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: San Francisco State University

Mailing Address: 1600 Holloway St, San Francisco CA 94132

Principal Investigator: Aariel Rowan, graduate student (SFSU Faculty PI:Jerry Davis)

Title: Graduate Student Institution: SFSU- Geography & Human Environmental Studies

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Grant Administrator: Susan Pelton

Telephone: 415/338-7090 Email address: spelton@sfsu.edu

PROJECT INFORMATION

RFP Study Topic # 6

Project Title Pre-restoration assessment of mudflat foraging habitat: Shorebird carrying capacity

Funding Request per year $ 25000 (+ 5000 first year) Number of years: 2

Confirmed in-kind or matching contributions: $ NA

Source of in-kind or matching contributions: NA

Purpose and Objectives:

Characterize habitat value and carrying capacity of the South Bay mudflats for wintering shorebirds.

Proposed starting date: May 2009 Estimated completion date: April 2011

Signature : [signature] Date: 12/4/08
Principal Investigator

Signature : [signature] Date: 12/4/08
Grant Administrator

San Francisco State University
Department of Geography and Environmental Science
1600 Holloway Ave.
San Francisco, CA 94132
5 December 2008

Effects of the South Bay Salt Pond Restoration Project on Mud Flats and their Carrying Capacity for Shorebirds

Abstract

A major question challenging the South Bay Salt Pond (SBSP) Restoration Project is whether conversion of existing salt ponds will result in decreased numbers of migratory birds supported in the region. The South Bay is renowned for its populations of shorebirds and has been designated as a Western Hemisphere Shorebird Reserve Network (WHSRN) Site of Hemispheric Importance. Yet, little is known determining why this highly urbanized area is so valuable to them. Most shorebirds feed on the intertidal mud flats adjacent to the salt ponds and in the salt ponds themselves. At least 50% of existing salt ponds are planned for conversion to salt marsh, and salt marsh supports a much lower density of shorebirds. Therefore, the availability of food resources on the mud flats and their carrying capacity will be a primary concern for conservation of shorebirds as salt ponds are converted. A study was recently initiated by the USGS to study the dynamics of the mud flats and macroinvertebrates in the South Bay. I will use these new datasets to develop a foraging model to estimate the carrying capacity of the mud flats adjacent to the project salt ponds for shorebirds.

Background and Justification

The San Francisco Bay (SFB) is part of the largest estuary in the western United States and supports a tremendous diversity of flora and fauna, including many special status species and millions of wintering and migratory waterbirds. SFB is of key importance to shorebird populations and hosts an average of 67% of all shorebirds on the west coast (Page *et al*. 1999). Extensive urban and agricultural developments in the last 200 years have resulted in loss of 80% of historic SFB tidal salt marshes and 40% of intertidal mud flats (Foxgrover *et al.* 2004, Goals Project 1999).

The recent transfer of over 5471 ha of evaporation ponds to government management in the South San Francisco Bay (South Bay) has resulted in the largest tidal restoration effort on the west coast (Goals Project 1999). The South Bay Salt Pond Restoration Project (SBSPRP) intends to restore these salt ponds to a mosaic of wetland habitats with tidal salt marsh parcels comprising 50-90% intermixed with managed ponds. The immense scale of this project will change the landscape of the South Bay and provide important habitat for a number of endangered species.

Yet, managers are concerned with the potential loss of intertidal mud flats that may occur as sediment is transported into subsided salt ponds from the open bay through tidal marsh restoration. This loss of intertidal mud flat habitat may be ameliorated by temporary mud flat creation as ponds fill with sediment and by improved quality of existing mud flat habitat through connection to restored tidal marshes. Detrital input from restored tidal marsh may lead to improved macroinvertebrate prey availability on intertidal mud flats (Hughes 2004). If these factors are not successful at offsetting adverse effects of mudflat loss, then adaptive management actions may be needed to restore intertidal mud flat during later restoration phases. These actions may involve removing bay front levees to actively target mud flat habitat in the restoration, or phasing the breaching in such a way as to match the supply and demand of mud flat habitat (South Bay Salt Pond Restoration Project 2007).

A primary goal of the SBSPRP is to conserve populations of the migratory bird species. The effect that marsh restoration will have on South Bay shorebird populations is largely unknown, though attempts have been made to identify management strategies to maximize water bird populations (Stralberg *et al. in press*). Most shorebirds feed on the intertidal mud flats adjacent to the salt ponds and in the salt ponds themselves (Takekawa *et al.* 2001, Warnock *et al.* 2002, Masero 2003). Salt marsh, however, supports a much lower density of shorebirds (Takekawa *et al.* 2001). Therefore, the availability of food resources on the mud flats and their carrying capacity will be a primary concern for conservation of shorebirds as salt ponds are converted to tidal marshes.

Because so many birds currently use these salt ponds, there is a large concern about whether alternative feeding grounds elsewhere in the estuary will be able to provide for their energetic needs (Stralberg *et al.* 2006). Therefore, it is imperative to understand whether mud flats adjacent to salt ponds are currently at carrying capacity or if they can sustain increased numbers of foraging waterbirds. Determining the carrying capacity of South Bay intertidal mud flats is a critical need for the SBSP project because it will help determine how the mix of tidal marsh conversions and managed ponds will sustain adequate resources for shorebirds.

Because different species of shorebirds are known to use different size classes and types of macroinvertebrates, I will focus my efforts on modeling carrying capacity for the Western sandpiper (*Calidris mauri).* The Western sandpiper utilizes similar macroinvertebrate resources as other small shorebirds like the least sandpiper (Davis and Smith 2001) and is very abundant on salt ponds and mud flats in the South Bay (Takekawa *et al.* 2006). Large polychaete worms, Cumaceans and harpacticoid copepods are the major prey items for Western sandpipers and will be the focus for mapping their carrying capacity (Sutherland *et al.* 2000).

Recent work conducted on South Bay mudflats has provided detailed information on the spatial and temporal avian use of the shoal habitat. An interdisciplinary team of USGS scientists is currently funded to collect detailed physical and biological information from the mudflat outside pond SF2 in the Ravenswood complex. The data coming from this large, comprehensive study are specifically tailored to address the issue of mudflat carrying capacity. Information on avian habitat use on mud flats near the Eden Landing and Alviso salt pond complexes is also available from studies as part of this work and from salt pond surveys conducted through the SBSP monitoring program (Takekawa *et al.* 2006). In addition, historical samples are available from USGS-related projects including a site sampled offshore of the Palo Alto baylands. My project will make use of information available through the California Avian Data Center (CADC).

Waterbird researchers from Bay Area organizations have developed an integrated proposal to address bird use of South Bay habitats and additional data needs (Priority Research Topic #6). These organizations include the Point Reyes Bird Observatory Conservation Science, USGS, and San Francisco Bay Bird Observatory. Another graduate student proposal (Athearn) will determine a carrying capacity for a number of different avian species within the pond system itself. A complementary modeling effort led by Oikonos, USGS, and University of Wyoming partners is already underway to determine carrying capacity for diving ducks in open water habitats. Thus, the modeling effort proposed here will bridge the knowledge gap to examine the carrying capacity of the mud flat habitats, located between the restored pond system and the open water bays.

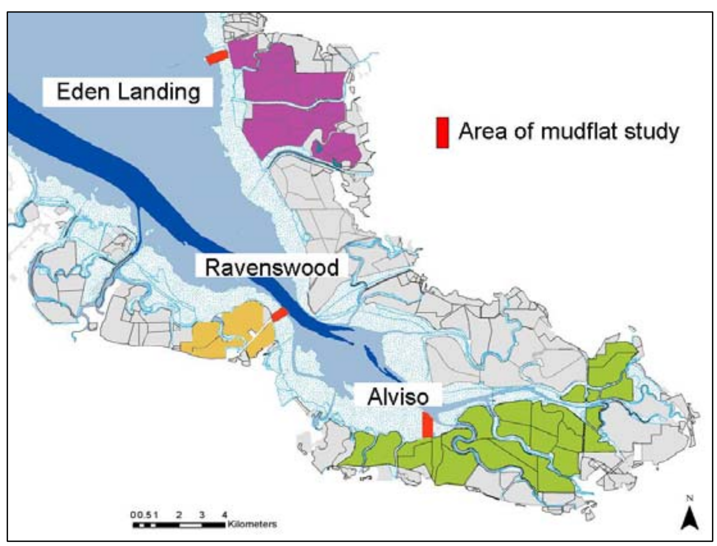
I propose to synthesize existing information on physical mud flat characteristics, daily tidal exposure regimes, macroinvertebrate prey availability, and shorebird energy requirements to determine the current carrying capacity for South Bay mud flats. My results will provide baseline information to allow the SBSPRP management team to guide and assess management actions to maintain shorebird populations within the South Bay.

Objectives

1. Estimate macroinvertebrate availability, densities, and patch structure on mud flats of the South Bay.

2. Determine carrying capacity of the South Bay mud flats for wintering shorebirds.

Study Area



This study is designed to examine mudflats available to shorebirds that are currently using salt ponds that are part of the SBSPRP. The work will be based on field data collected from South Bay mudflat habitats. USGS scientists are currently collecting detailed information for a shoals study focusing on the intertidal area directly adjacent to the Ravenswood complex. This mudflat is bound by pond SF2 to the west, the Dumbarton Bridge to the north, and the Southern Pacific Railroad Bridge to the south. Shorebird surveys have also been conducted in shoal habitats adjacent to the Eden Landing and Alviso complexes, and additional invertebrate samples will be collected from these sites. Invertebrates have already been collected from mudflats outside of the Alviso salt pond complex as part of the pre-ISP monitoring.

Approach

I will use a bioenergetics approach to develop a carrying capacity model for shorebirds. Estimates of their winter foraging requirements will be compared to the abundance and distribution of their macroinvertebrate prey in the South Bay. The modeling may be divided into four tasks, including:

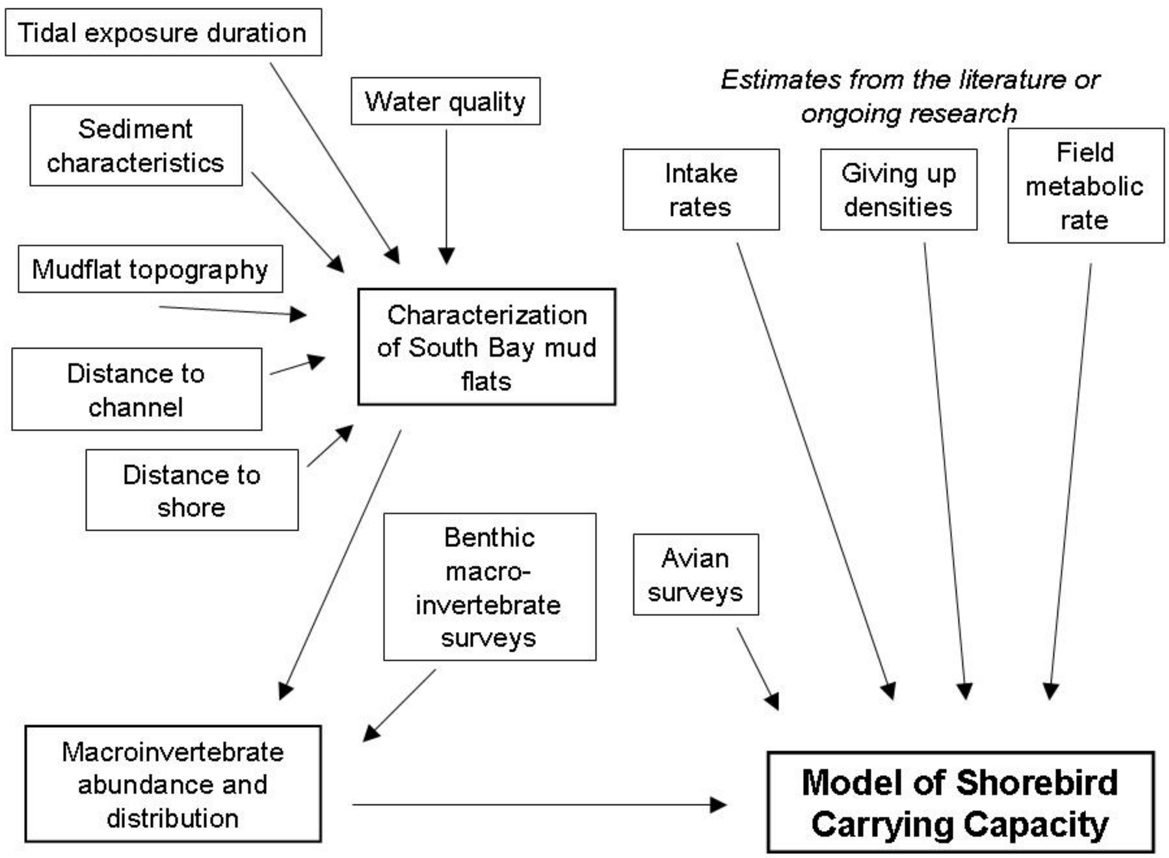
1. *Spatially characterize the physical parameters of South Bay mud flats, by integrating existing data on bathymetry and terrestrial LiDAR (Light Detection and Ranging), tidal exposure patterns, grain size, organic matter content, sediment flux, salinity, and water quality.*

   Elevation controls the schedule of tidal exposure of mud flats and influences the distribution of intertidal macroinvertebrates (Balwin and Lovvorn 1994). Tidal exposure changes the salinity, pH, temperature, and degree of desiccation experienced by these invertebrates (Nichols and Pamatmat 1988). Effects of mud flat elevation and tidal exposure on macroinvertebrates may vary with season and variations in sediment grain size, organic content, and microtopography (Wolff and de Wolf 1977, Quammen 1982, Hicklin and Smith 1984, Balwin and Lovvorn 1994). The sediment flux experienced by South Bay mud flats will be an important predictor of their ability to buffer possible changes due to sea level rise and sediment transport into breached subsided salt ponds (South Bay Salt Pond Restoration Project 2007).

   In the first step of this project, I will create a database and spatially relate all available imagery and data to describe the physical characteristics of South Bay mud flats. Scientists in the interdisciplinary USGS shoals study collected invertebrate and sediment samples by taking cores with 10cm depth and diameter. Field crews collected cores along 3 transects at distances 200m, 400m and 600m from the tide line (matching spatial zones of concurrent avian surveys). Each transect consisted of 9 stations of triplicate cores spaced 100m apart along each transect. Technicians rinsed samples with saltwater through a 0.5mm sieve. They enumerated, weighted, measured and identified invertebrates to lowest taxonomic level possible. I will analyze the results from this study to determine if this is the appropriate scale of invertebrate collection for the observed variation in patch structure. Once all existing data are evaluated, I will determine if invertebrate collections at other sites should be collected at the same intensity or if more extensive collections are better at describing the distribution of macroinvertebrates on the mud flats.

2. *Develop a GIS coverage of seasonal macroinvertebrate prey availability through interpolation of existing data from the USGS shoals project, ISP monitoring, and supplemental invertebrate sampling. Use ArcGIS Geostatistical Analyst (ESRI, Redlands, CA) to analyze for correlations between invertebrate distribution and physical parameters to explain patterns in patchiness.*

   Crustaceans, polychaete worms, gastropods, bivalves, and other macroinvertebrates support large concentrations of foraging birds in the South Bay mud flats (South Bay Salt Pond Restoration Project 2007). Yet, the factors that drive the distributions of these invertebrates are poorly understood. Because prey quality or shorebird foraging efficiency may be directly affected by a change in mud flat characteristics resulting from restoration, such effects should be identified before significant changes to mud flats occur (Quammen 1982, Shepherd and Boates 1999, Poulton *et al.* 2004). I will analyze for correlations between invertebrate patchiness and factors relating to SBSP restoration (e.g. distance to levees or intake and outflow valves) in relation to natural sources of variability (e.g. seasons) (Durell *et al.* 2005).



Mapping prey availability can give insight into the distribution of suitable shorebird habitat (Stillman *et al.* 2005). I will model macroinvertebrate distributions on mud flats adjacent to the three salt pond complexes using inverse distance weighting to interpolate macroinvertebrate densities from values at the nearest sampling stations (ArcGIS, ESRI, Redlands, CA). The spatial resolution of interpolated prey grids will be set at probable spatial scales (grain size, *sensu* Kotliar and Wiens 1990) at which the birds can detect variations in prey of different species (Lovvorn and Gillingham 1996a, Poulton et al. 2004, Klaassen et al. 2006). The resulting spatial grid will advise the foraging model described in step 3.

3. *Create a foraging model to determine shorebird use of mud flat prey.*

Spatially-explicit foraging models can account for variations in intake rate caused by spatial variations in prey density. By locating smaller patches with higher densities, predators can often increase their intake rates above that possible when foraging at the average density for the overall area (Sponberg and Lodge 2005). However, the potential gains for the predator depend on how widely prey density varies among patches, and how easily and predictably patches with high density can be located (Yates *et al.* 2000, Stillman *et al.* 2001). For example, even if there is high spatial variation in prey density, if the pattern is unpredictable the birds may not be able to develop a search strategy to capitalize on it and will do as well to feed at random locations within a generally suitable area (Lovvorn and Gillingham 1996b). In such cases, calculating carrying capacity based on average prey densities and average energy needs of the birds will yield similar results to a more sophisticated individual-based model that simulates the decisions and successes of individual birds in a patch-structured landscape (cf. Goss-Custard *et al*. 2003).

I will begin by characterizing the intensity and predictability of prey patch structure from our benthic sampling scheme which was specifically designed to detect those aspects. I will then decide whether to compare average bird energy requirements based on the literature to prey densities averaged over larger scales, or instead to develop individual-based models based on the very extensive body of work on foraging in shorebirds (Sutherland 2000, Kelly *et al*. 2002, Nebel and Thompson 2005). With the model based on averages, I will estimate the threshold prey density below which foraging is unprofitable based on published studies (Evans 1976, Yates *et al.* 2000), and consider the prey biomass above that density as being available. For an individual-based model, I will estimate that threshold from simulated energy balance at different prey densities. Even for the model based on averages, calculations will be broken down among larger areas of differing prey density as indicated by interpolation among benthic sampling stations.

The mud flat carrying capacity model will be based on the energy needs of shorebirds (from averages or simulations), the energy content of invertebrate prey, and the efficiency with which birds convert ingested prey to metabolic energy (Davis and Smith 2001, Richman and Lovvorn 2004, Miller and Eadie 2006, Weathers and Kelly 2007). I will then create a map of prey densities above the estimated threshold for profitability and integrate the total biomass above that threshold for the entire area (Evans 1976, Goss-Custard and Durell 1990, Lovvorn and Gillingham 1996a, Williams *et al.* 2007). That total biomass divided by the energy requirements of an individual shorebird (from literature values or simulations) will equal the carrying capacity of the area for shorebirds. If an individual-based approach would be useful, shorebird telemetry studies in the SFB will advise the core use areas needed to establish decision rules for the model (Warnock and Takekawa 1996).

4. *Validate the results of the model with existing survey data.*

In order to refine the model, I will use uncertainty analysis (Derby and Lovvorn 1997) to evaluate the relative importance of variation in selected variables (e.g. distance to channels, organic matter content) to carrying capacity of mud flats (biomass of macroinvertebrates available to foraging shorebirds). This analysis will also allow for changes in carrying capacity to be predicted from changes in mud flat resources that may occur as the SBSP restoration progresses

Although it will not be possible to verify carrying capacity itself, I will correlate the results of the macroinvertebrate and avian models with bird survey and benthic data not used in model development to test my results.

Data Archiving Procedures

Data handling and storage will follow Federal Geographic Data Committee (FGDC) metadata standards. All data will be compiled, QA/QC checked, and archived on a data server with mirrored drives, tape backup, and redundant copies offsite. Field data will be referenced in GIS coverages, data projected in UTM in NAD83 horizontal and NAVD88 vertical datum. Datasets will be made available with permission for use specified in the metadata. The databases will be made accessible through the SBSPRP website.

Work Schedule

My project will last from final signature of the agreement for a period of two years with an annual report delivered at the end of year one and all other products (with the exception of workshops and updates) at the end of year two.

Work Element for Mudflat Carrying Capacity Model	Year 1				Year 2			
	1	2	3	4	1	2	3	4
Gather and integrate existing data	x	x	x					
Collect data from additional sites as needed		x	x					
Create area map of invertebrate availability			x	x				
Develop and verify carrying capacity model			x	x	x	x	x	
Synthesize results for presentation						x	x	
Manuscript writing				x			x	x
Manuscript review				x			x	x

Expected Product(s)

A map of macroinvertebrate availability will be made available to project managers through the SBSPRP website, the avian data repository (CADC) and other appropriate media (end of year 1). At least one scientific paper will be submitted to a peer-reviewed journal and will serve as my academic thesis and final product. This manuscript will present a carrying capacity model for South Bay mudflats and will be completed by the end of year 2. I will present my findings at Science Symposia, relevant workshops and Science team updates. Along with an annual report and final product, I will provide detailed information on progress and report all expenditures. My results will be synthesized with a larger project (submitted by PRBO Conservation Science, USGS, SFBBO) to address the knowledge gap regarding the long-term ability of the South Bay to support existing numbers of waterbirds.

Literature Cited

Baldwin, J. R., Lovvorn, J. R. 1994. Habitats and tidal accessibility of the marine foods of dabbling ducks and brant in Boundary Bay, British Columbia. *Marine Biology* 120: 627-638

Davis, C. A., and L. M. Smith. 2001. Foraging strategies and niche dynamics of coexisting shorebirds at stopover sites in the southern great plains. *The Auk* 118 (2): 484-495

Derby, C. E., and J. R. Lovvorn. 1997. Predation on fish by cormorants and pelicans in a cold-water river: a field and modeling study. *Canadian Journal of Fisheries and Aquatic Sciences* 54 (7): 1480-1493

Durrell, S. E. A. L. V. d., S. McGrort, et al. (2005). A strategy for baseline monitoring of estuary Special Protection Areas. *Biological Conservation* 121: 289-301

Evans, P. R. 1976. Energy balance and optimal foraging strategies in shorebirds: some implications for their distributions and movements in the non-breeding season. *Ardea* 64: 117-139

Foxgrover, A. C., S. A. Higgins, M. K. Ingraca, B. E. Jaffe, and R. E. Smith. 2004. Deposition, Erosion, and Bathymetric Change in South San Francisco Bay: 1858-1983. *Open-file Report. U. S. Geological Survey*: 30.

Goals Project. 1999. Baylands Ecosystem Habitat Goals. A report of habitat recommendations prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. U. S. Environmental Protection Agency, San Francisco, Calif./S.F. Bay Regional Water Quality Control Board, Oakland, Calif.

Goss-Custard, J. D., and S. E. A. V. d. Durell. 1990. Bird behaviour and environmental planning: approaches in the study of wader populations. *Ibis* 132 (2): 273-289

Goss-Custard, J. D., R. A. Stillman, R. W. G. Caldow, A. D. West, and M. Guillemain. 2003. Carrying capacity in overwintering birds: when are spatial models needed? *Journal of Applied Ecology* 40 (1): 176-187

Hicklin P. W., P. C. Smith. 1984. Selection of foraging sites and invertebrate prey by migrant semipalmated sandpipers, *Calidris pusilla* (Pallas), in Minas Basin, Bay of Fundy. *Can J Zool* 62: 2201-2210

Hughes, R. G. 2004. Climate change and loss of saltmarshes: consequences for birds. *Ibis* 146 (s1): 21-28

Kelly, J. P., N. Warnock, G. W. Page, and W. W. Weathers. 2002. Effects of weather on daily body mass regulation in wintering dunlin. *J Exp Biol* 205 (1): 109-120

Klaassen, R. H. G., B. A. Nolet, and J. de Fouw. 2006. Intake rate at differently scaled heterogeneous food distributions explained by the ability of tactile-foraging mallard to concentrate foraging effort within profitable areas. *Oikos* 112: 322-331

Kotliar, N. B., and J. A. Wiens. 1990. Multiple scales of patchiness and patch structure: A hierarchical framework for the study of heterogeneity. *Oikos* 59 (2): 253-260

Lovvorn, J.R. and M. P. Gillingham. 1996a. Food Dispersion and Foraging Energetics: A Mechanistic Synthesis for Field Studies of Avian Benthivores. *Ecology* 77 (2): 435-451

Lovvorn, J. R., and M. P. Gillingham. 1996b. A spatial energetics model of cadmium accumulation by diving ducks. *Archives of Environmental Contamination and Toxicology* 30 (2): 241-251.

Masero, J.A. 2003. Assessing alternative anthropogenic habitats for conserving waterbirds: Salinas as a buffer areas against the impact of natural habitat loss for shorebirds. *Biodiversity and Conservation* 12: 1157-1173.

Miller, Michael R., and John McA. Eadie. 2006. The Allometric Relationship between Resting Metabolic Rate and Body Mass in Wild Waterfowl (Anatidae) and an Application to Estimation of Winter Habitat Requirements. *The Condor* 108 (1): 166-177

Nebel, S., and G. J. Thompson. 2005. Foraging behaviour of western sandpipers changes with sediment temperature: implications for their hemispheric distribution. *Ecological Research* 20 (4): 503-507

Nichols, F. H., M. M. Pamatmat. 1988. The ecology of the softbottom benthos of San Francisco Bay: a community profile. U.S. Fish & Wildlife Service Biological Report, 85(7.23)

Page, G. W., L. E. Stenzel, and J. E. Kjelmyr. 1999. Overview of Shorebird Abundance and Distribution in Wetlands of the Pacific Coast of the Contiguous United States. *The Condor* 101 (3): 461-471

Poulton, V. K., J. R. Lovvorn, and J. Y. Takekawa. 2004. Spatial and overwinter changes in clam populations of San Pablo Bay, a semiarid estuary with highly variable freshwater inflow. *Estuarine, Coastal and Shelf Science* 59(3): 459-473

Quammen, M.L. 1982. Influence of subtle substrate differences on feeding by shorebirds on intertidal mudflats. *Marine Biology* 71: 339-343

Richman S. E., Lovvorn J. R. 2004. Relative foraging value to lesser scaup ducks of native and exotic clams from San Francisco Bay. *Ecol Appl* 14: 1217–1231

South Bay Salt Pond Restoration Project. 2007. Draft Environmental Impact Statement/Report. Section 3.6 Biological Resources. http://www.southbayrestoration.org/pdf_files/SBSP_EIR_Final/3.6%20Biological%20Resources%20Final%20EIS_R.pdf

Shepherd, P.C.F. and J.S. Boates. 1999. Effects of a commercial baitworm harvest on semipalmated sandpipers and their prey in the Bay of Fundy Hemispheric Shorebird Reserve. *Conservation Biology* 13 (2): 347-356

Sponberg, A. F. and D. M. Lodge. 2005. Seasonal belowground herbivory and a density refuge from waterfowl herbivory for *Vallisneria americana*. *Ecology* 86(8): 2127-2134

Stillman, R. A., J. D. Goss-Custard, A. D. West, S. E. A. Le V. Dit Durell, S. McGrorty, R. W. G. Caldow, K. J. Norris, I. G. Johnstone, B. J. Ens, J. Van Der Meer and P. Triplet. 2001. Predicting shorebird mortality and population size under different regimes of shellfishery management. *Journal of Applied Ecology* 38, no. 4: 857-868

Stillman, R. A., A. D. West, J. D. Goss-Custard, S. McGrorty, N. J. 2005. Predicting site quality for shorebird communities: a case study on the Humber estuary, UK. *Marine Ecology Progress Series* 305: 203-217

Stralberg, D., M. Herzog, N. Warnock, N. Nur, S. Valdez. 2006. Habitat-based modeling of wetland bird communities: an evaluation of potential restoration alternatives for South San Francisco Bay. Final report to California Coastal Conservancy, December 2006 PRBO Conservation Science, Petaluma, CA.

Stralberg, D., D. L. Applegate, S. J. Phillips, M. P. Herzog, N. Nur, N. Warnock. *In press*. Optimizing wetland restoration and management for avian communities using a mixed integer programming approach. *Biological Conservation*

Sutherland, T. F., P. C. F. Shephard and R. W. Elner. 2000. Predation on meiofaunal and macrofaunal invertebrates by Western Sandpipers (*Calidris mauri*): Evidence for dual foraging modes. *Marine Ecology* 137: 983-993

Takekawa, J. Y, C. T. Lu and R. T. Pratt. 2001. Avian communities in baylands and artificial salt evaporation ponds of the San Francisco Bay estuary. *Hydrobiologia* 466:317-328 in J.M.

Takekawa, J. Y., N. D. Athearn, B. J. Hattenbach, and A. K. Schultz. 2006. Bird Monitoring for the South Bay Salt Pond Restoration Project. Data Summary Report, U. S. Geological Survey, Vallejo, CA. 74pp.

Warnock, S. E., and J. Y. Takekawa. 1996. Wintering site fidelity and movement patterns of western sandpipers Calidris mauri in the San Francisco Bay estuary. Ibis 138:160-167

Warnock, N., G. W. Page, T. D. Ruhlen, N. Nur, J. Y. Takekawa, J. T. Hanson. 2002. Management and Conservation of San Francisco Bay Salt Ponds: Effects of Pond Salinity, Area, Tide, and Season on Pacific Flyway Waterbirds. *Waterbirds* 25: 79-92

Weathers, W. W. and J. P. Kelly. 2007. Energy footprints on Tomales Bay: The importance of ephemeral food abundance to wintering waterbirds. *Ardeid:* 4-6

Williams, T.D., N. Warnock, J.Y. Takekawa, and M.A. Bishop. 2007. Flyway-scale variation in plasma triglyceride levels as an index of refueling rate in spring-migration Western sandpipers (*Calidris mauri*). *The Auk* 124 (3): 886-897

Wolff W. J., L. de Wolf. 1977. Biomass and production of zoobenthos in the Grevelingen estuary, The Netherlands. *Estuar cstl Shelf Sci* 5:1-24

Yates, M. G., R. A. Stillman, and J. D. Goss-Custard. 2000. Contrasting interference functions and foraging dispersion in two species of shorebird (Charadrii). *Journal of Animal Ecology* 69(2): 314-322

Qualifications of Investigators, Partnerships, and Cooperators

Aariel Rowan (CV attached) has been working for the USGS for over four years conducting monitoring and research related to wetland restoration in the SFB. She is now a graduate student at San Francisco State University studying Geography- Resource Management Environmental Planning. She will be the primary investigator for this project with an advisory team consisting of: Dr. Jerry Davis, Professor of Geography, San Francisco State University; Dr. John Takekawa, Wildlife Biologist, US Geological Survey; and Dr. Jim Lovvorn, Professor of Zoology, University of Wyoming (see attached letters and C.V.). She will coordinate the carrying capacity modeling with the team proposal (PRBO, USGS, SFBBO) to summarize bird habitats and data needs and with the diving duck carrying capacity model of the shallow bay habitats.

Budget and Staff Allocations

The budget for this project is limited to $55,000 over 2 years for the graduate fellowship and will be contracted with SFSU. See attached form for detailed budget information.

Project Budget Worksheet*

Timeframe**: Two years from dispersement of funds. Approx. May 2009 - Apr 2011

Budget Categories	**Total Project Budget**		**Total Grant Request**		**Total Proposed From Other Sources** *(please specify the source, if known)*
	Year 1	**Year 2**	**Year 1**	**Year 2**	
Labor- Graduate Fellow	22500	22500	22500	22500	
Consultant fees/ Contractual Services					
Travel to conference		227		227	
Project specific equipment, supplies/materials					
GIS Computer and software	3000		3000		
Soil Analysis	700		700		
Invertebrate Analysis	1073		1073		
Overhead (not to exceed 10%)	2727	2273	2727	2273	
Other:________________ *(please specify)*					
TOTAL	30000	25000	30000	25000	NA

Date Created: Dec 4, 2008

Equipment, sample processing, and travel expenses are only estimates, and may cost much less. As well, SFSU should be able to drop the overhead expenses since this is a student project, but we are waiting for final approval.

List of Potential Reviewers

Mark Herzog, PRBO Conservation Science, 3820 Cypress Drive #11, Petaluma, CA 94954; email: mherzog@prbo.org

Beth Huning, SFB Joint Venture Project Coordinator, 530C Alameda del Prado, Novato, CA 94949; tel: 415-259-0334; email: bhuning@sfbayjv.org

Nils Warnock, Oiled Wildlife Care Network, Wildlife Health Center, School of Veterinary Medicine, University of California, Davis, CA 95616; tel: (530) 752-5797; email: ndwarnock@ucdavis.edu

Necessary Assessments, Certifications, and Permits/ Animal Care and Use Certification

Most of this work does not require any field work (as it is using data from existing USGS projects) and does not need specific permits. Some additional invertebrate collection may be conducted at mudflats outside the Eden Landing and Alviso salt pond complexes under the DFG collection permit SC-004857. The USGS currently has permission to access the study area and will supervise any fieldwork.