Computational Assessments of Scenarios of Change in the Delta Ecosystem

CALFED Science Program Project SCI-05-C01-84
Semiannual Project Report
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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 (Current Fiscal Year)	Amount Invoiced to Date (All Years)	Projected Expenditures next 6 months
1	100.00%	$411.95	$151,827.79	$0.00
2	87.91%	$33,005.50	$441,505.85	$408,500.35
3	99.77%	$10,242.40	$236,574.80	$226,332.40
4	78.99%	$0.00	$253,307.00	$67,362.00
5	100.00%	$44,417.30	79633.54	$0.00
6	17.06%	$6,230.58	$12,706.08	$6,475.50
7	54.14%	$0.00	$137,098.00	$116,122.00
8	72.89%	$21,822.70	$31,814.70	$9,992.00
		$116,130.43	$1,344,467.76	$834,784.25

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. Some subregions of the data have been extracted and made available in this quarter. Development of downscaled values of other nonstandard variables is ongoing.

Task 2

After consulting with groundwater experts at the San Diego WSC, it was concluded that the groundwater withdrawals in the Sacramento basin simulated by CALSIM in the climate change runs (menioned in the previous report) are not unrealistic; in fact they are likely. Therefore they will not be adjusted out.

Daily flow data for all Delta quantities and for several upstream locations are now delivered, though future refinements are not ruled out. The algorithm used to produce these data by disaggregating the corresponding monthly CALSIM outputs was refined multiple times before releasing the final data.

Final datasets characterizing sea level rise inundation risks around San Francisco Bay are complete and will soon be available for download through the project website: http://cascade.wr.usgs.gov. An associated manuscript is in the final stages of review and is listed below.

Other products:

- A presentation titled " Projected Hydrologic Changes and Management Challenges Under CASCaDE Climate Change Scenarios" was delivered at the 2008 CALFED Science Conference and also at the 2009 Climate Change, Natural Resources and Coastal Management workshop in San Francisco, sponsored by USGS and USFW.
- The following paper will soon be published:
  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.

Task 3

Hydrodynamics

- We are curently running a series of simulations for the 2001/2002, 1992, and 1999 period. We are comparing these results with measured stage, flow, and salinity values throughout the Delta. The goal is to produce a peer reviewed journal article to discuss the strengths and weaknesses of the Delta TRIM model calibration.

- We are developing tools within Microsoft Access and Arc GIS to better visualize bathymetry grid information, station locations, interpolate salinity intial conditions and model output (such as drogue release simulations).

- Monsen presented a talk entitled: ”How do we apply what we learn from hydrodynamic models to ecosystem questions?” at the CALFED Science Conference. We concluded in this drogue study that conditions inseide Suisun Bay have the potential to influecne habitats upstream such as the western Delta. This is a piece of the puzzle to support the hypothesis that clams in Suisun Bay may cause a reductions of Chl a in the western Delta.

- Monsen has been in several meetings with other hydrodynamic modelers to explore future hydrodynamic modeling efforts that should occur for the Delta region. This meetings included a meeting at UC/Davis hosted by Bill Fleenor in early August with all the multi-dimensional modelers in attendance. Three meetings at Stanford University with professors Stephen Monismith, Oliver Fringer, and Jeffery Kosseff to discuss protential collaboration to extend SUNTANS into the Delta. There is an upcoming meeting at the end of March hosted by Steve Culberson at the CALFED Science Program.

- Monsen coordinated several meetings and discussions to develop a CASCaDE II proposal for the current RFP. That effort is on hold until a deadline is announced by the CALFED Science program.

Phytoplankton

A manuscript by Lucas, Thompson, and Brown entitled “Why are diverse relationships observed between phytoplankton biomass and transport time?” has been published as a review article in the journal *Limnology and Oceanography* (free download at http://www.aslo.org/lo/toc/vol_54/issue_1/0381.pdf). This paper describes a simple mathematical and graphical conceptual model which explains the range of phytoplankton-transport time relationships observed in nature The concepts in this manuscript are highly relevant to the Delta and to possible future changes to that ecosystem due to climate change or anthropogenic structural manipulations, in that the conceptual model presented lays out very simply how phytoplankton biomass should respond to changes in transport time scales (e.g. residence time) given particular estimated growth and loss terms. This paper calls attention to the common misconceptions that 1) longer transport times (e.g. residence times) result in more phytoplankton biomass and production, and 2) residence time may therefore be taken as a “surrogate” for phytoplankton biomass. The commonly expected positive relationship between transport time and phytoplankton biomass (phytoplankton increases as transport time increases) is frequently observed in nature, but so too are negative and non-relationships. If local algal losses (e.g. due to benthic and/or pelagic grazing) are faster than algal growth, then phytoplankton biomass will *decrease* with increased residence time. Therefore, if we slow down transport and thereby increase residence time, we cannot count on increased phytoplankton biomass and fuel at the based of the pelagic food web, especially if major grazers are present.

Development of the coupled Delta phytoplankton-hydrodynamic model continues. Lucas has explored and detailed a new, more reliable and computationally efficient way of calculating phytoplankton growth within the model, based in part on previous CALFED funded research (Jassby et al. 2002). She is working closely with Monsen on model re-calibration and re-validation. Lucas has worked with a GIS specialist to create interpolated grids of benthic grazing rate based on Thompson’s previous CALFED funded 2001-2003 field measurements to be used in the phytoplankton model for historical runs.

Also:

- Lucas is serving as "Community Mentor" for CALFED Postdoctoral Fellow Cecile Mioni, University of California, Santa Cruz, (May 2008 to present)
- Lucas presented a talk entitled "Assessing San Francisco Bay-Delta Phytoplankton and Clams for CASCaDE Scenarios of Change" at the CALFED Science Conference (Sacramento, October 2008)
- Lucas has submitted an invited chapter for a textbook on estuarine hydrodynamics and transport entitled "Contemporary Issues in Estuarine Physics" to be published by Cambridge University Press and edited by Prof. Arnoldo Valle-Levinson. Her chapter is entitled "Implications of Estuarine Transport for Water Quality" and highlights several examples of CALFED funded research in the Delta.
- Lucas participated in the 2-day "Delta Ecological Flows Tool (DELTA-EFT) Development Workshop" organized by The Nature Conservancy and ESSA Technologies Ltd. As a workshop participant, Lucas advised TNC and ESSA on Delta ecological processes and possible ways to simplify and parameterize them for potential use in the CALFED-funded DELTA-EFT decision support tool. She also initiated a discussion with ESSA of possible linkages between CASCaDE and DELTA-EFT. (Rancho Cordova, January 2009)

Water Temperature

The emphasis in the past 6 months for us has been on communicating the results of our temperature modeling activity, and analyzing the implications of our long-term temperature projections. Additional analysis has been explored to illuminate the spatial variability in Delta temperature dynamics, potentially including the effects of Sacramento and San Joaquin flow variability.

Communication of Results

During the last 6 months, while pursuing a couple of new analyses (outlined below), we have really focused on communicating the results of our modeling analysis. First, at the Calfed conference in October, Wayne Wagner presented our analysis during the Cascade special session (presentation available at http://cascade.wr.usgs.gov). In the months following, we have begun work on a manuscript that describes the model development and application to long-term projections, as well as incorporating the more recent analyses described in this report. We intend to submit this manuscript to San Francisco Estuary and Watershed Science in the coming months.

Analysis of Implications of Water Temperature Projections

Using our long-term projections for Delta water temperature, we have started to analyze the exceedence of specific temperature thresholds. We have focused on the 25 degree Celsius threshold that represents the limit for Delta Smelt survival. Not surprisingly, under climate warming scenarios, the exceedence of this threshold increases significantly, particularly for the more extreme scenarios (see slides 21 and 28 in Calfed presentation attached to this report). Interestingly, however, there are spatial differences in the changes to the threshold exceedence (slides 24 and 31 in report at link given above). In the south Delta, the number of exceedences does not increase significantly under warming scenarios, due to frequent threshold exceedences under today's conditions. Along the Sacramento Corridor, however, the frequency of exceedence increases several-fold under more warming scenarios, with important implications for Delta Smelt survival.

Spatial Analysis of Historical Water Temperature Data

The statistical model of temperature dynamics in the Delta has not been altered, but we have returned to the temperature data itself to explore the spatial structures in the observations. We have begun the process of applying empirical orthogonal function (EOF) analysis to the historical records of temperature. The first, and strongly dominant, EOF is the annual cycle of heating and cooling that affects the entire Delta. As we refine the analysis in the coming months, we hope that the remaining EOFs will provide with a quantified measure of how

other forcing, specifically flows and in-Delta operations, alter the temperature dynamics regionally within the Delta.

Task 4

ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS:
Presentations on the geomorphic modeling of San Pablo and Suisun Bays were made at the 2008 CALFED Science Conference CASCaDE special session. A statistical model of Delta turbidity that is based on suspended-sediment concentration in the Sacramento River at Freeport and in Suisun Bay at Mallard Island was outlined. A strategy to develop morphologic hydrographs from the daily scenario hydrographs was formulated. The morphologic hydrographs will be used in the final scenario simulations.

The hindcast of deposition characteristics of San Pablo Bay was quite successful and shows that a 3D model with best-guess model parameter settings leads to deposition volumes that are similar to measured volumes. Variation of the model parameter settings leads to comparable results. The hindcast of sediment allocation scores reasonable on the Brier Skill Score, which is a good result considering the complexity of the problem.

The hindcast of San Pablo Bay erosion between 1951 and 1983 appears very sensitive to the allocation and definition of the sediment fractions. Closer analysis of low and high river discharge conditions shows distinct erosion and deposition characteristics that compare qualitatively well with observations. Reasonable results were obtained by systematically varying the definitions of sediment fractions.

Model runs exploring the impact of sea level rise shows a surprising preliminary result, i.e. the maximum shear stresses in San Pablo Bay decrease under a 1 m higher sea level. A possible explanation is that the tidal prism is conveyed through a larger cross-section (due to larger water depths), which decreases tidal velocities. The fact that the tidal amplitude and prism somewhat increases (due to smaller friction effects) seems to have only a minor effect. This observation will have implications for future sediment transports and turbidity levels in the Bay and Delta, which will probably reduce due to sea level rise.

PROBLEMS OR DELAYS ENCOUNTERED: he research on San Pablo Bay is somewhat behind schedule to estimate SLR impacts.

DELIVERABLES PRODUCED:

- Presented and published: Jaffe, B.E., 2009, Geomorphic response of estuaries to sea level rise and climate change, Climate Change, Natural Resources, and Coastal Management: A Workshop on the Coastal Ecosystems of California, Oregon, and Washington, San Francisco, California, January 29-30, 2009.

- In press: van der Wegen, M., Jaffe, B.E., and Roelvink, D., accepted, Generation of initial bed composition for morphodynamic hindcasting of hydraulic mining deposits in San Pablo Bay, California, Intercoh '09 Conference.

- Published: Ganju, N.K., and Schoellhamer, D.H., 2009, Calibration of an estuarine sediment transport model to sediment fluxes as an intermediate step for simulation of geomorphic evolution: Continental Shelf Research, v. 29, no. 1, p. 148-158.

- Presented and published: Ganju, N.K., Schoellhamer, D.H., van der Wegen, M., and Jaffe, B.E., 2008, CASCaDE hindcast of bathymetric change in Suisun Bay, 1867-1990: model uncertainty and parameter selection: Proceedings of the 2008 CALFED Science Conference, Sacramento, California, October 22-24, 2008.

- Presented and published: Wegen, M.V., Roelvink, D., Jaffe, B., Ganju, N., and 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: Proceedings of the 2008 CALFED Science Conference, Sacramento, California, October 22-24, 2008.

- A journal article by Ganju, N.K., Schoellhamer, D.H., and Jaffe, B.E., entitled “Simulation of decadal-timescale estuarine bathymetric change with a tidal-timescale model: application to historical change and future scenarios” is in review with the Journal of Geophysical Research-Earth Surface.

Task 5

Since the last semiannual report we have presented results at the Calfed Science meeting in October 2008, "Modeling selenium and mercury in food webs of the San Francisco Estuary in response to CASCaDE scenarios of change". In this presentation we highlighted a significant finding that has limited our understanding of factors driving seasonal and interannual changes in Se concentrations in biomonitoring species (i.e. Corbula amurensis). We illustrated that mass-specific filtration rates can lead to significant differences in apparent Se concentrations in bivalves (<30%). If you correct for the influence of size patterns in time and space can be detected. For example, after correcting Se concentrations in clams for subtle differences in size among years (1995-2004) a 25% reduction in Se concentrations of refinery effluents was apparent, where before it was not. This finding for Se accumulation in this bivalve has not be explained before and does not appear to be relevant for other trace metals. Sam Luoma and Robin Stewart also attended a Se workshop hosted by the Society of Toxicology and Chemistry in Pensacola, Florida where the state of the science of Se was discussed and book synthesizing major findings was written. Sam Luoma was on the Steering Committee for the workshop and Robin Stewart chaired the work group writing the Chapter - Bioaccumulation and trophic transfer. This book highlights the modeling work described in the last semiannual report and the work presented in the fall at the Calfed Science conference. Further, Sam Luoma (edited) and Robin Stewart contributed to the Water Quality chapter of Calfed's State of the Science Report 2008 and highlight their work on Se and mercury modeling.

Task 6

ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS: Parameters for models are being further refined as we find better approximations on some rates. We have projected the X2 values for the 4 scenarios and find that based on monthly averages the salinity standard used today will become more difficult to achieve for all of the climate scenarios. We also see that *Corbula* will invade well upstream of the confluence for all scenarios but is likely to have a major presence in the western Delta for the warmer scenarios. Daily watershed

projections which are currently being produced will allow us to further refine the initial conditions for clam distributions for our models.

We have developed two DRERIP conceptual models as part of our model building in CASCaDE, one on the life history and ecology of *Corbula amurensis* and another on the same for *Corbicula fluminea.* Both models are in review in CALFED. We have already used these models in a CALFED workshop ("Linking Physical and Biological Models for Ecosystem Prediction, Planning, and Performance"). More recently Thompson has been taking part in the BCDC workshop on proposed actions in the Delta (January 14-15, and continuing). That group is evaluating various suggested actions (flooding Yolo bypass etc) actions based on conceptual models of the important processes in the ecosystem. We have been asked to evaluate how the two bivalves will respond to changes and how changes in their distribution could affect the ecosystem processes.

Thompson gave an invited plenary talk at the "Climate change, natural resources and coastal management" meeting in the Adapting Our Management and Decision Making Session in San Francisco January 29-30. The title of the talk was "CASCaDE A Decision Tool for Examining the Effect of Climate Change on the San Francisco Delta Ecosystem".
Thompson gave a talk to the IEP Estuarine Ecology Meeting in January 2009 on "What drives the spatial and temporal variability in *Corbula amurensis*: can we limit its distribution?"

PROBLEMS OR DELAYS ENCOUNTERED: None.

DELIVERABLES PRODUCED:

Thompson, J. and F. Parchaso, 2008. "*Corbula amurensis* Distribution and biomass Response to Hydrology and Food: A Model for CASCaDE Scenarios of Change" Abstract and Poster presented at CALFED 2008 Science Conference and available on the CASCADE Public Website:
http://cascade.wr.usgs.gov/presentations/20081024calfed/Poster1_Task6_JanThompson.pdf

Parchaso, F. and J. Thompson. 2008. "*Corbicula fluminea* Distribution and biomass Response to Hydrology and Food: A Model for CASCaDE Scenarios of Change" Abstract and Poster present at CALFED 2008 Science Conference and available on the CASCADE Public Website:
http://cascade.wr.usgs.gov/presentations/20081024calfed/Poster2_Task6_JanThompson.pdf

Lucas, L.V., JK Thompson, LR Brown. 2009. Why are diverse relationships observed between phytoplankton biomass and transport time? Limnol Oceanogr. 54(1): 381-390.

Task 7

ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS: We continued to summarize existing information on the environmental tolerances of our fish species of interest. This information will feed directly into the species life cycle models. We have also begun analysis of daily stream flows and temperature data produced by the other tasks. We have identified several manuscripts that will interpret the possible effects of the climate change scenarios on selected fish populations. We completed a manuscript based on analyses of flow before and after construction of the major hydrologic infrastructure in the watershed. The manuscript is presently being reviewed within USGS and we expect to submit it within several weeks.

PROBLEMS OR DELAYS ENCOUNTERED: None.

DELIVERABLES PRODUCED:
Larry Brown delivered a presentation co-authored by Christa Woodley, and Bill Bennett at the 2008 CALFED Science Conference, "Increased water temperatures from CASCaDE climate-change scenarios: implications for California fishes."
Larry Brown delivered a seminar presentation to Ecology and Environmental Issues class, California State University, Sacramento, California, "Assessing the possible effects of climate change on fish populations of Central Valley rivers and the San Francisco Estuary." November 5, 2008.

Larry Brown delivered a presentation co-authored by Bill Bennett at Climate Change, Natural Resources, and Coastal Management, A Workshop on the Coastal Ecosystems of California, Oregon, and Washington, San Francisco, California, "Increased water temperatures from CASCaDE climate-change scenarios: implications for selected California fishes." January 29-30, 2009.

Task 8

Presentations from recent meetings by CASCaDE team members are available through the project website: http://cascade.wr.usgs.gov. A meeting of the CASCaDE principal investigators was held in October 2008 to practice talks for a special CASCaDE session at the 2008 CALFED Science Conference and to present investigator plans for 2009 activities. A second meeting was held in February 2009 to plan a synthesis article that encapsulates model-based results into a series of indicators to depict how the Bay-Delta-watershed system will respond to scenarios of climate change through the 21st century. Agendas for both meetings follow:

CASCADE PI Meeting – Menlo Park, Bldg 15 Room 3255 – October 20, 2008
Purpose: practice/coordinate/discuss talks for Calfed Science Conference
AND meet new PES Coordinator

Load talks on Nancy's laptop 10:30-11:00

The CASCaDE Project—Overview and Climate-change Scenarios Michael D. Dettinger, USGS	11:00-11:30
Sea Level Change in San Francisco Bay during the 21st Century: The CASCaDE Study Daniel R. Cayan, Scripps Institution of Oceanography	
Projected Hydrologic Changes and Management Challenges Under CASCaDE Climate Change Scenarios Noah Knowles, USGS	11:30-12:00
How Do Transport Timescales in the Delta Change under the CASCaDE Climate Scenarios? Nancy E. Monsen, USGS	12:00-12:30
Statistical Models of Temperature and Salinity in the Sacramento-San Joaquin Delta under Climate-Change Scenarios: A CASCaDE Project Wayne Wagner*, UC Berkeley	1:30-2:00
CASCaDE Hindcast of Bathymetric Change in Suisun Bay, 1867-1990: Model Uncertainty and Parameter Selection David H. Schoellhamer, USGS	2:30-3:00
CASCaDE Research on Hindcasting Bathymetric Change in San Pablo Bay, 1856-1983: A Step towards Assessing Likely Geomorphic Change in Response to Climate Change Mick V.D. Wegen, UNESCO-IHE	3:00-3:30
	BREAK
Assessing San Francisco Bay-Delta Phytoplankton and Clams for CASCaDE Scenarios of Change Lisa V. Lucas, USGS	4:00-4:30
Modeling Selenium and Mercury in Food Webs of the San Francisco Estuary in Response to CASCaDE Scenarios of Change Andrea R. Stewart, USGS	4:30-5:00
Increased Water Temperatures from CASCaDE Climate-change Scenarios: Implications for California Fishes Larry R. Brown, USGS	5:00-5:30

CASCADE PI Meeting – Menlo Park, Bldg 15 Room 3255 – October 21, 2008
Purpose: describe 2009 tasks, products, timelines for each element

9:00	Dettinger & Cayan
9:30	Knowles
9:50	Monsen
10:10	Wagner/Stacey – discuss their writeup
10:30	Jaffe
10:50	Schoellhamer
11:10	Lucas
11:30	Stewart
11:50	Thompson
12:10	Brown
12:30	Open Discussion
1:00	adjourn, lunch, head for Sacramento

CASCaDE PI Meeting – Teleconference – 9 February 2009 – 09:30 start
Theme: Indicators, Indices, Thresholds (pick a word)

"Average temperatures never kill fish"
"people are interested in what is going to happen in extreme events"
Mike Healey, Cascade PI Meeting, Ryde Hotel, 17 September 2007

As a starting place, I suggest that we consider simple metrics to capture changes across three general areas of concern. I've entered a few suggestions for each, but am confident you all will be much more creative in your thinking. Implicit in these metrics is the assumption of today's Delta configuration – a starting place for examining how changes in Delta configuration will interact with changes depicted below from Cascade I:

Risks to Human Health and Infrastructure

- Heat waves (remember the remarkable number of deaths across western Europe in 2003)
- Air quality – can we compute frequency of spare-the-air days as an index of changing air quality?
- Extreme floods
- Extreme tides
- Areal extent of inundation

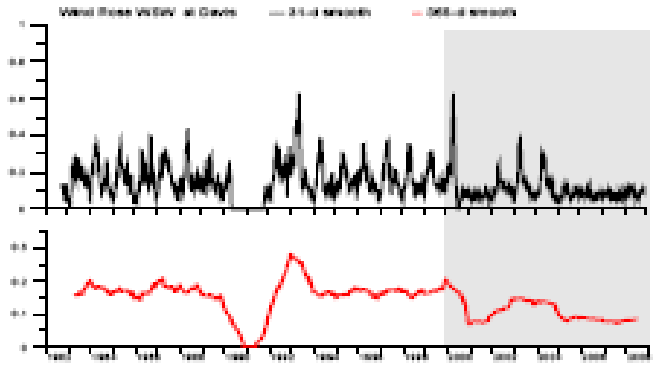
Water Quantity and Quality

- Snowpack quantity; date of peak snowmelt
- Drought indices (duration, magnitude, …)
- Ratios of water source, such as GW:SW in Delta Inflow (as I gather from Noah's talks, we will rely more and more on ground water to meet water demands; this will affect water quality in the Delta); ratio of San Joaquin:Sacramento inflows to the Delta (or, including sources from the Bay or Delta ag drainage)
- Translations of these ratios into indices of Se or Hg contamination or DOC in drinking water supplies
- Within-Delta salinity and implications for drinking water quality
- Index of cyanobacterial bloom potential (as a function of air temperature and wind speed, following recent paper by Paerl and Huisman)
- Indices of the human footprint on Delta Inflow and its routing (e.g ratio unimpaired runoff:Delta inflow; flow through Middle River)
- Total annual reservoir inflow, and relative contributions from Sacramento and San Joaquin watersheds

Habitat Quality

- Residence time of the central-Delta water mass
- X2 and the challenge of meeting the current standard
- Yolo Bypass flooding (timing, duration)

- Sediment supply to the Delta and then to the Bay
- Turbidity in the Delta
- Habitat area for submerged plants (*Egeria*)
- Hypsograph of the Bay
- Habitat area for *Corbula* and *Corbicula*
- Habitat area for fish species of concern: delta smelt (following the habitat indice of Feyrer et al., based on temperature, salinity, turbidity), salmonids, sturgeon, and invasives (blue gills, lm bass)
- Degree days for air and water temperature of the Delta
- Physiological indices for fish species of concern
- Wind speed and direction across the Delta (CIMIS data from Davis suggest there might have been a shift in wind direction around the time of the latest POD. Is this real, and could it be important?)



- Maximum annual air and water temperature
- Temperature thresholds for fish, both in rivers and the Delta (would we dare compute a probability of extinction [or sustainability] based on water temperature?)
- Primary production, computed from solar radiation, turbidity, and projections of phytoplankton biomass
- Indices of 'memory effects' (a la Dan Cayan)