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Title: Climate-Driven Geomorphic Alteration of Intertidal Foraging Habitats for Migratory Birds in the San Francisco Bay Estuary

Project Goals:
We propose to evaluate the effects of global climate change and sea level rise on estuarine intertidal habitats in the San Francisco Bay estuary and the Pacific Flyway migratory waterbirds that rely on this critically important habitat. Specifically, our overall objectives are to:

1) use downscaled climate change models to translate climatic predictions into habitat quantity predictions through three-dimensional geomorphic modeling;

2) simulate response of benthic invertebrates to changes in intertidal geomorphology;

3) model shorebirds and waterfowl response to geomorphologic and invertebrate change; and

4) integrate predictive changes in habitat quantity and prey abundance to generate spatially-explicit predictions of avian response to changes expected from climate change and sea level rise.

Partners:
The USGS Pacific Science Center (Jaffe) and UNESCO-IHE (van der Wegen, Roelvink) will provide geomorphic modeling expertise. USGS Western Ecological Research Center (Takekawa, Woo, Brand, and De La Cruz) will provide invertebrate, bird and water depth relations and ecological modeling, while the USGS California Water Science Center (Schoellhamer) will provide geomorphic modeling expertise and watershed boundary conditions, primarily sediment supply, to inform geomorphic modeling efforts.

How Project will advance LCC Goals:
Our study would provide the first data to address the effects of climate change and sea level rise on shoal habitats critical for the health of migratory birds in coastal estuaries. The information provided would help resource managers assess how waterbird populations would respond to sea level rise and altered freshwater flow and sediment supply, and help them plan management actions accordingly. Resource managers and public entities that would benefit from our research include: the U.S. Fish and Wildlife Service (Division of Migratory Birds Management, San Francisco Bay National Wildlife Refuges among others), California Department of Fish and Game, South Bay Salt Pond Restoration Project, Bay Conservation and Development Commission

(Subtidal Habitat Goals) U.S. Army Corps of Engineers (South Bay Shoreline Study), Department of Water Resources, the CALFED Bay/Delta Program (the state and federal resource agencies responsible for management of this estuary who funded the CASCaDE project to develop the geomorphic model), as well as non-governmental organizations concerned with waterbird populations along the Pacific Flyway.

Methods:

The study will quantify and map changes in availability of migratory waterbird habitats in estuaries caused by sea level rise and the likely response of the birds to these changes. We will accomplish this through information derived from downscaled global climate models, geomorphologic models that generate intertidal extent and elevations, and foraging models based on data collected in San Francisco Bay. A brief summary of each component follows.

Downscaled Global Climate Modeling

The CASCaDE project has developed data on the cascading effects of changes under different climate scenarios as they propagate from the climate system to watersheds to river networks to the Delta and San Francisco Bay (Cayan et al. 2008a, 2008b, 2008c, Ganju et al. 2008, Ganju and Schoellhamer 2009). Global climate models are run under selected scenarios of future greenhouse gas emissions, and resulting precipitation and temperature projections are downscaled for use in the hydrologic model, which provides input for the estuarine models. This model output, which is available now, is the input for the geomorphic model.

Geomorphic Modeling

Ultimately, the Delft3D modeling system will be used to investigate sediment transport, hydrodynamics, and morphologic change. We will use a combination of the Delft 2DH (Roelvink et al. 2001) and 3D (Lesser et al. 2004, Winterwerp 2001) coupled hydrodynamic, sand and mud transport models and morphology models within the Delft3D system (http://delftsoftware.wldelft.nl/index.php?option=com_content&task=view&id=109 and http://www.wldelft.nl/soft/d3d/intro/) to assess likely changes to the intertidal, and because of its influence on the intertidal, the subtidal. Changes in depth, due to sediment redistribution, and sea-level rise, alter the distribution of available habitat. Freshwater inflows and sediment supply are simulated from GCCM output and combined with sea level rise and estuarine hydrodynamics to estimate likely future geomorphic change (Ganju et al., 2009; Van der Wegen et al., in review). These models are informed by research on historical intertidal changes in the northern San Francisco Estuary (Jaffe et al. 2007, Jaffe et al. 1998, Capiella et al. 1999). The same data also allow calibration and validation of the geomorphic models.

Initially, modeled shoal changes for Suisun Bay (Ganju and Schoellhamer, 2010) will be used to develop methodologies for quantifying intertidal habitat change resulting from climate change and sea level rise. These simulations showed an increase in erosion of intertidal areas when a base-case scenario was compared with a scenario of

warming, sea level rise, and decreased watershed sediment supply. GIS tools will be developed that integrate with foraging model.

Foraging Modeling

The USGS Western Ecological Research Center has investigated the foraging ecology of migratory birds in San Francisco Bay for over 20 years. We will apply our extensive existing datasets on foraging behavior, as well as the results of detailed shorebird and invertebrate prey surveys from the USGS Shoals Project and our knowledge of current and past baywide distribution of migratory waterbirds (Takekawa et al. 2001, Takekawa et al. 2002, Warnock et al. 2002, Takekawa et al. 2006, Hickey et al. 2007, Takekawa et al. 2009) and model simulations to determine how sediment and morphological changes may affect community composition and availability of their macroinvertebrate food resources. We will use CANOCO 4 (ter Braak and Smilauer 1998) to perform canonical correspondence analyses (CCA; ter Braak 1986, ter Braak 1988) to reveal gradients in species composition and relate log-transformed macroinvertebrate abundance values to environmental variables (salinity, bed elevation, sediment grain size).

We will use spatially-explicit geographic information system-based analyses (ArcGIS, ESRI Systems, Redlands, CA) to map expected macroinvertebrate densities in response to changing physical conditions and to compare the current and projected extent of shoal habitats through the next half of a century with our knowledge of foraging ecology of migratory birds to estimate likely functional and numerical responses to alteration of their foraging resources. Our goal is a spatially explicit evaluation of: a) quantitative change in habitat availability for key waterbird species, incorporating both climate change-driven changes in sediment distribution and increased sea level rise; and b) change in distribution and relative abundance of waterbird species, incorporating changes in habitat quantity and quality (i.e., invertebrate food resource changes due to changes in salinity or sediment grain size).

Products:

In FY2010, we will address the following specific elements to initiate our integrated program:

- Host a modeling workshop with partners to identify what parameters are needed to model effects of sea level rise on the ecology of shoals and migratory birds
- Use existing shoals modeling grids (Ganju and Schoellhamer, 2010) to develop methodology of quantifying key metrics for habitat change
- Conduct a comprehensive review on foraging of migratory birds on shoal habitats
- Complete a report on the findings of the workshop and proposed habitat change metrics from the grid approach

Ongoing Project Updates:

USGS Shoals Project: A key uncertainty in the South Bay Salt Pond Restoration Project is the effect of restoration on the estuarine shoals that support most of the region's

migratory birds and fishes. In advance of restoring the first salt pond (SF2) on the Fish and Wildlife Service's San Francisco Bay National Wildlife Refuge, our USGS science team completed the first phase of sampling and instrumentation in the shoals adjacent to SF2 from late FY2008 through the second quarter of FY2009. Pond SF2 construction began in February 2009 with restoration to the Bay planned for August 2010.

USGS CAWSC scientists installed instruments on the Dumbarton Bridge and in the shallows to examine sediment movement and wind waves, and established a sediment station on a major tributary (Coyote Creek). USGS PSC scientists used interferometirc side-scan sonar to map the channel and deeper shoal habitats, and obtained sediment samples to analyze composition. USGS MPSC scientists applied advanced terrestrial light detection and ranging (lidar) surveys to map the shallows and part of SF2 in advance of the restoration. USGS WERC scientists established baseline waterbird surveys and conducted behavior scans; captured shorebirds and sampled isotopes to determine diet; and collected benthic cores to enumerate invertebrates along an elevation gradient. This comprehensive effort should provide detailed science support for management of the restoration and its future phases. The scientific studies will continue with detailed real-time monitoring of SF2 as the pond is restored.

CASCaDE: Four of the scientists involved with this study (Schoellhamer, Jaffe, van der Wegen, and Roelvink) are PIs or investigators in the CASCaDE project. This allows seamless transfer of data and results from that project to this project.

Timetable for Completion (identified by each deliverable):

	Jun	Jul	Aug	Sep	Oct
Organize Modeling Workshop	X	X	X		
Develop Initial Habitat Change Metrics		X	X	X	
Conduct Review of Foraging Migratory Birds	X	X	X		
Conduct Modeling Workshop				X	
Complete Summary Report					X

Performance Metrics:
Our performance metrics will include four measurable products: 1) conducting the first workshop to address climate change effects on shoals (Sep), 2) developing initial habitat change metrics (Jul-Sep), 3) providing a review on foraging birds (Jun-Aug), and 4) completing a summary report of the initial project accomplishments (Sep).

Conservation Outcomes:
Our research project will quantify and map changes in availability of migratory waterbird habitats in estuaries caused by sea level rise and climate change. The shoals support the majority of shorebirds and large numbers of waterfowl in the estuary, and geomorphic changes in them have the greatest impact on migratory bird foraging habitat.

The proposed project is a key step in preparing resource managers to address climate change and sea level rise effects on the San Francisco Bay estuary. This initial effort will highlight the issue of climate change effects on migratory birds and their critical shoals habitats, including metrics that should be addressed to understand the climate change effects.

Budget:

Under this grant, we will initiate the first task of a comprehensive migratory birds and shoals habitat program through a modeling workshop, development of habitat change metrics, completion of a foraging behavior review, and delivery of a summary report. The target for completion of these goals is 1 October 2010.

Description	**Cost**
Salary Costs	
Principal Investigators (2@ 1 pp)	13,061
Workshop and Report Coordinator (6 pp)	17,712
Migratory Bird Biologist (4 pp)	7,576
Habitat Change Analyst (4 pp)	7,576
Subtotal	*45,925*
Operating Costs	
Miscellaneous supplies (software, report)	2,000
Meeting and Travel Costs (2 Intl)	19,675
Subtotal	*21,675*
Direct Costs	*67,600*
Indirect Costs (DOI client: 21.97%)	14,852
Total Costs	***82,452***

Matching Funds:

USGS contributed funds includes ongoing research programs for Shoals Project ($221K), Climate Change Program ($176K), and specialized equipment, for a total matching funds of $397K.

Letters of Support:

Two letters of support are in Attachment A.

A third letter, by Steve Goldbeck, Bay Conservation and Development Commission (steveg@bcdc.ca.gov) is on track to be sent by June 15.

Appendix. Cited References

Cappiella, K, Malzone, C, Smith, R. E., and Jaffe, B.E., 1999, Sedimentation and bathymetry changes in Suisun Bay, 1867-1990: U.S. Geological Survey Open-File Report 99-563 [URL: http://geopubs.wr.usgs.gov/open-file/of99-563/].

Cayan, D., A. Luers, G. Franco, M. Hanemann, B. Croes, and E. Vine. 2008a. Overview of the California climate change scenarios project. Climate Change 87: 1-6.

Cayan, D., E. Maurer, M. Dettinger, M. Tyree, and K. Hayhoe. 2008b. Climate change scenarios for the California region. Climate Change 87: 21-42.

Cayan, D., P. Bromirski, K. Hayhoe, M. Tyree, M. Dettinger, and R. Flick. 2008c. Climate change projections of sea level extremes along the California coast. Climate Change 87: 57-73.

Ganju, N.K., and D. H. Schoellhamer. 2010. Decadal-Timescale Estuarine Geomorphic Change Under Future Scenarios of Climate and Sediment Supply. Estuaries and Coasts 33:15-29.

Ganju, N.K., N. Knowles, and D.H. Schoellhamer. 2008. Temporal downscaling of decadal sediment load estimates to a daily interval for use in hindcast simulations. Journal of Hydrology 349: 512-523.

Ganju, N.K., Schoellhamer, D.H., and Jaffe, B.E., 2009, Simulation of decadal-timescale estuarine geomorphic change with a tidal-timescale model, Journal of Geophysical Research-Earth Surface, doi:10.1029/2008JF001191.

Goals Project, 1999. Baylands Ecosystem Habitat Goals. A Report of Habitat Recommendations Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. San Francisco, California: U.S. Environmental Protection Agency, and Oakland, California: S.F. Bay Regional Water Quality Control Board, 209p.

Hickey, C., N. Warnock, J.Y. Takekawa, and N. D. Athearn. 2007. Space use by black-necked stilts in the San Francisco Bay estuary. Ardea 95: 275-288.

IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning,Z. Chen, M. Marquis, K.B. Avery, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Jaffe, B.E., Smith, R. E., and Torresan, L. Z., 1998, Sedimentation and bathymetric change in San Pablo Bay: 1856 to 1983: U.S. Geological Survey Open-File Report 98-759 [URL: http://wrgis.wr.usgs.gov/open-file/of98-759/].

Jaffe, B.E. and Foxgrover, A.C., 2006, A history of intertidal flat area in South San Francisco Bay, California: 1858 to 2005, U.S. Geological Survey Open-File Report 2006-1262, 32 pp. [URL: http://pubs.usgs.gov/of/2006/1262].

Jaffe, B.E. and Foxgrover, A.C., 2006, Sediment Deposition and Erosion in South San Francisco Bay, California from 1956 to 2005, U.S. Geological Survey Open-File Report 2006-1262, 24 pp. [URL: http://pubs.usgs.gov/of/2006/1287].

Jaffe, B.E., Smith, R.E., and Foxgrover, A.C., 2007, Anthropogenic influence on sedimentation and intertidal mudflat change in San Pablo Bay, California: 1856 to

1893. Estuarine. Coastal and Shelf Science 73 (1-2), 175-187, doi:10.1016/j.ecss.2007.02.17.
Lesser, G. R., J. A. Roelvink, J. A. T. M. van Kester, and G. S. Stelling, 2004, Development and validation of a three-dimensional morphological model, Coastal Eng., 51, 883 – 915, doi:10.1016/j.coastaleng.2004.07.014.
Roelvink, J.A., Jeuken, M.C.J.L., van Holland, G., Aarninkhof, S.G.L. and Stam, J.M.T., 2001. Long-term, process-based modelling of complex areas. Proceedings 4th Coastal Dynamics Conference, Lund, Sweden, pp 383-392.
Takekawa, J. Y., C. T. Lu, and R. Pratt. 2001. Avian communities in salt evaporation ponds and baylands of the northern San Francisco Bay estuary. Hydrobiologica 466: 317-328.
Takekawa, J. Y., N. Warnock, G. M. Martinelli, A. K. Miles, and D. C. Tsao. 2002. Waterbird use of bayland wetlands in the San Francisco Bay estuary: movements of long-billed dowitchers during the winter. Waterbirds 25: 93-105.
Takekawa, J. Y., A. K. Miles, D. H. Schoellhamer, N. D. Athearn, C. Jannusch, M. K. Saiki, W. D. Duffy, and S. Kleinschmidt. 2006. Trophic structure and avian communities across a salinity gradient in evaporation ponds of the San Francisco Bay estuary. Hydrobiologia 567: 307-327.
Takekawa, J. Y., A. K. Miles, D. C. Tsao-Melcer, D. H. Schoellhamer, S. Fregien, and N. D. Athearn. 2009. Dietary flexibility in three representative waterbirds across salinity and depth gradients in salt ponds of San Francisco Bay. Hydrobiologia 626:155–168.
ter Braak, C.J.F.,1986. Canonical correspondence analyses: a new eigenvector method for multivariate direct gradient analysis. Ecology 67: 1167-1179.
ter Braak, C.J.F., 1988. Partial canonical correspondence analysis. In Classification and Related Methods of Data Analysis (H.H. Bock, ed.), North-Holland, Amsterdam pp. 551-558.
ter Braak, C.J.F. & P. Smilauer, 1998. CANOCO Reference Manual and User's Guide to CANOCO for Windows: Software for Canonical Community Ordination, version 4, Microcomputer Power, Ithaca, NY.
USGS. 2007. CASCaDE: Computational Assessments of Scenarios of Change for the DeltaTakekawa, J. Y., A. K. Miles, D. H. Schoellhamer, N. D. Athearn, C. Jannusch, M. K. Saiki, W. D. Duffy, and S. Kleinschmidt. 2006. Trophic structure and avian communities across a salinity gradient in evaporation ponds of the San Francisco Bay estuary. Hydrobiologia. 567: 307-327.
USGS. 2007. CASCaDE: Computational Assessments of Scenarios of Change for the Delta Ecosystem: URL http://sfbay.wr.usgs.gov/cascade/
van der Wegen, M., Jaffe, B.E., and Roelvink, D., in review, Process-based, morphodynamic hindcast of decadal deposition patterns in San Pablo Bay, California, 1856-1887, Journal of Geophysical Research-Earth Surface.
van der Wegen, M., Roelvink, D., Jaffe, B.E., Ganju, N., Schoellhamer, D., 2008, CASCaDE research on hindcasting bathymetric change in San Pablo Bay, 1856-1983: A step towards assessing likely geomorphic change in response to climate change (abs.) Fifth Biennial CALFED Science Conference, p. 207. 567: 307-327.
Velasquez, C. 1992. Managing artificial saltpans as a waterbird habitat: species' response to water level manipulation. Colonial Waterbirds 15: 43-55.

Warnock, N., G.W. Page, T.D. Ruhlen, N. Nur, J.Y. Takekawa, and 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.Winterwerp, J.C. , Stratification effects by cohesive and non-cohesive sediment, 2001, Journal of Geophysical Res., Vol. 106, No. C10, pp 22,559-22,574.

Attachment A. Letter of Support: Coastal Conservancy

Coastal Conservancy

National Climate Change and Wildlife Science Center
U.S. Geological Survey
Biological Resources Discipline, Office of the Chief Scientist
12201 Sunrise Valley Drive
Reston, Virginia 20192

June 23, 2009

Attn: Robin Schrock

RE: Support for RFP 2009-2011 proposal titled "Climate-driven geomorphic alteration of intertidal foraging habitats for migratory birds in the San Francisco Bay estuary".

Dear Ms. Schrock:

I am writing to express the California Coastal Conservancy's strong support for funding the USGS proposal titled "Climate-driven geomorphic alteration of intertidal foraging habitats for migratory birds in the San Francisco Bay estuary."

In recent years, the Coastal Conservancy has expended tens of millions of dollars to fund the acquisition and restoration of marshes throughout the San Francisco Bay region. While the impacts due to climate change are likely to be tremendous along much of California's shoreline, the San Francisco Bay area stands to experience the most significant impacts from sea level rise because tens of thousands of acres of low elevations currently support development and vast areas of tidal marshes. These marshes, the largest along the west coast, provide crucial habitat for birds and other species, as well as numerous other benefits to the quality of life for a dense urban population of nearly 8 million persons.

Located along the Pacific Flyway, San Francisco Bay is a critical regional stopover and wintering area for migratory shorebirds and waterfowl. A healthy bay enhances wildlife habitat as well as quality of life for its human residents, providing recreational and aesthetic value to the area. Over 35,000 acres of coastal wetland restoration projects are currently planned or in progress, yet climate change is a major uncertainty affecting the success of these projects as well as long-term habitat values within the estuary.

The Conservancy is pro-actively considering how future expenditures should be allocated in consideration of predicted climate change impacts. The Board recently adopted a Climate Change Policy and Project Selection Criteria to help address climate change as an area of focus for directing project priorities. However, our current understanding of the effects of climate change on local habitats is generally insufficient to effectively factor in the effects of climate change on local tidal marsh restoration and enhancement

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California State Coastal Conservancy

projects. This study, "Climate-driven geomorphic alteration of intertidal foraging habitats for migratory birds in the San Francisco Bay estuary," will provide critical information for many stakeholders involved in long-term habitat planning within the estuary, and will likely inform efforts in similar habitats in other locations as well. I urge you to strongly consider the potential for wide and immediate application of this important project to advance the planning and management of the tremendously high-value wetlands in the SF Bay area.

Sincerely,

Nadine P. Hitchcock

Nadine P. Hitchcock
Deputy Executive Officer
CA Coastal Conservancy

Attachment B. Letter of Support: San Francisco Bay Joint Venture

SAN FRANCISCO BAY JOINT VENTURE

June 23, 2009

The Office of the Chief Scientist for Biology
U.S. Geological Survey
Biological Resources Discipline
Office of the Chief Scientist (MS301) Attn: Robin Schrock
12201 Sunrise Valley Drive
Reston, Virginia 20192

SUBJECT: Climate-driven geomorphic alteration of intertidal foraging habitats for migratory birds in the San Francisco Bay estuary

I am writing on behalf of the San Francisco Bay Joint Venture (SFBJV) in support of the above named proposal.

The SFBJV is a partnership of non-governmental organizations, utilities, landowners, and non-voting agencies with a goal to protect, restore and enhance 200,000 acres of wetlands on San Francisco Bay and on the coasts of San Mateo, Marin, and Sonoma Counties. The San Francisco Bay Joint Venture is one of the seventeen wetland habitat Joint Ventures operating under the certification of the North American Waterfowl Management Plan, a Congressional agreement between the United States, Canada, and Mexico. It is a priority of the San Francisco Bay Joint Venture to conserve habitat for water birds in San Francisco Bay, a region of high importance for migratory and wintering shorebirds and waterfowl. The USGS Western Ecological Research Center/San Francisco Field Station has been a major partner on needed research to help the SFBJV achieve our species protection and habitat goals.

Climate change is perhaps the largest challenge affecting bird habitats and in coastal areas, and yet our understandings of its impacts are limited. Research efforts directed towards predicting specific potential effects of climate change on coastal and estuarine habitats for water birds will be critical to addressing these challenges, and thus I am writing in support of the USGS proposal titled "Climate-driven geomorphic alteration of intertidal foraging habitats for migratory birds in the San Francisco Bay estuary."

The SFBJV has played a coordinating role with partner agencies and NGO's to identify the needed research and models that will provide the information and data necessary to drive informed restoration decisions. We recognize that our current understanding of the effects of climate change on local avian habitats is generally insufficient to effectively factor the effects of climate change into landscape-level conservation planning. Our estuarine habitats are vital foraging resources for birds, and changes in the availability and quality of these habitats are critical for long-term habitat conservation planning in the estuary. The proposed study will provide necessary information for long-term habitat planning within the estuary, and will likely inform efforts in similar habitats in other locations as well. We support this effort to obtain critically important information to support long-term planning and research efforts in the San Francisco Bay estuary.

If you have any questions about the SFBJV or our support of this proposal, please contact our Coordinator, Beth Huning.

Sincerely,

Frederic A. Reid

Frederic A. Reid, Ph.D.
Chair