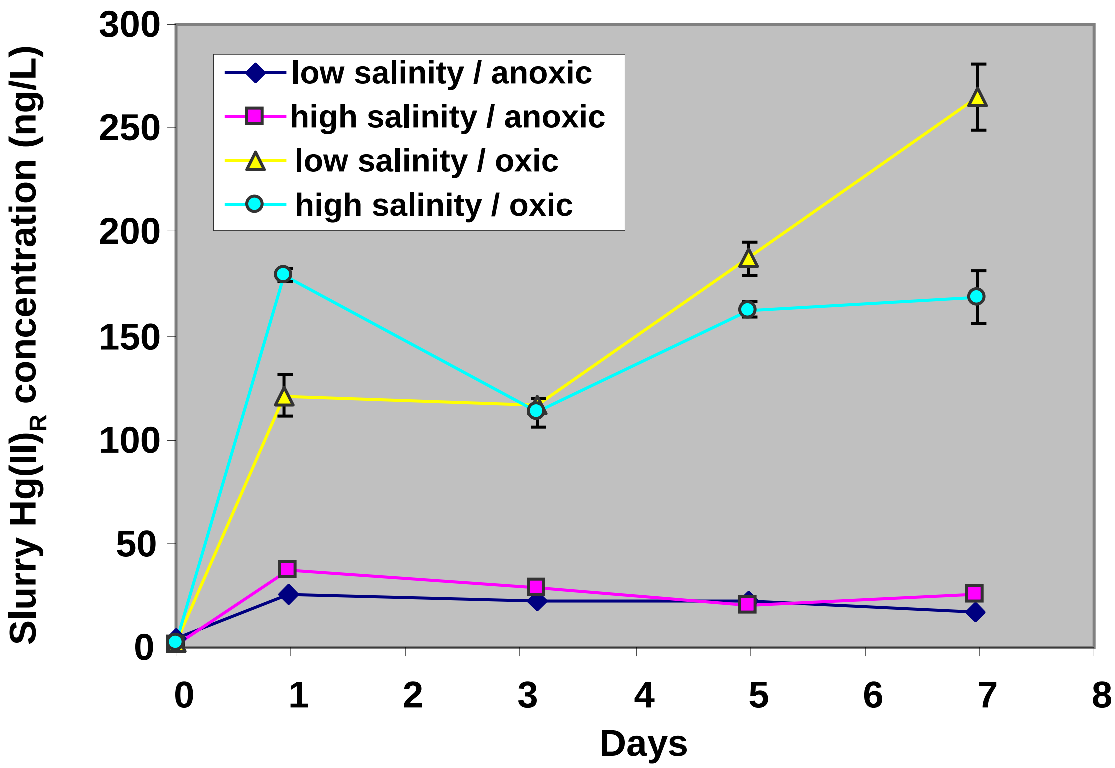

Figure 3. Time course plot of reactive mercury concentrations associated with the slough scour simulation experiment

Changes in reactive inorganic mercury ($Hg(II)_R$) concentrations in sediment / overlying slough water slurries repeatedly sampled over 7 days, under four treatment conditions (see inset legend). Error bars reflect the relative difference of n=2 sub-samples per treatment and time point. When not shown, error bars were smaller than the treatment symbol. Taken from Marvin-DiPasquale and Cox (2007).

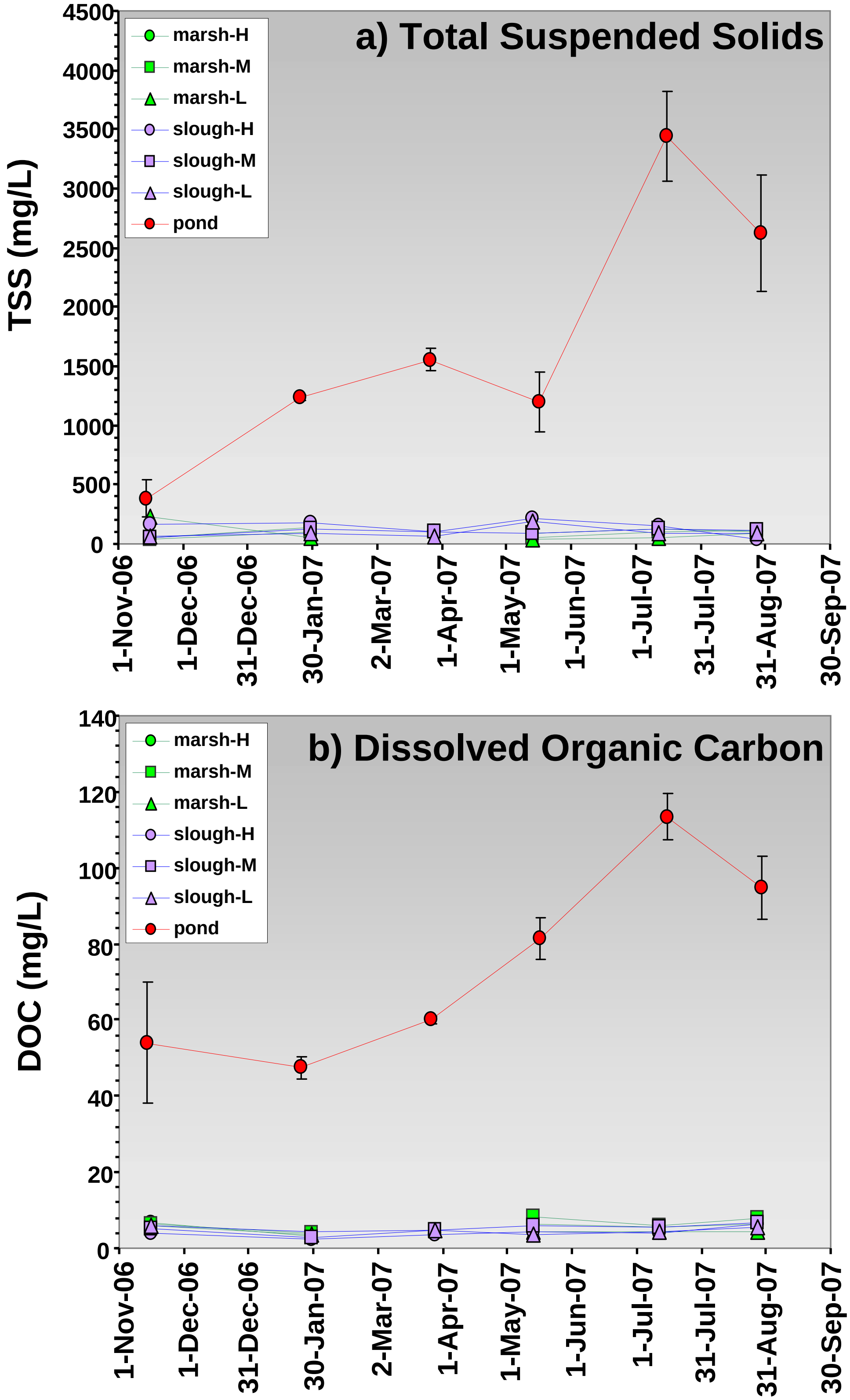

Figure 4. Time series graphs of <u>overlying water</u> concentrations of total suspended solids (a) and dissolved organic carbon (b), in waters collected from Alviso Marsh and Slough (high [H], mid [M] and low [L] along the salinity gradient), and Pond A8. Alviso Slough and Marsh symbols represent the average of N = 2 and N = 1 site(s), respectively. Pond A8 symbols represents the average of N = 7 sampling sites, and error bars represent ± 1 standard error of the mean. Visual examination of the samples indicates that the TSS in Pond A8 was almost completely phytoplankton. Taken from Grenier et al. (2008); unpublished.

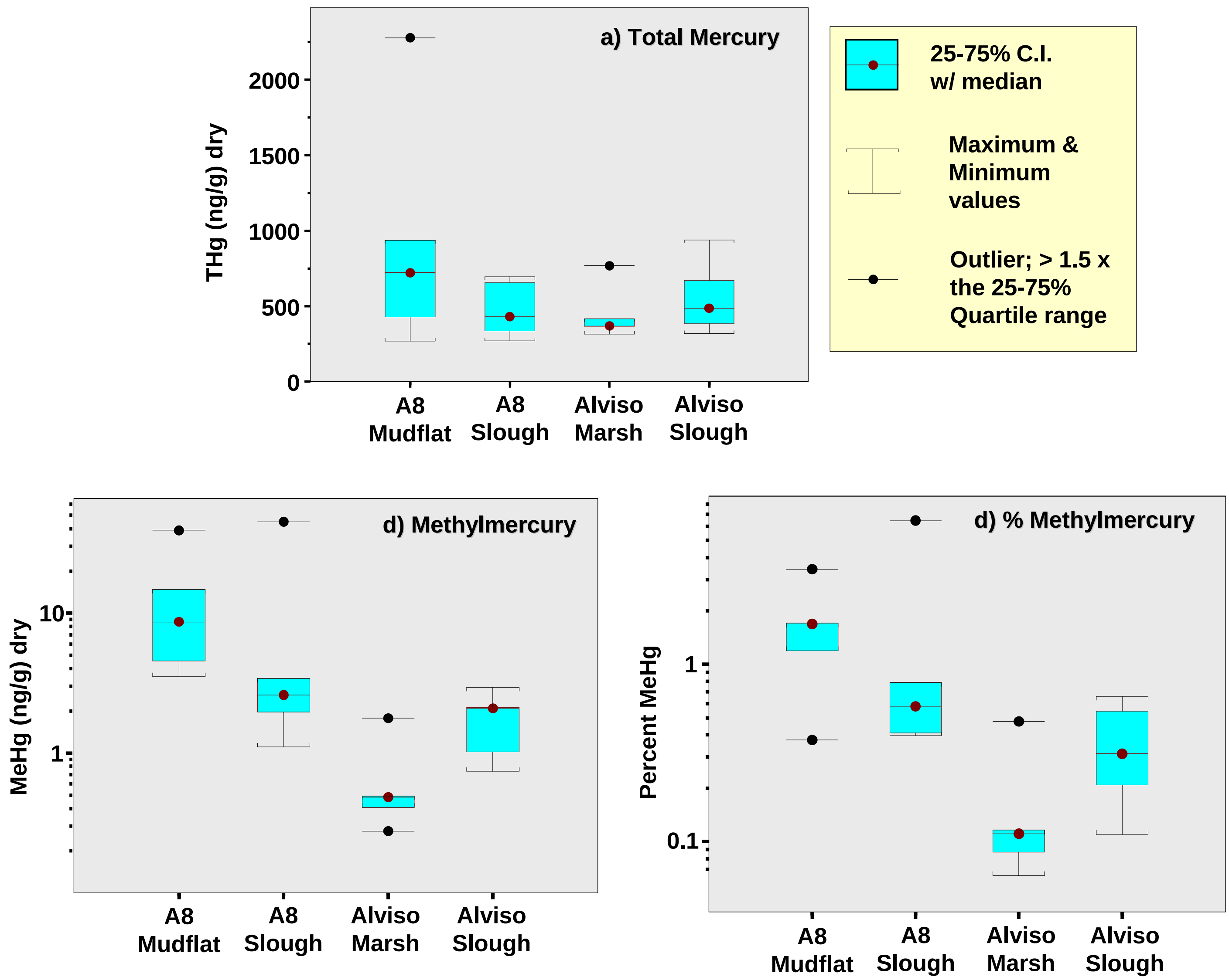

Figure 5. Box and whisker plots of sediment total mercury (THg), and methylmercury (MeHg) in Pond A8 and Alviso slough and Marsh, sampled between May and July 2007. Each habitat represents N = 5 individual sites. Taken from Greneir et al. (2008); unpublished.

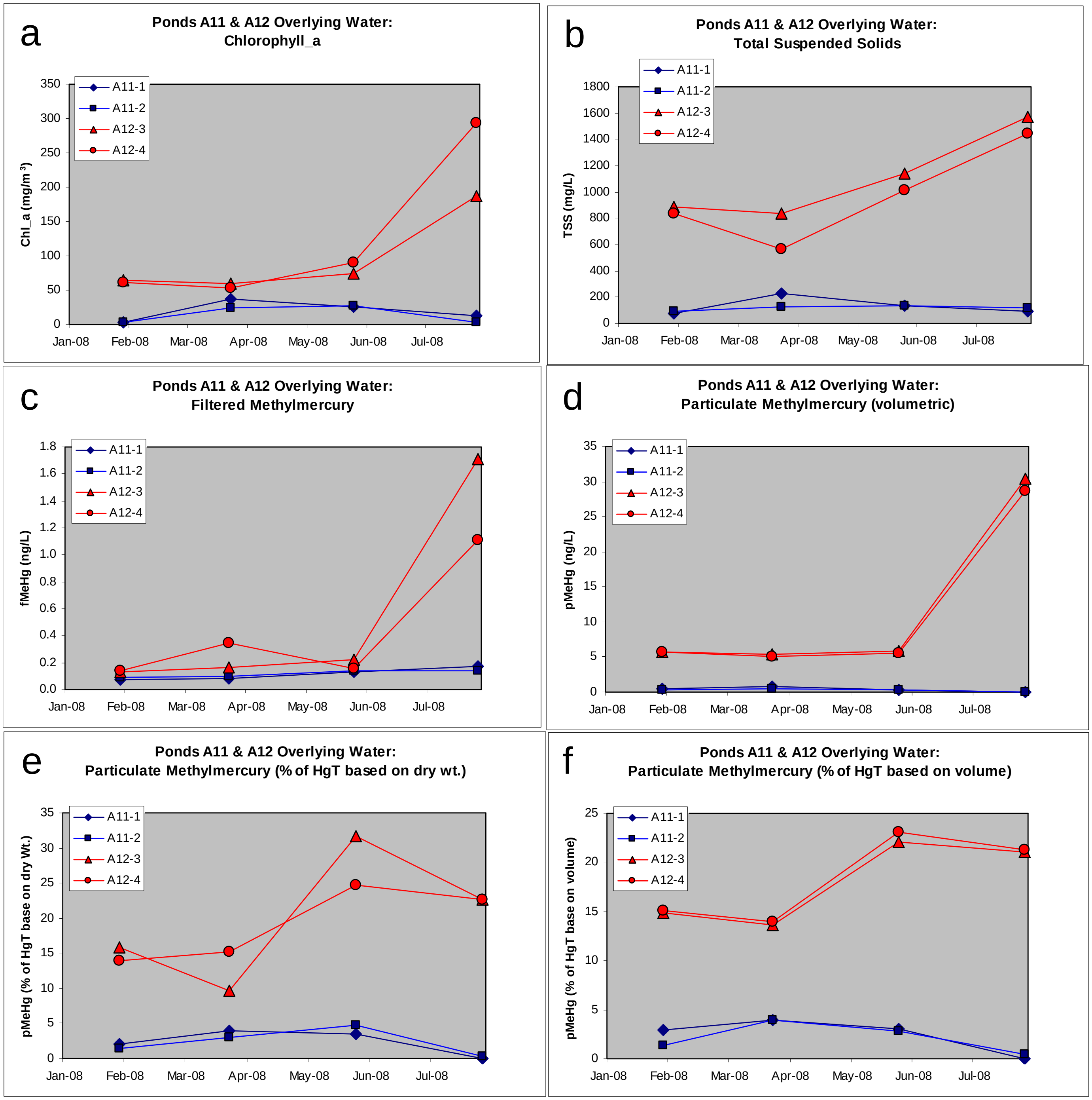

Figure 6. Time series graphs of overlying water concentrations of chlorophyll (a), total suspended solids (b) filtered MeHg (c), particulate MeHg (d), and percent MeHg on particles (e) and in whole water (f) in 2008 from two sites from Pond A11 and Pond A12. Marvin-DiPasquale, unpublished data.

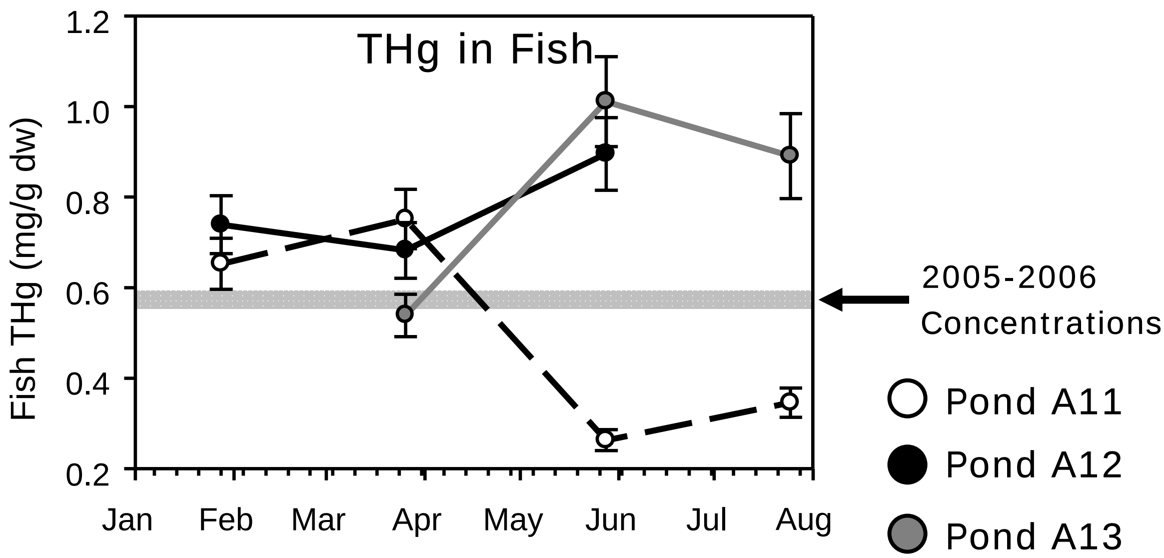

Figure 7. Temporal trend of THg concentrations in biosentinel fish from a reference pond (Pond A11), and pond undergoing management actions to increase waterbird nesting habitat (A12 and A13). Eagles-Smith and Ackerman, unpublished data.

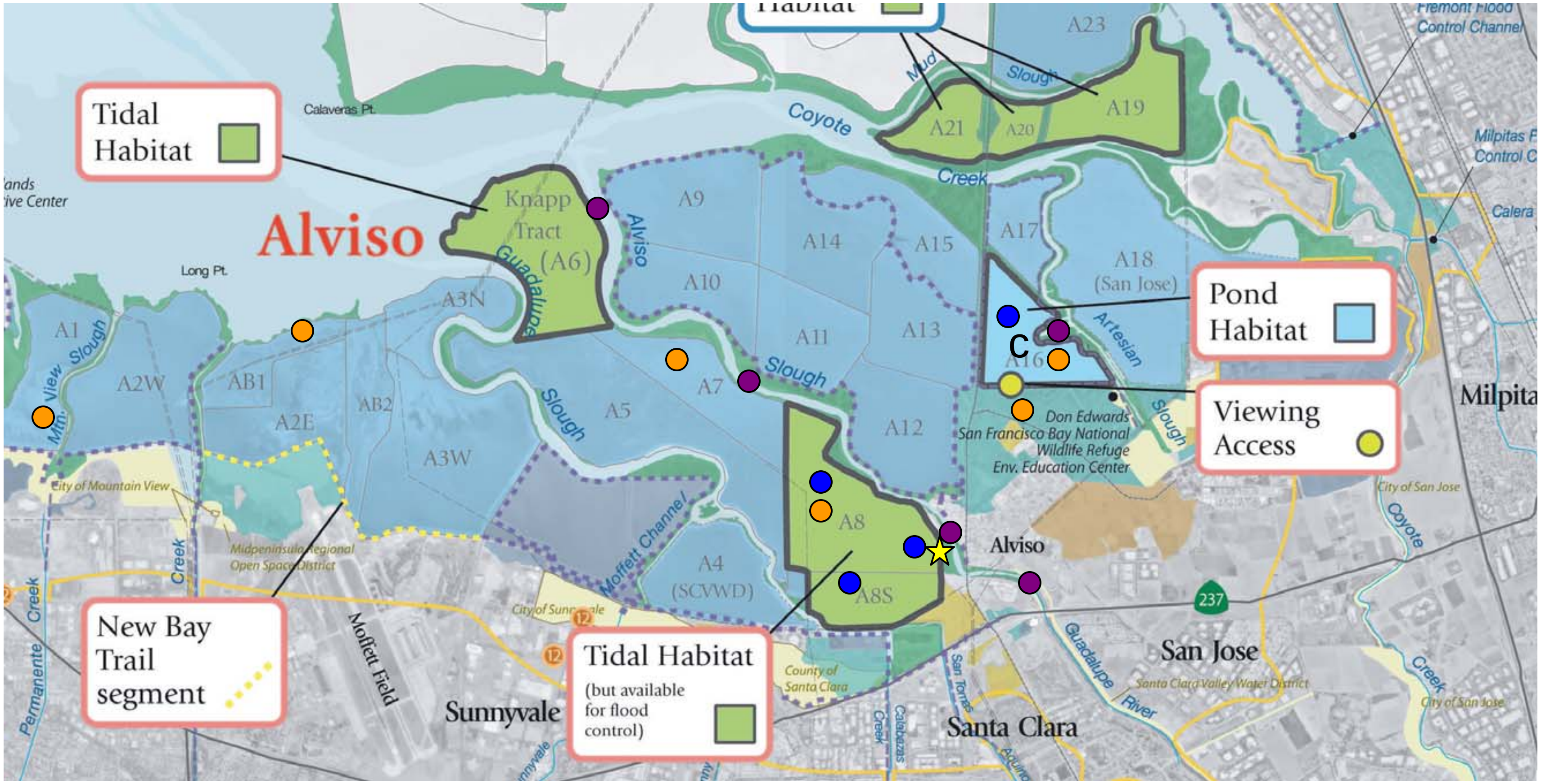

Figure 8. This example map shows how the study design relates to the geography of the SBSPRP. Orange circles indicate potential waterbird sampling sites representing a gradient of influence from Pond A8. Blue circles indicate example sampling location in ponds (Pond A8 and reference site). Purple circles indicate example sampling locations in sloughs and fringing marshes (Alviso Slough and reference site). Here, Pond A16 and Mallard Slough are depicted as reference sites as an example, but the final choice is to be determined. The yellow star shows the approximate location of the future notch in the levee of Pond A8. Map from www.southbayrestoration.org.

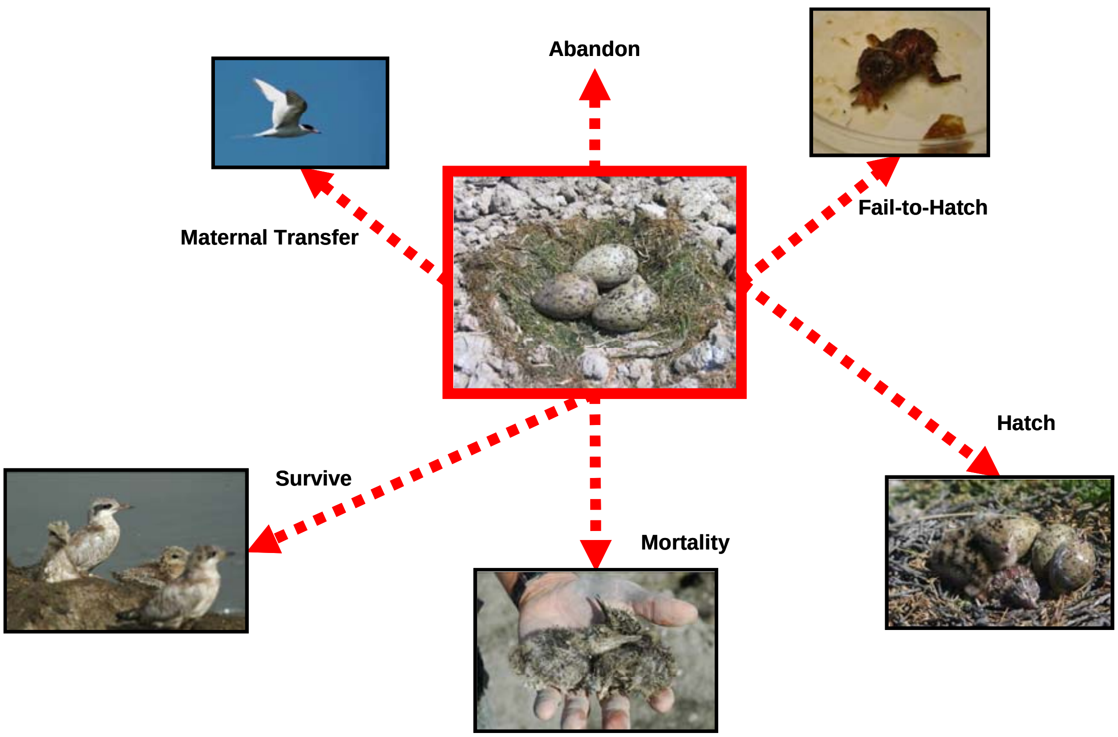

Figure 9. Conceptual model demonstrating the utility of using eggs as a monitoring tool for multiple lifestages, incorporating effects to adults, chicks, and eggs into a single tissue monitoring matrix – *eggs*. Once toxicity thresholds are developed for each lifestage shown, they can be translated into equivalent concentrations in eggs. Thereafter, toxicity thresholds for eggs will incorporate mercury's effect on hatchability, chick growth and survival, and the probability of adult nest abandonment. Ackerman and Eagles-Smith 2008b.

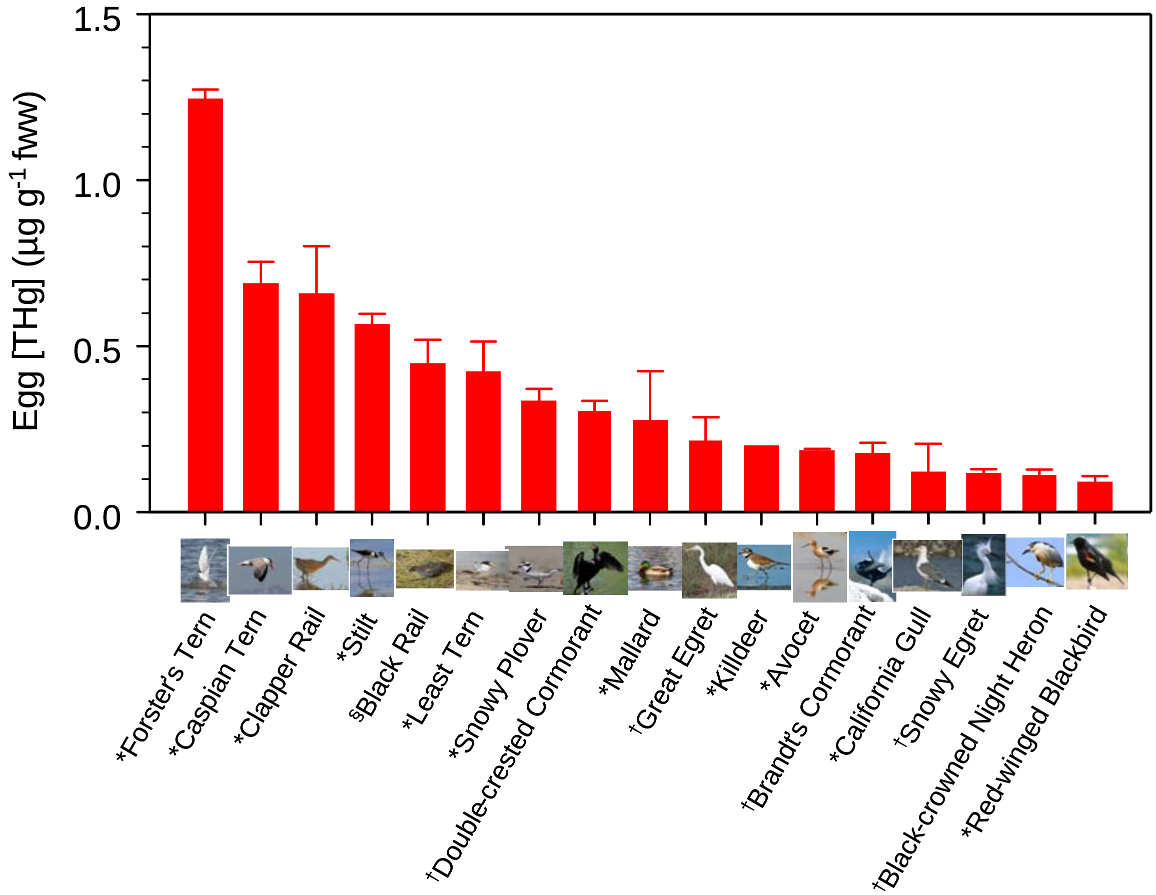

Figure 10. Geometric ± SE mean mercury concentrations in 17 species of aquatic bird eggs (µg g^{-1} fresh wet weight [fww]) in the San Francisco Bay Estuary, California. Of the birds studied, Forster's Terns have the highest egg mercury concentrations, other fish and invertebrate eating waterbirds have moderate mercury concentrations, and aquatic dependent songbirds have the lowest mercury concentrations. *unpublished data from Ackerman and Eagles-Smith 2008b. †data from Schwarzbach and Adelsbach 2003. §data from Tsao et al. 2008.

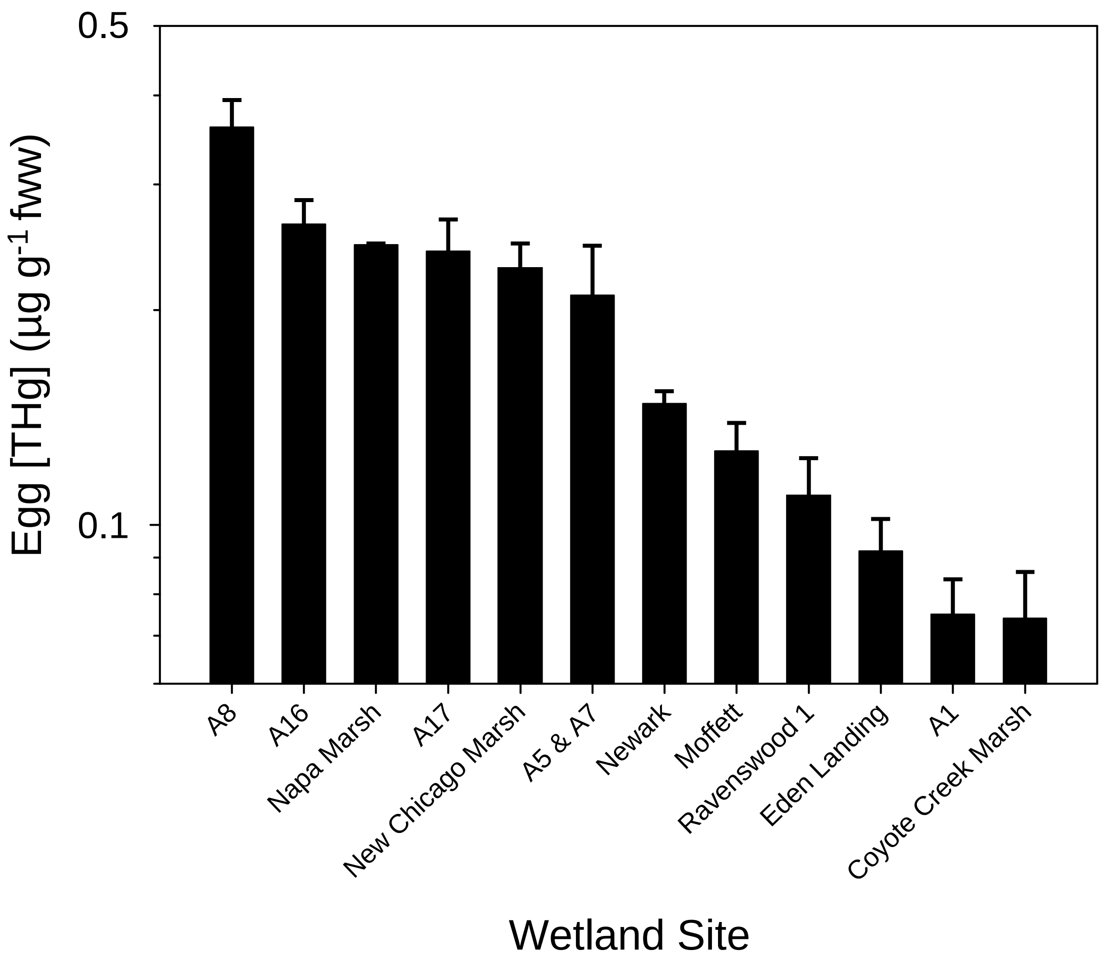

Figure 11. Average±SE mercury concentrations in Avocet eggs collected in San Francisco Bay between 2005-2007. Concentrations vary by up to 5-fold among individual wetlands, highlighting the utility of Avocet eggs to determine wildlife exposure on a pond-specific basis.

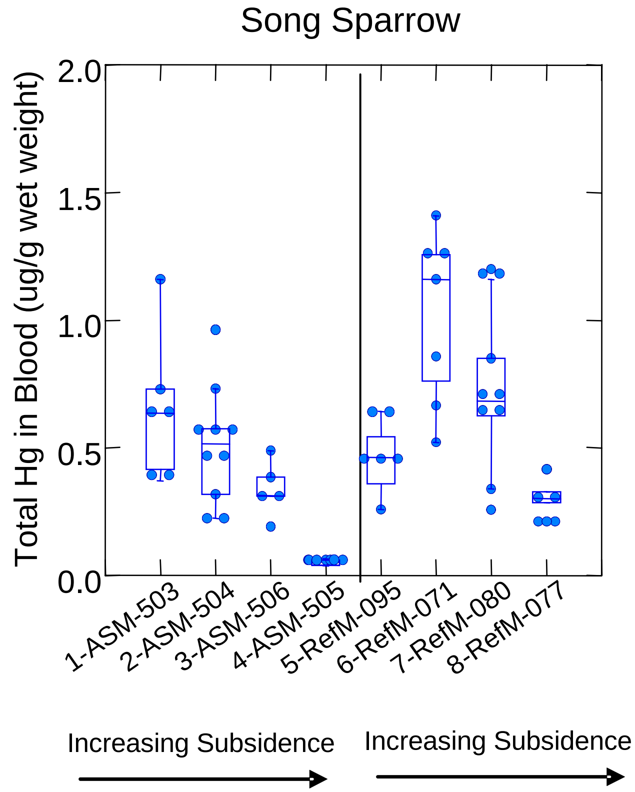

Figure 12. Mercury in sparrow biosentinels differed among sites in South Bay in 2007. Alviso Slough marshes (A) as a population had slightly lower bioaccumulation of mercury in sentinels than ambient South Bay marshes (B). Variation among marshes was correlated with extent of subsidence from groundwater pumping in previous decades. Reference marsh 095 was a consistent outlier to this pattern across marsh songbird species, which may be because it was the only freshwater unsubsided marsh in the study area. Adapted from Grenier et al. (2007).

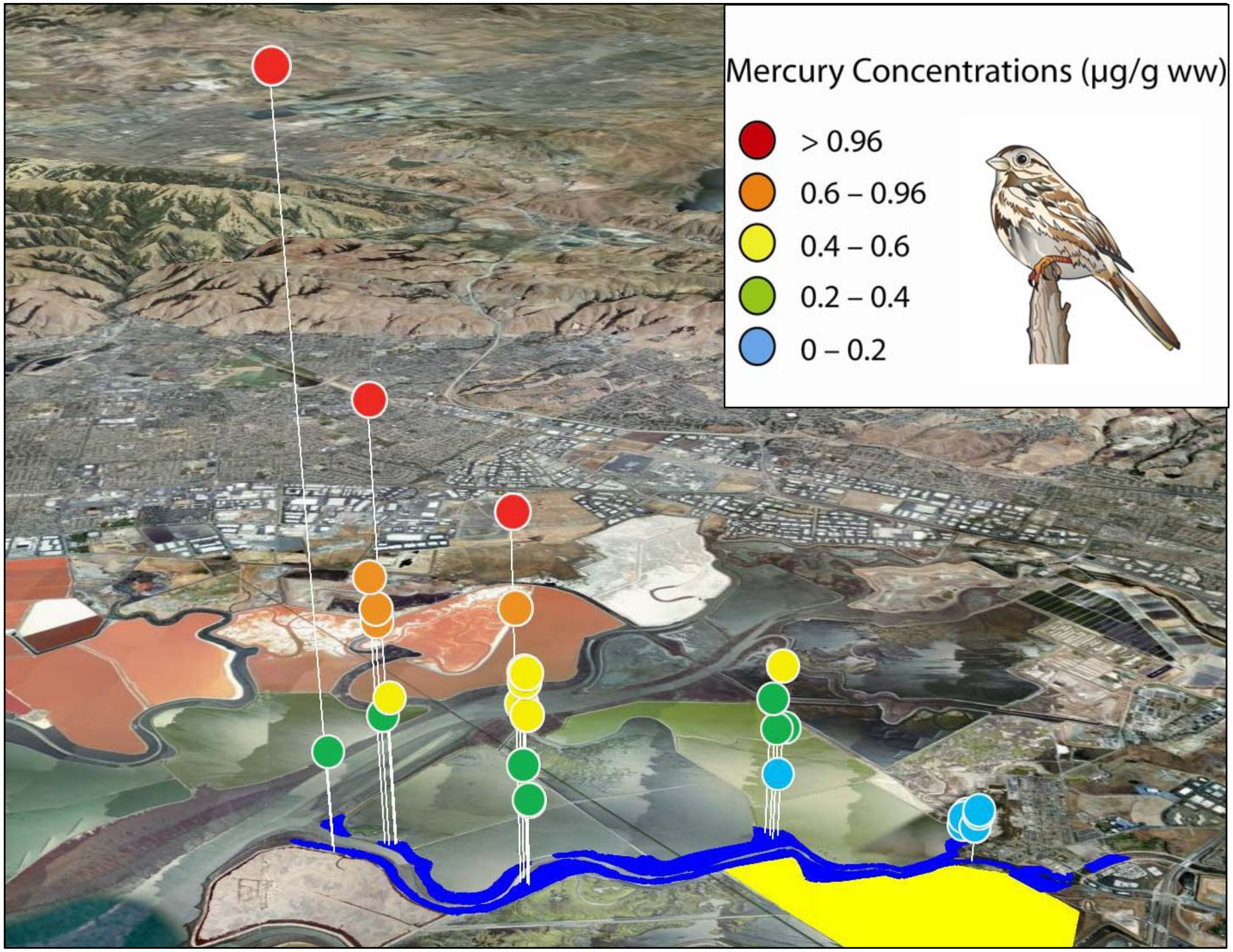

Figure 13. The localized spatial footprint of Song Sparrow sentinels makes them ideal for assessing gradients of impact. These data from 2007 show differences in sparrow mercury along the gradient of Alviso Slough (in blue), from salt to fresh water and from less subsided to more subsided (left to right). Each colored dot represents the blood concentration of THg from an individual bird. The color of the circle and the height of the bar indicate the concentration. Previous data such as these will be used to assess any change away from the pre-notch pattern of sparrow Hg bioaccumulation along Alviso Slough that is shown here. Adapted from Grenier et al. (2007).

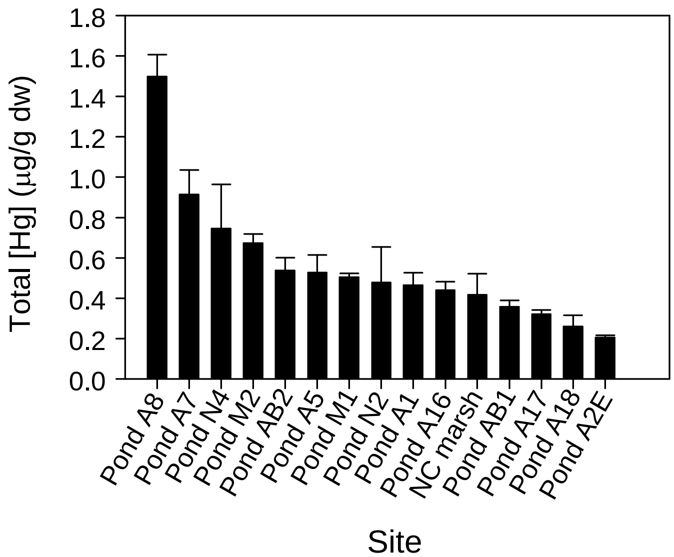

Figure 14. Average (SE) mercury concentrations in three-spined stickleback sampled in saltponds throughout the South Bay Restoration Project Area between 2005-2007.

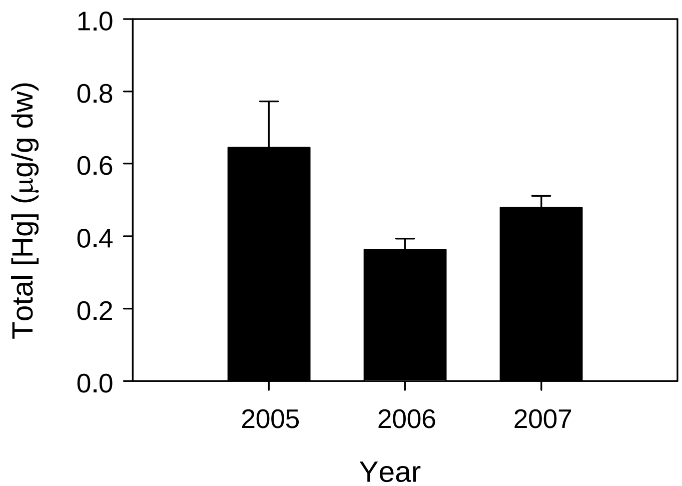

Figure 15. Yearly differences in average (SE) mercury concentrations in three-spined stickleback sampled in saltponds throughout the South Bay Restoration Project Area between 2005-2007.

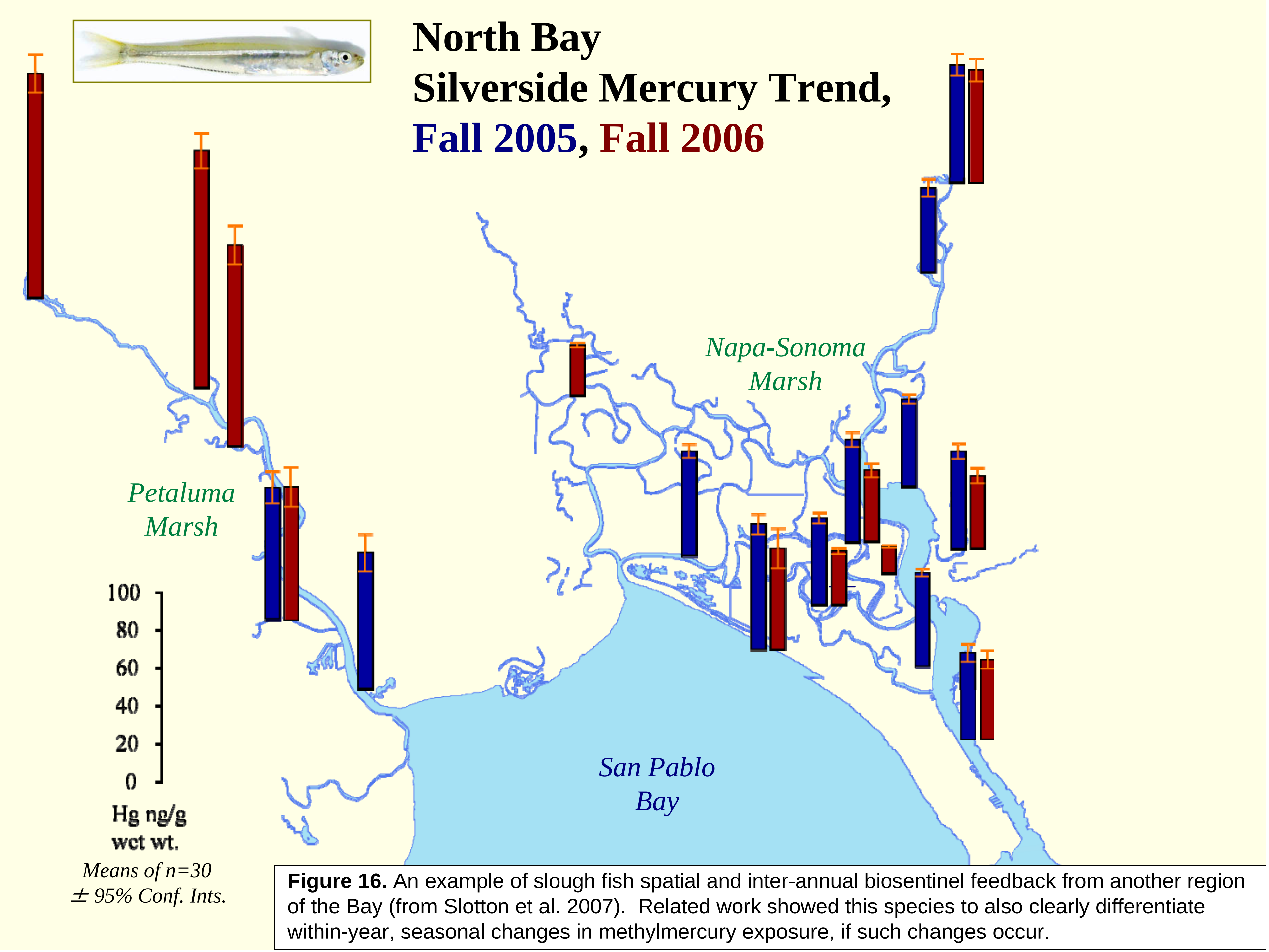

Figure 16. An example of slough fish spatial and inter-annual biosentinel feedback from another region of the Bay (from Slotton et al. 2007). Related work showed this species to also clearly differentiate within-year, seasonal changes in methylmercury exposure, if such changes occur.

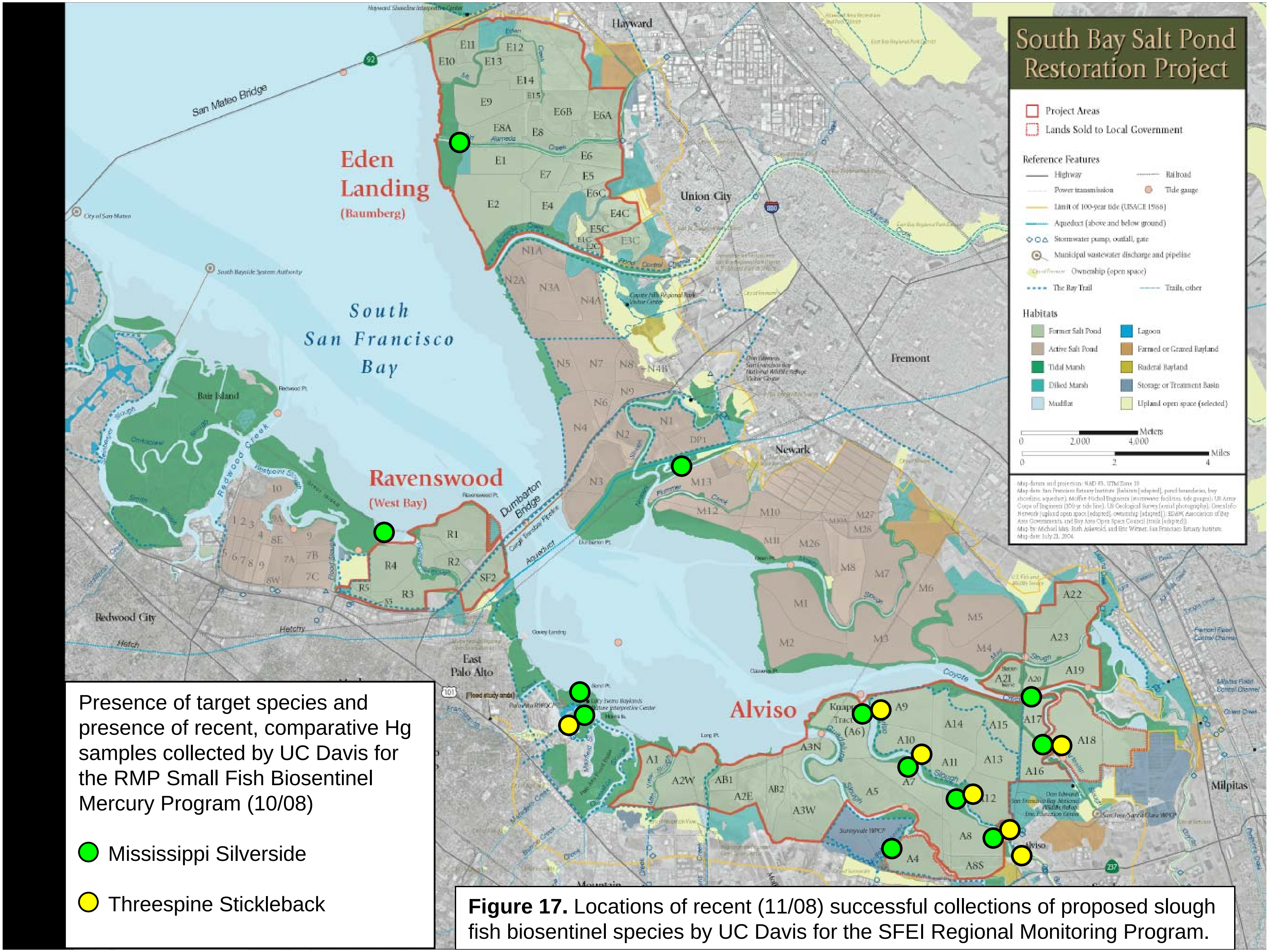

Figure 17. Locations of recent (11/08) successful collections of proposed slough fish biosentinel species by UC Davis for the SFEI Regional Monitoring Program.

COLLIN A. EAGLES-SMITH

US Geological Survey, Western Ecological Research Center, Davis Field Station
One Shields Ave, UC Davis, CA 95616, ceagles-smith@usgs.gov, 530-754-8130

EDUCATION

Ph.D. Ecology. University of California, Davis (2006)
B.S. (Magna Cum Laude) Env. Resource Sciences. University of California, Davis (2000)

RELEVANT EXPERIENCE AND RESEARCH INTERESTS

I have studied mercury bioaccumulation in aquatic food webs for the past 8 years, and have been leading research on mercury bioaccumulation and risk in waterbirds and fish in the South Bay Salt Ponds for the past 5 years. I am also currently a collaborator on several other mercury projects in the region that are developing specific biosentinels to evaluate the impact of wetland restoration on Hg bioaccumulation. My larger scale research interests focus on integrating trophic and community ecology to assess how mercury bioaccumulates through different components of the food web, and well as how changes in food web structure can influence mercury bioaccumulation. I have also recently focused on quantifying ecological risk of mercury exposure and determining thresholds of impairment in waterbirds.

EXPECTED CONTRIBUTIONS TO THIS PROJECT

I will lead the oversight and administration of this project. I will also be the lead researcher for the waterbird and pond biosentinel components of the study. I will coordinate and supervise the sample collection of waterbird and pond biosentinels, and collaborate on summary, analysis, and reporting of project results.

PROFESSIONAL EXPERIENCE

Wildlife Biologist, USGS, WERC, UC Davis Field Station (8/07-present).
Senior Biologist, US Fish and Wildlife Service, Sacramento (2/07-8/07).
Staff Biologist, US Fish and Wildlife Service, Sacramento (2/03-2/07).
Doctoral Research, Dept. of Wildlife, Fish and Cons. Biology, UC Davis (9/00-11/06).
Staff Research Assistant, Dept. of Wildlife, Fish and Cons. Biology, UC Davis (2/98-9/00).

PUBLICATIONS: *21 peer-reviewed journal publications (4 lead), 6 popular articles (4 lead), 8 technical reports, and 63 scientific presentations. Below is a selected list of publications.*

Eagles-Smith, CA, TH Suchanek, AE Colwell, NL Anderson, PB Moyle. 2008. Changes in fish diets and food web mercury bioaccumulation induced by an invasive planktivorous fish. Ecological Applications, in press.

Eagles-Smith, CA, TH Suchanek, AE Colwell, NL Anderson. 2008. Mercury trophic transfer in a eutrophic lake: the importance of habitat-specific foraging. Ecological Applications, in press.

Eagles-Smith, CA, JT Ackerman, J Yee, and TL Adelsbach. 2009 Mercury demethylation in livers of four waterbird species: evidence for dose-response thresholds with liver total mercury. Environmental Toxicology and Chemistry, in press.

Stebbins, KR, JD Klimstra, **CA Eagles-Smith**, JT Ackerman, GH Heinz. 2009. Micro-sampling eggs to monitor the effects of methylmercury on wild birds. Environmental Toxicology and Chemistry. In press.

Eagles-Smith, CA, JT Ackerman, TL Adelsbach, JY Takekawa, AK Miles, RA Keister. 2008. Mercury correlations among six tissues for four waterbird species breeding in San Francisco Bay, California, USA. Environmental Toxicology and Chemistry 27:2136-2153.

Ackerman, JT, **CA Eagles-Smith**, JY Takekawa, SA Iverson. 2008. Survival of postfledging Forster's terns in relation to mercury exposure in San Francisco Bay. Ecotoxicology. 17: 789-801.

Ackerman, JT, **CA Eagles-Smith,** JY Takekawa, JD Bluso, TL Adelsbach. 2008. Mercury concentrations in blood and feathers of pre-breeding Forster's terns in relation to space use of San Francisco Bay habitats. Environmental Toxicology and Chemistry 27:897-908

Ackerman, JT, JY Takekawa, JD Bluso, JY Yee, **CA Eagles-Smith**. 2008. Gender identification of Caspian Terns using external morphology and discriminant function analysis. The Wilson Journal of Ornithology. 120:378-383.

Ackerman, JT, JY Takekawa, **CA Eagles-Smith**, SA Iverson. 2007. Mercury contamination and effects on survival of American avocet and black-necked stilt chicks in San Francisco Bay. Ecotoxicology 17:103-116.

Ackerman, JT, **CA Eagles-Smith**, JY Takekawa, SA Demers, TL Adelsbach, JD Bluso, AK Miles, N Warnock, TH Suchanek, and SE Schwarzbach. 2007. Mercury concentrations and space use of pre-breeding American avocets and black-necked stilts in San Francisco Bay. Science of the Total Environment 384: 452-466.

Anderson, DW, TH Suchanek, **CA Eagles-Smith**, T Cahill. 2008. Mercury residues in ospreys and grebes in a mine-dominated ecosystem: Clear Lake, California. Ecological Applications. In press.

Suchanek, TH, **CA Eagles-Smith**, DG Slotton, EJ Harner, D Adam, AE Colwell, NL Anderson, D Woodward. 2008. Mine-derived mercury: effects on lower trophic species in Clear Lake, California. Ecological Applications. In press

Suchanek, TH, **CA Eagles-Smith**, EJ Harner. 2008. Is Clear Lake methylmercury decoupled from bulk mercury loading? Implications for lake management and TMDL implementation. Ecological Applications. In press

Suchanek, TH, **CA Eagles-Smith**, DG Slotton, EJ Harner, AE Colwell, NL Anderson, L Mullen, J Flanders, D Adam, K McElroy. 2008. Spatio-temporal trends of mercury in fish from a mine-dominated ecosystem at Clear Lake, California: individual, species, and population trends. Ecological Applications. In press.

Suchanek, TH, **CA Eagles-Smith**, EJ Harner, D Adam. 2008. Mercury in abiotic compartments of Clear Lake, California: human health and ecotoxicological implications. Ecological Applications. In press

Richerson, P, TH Suchanek, R Zierenberg, D Osleger, A Heyvaert, D Slotton, **CA Eagles-Smith**, C Vaugh. 2008. Anthropogenic stressors and changes in the Clear Lake ecosystem as recorded in sediment cores. Ecological Applications. In press.

Suchanek, TH, PJ Richerson, DC Nelson, **CA Eagles-Smith**, DW Anderson, JJ Cech, Jr., G Schladow, R Zierenberg, JF Mount, SC McHatton, DG Slotton, LB Webber, AL Bern, and BJ Swisher. 2003. Evaluating and managing a multiply-stressed ecosystem at Clear Lake, California: A holistic ecosystem approach. In: Managing For Healthy Ecosystems, Case Studies; CRC/Lewis Press, Boca Raton, FL, USA.

J. LETITIA GRENIER

San Francisco Estuary Institute, Wetlands Science and Contaminants Monitoring and Research Programs, 7770 Pardee Lane, 2nd Floor, Oakland, CA 94726, 510-746-7388, letitia@sfei.org

Education

2004 Ph.D. Environmental Science, Policy and Management. University of California, Berkeley.
1994 B.A. Biology and Film/Video. Middlebury College, Vermont.

Experience Relevant to this Project

For the past three years, I have lead the biosentinel component of the South Baylands Mercury Project, which has provided scientific answers for the South Bay Salt Pond Restoration Project Management Team and their partners regarding a course of action to follow for Pond A8 relative to the mercury risk. I have also coordinated among the PI groups to produce integrated Annual Progress Reports and to coalesce the sediment, water, and biota results to produce a coherent scientific message for managers. My previous and ongoing experience with mercury science as part of the CalFed Fish Mercury Project, CalFed Petaluma River Mercury Project, SWAMP Historical Bioaccumulation Review, and the Regional Monitoring Program for Water Quality also position me to excel in my contributions to this proposal. My expertise from both SFEI and UC Berkeley in wetlands ecology, tidal marsh food webs, and tidal marsh avian behavior and ecology provide me with the detailed knowledge of San Francisco Bay tidal marshes and their fauna that is necessary to lead the marsh biosentinel work.

Expected Contributions to this Project

I will lead the marsh biosentinel (Song Sparrow) component of this project and integrate marsh results with data from the other project components. In particular, I will be responsible for obtaining samples in the field, analyzing and interpreting data, report writing, and project management.

Relevant Publications

Robinson, A., A. Cohen, B. Lindsey, and J. L. Grenier. *In review*. Distribution of macroinvertebrates across a tidal gradient in the China Camp State Park salt marsh, Marin County, CA. Invited paper for San Francisco Bay National Estuarine Research Reserve book.

Grenier, J. L., and R. Greenberg. 2006. Trophic adaptations in sparrows and other vertebrates of tidal marshes. (Invited paper for the Vertebrates of Tidal Marshes Symposium, Patuxent Wildlife Research Center, Maryland, 2002). Studies in Avian Biology 32:130-139.

Takekawa, J. Y., I. Woo, H. Spautz, N. Nur, J. L. Grenier, K. Malamud-Roam, J. C. Nordby, A. N. Cohen, F. Malamud-Roam, S. E. Wainwright-De La Cruz. 2006. Environmental threats to tidal marsh vertebrates of the San Francisco Bay Estuary. Studies in Avian Biology 32:176-197.

Latif, Q., J. L, Grenier, S. Heath, G. Ballard, and M. E. Hauber. 2006. First evidence of conspecific brood parasitism and egg ejection in song sparrows, with comments on methods sufficient to document these behaviors. Condor 108:452-458.

Grenier, J. L and R. Greenberg. 2005. A biogeographic pattern in sparrow bill morphology: parallel adaptation to tidal marshes. Evolution 59, 1588-1595.

Davis, J. A., J. L. Grenier, and R. Grossinger. 2005. Water quality concerns related to the South Bay Salt Pond Restoration Project. The Pulse of the Estuary: Monitoring and Managing Water Quality in the San Francisco Estuary. SFEI Contribution 411. San Francisco Estuary Institute, Oakland, CA.

Grenier, J. L. and S. R. Beissinger. 1999. Variation in the onset of incubation in a Neotropical parrot. Condor 101:752-761.

Recent Grants and Awards

2007 *California State Coastal Conservancy*. Assessment of the ecological risk associated with restoring managed salt ponds to tidal marsh, using marsh birds, fish, and invertebrates as biosentinels for mercury. $110,000.

2007 *San Francisco Foundation: San Francisco Bay Fund*. Application of biosentinel wildlife species as ecological risk assessment and adaptive management tools for tidal marsh restoration. $50,000.

2006 *California State Coastal Conservancy*. Development of biosentinel wildlife species of birds, fish, and invertebrates to assess the ecological risk of mercury bioaccumulation associated with restoring salt ponds to tidal marsh. $270,000.

2005 *San Francisco Foundation: San Francisco Bay Fund*. Development of wildlife as adaptive management tools for mercury in tidal marshes. $40,000.

2002 *Budweiser Conservation Scholarship*. Research on tidal marsh sparrow trophic and behavioral ecology. $10,000.

2002 *Garden Club of America Award in Coastal Wetlands Studies*. Research on the influence of the tidal marsh gradient on the food web and marsh bird behavior. $5,000.

2001 *San Francisco Foundation: San Francisco Bay Fund*. Research on the structure of the tidal marsh food web. $15,000.

Professional and Research Experience

2004-Present *San Francisco Estuary Institute, Oakland, CA*
Scientist. Conduct research and manage projects in estuarine science, particularly in the areas of wildlife conservation, tidal marsh ecology, and food-web contamination. Develop wildlife biosentinels as tools for adaptive management of mercury bioaccumulation in the food web of wetlands.

1999-2004 *University of California, Berkeley, CA*
Doctoral Student. Designed and implemented an independent research project on tidal marsh food webs and Song Sparrow behavioral ecology. Developed scientific ideas, collected data, secured grants and permits, fostered collaborations, administered project, trained field assistants, analyzed data, and published results.

Science Advisory Roles

Development Team for California State Wetlands and Riparian Protection Policy

Technical Review Team, Contaminants Review Team, High-Marsh Design Team for Montezuma Wetlands Restoration Project

San Francisco Bay Regional Water Quality Control Board Wetland Monitoring Group

DARELL G. SLOTTON

Department of Environmental Science and Policy, University of California, Davis
Tel: (530) 756-1001; Fax: (530) 756-4950 *dgslotton@ucdavis.edu*

Role in Project: Directing slough fish biosentinel component, providing a linkage between Pond A8 alterations and potential export of methylmercury exposure to surrounding waters.

Relevant Experience: Dr. Slotton has directed applied research projects addressing heavy metal contamination and bioaccumulation issues in California for 20 years, with a primary focus on mercury. He runs a mercury analytical and research laboratory at UC Davis. In the 1990s, Dr. Slotton worked throughout the gold mining region of the Sierra Nevada, using benthic invertebrates and fish as sentinels of relative bioavailable mercury exposure. Slotton has led numerous mercury studies throughout Coast Range watersheds and was a long-time participant in the Clear Lake Superfund Mercury Project. A multi-year project addressed mercury bioaccumulation in the Truckee River and Pyramid Lake, Nevada. International projects include mercury bioaccumulation and source assessment studies in the Lake Titicaca watershed of Peru and the Ayeyarwaddy River system of Myanmar. Since 1998, Slotton's primary focus has been directing several regional projects, primarily developing and refining mercury biosentinel techniques for the state in the Sacramento-San Joaquin Delta, Cache Creek, Yuba River and, most recently, across the Bay-Delta watershed. His team is now conducting much of the newly expanded RMP small fish mercury biosentinel program for SFEI throughout the Bay.

EDUCATION:

B.A. Biogeography/Ecosystems Analysis, University of California, Los Angeles (1980)
M.S. Ecology, University of California, Davis (1988)
Ph.D. Applied Aquatic Ecology, University of California, Davis (1991)

PROJECTS/GRANTS (partial list)

Davis Creek Watershed Water Quality and Mercury Monitoring Program (1985-2002).
Camanche Reservoir Sediment Metals Distribution and Resuspension Study (1991-1993).
Clear Lake Superfund Mercury Project (team member) (1992-1996).
Gold Mining Impacts on Food Chain Mercury in NW Sierra Nevada Streams (1993-1996).
Marsh Creek Watershed Mercury Assessment Program (1995-1998).
Putah Creek Watershed Biological Mercury Assessment (1996).
Lake Tahoe Sediment Core Paleo-reconstruction Research (team member) (1995-2000).
The Effects of Wetlands Restoration on the Production and Bioaccumulation of Methylmercury in the Sacramento-San Joaquin Delta, California (1998-2002).
Pope Creek Watershed Mercury Assessment (1998).
Mercury Bioaccumulation and Trophic Transfer in the Cache Creek Watershed (2000-2003).
Pyramid Lake and Lower Truckee River Mercury Assessment Program (2001-2006).
Lower Cache Creek Small Fish Monitoring of Off-Channel Gravel Mining Lakes (2001-2007).
Upper Yuba River Studies Program: U.C. Davis Biological Mercury Component (2002-2005).
Lake Titicaca Mercury Source Study; Biological Component (2002-2006).
Reconnaissance of Fish Mercury in the Ayeyarwaddy River System (2003-2005).
Bay-Delta Watershed Fish Mercury Project: U.C. Davis Biosentinel and Restoration Monitoring Components (2005-2008).
SF Bay SFEI Regional Monitoring Program Small Fish Biosentinel Subcontract (2008-2011).

SELECTED PUBLICATIONS

Slotton, D.G., S.M. Ayers, J.E. Reuter, and C.R. Goldman. 1995. Gold mining impacts on food chain mercury in northwestern Sierra Nevada streams. *Technical Completion Report for the University of California Water Resources Center, Project W-816*, August 1995, 46 pp.

Slotton, D.G. and J.E. Reuter. 1995. Considerations of heavy metal bioavailability in intact and resuspended sediments of Camanche Reservoir, California, USA, with emphasis on copper, zinc, and cadmium. *Marine and Freshwater Research*, 46:257-265.

Slotton, D.G., J.E. Reuter, and C.R. Goldman. 1995. Mercury uptake patterns of biota in a seasonally anoxic northern California reservoir. *Water, Air, and Soil Pollution*, 80:841-850.

Suchanek, T.H., L.H. Mullen, B.A. Lamphere, P.J. Richerson, C.E. Woodmansee, D.G. Slotton, E.J. Harner and L.A. Woodward 1997. Redistribution of mercury from contaminated lake sediments of Clear Lake, California. *Water, Air and Soil Pollution*, 1042:77-102.

Heyvaert, A.H. , J.E. Reuter, D.G. Slotton, and C.R. Goldman. 2000. Paleolimnogical reconstruction of historical atmospheric lead and mercury deposition at Lake Tahoe, California, Nevada. *Environmental Science and Technology*, 34:3588-3597.

Slotton, D.G., T.H. Suchanek, and S.M. Ayers 2000. Delta wetlands restoration and the mercury question. *Interagency Ecological Program Newsletter*, 13(4):40-50.

Reuter, J.E., D.G. Slotton, R.P. Axler, and S.M. Ayers 2001. Mercury bioaccumulation in a stream fish population residing in the vicinity of an abandoned Hg mine. *Verh. Internat. Verein. Limnol.*, 27:1-12.

Slotton, D.G., S.M. Ayers, T.H. Suchanek, R.D. Weyand, and A.M. Liston, C. Asher, D.C. Nelson, and C. Asher. 2002. The effects of wetlands restoration on the production and bioaccumulation of methylmercury in the Sacramento-San Joaquin Delta. *Report for the CALFED Bay-Delta Agency*. 76 pp. http://loer.tamug.tamu.edu/calfed/FinalReports.htm

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EDUCATION

- State University of N.Y., Stony Brook, NY. 1985-87. B.S., Chemistry.
- University of Maryland, Chesapeake Biological Laboratory, Solomons, MD. 1987-95. Ph.D., Marine and Estuarine Environmental Sciences. Research Focus: Aquatic Microbial Ecology and Biogeochemistry

RELEVANT EXPERIENCE TO THIS PROJECT

I am Project Chief at the U.S. Geological Survey, overseeing the science initiative entitled "*Biogeochemical Cycling at Regional Scales*". During most of my 13 year tenure at the USGS, my research focus has been largely involved with mercury cycling at various ecosystem scales. Previous and current mercury investigations include those in: the San Francisco Bay watershed and associated mining areas throughout CA; the FL Everglades; the Carson River, NV (mercury Superfund site); Lake Pontchartrain and coastal Louisiana; the Patagonia region of Argentina; Puget Sound, WA; and USGS-NAWQA Study Units (Stream/River systems) in OR, FL, WI, SC and NY. I also served a 1.5 year term (from late 2003 until early 2005) on the Science Team for the South San Francisco Bay Salt Ponds Restoration.

EXPECTED CONTRIBUTIONS TO THIS PROJECT

I will lead the water column chemistry and mercury speciation component of this research project, including coordinating data collection, analysis, and interpretation, and will co-author the final report.

PROFESSIONAL EXPERIENCE

- National Research Council Associate, U.S. Geological Survey, Menlo Park, CA, 1995-1998.
- Microbial Ecologist, U.S. Geological Survey, Menlo Park, CA, 1998-2004.
- Project Chief, U.S. Geological Survey, Menlo Park, CA, 2004-present.

SELECT PUBLICATIONS

Marvin-DiPasquale, M., and Capone, D.G., 1998, Benthic sulfate reduction along the Chesapeake Bay central channel. I. Spatial trends and controls: Marine Ecology Progress Series, v. 168, p. 213-228.

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Marvin-DiPasquale, M., Lutz, M.A., Brigham, M.E., Krabbenhoft, D.P., Aiken, G.R., Orem, W.H., and Hall, B.D., *in press*, Mercury cycling in stream ecosystems: 2. Benthic methylmercury production and bed sediment-pore water partitioning: Environ. Sci. Technol.

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EDUCATION

Ph.D. Ecology. University of California, Davis (2002).
B.S. (High Honors) Wildlife, Fish, and Conservation Biology. University of California, Davis (1997).

RELEVANT EXPERIENCE TO THIS PROJECT

As a Principal Investigator with the USGS Western Ecological Research Center, I lead several research projects investigating waterbird ecology, avian reproduction, and mercury bioaccumulation in the San Francisco Bay Estuary. I have been conducting research on mercury in waterbirds and fish in the South San Francisco Bay for five years and have led several studies investigating mercury bioaccumulation and ecotoxicological effects of mercury on avian reproduction. Important to this proposal, I have lead several biosentinel mercury projects in the South Bay, including the CALFED Bird Mercury project and Regional Monitoring Program Tern Mercury studies.

EXPECTED CONTRIBUTIONS TO THIS PROJECT

I will co-lead the research tasks assessing mercury bioaccumulation in waterbirds and pond fish, and I will participate in data collection, analysis, and reporting project results.

PROFESSIONAL EXPERIENCE

Research Wildlife Biologist, USGS, BRD, WERC, UC Davis Field Station (2/04-present)
Post-doctoral Researcher, John Muir Institute of the Environment, UC Davis (8/02-2/04)
Doctoral Research, Dept. of Wildlife, Fish, and Conservation Biology, UC Davis (9/97-7/02)
Waterfowl Research Associate, California Waterfowl Association, Sacramento (10/99-4/00)

PUBLICATIONS: *I have authored 33 peer-reviewed journal papers (19 lead), 13 popular articles (9 lead), 16 technical reports, and 138 scientific presentations. Below is a selected list of publications.*

Ackerman, JT, and CA Eagles-Smith. Integrating toxicity risk in bird eggs and chicks: using chick down feathers to estimate mercury concentrations in eggs. Environmental Science and Technology, submitted.

Ackerman, JT, JD Bluso, and JY Takekawa. Postfledging Forster's tern movements, habitat selection, and colony attendance in San Francisco Bay. Condor, submitted.

Eagles-Smith, CA, **JT Ackerman**, J Yee, and TL Adelsbach. 2008. Mercury demethylation in livers of four waterbird species: evidence for dose-response thresholds with liver total mercury. Environmental Toxicology and Chemistry, in press.

Stebbins, KR, JD Klimstra, CA Eagles-Smith, **JT Ackerman**, and GH Heinz. 2008. A non-lethal micro-sampling technique to monitor the effects of mercury on wild bird eggs. Environmental Toxicology and Chemistry, in press.

Iverson, SA, JY Takekawa, S Schwarzbach, CJ Cardona, N Warnock, MA Bishop, GA Schirato, S Paroulek, **JT Ackerman**, H Ip, and WM Boyce. 2008. Low prevalence of avian influenza virus in shorebirds on the Pacific Coast of North America. Waterbirds, in press.

Demers, SA, MA Colwell, JY Takekawa, and **JT Ackerman**. 2008. Breeding stage influences space use of American avocets in San Francisco Bay, California. Waterbirds, in press.

Demers-Bluso, JD, MA Colwell, JY Takekawa, and **JT Ackerman**. 2008. Space use by Forster's terns breeding in South San Francisco Bay. Waterbirds 31:357-364.

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Ackerman, JT, JY Takekawa, DL Orthmeyer, JP Fleskes, JL Yee, and KL Kruse. 2006. Spatial use by wintering greater white-fronted geese relative to a decade of habitat change in California's Central Valley. Journal of Wildlife Management 70:965-976.

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Ackerman, JT, JM Eadie, GS Yarris, DL Loughman, and MR McLandress. 2003. Cues for investment: nest desertion in response to partial clutch depredation in dabbling ducks. Animal Behavior 66:871-883.

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