Computational Assessments of Scenarios of Change in the Delta Ecosystem

CALFED Science Program Project SCI-05-C01-84
Final Semiannual Project Report
Report No. 7: March 1, 2009 – October 31, 2009

CONTRACTOR/GRANT RECIPIENT CONTACT INFORMATION

Program Administrator
NAME: Cynthia Brown
INSTITUTION: U.S. Geological Survey
ADDRESS: 345 Middlefield Rd. MS 466, Menlo Park, CA 94025
PHONE: 650-329-4477
EMAIL: ewarren@usgs.gov

Principal Investigator/Lead Principal Investigator
NAME: James E. Cloern
INSTITUTION: U.S. Geological Survey
ADDRESS: 345 Middlefield Rd. MS 496, Menlo Park, CA 94025
PHONE: 650-329-4594
EMAIL: jecloern@usgs.gov

GRANTING PROGRAM CONTACT INFORMATION

Technical Contact
NAME: Michelle Shouse
TITLE: USGS Coordinator
AGENCY: California Bay Delta Authority
ADDRESS: 650 Capitol Mall, 5th Floor, Sacramento, California 95814
PHONE: 916-445-0641
EMAIL: mkshouse@calwater.ca.gov

Contract/Administrative Contact
NAME: N/A
TITLE:
AGENCY: California Bay Delta Authority
ADDRESS: 650 Capitol Mall, 5th Floor, Sacramento, California 95814
PHONE:
E-MAIL:

I. INTRODUCTION AND BUDGET SUMMARY

Funding Source: ***BOR Reimbursible funds through USGS***

Project Location: U.S. Geological Survey, Menlo Park, CA

Brief Description of Project: This project constitutes a model-based approach for developing a long view of the Bay-Delta-River-Watershed system. The long view is developed through simulations with linked models to project changes under a range of plausible scenarios of climate change, Delta configurational changes, and land-use/population change. Elements of the Bay-Delta River-Watershed system addressed by this project are:

① Climate Modeling and Downscaling
② Sacramento-San Joaquin Watershed and San Francisco Bay Modeling
③ Delta Modeling: Hydrodynamics with Temperature and Phytoplankton
④ Sediment, Geomorphology and Tidal-Habitat Modeling
⑤ Fate and Effects of Selenium, Mercury, Silver and Cadmium
⑥ Invasive Species– *Potamocorbula*, *Corbicula*, and *Egeria*
⑦ Native and Alien Fish Population Trends

The cascading effects of changes under these scenarios will be followed as they propagate through these elements, from the climate system to watersheds to river networks to the Delta and San Francisco Bay.

Budget Summary (All tasks should exactly match those identified in the project Scope of Work.)

Task #	% Complete (by dollars)	Amount Invoiced (Fiscal Year 2009)	Amount Invoiced to Date (All Years)	Projected Expenditures next 6 months
1	100.00%	$0.00	$258,270	$0.00
2	100.00%	$93,998	$395,808	$0.00
3	100.00%	$10,794	$237,127	$0.00
4	100.00%	$44,697	$320,670	$0.00
5	100.00%	$22,947	$79,634	$0.00
6	100.00%	$68,019	$74,497	$0.00
7	100.00%	$127,643	$253,220	$0.00
8	100.00%	$33,654	$43,647	$0.00
		$401,752	$1,662,873	$0.00

Note: Amounts above do not include the $161,000 amendment to Task 5 that was added (and spent) in FY2009.

II. CURRENT TASK STATUS REPORTS

This section presents accounts of each task's activities during the present reporting period.

Task 1

The basic downscaled products have been delivered. Development of some downscaled values of other nonstandard variables (specifically wind) is ongoing.

Task 2

Since March 1, 2009, some additional revisions were made to the daily Delta flow data for the four climate scenarios. These changes were made to ensure more physically realistic outflows were the end product, after consultation with Jan Thompson, who is using these data in her part of the Cascade study.

Additionally, several indices from this component of Cascade were selected for inclusion in the paper on indicators and thresholds, led by Jim Cloern. Three of the four indicator time series have already been produced.

Work is ongoing with Mick van derWegen (Task 4) to use his Delft hydrodynamic model to estimate salinity changes associated with sea level rise and warming-induced inflow changes. Salinity projections in the northern reach will constitute the fourth indicator.

The following report was peer-reviewed and published as part of the California Climate Action Team's Report to the Governor:

Knowles, Noah. 2008. Potential Inundation Due to Rising Sea Levels in the San Francisco Bay Region. California Climate Change Center. CEC-500-2009-023-F.

Associated information was also made available on the Cascade web site: http://cascade.wr.usgs.gov

A similar manuscript was also accepted with minor revisions:

Knowles, Noah. 2009. Potential Inundation Due to Rising Sea Levels in the San Francisco Bay Region. *San Francisco Estuary and Watershed Science*, in revision.

Also, a web site containing Google Earth visualizations of various climate-change-related datasets, including the sea level rise results from this project, was unveiled by Governor Schwarzenegger at a press conference on Dec 12 on Treasure Island. The web site is http://www.climatechange.ca.gov/visualization/index.html

The Bay Conservation and Development Commission (http://www.bcdc.ca.gov/) is using the sea level rise data from this project as the basis for a proposed amendment to their *Bay Plan*, which is their guiding document for making permitting decisions on development in and around San Francisco Bay.

Data from this project were used to develop an educational/interpretive installation at Crissy Field in San Francisco depicting areas at risk of inundation there, and also water heights associated with various future scenarios. I also was interviewed about the sea level rise study for the NPS "Golden Gate Climate Change Update" audio Podcast, 11/2009.

I gave the following talks on Cascade-related work:

Knowles, N. 2009. Sierra Hydrology in Response to a Changing Climate. A Symposium on Coping with Climate Change in Sierran Systems: Incorporating Climate into Land and Resource Management and Developing Adaptation Strategies, March 17-18, 2009, Incline Village, Nevada.

Knowles, N. 2009. Cascading Effects of Climate Change in the Delta and its Watershed. John Muir Institute for the Environment Distinguished Speaker Series, University of California at Davis, April 30, 2009, Davis, California.

Knowles, N. 2009. Cascading Effects of Climate Change in California: Projections of Hydrological and Biological Responses. U.S. Geological Survey Research Committee Meeting, May 19, 2009, Flagstaff, Arizona.

Knowles, N. 2009. Climate Change From Both Ends: Projected Sea Level Rise and Inflow Changes in San Francisco Bay. 90th Annual Meeting of the Pacific Division of the American Association for the Advancement of Science, August 14-19, 2009, San Francisco, California. [This AAAS session was written up in Science (25 Sept 2009, p.1637-8), including a figure from my work.]

Knowles, N. 2009. Climate Change From Both Ends: Projected Sea Level Rise and Inflow Changes in San Francisco Bay. USGS/DOI workshop on sea-level rise, coastal vulnerability, and decision support, September 15-16, 2009, Herndon, Virginia.

Knowles, N. 2009. Potential Inundation in the San Francisco Bay Region Due to Rising Sea Levels. AGU Fall Meeting, December 14-18, 2009, San Francisco, California.

Task 3

(Overview: Hydrodynamics)
Major progress was made to improve the bathymetric grid for DeltaTRIM and to develop tools necessary to more realistically simulate phytoplankton dynamics. Our confidence the stage predictions throughout the Delta and flow predictions in the Delta Cross Channel region has greatly improved during this period with the aid of new tools we developed.

(Detailed status)

Bathymetry data is the most important input parameter for the Delta TRIM model. When the Delta TRIM model was originally developed, the user interface for the grid was a limited SGI based tool that could barely handle the complexity of the Delta bathymetry. During CASCaDE, we have worked on developing both a database of bathymetry and elevation data including levee heights in the ArcGIS format. This database will allow us to create many different configurations of the Delta for model simulations. In the last seven months, we have used the database to greatly improve the calibration and verification of Delta TRIM. We are now able to quickly visualize the cell representation of bathymetry and identify regions of the grid that need improvement. (Figure 1) This ArcGIS format will play a critical role in the development of the overlayed phytoplankton model.

One of the tools we developed in the last seven months was a interpolation tool for the Delta. (Figure 2) So far, we have used this tool to create initial salinity conditions and benthic grazing rates throughout the Delta. There are multiple salinity stations throughout the Delta. Nancy Monsen created a Microsoft Access database that has

all measurement stations throughout the Delta. UTM coordinates as well as the coordinates i, j grid coordinates for the system. This tool can interface to ArcGIS to specify salinity conditions throughout the Delta. Nancy Monsen, Lisa Lucas, and Sarah Foster, over the course of three weeks, created a ArcGIS layer that specifies the levee boundaries of all the channels in the Delta. Now, using the ArcToolbox Spline with Barriers interpolation tool, we are able to interpolate observed data along the channels and map that interpolation onto the Delta TRIM grid.
Over the last seven months, the focus on the hydrodynamic simulations has been modeling the base case scenarios, 1999 (wet year) and 1992 (dry year) and comparing the results with a suite of observed stage, flow and salinity values throughout the system. During these simulations, Monsen identified several key elements that are necessary to model full year simulations. (Prior to this project, Delta TRIM simulations were limited to 3 month simulations.) Monsen has added variable salt concentrations on the Sacramento and San Joaquin flow boundaries. Flow and salinity boundaries for Yolo Bypass and East Side streams are needed to represent high flow events. Figure (3-5) show examples of model representation of stage, flow, and salinity for 1999 period.

Monsen participated in two different workshops. At the request of CALFED Science, she attended the Delta Hydrodynamics modeling community meeting. This group identified key directions for hydrodynamic modeling in the future and resources need to make vision a reality. Monsen was also invited to present a talk at the IEP Public Workshop series ”Physical modeling and Fish Management” (www.water.ca.gov/iep/docs/prstns/ws1_Monsen_52709.pdf).

Although funding for CASCaDE has ended, the USGS has extended Monsen’s research until December 10, 2009. During this remaining period, she will continue to improve base line simulation, create simulations that are linked to the CASCaDE scenario data, and will transfer the Delta TRIM model, grid tools, and other methods to Lisa Lucas for her continued use in the phytoplankton model development.

Monsen is currently setting up boundary conditions for simulations for climate scenarios for years 2091 and 2097 for both th PCMB1 and GFDLA2 scenarios. These will represent ”wet year” cases to be compared to our base year of 1999. Our dry year simulation will be compared to 2089. These years were selected using a similar method used to select our base years using historical data.

(Overview:Phytoplankton)

Numerous refinements to the biological model have been coded and tested. The phytoplankton model has been merged with the latest version of the hydrodynamic model and grid.

(Detailed Status)

The Delta phytoplankton model has undergone a significant round of development and refinement. A new approach (following Cole & Cloern 1984, 1987; Brush et al. 2002; Jassby et al. 2002) to describing phytoplankton production and growth has been implemented, troubleshooted, tested, and compared to the previous more classic approach, which was based on photosynthesis-irradiance curves and thus depended on 2 parameters (Pmax, alpha) which are incredibly variable spatially and temporally in the Delta. The new approach (termed “BZI” by Brush et al.) describes phytoplankton productivity as a simple function of surface irradiance, turbidity and phytoplankton biomass; Jassby et al. (2002) calibrated the BZI relationship for the Delta based on productivity measurements across habitats and seasons for that system; this productivity relationship correlates (very) significantly with measurements, does not rely on the pesky variable Pmax and alpha parameters, and provides a basis from which to derive algal growth rates in the model. This appears to be the most reliable way of estimating algal production and growth rate for this system, and calculated phytoplankton biomass concentrations improved in some parts of the central and western Delta for which the model had previously (with the old method) underestimated biomass.

Whereas the model previously used constant (e.g. monthly or seasonal average) surface irradiance (I0) to drive algal growth, daily varying I0 from CIMIS measurements at Davis have been incorporated. The daily to weekly variability in I0 is found to have a significant effect on the daily to weekly variability in calculated phytoplankton biomass.

Previously, constant phytoplankton biomass (chlorophyll *a*) concentrations were specified at the model boundaries (Mossdale, Freeport, Martinez) based on average measurements (IEP, BDAT) for a particular month or season and year. Time-varying boundary conditions for phytoplankton have now been implemented, integrated with the hydrodynamic model, and tested. Approximately monthly chlorophyll *a* measurements for a particular historic time period of simulation are read in, interpolated linearly in time, and now used to drive chlorophyll flux at the boundaries. This refinement has also significantly improved the model.

A significant empirical relationship for chlorophyll at Mossdale has been developed as a function of Vernalis flow and Mossdale water temperature; ultimately, this relationship will be used to produce chlorophyll boundary conditions at Mossdale for future scenario runs (using Knowles' projections of river flow and Wagner/Stacey's empirical water temperature relationships coupled with Dettinger's projected air temperatures for future scenarios). Similar approaches will be used to develop future scenarios boundary conditions for chlorophyll at Freeport and Martinez.

An extremely simple approach to the specification of zooplankton grazing rate has been used from the beginning of model development. Specifically, we specify a constant and uniform zooplankton grazing rate of 0.2 [1/d], based on field measurements from previous CALFED funded projects in the Mildred Island and Franks Tract vicinities. Other than grazing rates derived from these previous studies, we are not aware of any other estimated of zooplankton grazing rates for this system. In recent months, two (still simple) refinements to this approach have been implemented and tested. First, instead of specifying a rate of 0.2 everywhere, we specified a region around Franks Tract with a lower value (0.15), with 0.2 being applied every where else; this was based on lower measured zooplankton grazing at Franks Tract. This approach did improve predicted chlorophyll concentrations in the Franks Tract region somewhat. The second approach involved calculating zooplankton grazing rate as an empirical relationship presented by Lopez et al. (2006, also from previous CALFED funding); this function allows for zooplankton grazing rate to be estimated as a function of water depth and primary productivity. This approach also improved modeled chlorophyll in the Franks Tract region, but caused greater deviations from measurements in other parts of the Delta. These and likely other parameterizations for zooplankton grazing will be revisited once the best possible distributions of other better-informed parameters (e.g. benthic grazing, light attenuation) are finalized and incorporated into the model.

In the last couple months, Lucas integrated the biological code with the latest version of Monsen's hydrodynamic code, which includes many model improvements to the physical description of the Delta system. For example, Monsen's improvement of the hydrodynamic model's representation of temporary barriers (infinitely high vs. half water height) in the southern Delta was shown to greatly improve modeled stages in that region. The effect of barrier treatment on modeled phytoplankton has been tested and shown to be important, especially at station D28A (lowered barriers allow more chl to get through from the south), P8 (presumably through modulating residence time and phytoplankton production on the SJR) and at other stations.

In addition, Lucas has worked closely with Monsen on continual refinements to the model grid, in some cases using the modeled growth of phytoplankton to highlight and help identify regions where grid imperfections may lead to unreasonably slow flushing. Lucas has also worked with Monsen in developing the GIS based interpolation approach to be used for creating model grids of benthic grazing rate from Thompson & Parchaso's measurements (for historical periods). Lucas has met frequently with Thompson and Parchaso to discuss benthic grazing rate distributions (based on their field measurements) which they are developing for historical simulations that Lucas is/will be running with the phytoplankton model. Thompson and Parchaso's distributions will soon be converted to interpolated, gridded maps, which will be read into the phytoplankton model.

"Generic" (no biology) runs have provided a tool for running simple model problems for which target concentrations are known. With these runs, some numerical issues have been investigated to increase accuracy of the model. Accuracy will be assessed with biology on and off.

Lucas gave a recent presentation at Stanford University and will soon give a talk at the Coastal and Estuarine Research Federation conference on the topic presented in the manuscript co-authored with Thompson and Brown and published this year in Limnology & Oceanography. This paper is a CASCaDE product and describes the range of relationships phytoplankton may have with residence time.

Task 3 Temperature Modeling:
Summary Report of CASCaDE activity, Mark Stacey
Reporting Period, February-October 2009

In the final 6 months of our activity, we have been focused on wrapping up the analysis and communication of the water temperature projections. This activity has culminated in the submission of a manuscript ("Statistical Models of Temperature in the Sacramento-San Joaquin Delta under Climate Change Scenarios and Ecological Implications," by Wagner, Stacey, Brown and Dettinger) to *Estuaries and Coasts*. This manuscript describes the development, calibration and verification of a statistical model of water temperature in the Delta, the application of the model to projecting water temperatures under climate change scenarios, and analyzes and discusses the ecological implications (primarily for Delta smelt) of the projected warming. The manuscript is currently in review at Estuaries and Coasts (it was submitted in late September 2009). In this report, we will summarize the key points, but would be happy to provide the manuscript for a more complete discussion.

Summary of Statistical Model

As has been outlined in previous reports, we found that a simple statistical model that regressed today's water temperature against yesterday's water temperature, today's air temperature and today's solar radiation was highly predictive of water temperatures in the Delta. Water temperature data was available at 16 sites in the Delta, although only a handful had more than 1 year of data, which was found to be a minimum data record for predictions of acceptable quality. Meteorological forcing was taken from CIMIS data sites, then averaged over the Delta; because we were only using air temperature and radiation (and not wind), a spatial average was found to be appropriate. An example of the calibration and verification of this model at Antioch is given in Figure 1, where the high model skill is evident during both the calibration and verification periods.

Projection of Climate Change Effects

Using the downscaled climate scenarios developed as part of the CASCaDE effort to define atmospheric conditions, we then explored the implications of climate change for Delta water temperatures. In Figure 2, the mean annual cycle of projected temperatures for the years 2097-2099 is compared to the observed mean annual cycle for the year 1997-1999. Over the 100 years analyzed as part of the CASCaDE effort, all scenarios showed warming of 3-5 C during the summer months, with slightly less warming during the winter.

Ecological Implications

Finally, using the projected water temperatures, we explored the implications of climate-induced warming for Delta smelt. Temperature bands were defined based on smelt biological functions and health: temperatures between 15-20 C in the spring were defined as the spawning season; temperatures between 20-25 C were defined to cause stress; temperatures greater than 25 C were defined as lethal to the smelt. Binning water temperature projections based on these thresholds emphasizes the severe consequences of water temperature increases (Figure 3). While the increase in the number of days exceeding the lethal limit is clear from this presentation, a more subtle effect involves a shift in the timing of the temperature-defined spawning window. Under all climate scenarios, the spawning window shifts earlier (Figure 4), typically by 10-15 days, but in the most extreme scenario by nearly 25 days.

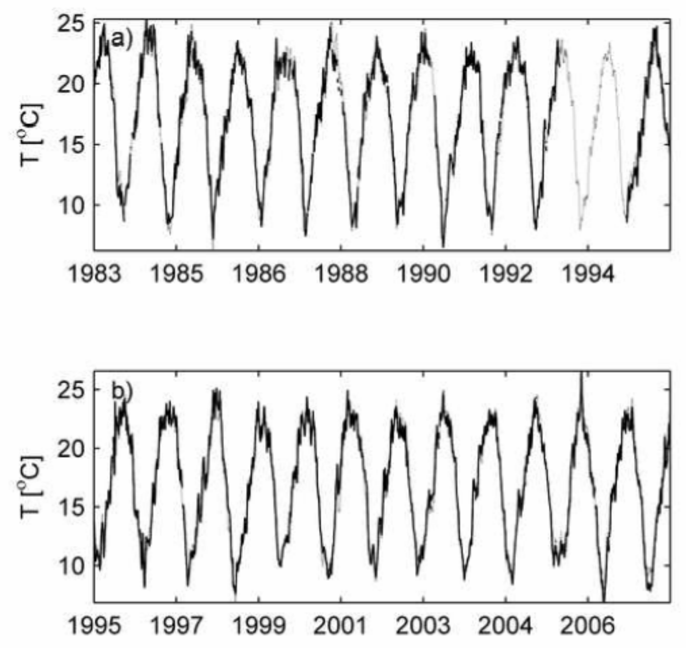

Figure 1 (Figure 5, Wagner et al. Submitted): Calibration (a) and verification (b) at the San Joaquin River at Antioch (station 2). The measured values are indicated with the solid line; the modeled values are indicated with the grey line. The calibration R^2 was 0.981; verification R^2 was 0.978.

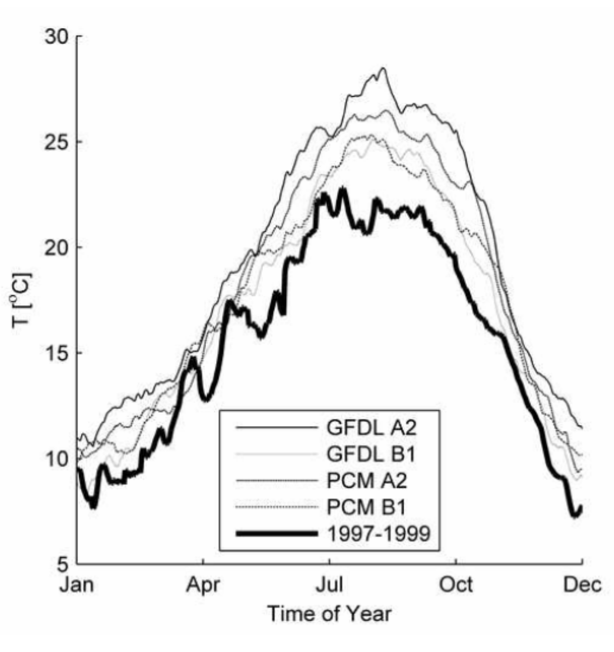

Figure 2 (Figure 9, Wagner et al., submitted): Projected yearly cycle of water temperatures at Sacramento River at Rio Vista (station 15) averaged from 2097-2099. The mean of the measured water temperatures at the same location from 1997-1999 is included for comparison.

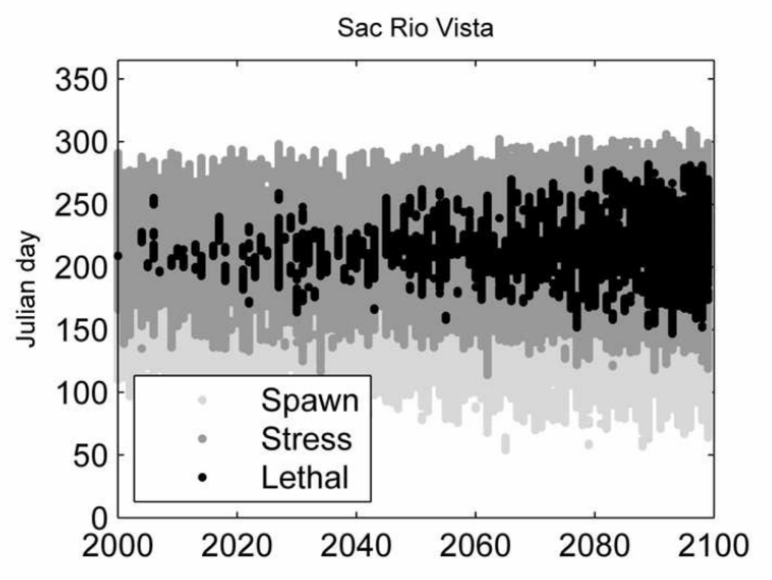

Figure 3 (Figure 11, Wagner et al., submitted): Long-term shift in water temperatures on the Sacramento River at Rio Vista (station 15) under GFDL A2 forcing. Using projected temperatures, each day is grouped as it impacts the Delta smelt: spring spawning (daily average temperatures from 15 – 20 C), stress (daily average temperatures from 20 – 25 C), and lethal (daily average temperatures > 25 C).

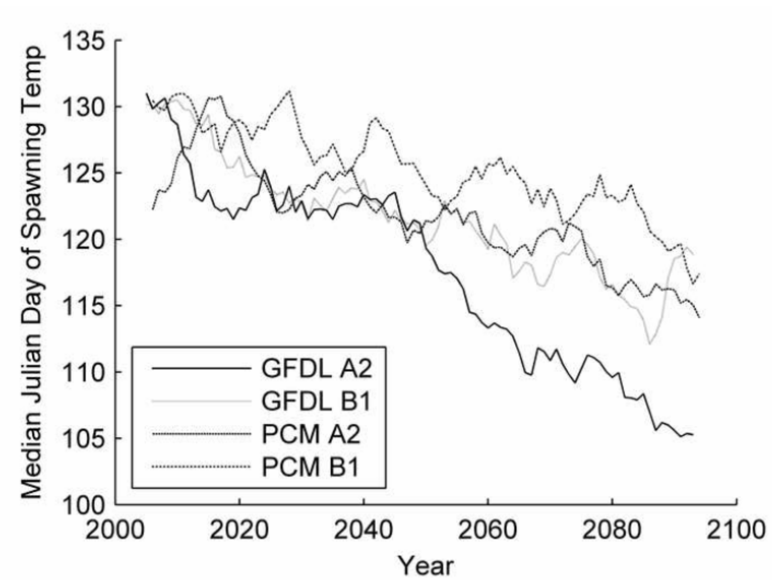

Figure 4 (Figure 12, Wagner et al., submitted): Projected shift in the median day of the spawning period due to temperature on the Sacramento River at Rio Vista (station 15). The median day of the spawning period was calculated for each year under each scenario. The medians were smoothed with a 10-year running average.

Task 4

Geomorphology, Schoellhamer, Wegen and Jaffe

A journal article on hindcasting geomorphic change in an estuary with a tidal time scale model was revised and accepted by *Journal of Geophysical Research – Earth Surface*. Hindcasting decadal-timescale bathymetric change in estuaries is prone to error due to limited data for initial conditions, boundary forcing, and calibration; computational limitations further hinder efforts. We developed and calibrated a tidal-timescale model to bathymetric change in Suisun Bay, California, over the 1867-1887 period. A general, multiple-timescale calibration ensured robustness over all timescales; two input reduction methods, the morphological hydrograph and the morphological acceleration factor, were applied at the decadal timescale. The model was calibrated to net bathymetric change in the entire basin; average error for bathymetric change over individual depth ranges was 37%. On a model cell-by-cell basis, performance for spatial amplitude correlation was poor over the majority of the domain, though spatial phase correlation was better, with 61% of the domain correctly indicated as erosional or depositional. Poor agreement was likely caused by the specification of initial bed composition, which was unknown during the 1867-1887 period. Cross-sectional bathymetric change between channels and flats,
driven primarily by wind-wave resuspension, was modeled with higher skill than longitudinal change, which is driven in part by gravitational circulation. The accelerated response of depth may have prevented gravitational circulation from being represented properly. As performance criteria became more stringent in a spatial sense, the error of the model increased. While these methods are useful for estimating basin-scale sedimentation changes, they may not be suitable for predicting specific locations of erosion or deposition. They do, however, provide a foundation for realistic estuarine geomorphic modeling applications.

A journal article on future scenarios of geomorphic change in Suisun Bay was completed and submitted to *Estuaries and Coasts*. Future estuarine geomorphic change, in response to climate change, sea-level rise, and watershed sediment supply, may govern ecological function, navigation, and water quality. We estimated geomorphic changes in Suisun Bay, California, under four scenarios using a tidal-timescale hydrodynamic/sediment transport model. Computational expense and data needs were reduced using the morphological hydrograph concept and the morphological acceleration factor. The four scenarios included 1) present-day conditions; 2) sea-level rise and freshwater flow changes of 2030; 3) sea-level rise and decreased watershed sediment supply of 2030; and 4) sea-level rise, freshwater flow changes, and decreased watershed sediment supply of 2030. Sea-level rise increased water levels thereby reducing wave-induced bottom shear stress and sediment redistribution during the wind-wave season. Decreased watershed sediment supply reduced net deposition within the estuary while minor changes in freshwater flow timing and magnitude induced the smallest overall effect. In all future scenarios net deposition in the entire estuary and in the shallowest areas did not keep pace with sea-level rise, suggesting that intertidal and wetland areas may struggle to maintain elevation. Tidal-timescale simulations using future conditions were also used to infer changes in optical depth: though sea-level rise acts to decrease mean light irradiance, decreased suspended-sediment concentrations increase irradiance, yielding small changes in optical depth. The modeling results also assisted with the development of a dimensionless estuarine geomorphic number representing the ratio of potential sediment import forces to sediment export forces; we found the number to be linearly related to relative geomorphic change in Suisun Bay. The methods implemented here are widely applicable to evaluating future scenarios of estuarine change over decadal-timescales.

Application of the numerical models used to simulate geomorphology in San Pablo and Suisun Bays to the Delta is beyond the scope of CASCaDE-I. The fish and phytoplankton CASCaDE-I tasks, however, need suspended-sediment concentration (SSC) scenarios in the Delta. We are developing statistical models of SSC in the Delta as a function of boundary conditions on the Sacramento River at Freeport, San Joaquin River at Vernalis, and Suisun Bay at Mallard Island. Such models could also be used with future scenario boundary conditions as indicators of ecosystem change. To date, the relations have been statistically disappointing but development will continue with USGS PES funds.

A journal article on hindcasting geomorphic change during in San Pablo Bay is in review. Process-based numerical models are able to describe morphodynamic developments over time. However, the results of these models depend to a high degree on model parameter settings related to sediment transport, bed composition, the schematization of boundary conditions and the morphodynamic update scheme. The (historic) values of these parameters are often not known in detail. This study assesses the value of process-based morphodynamic modeling by hindcasting decadal morphodynamic development in San Pablo Bay, California, USA. Focus of the hindcast is on the 1856 to 1887 depositional period in which upstream hydraulic mining resulted in a high sediment input to the Bay. The (Delft3D) model includes processes like wind waves, salt and fresh water interactions and graded sediment transport for both sand and mud fractions. Model outcomes include an extensive sensitivity analysis on model parameter settings and are evaluated against measured bathymetric developments. A model applying best-guess model parameter settings predicts decadal morphodynamic developments in San Pablo Bay quite well. Furthermore, results do not deviate much under reasonable variations of the parameter settings and the results compare well with measured deposition volumes. Variations in sediment concentration, river discharge and wind waves have the most significant effect on deposition volumes, whereas waves have the most impact on sediment allocation within San Pablo Bay.

A journal article on the generation of initial bed composition for morphodynamic hindcasting is in review with the Ocean Dynamics. Bed composition generation does not include bed level changes, but allows for sediment re-distribution of multiple sediment fractions over the model domain. The bed composition model applies the concept of an active layer (that may change in composition) on top of an under layer of fixed composition. Model results applied on the case study of San Pablo Bay show that the model reallocates sand and mud sediment fractions over the modeling domain. After the spin-up time interval in which major sediment redistribution takes place, changes in sediment transports and bed composition are minor. Increasing the value of the morphological factor or decreasing the active layer thickness shortens the adaptation time scale, but not the general trend. The bed composition generation technique proposed eliminates the ad hoc specification of sediment size in the model and the associated artifacts in geomorphic change.

Model runs exploring the impact of sea level rise with a focus on the area around Mallard island lead to preliminary estimates of salinity intrusion and suspended sediment concentration (which can be related to light attenuation) under a sea level rise of 0.75 and 1.5 m, (both for a low and high river discharge).

DELIVERABLES THIS PERIOD:

Published: Ganju, N.K., Lucas, L.V., Cloern, J.E., Knowles, N., Dettinger, M., Cayan, D., and Schoellhamer, D., 2009, CASCaDE: Computational Assessments of Scenarios of Change for the San Francisco Bay-Delta Ecosystem, in Brady, S.R., ed., Proceedings of the Second All-USGS Modeling Conference, February 11–14, 2008—Painting the Big Picture: U.S. Geological Survey Scientific Investigations Report 2009–5013, p. 20. http://pubs.usgs.gov/sir/2009/5013/.

Accepted: Ganju, N.K., Schoellhamer, D.H., and Jaffe, B.E., Hindcasting of decadal-timescale estuarine bathymetric change with a tidal-timescale model: Journal of Geophysical Research, Earth Surface.

Submitted: Ganju, N.K., and Schoellhamer, D.H., Decadal-timescale estuarine geomorphic change under future scenarios of climate and sediment supply: Estuaries and Coasts.

Presented and published: Van der Wegen, M., Jaffe, B.E., and Roelvink, D., (2009), Generation of initial bed composition for morphodynamic hindcasting of hydraulic mining deposits in San Pablo Bay, California, Intercoh '09 Conference Rio de Janeiro, Brazil.

Published: Van der Wegen, M., Jaffe, B.E., and Roelvink, D., (2009), Process-based, morphodynamic hindcast of decadal deposition (1856-1887) and erosion (1951-1983) patterns in San Pablo Bay, California, American Geophysical Union Fall meeting '09, San Francisco. CA.

Submitted: Van der Wegen, M., Jaffe, B.E., and Roelvink, D., (2009), Process-based, morphodynamic hindcast of decadal deposition patterns in San Pablo Bay, California, 1856-1887, Journal of Geophysical Research, Earth Surface.

In Review: Van der Wegen, M., Jaffe, B.E., Dastgheib, A., and Roelvink, D., (2009), Generation of initial bed composition for morphodynamic hindcasting of hydraulic mining deposits in San Pablo Bay, California, Ocean Dynamics.

Task 5

Over the last six months we have continued to build and refine models for the prediction of mercury and selenium bioaccumulation in aquatic food webs. We have utilized existing datasets to test modelling approaches, both in understanding base case scenarios in San Francisco Bay, as well as other systems in California and across the United States.

Selenium modeling:

Sam Luoma has further refined the Se model and has published a paper with Theresa Presser explaining the modeling approach and its applications that is featured in this November's issue of Environmental Science and Technology (ES&T) and is highlighted on the cover page. The paper describes how the "global" Se model can be used to: 1) understand patterns of Se bioaccumulation in field biota; 2) the linkages between aqueous Se concentrations and observed concentrations in charismatic species, and; 3) develop site specific objectives (SSO) for aqueous Se that are protective of aquatic fish and birds. Further, Sam Luoma and Theresa Presser have applied the global model in this capacity to develop a SSO for Se in Newport Bay, California.

In terms of refining the Se model for San Francisco Bay we are developing a manuscript (Stewart et al. In prep) that evaluates historical Selenium concentrations in the invasive clam Corbula amurensis. Additional, funding from Calfed was instrumental in completing these analyses and extending the dataset that began in 1995 and now extends through 2007. The manuscript will focus on describing trends in the clams relative to what we have learned to be important parameters for the biodynamic modeling of Se in this species of clams. A next important step in refining the model for San Francisco Bay will be to work closely with Dave Schoellhamer, Lisa Lucas and Jan Thompson to evaluate the role of site specific variation in suspended sediment concentrations and processes corresponding to the sites at Carquinez Strait and at the confluence of the Sacramento and San Joaquin Rivers where we have historical Se data for *Corbula amurensis*. Through our model development we have identified a specific challenge, which will be to understand how particles are transported and transformed in the estuary in order to derive relevant Se concentrations in the food of *Corbula amurensis* that can be fed into the model.

Mercury modeling:

Using datasets from studies of mercury in food webs in the central Delta, tributaries, Camp Far West Reservoir in the Sierra Nevada in addition to freshwater streams in Oregon, Wisconsin and Florida we have developed a food web model that effectively predicts mercury concentrations in top predator fish. This model was presented by Robin Stewart at this years International meeting of the Society of Environmental Toxicology and Chemistry in New Orleans, Louisiana. The talk "Developing appropriate bioaccumulation factors for mercury and selenium one step at a time" was well recieved and is currently being developed into a manuscript Stewart et al. In prep) to be submitted very soon to Environmental Toxicology and Chemistry. This model uses concentrations of methylmercury (MeHg) in herbivorous invertebrates at the base of the food web and links them to top predator fish using estimates of trophic transfer efficiency and food chain length. The model provides a mechanistic understanding of the patterns of mercury bioaccumulation in field setting, but also can form the basis of modeling of scenarios for ecosystems with a range of ecological parameters.

The modeling of mercury in this way has identified a few data gaps that when filled could further extend the model from water through invertebrates and top predators. In our collaboration with Nick Fisher we have identified some important differences in the degree to which invertebrate species assimilate methylmercury from their food. Assimilation efficiencies for MeHg currently exist for zooplankton and amphipods, but are missing for other key species including aquatic insects (mayflies) and snails. We have the expertice to conduct feeding experiments with these species at the USGS in Menlo Park using enriched stable isotopes of MeHg, but would require funding to complete them. We intend to pursue funding for these studies in the near future.

Outreach:

Robin Stewart was invited and attended the Lab-Field Bioaccumulation Workshop´ held in New Orleans, 18-19 November, 2009. The workshop consisted of 3 working groups covering different angels of the topic: WG1 '**Lab to field comparison of Bioaccumulation Measurements of Organic Contaminants**'; WG2 '**Impacts of Physiology and Biology of the Organism on Field Bioaccumulation Measurements**' and WG3 '**Impacts of Ecosystem and Ecological Variables on Field Bioaccumulation Measurements and TMFs**'. Robin Stewart will be a coauthor on several publications coming out of the workshop including a modeling scenario for several classes of organic contaminants.

Products:

Samuel N. Luoma, Theresa S. Presser **Emerging Opportunities in Management of Selenium Contamination.** *Environmental Science & Technology* **2009** *43* (22), 8483-8487

Stewart, A.R., and Luoma, S.N. in preparation. Trends in selenium concentrations in the invasive clam Corbula amurensis in the San Francisco Bay ecosystem.

A.R. Stewart, S.N. Luoma, and N.S. Fisher. Using invertebrate base MeHg concentrations, trophic enrichment and food chain length to predict top predator MeHg concentrations across diverse systems.

Task 6

ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS: Benthic grazing projections based on available data and model parameters have been done for 1992, 1999, 2002. These data will be used in the hydrodynamic/phytoplankton validation and calibration runs. We continue to refine our model parameters in preparation for final runs with the phytoplankton model.

Thompson gave invited presentations that incorporated much of what we have learned in this study: (1) American Association for the Advancement of Science Fall Meeting in August on our present state of knowledge on the benthic community in the system and its affect on the ecosystem. (2) State of the Estuary on trends in bivalves in the system. Thompson also has been taking part in two ongoing workshops looking at critical issues in the estuary in which the benthic bivalves are known to play an important part: (1) The National Center for Ecological Analysis and Synthesis Working Group on "Interactions between the near-coastal ocean and the San Francisco Estuary" and (2) : Interagency Ecological Program: Pelagic Organism Decline Team and Habitat Study Group for Delta Smelt

DELIVERABLES PRODUCED:
Thompson, J. and F. Parchaso. In revision. *Corbula amurensis:* A Conceptual Model

Task 7

ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS:

Rivers: We completed the journal article documenting the effect of hydrologic infrastructure on flow regimes of Central Valley rivers (publication listed below). We collaborated with Dr. Mark Gard (USFWS) to calculate weighted usable area for various life stages of salmonids in the Sacramento River and Yuba River based on Gard's 2-dimensional instream flow models and daily flows. We completed compilation of monthly flow data from the projections and obtained available historical data to provide a baseline for comparison in the Sacramento and American Rivers. We have identified several manuscripts that will interpret the possible effects of the climate change scenarios on selected river fish populations.

Delta: We collaborated with Fred Feyrer (USBR) to calculate delta smelt habitat area based on X2 position. X2 position was generated by Dr. Janet Thompson from projected daily flow data. We obtained final temperature data from Wayne Wagner for delta temperature stations. In addition to daily temperatures we compiled values for number of days available for spawning, median date of the spawning period, number of days stressful for delta smelt, and number of days lethal for delta smelt. We calculated number and frequency of flood events in Yolo Bypass and calculated production of Sacramento splittail based on relationships available in the literature. These results will provide the basis for several manuscripts that will interpret the possible effects of the climate change scenarios on selected delta fish populations.

PROBLEMS OR DELAYS ENCOUNTERED: None.

DELIVERABLES PRODUCED:

Brown, L.R. and M.L. Bauer. 2009. Effects of hydrologic infrastructure on flow regimes of California's Central Valley rivers: Implications for fish populations. River Research and Applications: 10.1002/rra.1293

Task 8

Meetings of the CASCaDE principal investigators were held April 23-24 and August 5, 2009. Both meetings were organized to plan a final synthesis product from CASCaDE, a scorecard to depict changes in a suite of environmental indicators as responses to global change through the 21st century. Purpose of the April meeting was to discuss and rank a series of proposed indicators and then make group decision on which to develop in a final synthesis paper. We invited outside experts to give advice/guidance during this meeting, including Cliff Dahm (CALFED Lead Scientist), Anke Mueller-Solger (IEP Lead Scientist), Chris Enright (CA Department of Water Resources), and William Bennett (Bodega Bay Marine Lab, UC Davis). The August meeting was used to present/discuss progress in development of the environmental indicators which emerged from the April meeting. Agendas for both meetings follow:

CASCaDE PI Meeting – 23&24 April 2009
USGS-Menlo Park, Bldg. 3 Room C
Theme: Indicators, Indices, Thresholds

April 23

10:30 Start

- Introductions; note-taker Caitrin Phillips
- Purpose and goals of this meeting
- What is an ecological indicator? An environmental indicator? (see below)
- Opening comments from invited advisors
- Comments from Dave Marmorek (see below)
- Comments from Sam Luoma (see below)
- Begin presentations on proposed Cascade indices/indicators

12:30 Lunch on site
1:30 Continue presentations on proposed indices/indicators
3:00 Nancy Monsen Delta TRIM calibration/verification/simulations
4:00 Break
4:30 Continue presentations on proposed Cascade indices/indicators
6:00 End
7:00 Dinner at Straits Café, 3295 El Camino Real, Palo Alto, 4 miles S. of Red Cottage Inn

April 24

9:00 Continue presentations on proposed Cascade indices/indicators (Robin Stewart here)
12:00 Lunch on site
1:00 Reconvene

- Conclude presentations on proposed Cascade indices/indicators
- Group discussion: which indices to develop and apply; how will the indices be expressed or measured? Which will be developed in separate papers? How can we develop a synthetic interpretation? timeline for a final report; potential outlets; partnerships/linkages – e.g. Bay Delta monitoring report card, California Climate Action Team's 2nd Biennial Report, EPA Report on Environmental Indicators of response to climate change
- Closing comments from invited advisors
- Group discussion for Cascaders:

- The last 5 months and conclusion CascadeI
- Products in development and products that will be developed post Cascade
- Future PI meetings
- Mick's suggestion of a session for 2010 Ocean Sciences Meeting "From Observation to Prediction in the 21st Century", February 22-26, 2010 in Portland Oregon

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CASCaDE PI Meeting – Teleconference 5 August 2009 9:30 Start
Purpose: Progress Reports on Environmental Indicators

Guest: Ariel Rubissow-Okamoto, Science Writer

Cloern – goals/objectives/review (strawman)

Dettinger -- Panels showing the change within scenarios for temp, wind, precip, long wave, etc

Cayan - water levels, perhaps near golden gate and at a location(s) in Delta (Sea Level Rise)

Knowles: -- (1) fraction of annual runoff as snow storage (timing of annual flow); (2) Sac vs SJQ Delta inflows (3) Extreme events (drought, flood)

Tara Morgan -- Turbidity < 18NTU (relates to Delta smelt and striped bass)

Brown – (1) Winter-run salmon egg incubation temperature (# years with temperatures greater than temperature threshold); (2) Yolo Bypass flooding and temp (Flooding of ~30 days is a good Splittail indicator, with temp thresholds); (3) Delta temperatures (# of days in the spring months that temp is above temp threshold. When it goes above and stays, Julian Day)

Ted Sommer – Habitat quality for delta smelt

Thompson/ Lucas -- Grazing control (quantify a pelagic vs benthic dominated water column, apply data points (red, yellow, green) on a map of delta)

Cloern -- Annual abundance of marine fish, crabs, shrimp in SFBay

Group Discussion -- approaches for presenting a synthesis of results and plans toward publication (revisit strawman)