Proposal submission for the CALFED 2007 Supplemental PSP

Name of PI: James Cloern
Agency: U.S. Geological Survey

Title of Supplemental Proposal: CASCaDE: Computational Assessments of Scenarios of Change for the Delta Ecosystem

Funding Amount Requested: $ 166,117

Original Proposal Title: CASCaDE: Computational Assessments of Scenarios of Change for the Delta Ecosystem

Year of Original Proposal Submission: 2006

Project Purpose: To further develop an empirical relationship between freshwater outflows, the proportion of San Joaquin River flow into the estuary, the stable carbon isotopic composition of the clams (as a surrogate for relative freshwater/estuarine water sources) and Selenium (Se) concentrations in clams. Funds requested will allow for the analysis of archived *Corbula amurensis* samples for Se and stable isotopes collected monthly from January 2003 through December 2007. This is a crucial extension of a data set that we recently discovered ties San Joaquin inflows to increased Se concentrations in *Corbula*. The validity of our modeling will be greatly enhanced by adding such data.

Background and Conceptual Models:
Since 1995 Se concentrations in *C. amurensis* have been monitored in Carquinez Strait near Suisun Bay in order to track trends in Se concentrations in the estuary. Selenium concentrations in clams have been used to better understand spatial and temporal patterns in Se concentrations in the estuary and the processes that control them ((Linville *et al.* 2002) and the clams themselves have been shown to be important vectors of Se to higher trophic levels and species of concern in the estuary including White sturgeon(Stewart *et al.* 2004). By analogy, Green sturgeon which are listed as an endangered species are probably similarly threatened.

Previous studies have pointed to two primary sources of Se to the estuary and food web (aqueous Se → phytoplankton → clams) including oil refineries and the San Joaquin River, which drains agricultural lands from the Central Valley contaminated with naturally occurring Se (Meseck and Cutter 2006). The challenge has been to link changing Se concentrations in clams over time to changes in source inputs from both refineries and the San Joaquin River. In 1999, oil refineries made significant changes to waste water treatment resulting in a 60% reduction in selenite concentrations (Cutter and Cutter 2004). At approximately the same time changes in water management resulted in an increase in the load of San Joaquin River water entering the estuary (Cutter and Cutter 2004). Selenium concentrations in the clams show a fairly consistent trend of increasing concentrations of Se in the fall/winter and declines in the spring before and after the management change in 1999. Since monitoring began in 1995 there have been measurable differences in Se in clams among years, although the maximum concentrations typically stay within16-20 µg/g. It is not clear what processes are driving those interannual changes, but changes in delta outflow, including source inputs from the San Joaquin River, are likely important. These seasonal changes were not evident in data from the 1980's (*Corbicula fluminea*); suggesting physical inputs to the Bay have changed since that drought period. Climate change could result in similar differences in physical processes.

Summary of progress to date and need for funding:
Explanation of request:
In anticipation of receiving output from climate/hydrologic/geomorphology models based on defined scenarios we have been refining contaminant models for Se and mercury (Hg) (Figure 1). The Se modeling work completed to date has focused on existing biodynamic parameters characterizing uptake of Se into the clams for dissolved Se inputs from both refinery and riverine sources (Luoma and Presser 2000). We are presently working with

USEPA to refine the bioaccumulation model to predict the water values they will use in regulating Se inputs to the Bay; and we are working with the Regional Water Quality Control Board and USEPA on the Se TMDL to determine what role the Central Valley plays in Se contamination in the Bay. Climate change will affect the concentration parameter in the models if it modifies the proportion of San Joaquin inputs to the Bay. Clam Se and clam stable isotope data are a critical, heretofore unavailable, parameters in tying SJR inputs from the Central Valley to Se bioaccumulation. Additional verification of the recent breakthrough in making the tie between SJR inputs and elevated Se concentrations could greatly enhance the credibility of the Se modeling effort and would be very valuable to both the regulatory agencies and the climate change forecasts.

Our emphasis for the Hg models has been to identify and bound ranges of responses in Hg accumulation by food webs to 1) environmentally realistic ranges in aqueous MeHg concentrations, 2) potential ranges in trophic transfer efficiencies, and; 3) potential ranges in growth efficiency. The additional technician time will allow for greater emphasis on these complex calculations.

Justification: We have also been conducting a more rigorous evaluation of existing data for *C. amurensis* in the estuary and *Corbicula fluminea* in the delta collected as part of several Calfed-funded studies from 1999 through 2003 to better understand relationships among clam biology (growth, condition, stable isotopes of carbon and nitrogen), clam Se concentrations, water flow (proportion of San Joaquin River outflow) and phytoplankton population dynamics (quantity and source of ancestral population). An important concept developed earlier is that the clams integrate the temporally and spatially complex carbon and nitrogen isotope signatures, reducing variability to levels that are interpretable in time and space. As part of the development of a manuscript Dr. Stewart has been evaluating the relationship between freshwater flow into the estuary and seasonal shifts in the stable isotopic composition of *C. amurensis*. We recently found that changes in the clam's carbon isotopic signature appears to be related to the timing and proportion of the ratio of San Joaquin to Sacramento River inflow into the estuary (a result supported by earlier work on spatial trends in isotopes in the estuary (Canuel *et al.* 1995; Spiker and Schemel 1979)). Greater San Joaquin River inflow is associated with increasing concentrations of Se in the clams (Figure 2). This pattern is evident for the months of June through February for multiple years (1999-2000, 2000-2001, 2001-2002, and 2002-2003) (Figure 3). There is some uncertainty about whether the onset and magnitude of freshwater flows or the proportion of San Joaquin River outflow are important mechanisms driving the seasonal increases in Se or if they are just coincident. More monthly data of clam stable isotopes and Se are needed to understand this critical relationship.

Potential exists also for using the stable isotope composition of clams to validate numerical models of coupled hydrodynamics and phytoplankton dynamics. Dr. Lucas and Dr. Stewart are exploring the usefulness of such a stable isotope based tool in conjunction with the CASCaDE project. Dr. Lucas plans to use the coupled physical-biological model to understand not only quantities and distribution of phytoplankton biomass in the Delta and northern Bay but also the mixtures of water and phytoplankton source populations. The primary water sources of the Delta (Sacramento River, San Joaquin River and Estuary) have distinct carbon and nitrogen isotopic signatures associated with dissolved inorganic carbon and nutrients, respectively, utilized by phytoplankton. Depending on the proportion of the different water and phytoplankton sources and rates of phytoplankton population turnover, phytoplankton and the clams that consume the phytoplankton will have a unique carbon and nitrogen isotopic composition reflecting the water source. The relationship between unique isotopic end-member signatures for the water sources, concentrations of phytoplankton biomass in source waters, and the primary consumer of phytoplankton (clams) may provide a novel tool for validating numerical models of phytoplankton and transport. Preliminary results from these investigations were presented by Dr. Lucas at the Estuarine Research Federation's biannual meeting in November 2007 (abstract attached). We expect the work proposed herein to support the current and future development of numerical models and the exploration of novel validation tools for evaluating models' characterization of the influence of differential river inflows on bioavailable carbon sources.

Approach and scope of new work:

We request additional funds to complete archived analyses of stable isotopes and Se in *C. amurensis* in order to extend the dataset to years with greater variability in freshwater flow (2003-2007 were considered wetter than years 1999-2002) and link trends in Se in clams to changes in freshwater flows. We propose to analyze frozen samples of *C. amurensis* collected on monthly R.V. Polaris cruises from January 2003 through January 2008 at stations 8.1 (Suisun Bay @ Carquinez Strait), 415 (Suisun Bay @ Montezuma Slough) and 4.1 (Honker Bay) for stable isotopes of carbon and nitrogen and Se concentrations. Clam samples are composed of 2-3 composites of 10-20 individual clams per site/per month for a maximum of 540 samples at a cost of $50,320 ($46,000 for Se; $4320 for stable isotopes). Methods for the collection, processing and analysis of stable isotopes (Stewart *et al.* 2004; Canuel *et al.* 1995) and Se (Linville *et al.* 2002) are well described.

Data generated from the above analyses will be combined with existing data to:
Evaluate relationships among clam stable isotope composition, Se concentrations and flows for the years 1999 through 2008 using a variety of statistical approaches including regression. Flow metrics including proportion of San Joaquin outflow (including barrier operations), will be provided by Dr. Monsen and salinity ranges by Dr. Knowles for the years in question. These are critical to validating the interpretation of the bivalve stable isotope ratios. We anticipate that both the slope and intercept of the relationship between carbon isotopes in the clams and Se will be important in understanding how the timing and proportion of Se-enriched San Joaquin River water entering the estuary influences the year to year variation in Se concentrations in the clams. These metrics as well as the raw data will also be used to validate model-predicted concentrations in clams based on variable flows from the San Joaquin River (see Explanation of Request). In collaboration with CASCaDE colleagues we will examine how different changes in flows (climate verses management induced change) influence the ranges in clam Se concentrations.

Analytical results will be completed by September 2008 and preliminary statistical evaluations will be completed by December 2008. We expect further refinements of the relationships as new results emerge from other components of the CASCaDE project.

Relevance to the CALFED Science program:

The new work proposed is highly relevant to our existing CALFED project (CASCaDE) and other CALFED work evaluating water conveyance options for the Delta. The new work will provide an opportunity to complete a dataset necessary to evaluate critical responses in a keystone species to changing flows in response to either climate change or water management. There are virtually no data or research evaluating how changes in San Joaquin River flow will affect the Estuary. Transcripts from expert panels convened by Calfed via workshops (August 22, 2007; September 11, 2007), as well as recent papers (Monsen *et al.* 2007) highlighted a number of potential changes associated with water quality (salinity, dissolved oxygen, contaminants) and habitat structure and function (algal blooms, carbon sources) that may result from infrastructure changes that could change San Joaquin River flow relative to Sacramento flow. Climate change could have similar effects. Both would have consequences for drinking water and species of concern. These issues are further explained in Calfed's State of Science Report on Water Quality (Luoma *et al.* 2008). The proposed work has a high likelihood of success and relevance due to 1) we have existing data and knowledge of Se processes in the estuary and Delta, 2) we will work closely with CASCaDE colleagues who are experts on climate and physical transport processes to ensure accurate estimates and characterization of freshwater flows, 3) stable isotope data in clams tell us not only about Se bioaccumulation, but also source of food (phytoplankton) consumed by an important consumer in the estuarine food web *C. amurensis*, 4) the clam samples are available for analysis but the funding has not been available to do the considerable work involved preparation and analysis; and 5) potential use in physical/phytoplankton model validation.

New project staff and qualifications:

Technician time is essential to do the sample preparation and data reduction. That has been the bottle neck to expanding this data set, in additions to funds to complete the analyses.

Budget and justification:

The total cost of this portion of the new work is $166,117 (57% overhead = $60,309.82). These costs include hiring a GS7 technician full-time (with 30% benefits) for 1 year to process samples for Se and stable isotope analyses, incorporate results into database and assist with statistical analyses. Selenium analyses will cost $85 per sample and will be completed by the USGS laboratory in Atlanta, Georgia who have analyzed all clam Se samples since 1995. Stable isotope samples will cost $8 per sample (provides both $\delta^{13}C$ and $\delta^{15}N$ and molar C:N values) and will be performed by the UC Davis Stable isotope facility who have analyzed all stable isotope clam samples since 1999.

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CASCaDE: Computational Assessments of Scenarios of Change for the Delta Ecosystem

Project ID: SCI-05-C84

Project starts 3 months into federal fiscal year.
fiscal year #1 (January 2006 - September 2006): 9 project months
fiscal year #2 (October 2006 - September 2007): 12 project months
fiscal year #3 (October 2007 - September 2008): 12 project months
fiscal year #4 (October 2008 - December 2008): 3 project months

	Federal Fiscal Year									
Task #	**1**	**2**	**3**	**4**	**Totals**	**Supplement**	**Task**	**Total Budget**		
1	$64,567	$86,090	$86,090	$21,522	**$258,270**		**1**	$258,270		Climate Modeling
2	$86,427	$115,235	$115,235	$28,809	**$345,706**		**2**	$345,706		Watershed-Estuary Modeling
3	$58,104	$77,472	$77,472	$19,368	**$232,417**		**3**	$232,417		Delta Modeling
4	$77,422	$103,230	$103,230	$25,807	**$309,689**		**4**	$309,689		Sediment, Geomorphology
5	$19,908	$26,545	$26,545	$6,636	**$79,634**	**$166,117**	**5**	**$245,750**		Fate and Effects of Se
6	$18,624	$24,832	$24,832	$6,208	**$74,497**		**6**	$74,497		Invasive Species
7	$32,448	$43,264	$135,835	$41,673	**$253,220**		**7**	$253,220		Native Fish
8	$27,360	$36,480	$36,480	$9,120	**$109,439**		**8**	$109,439		Admin
Totals	$384,861	$513,147	$605,718	$159,144	**$1,662,870**			**$1,662,870**		Amount Granted in PSP

CASCaDE Budget as Submitted to CALFED	**Task 1** Climate Modeling		**Task 2** Watershed-Estuary Modeling		**Task 3** Delta Modeling		**Task 4** Sediment, Geomorphology		**Task 5** Fate and Effects of Se		**Supplemental** **Task 5** Fate and Effects of Se		**Task 6** Invasive Species		**Task 7** Native Fish		**Task 8** Project Administration			
Labor																				
Number of USGS Salaries covered	3	Dettinger, Cayan, Peterson	3	Dettinger, Cayan, Peterson	2	Cloern, Lucas	1	Jaffe	1	Stewart			1	Thompson			1	Cloern		
USGS Salaries							$28,536	Schoellhamer							$50,682	Brown				
Postdocs already at USGS		Knowles (covered in Task 2)	$200,651	Knowles	$132,162	Monsen	$57,564	Ganju *confirm as PostDoc									$26,754.00	Knowles		
Positions to be hired	$103,871	PostDoc TBH				Postdoc Task 3- not covered here	$53,643	Post Doc TBH	$42,479	Post Doc TBH	GS7	42759	$16,261	Biologist 1	$50,585	Post Doc TBH				
	$36,747	Operations modeler											$15,204	Biologist 2						
Labor: Benefits																				
Number of USGS Benefits covered	3	Dettinger, Cayan, Peterson	3	Dettinger, Cayan, Peterson	2	Cloern, Lucas	1	Jaffe	1	Stewart										
USGS Salaries							$7,134	Schoellhamer							$11,114	Brown				
Postdocs already at USGS		Knowles (covered in Task 2)	$44,144	Knowles	$29,074	Monsen	$14,391	Ganju *confirm as PostDoc									$5,886.00	Knowles		
						Postdoc Task 3- not covered here	$11,801	Post Doc TBH	$12,743	Post Doc TBH										
Positions to be hired	$31,161	PostDoc TBH									GS7	12827.7	$6,969	Biologist 1	$11,129	Post Doc TBH				
	$11,024	Operations modeler											$6,516	Biologist 2						
Travel Expenses					$4,000	Presentations at Conferences	$6,000	Field work					$3,000	Travel to conferences	$4,450	Conferences	$12,000.00	Conferences		
					$2,000	Scientific illustrations	$6,360	Travel for Schoellhamer group									$12,000.00	Meetings w/ collaborators		
Equipment						PC to run DeltaTRIM model (PES)		PC to run ROMS model (PES)							$3,300	PC/Software				
							$3,600	Software												
Supplies and Expendables											Se analyses (540@$85/sample)	45900	$1,500	Misc supplies	$1,650	Misc supplies	$14,000.00	Illustrations, pub costs		
											SIA (540@$8/sample)	4320	$2,500	STELLA software						
Sum of Costs	$182,803		$244,795		$167,236		$189,029		$55,222			$105,806.70	$51,950		$132,910		$70,640.00			
PES Contribution (Temp/TERM)	$18,300		$24,600		$16,200		$13,800		$4,500				$4,500		$6,300	Under Jan T funds	$3,300.00		$91,500	**PES Contribution**
PES Contribution (Equipment)					$3,000		$6,000													
Sum of Costs (minus PES)	$164,503		$220,195		$148,036		$169,229		$50,722				$47,450		$126,610		$67,340			
Indirect Costs (Overhead)	$93,767	57%	$125,511	57%	$84,381	57%	$140,460	83%	$28,912	57%	57%	$60,309.82	$27,047	57%	$126,610	100%	$38,383.80	57%		
Savings in Overhead from PES	$10,436		$14,022		$14,356		$22,087		$2,566				$2,566		$6,300		$1,881		$74,215	**Savings in overhead (b/c of PES)**
																			GRAND TOTAL	
Total Costs	$258,270		$345,706		$232,417		$309,689		$79,634			$166,117	$74,497		$253,220		$105,723.80		$1,659,155	
																	$109,438.51	(leftover $ added to Admin)		
SCIENCE PROGRAM REPORT BY YEAR																				
																*Approach to		**AMOUNT GRANTED**	$1,662,870	
Year 1 (9 months)	$64,567		$86,427		$58,104		$77,422		$19,908				$18,624		$32,448	Brown distribution	$27,360			
Year 2	$86,090		$115,235		$77,472		$103,230		$26,545				$24,832		$43,264	different because	$36,480	**Difference to make up**	-$3,715	
Year 3	$86,090		$115,235		$77,472		$103,230		$26,545				$24,832		$135,835	Post-Doc in only	$36,480			
Year 4 (3 months)	$21,522		$28,809		$19,368		$25,807		$6,636				$6,208		$41,673	the last year.	$9,120			
Total of break down	$258,270		$345,706		$232,417		$309,689		$79,634				$74,497		$253,220		$109,439	Total	$1,662,870	

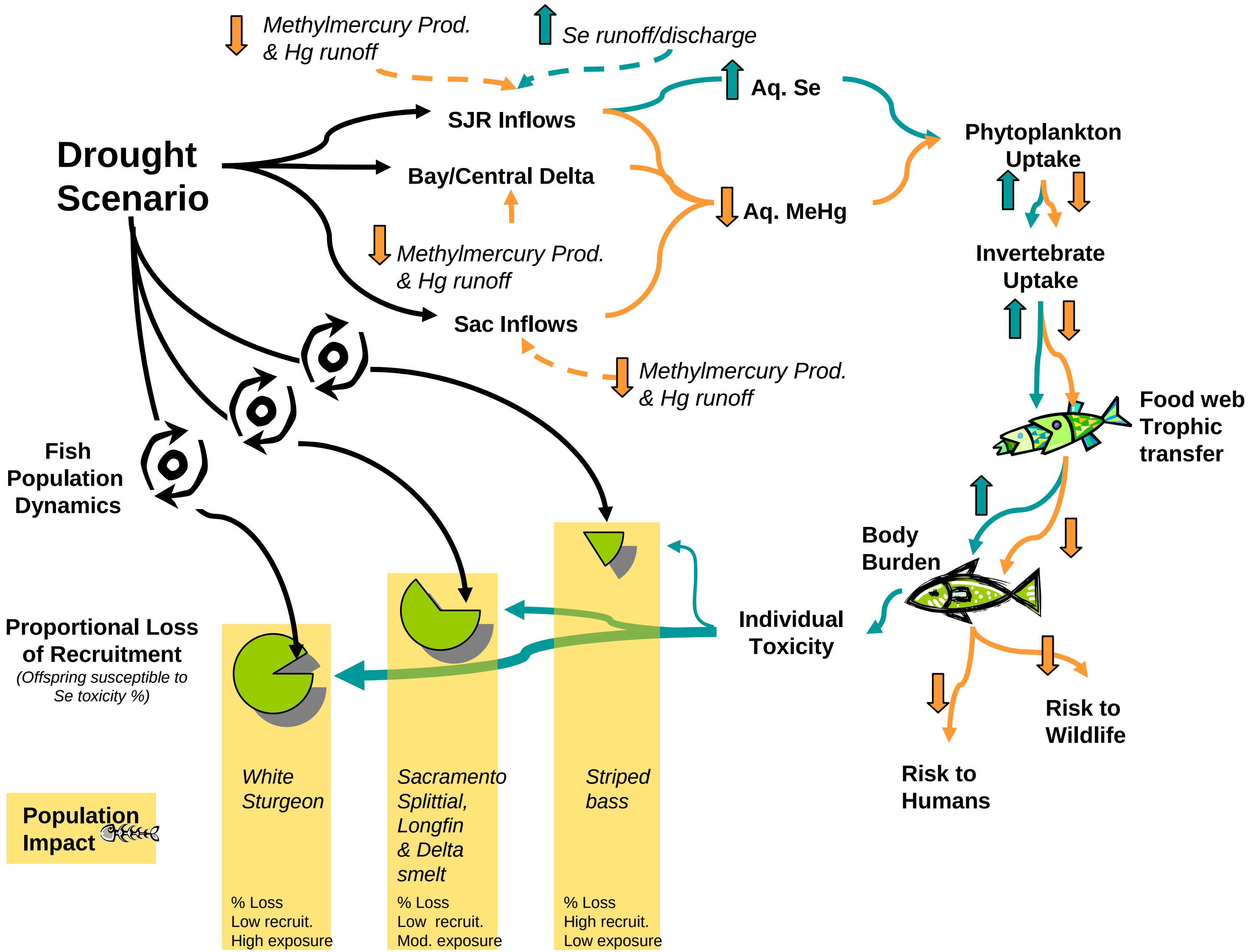

Figure 1. Contaminant Conceptual Model describing the critical physical, chemical and biological processes and their interactions that determine the fate and effects of contaminants in the San Francisco Bay and Delta under different scenarios of change (e.g. Drought scenario shown). Output from sub models that characterize individual processes are incorporated in successive sub models to determine bioaccumulation and effects in different levels of the food web. Blue and orange arrows indicate potential responses of selenium and mercury, respectively, at each step of the model.

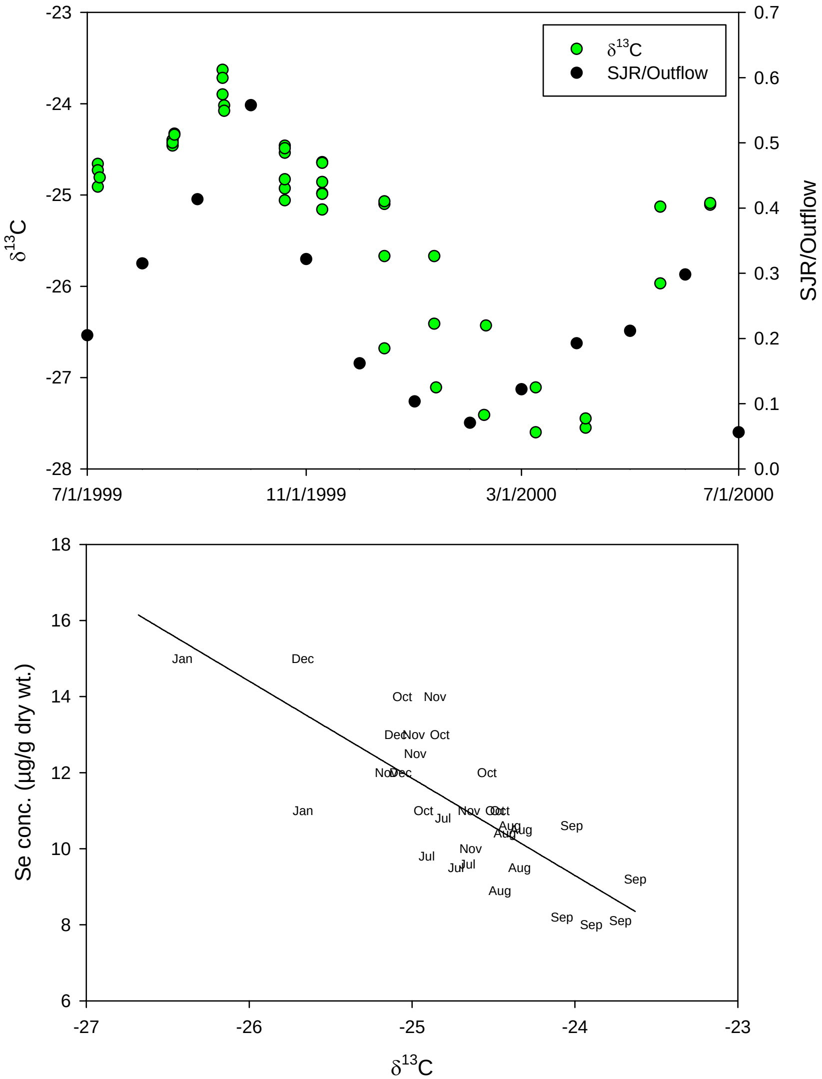

Figure 2. Relationships between stable isotope values and selenium concentrations in *Corbula amurensis* in Suisun Bay (R.V. Polaris stations 6.1 and 411.1) and San Joaquin River outflow from July 1999 through July 2000. A.δ^{13}C values in clams and calculated proportion of San Joaquin R. to total Delta outflow. B. Selenium concentrations in clams plotted against δ ^{13}C in clams.

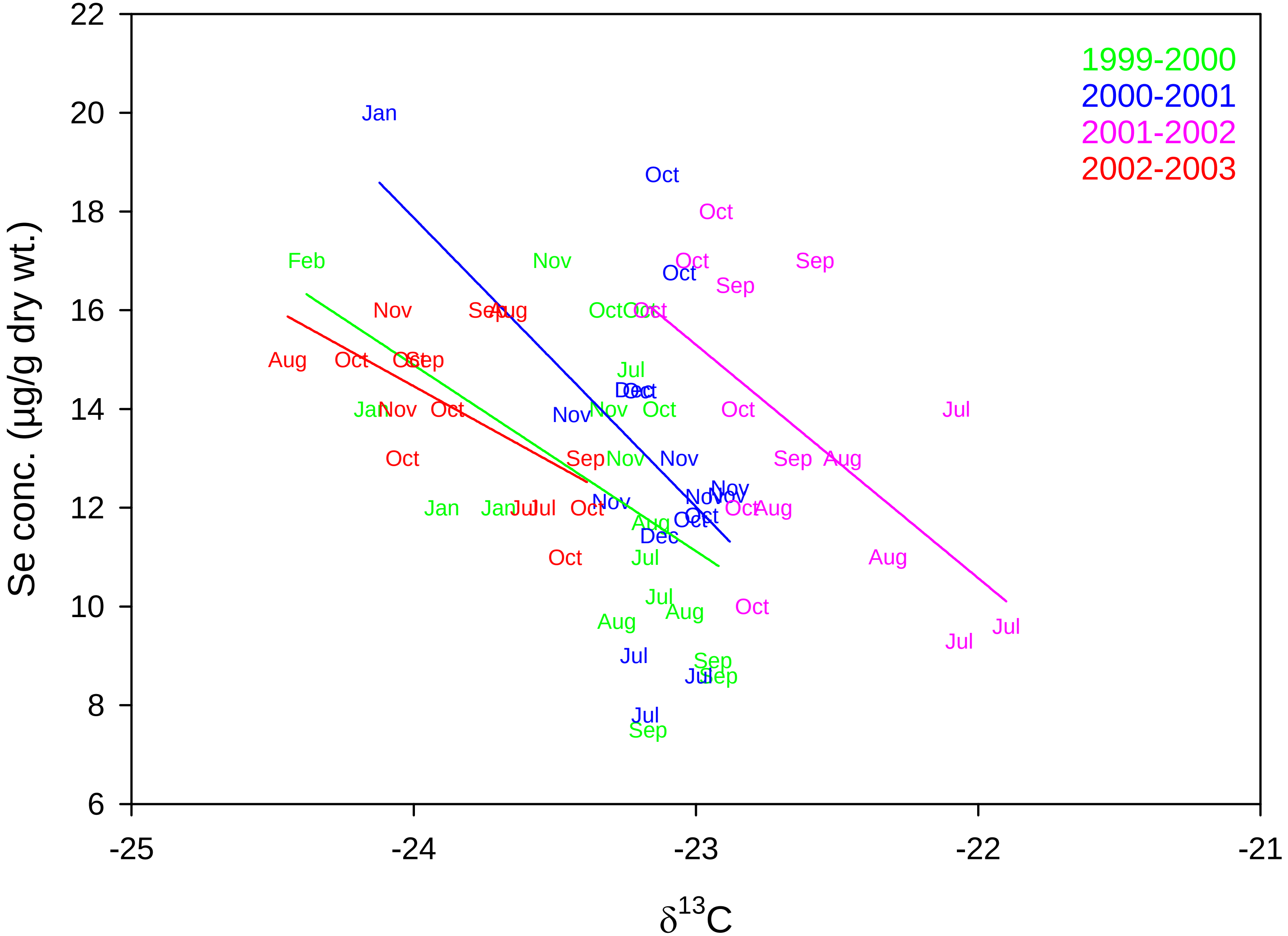

Figure 3. Relationships selenium concentrations and $\delta^{13}C$ values in *Corbula amurensis* in Suisun Bay (R.V. Polaris stations 8.1). Regression lines are shown for individual months within a defined exposure year (Se concentrations in clams tend to build from June through February) and are significant at $p < 0.05$.