Modeling The Delta Smelt Population Of The San Francisco Estuary

prepared by Kimmerer, Wim J.

submitted to Science Program 2004

compiled 2005−01−06 14:17:34 PST

Project

This proposal is for the Science Program 2004 solicitation as prepared by Kimmerer, Wim J..

The submission deadline is 2005−01−06 17:00:00 PST (approximately 162 minutes from now).

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Proposal Title	***Modeling the Delta Smelt Population of the San Francisco Estuary***	
Institutions	San Francisco State University University of California at Davis Louisiana State University Stanford University	*List each institution involved, one per line.*
Proposal Document		*You have already uploaded a proposal document. View it to verify that it appears as you expect. You may replace it by uploading another document*
Project Duration	***36 months***	

Is the start date a determining factor to the successful outcome of the proposed effort?
X No.
− Yes. Anticipated start date of this effort:

Select all of the following study topics which apply to this proposal.
X life cycle models and population biology of key species
X environmental influences on key species and ecosystems
X relative stresses on key fish species
X direct and indirect effects of diversions on at−risk species
− processes controlling Delta water quality
− implications of future change on regional hydrology, water operations, and environmental processes
− water management models for prediction, optimization, and strategic assessments
− assessment and monitoring
− salmonid−related projects
X Delta smelt−related projects

Select as many keywords as necessary to describe this proposal (minimum of 3).
− ***adaptive management***
− ***aquatic plants***
− ***benthic invertebrates***
− ***biological indicators***
− ***birds***
− neotropical migratory birds
− shorebirds
− upland birds
− wading birds
− waterfowl
− ***climate***
− climate change
− precipitation
− sea level rise
− snowmelt
− ***contaminants / toxicants / pollutants***
− contaminants and toxicity of unknown origin
− emerging contaminants

− mercury
− nutrients and oxygen depleting substances
− organic carbon and disinfection byproduct precursors
− persistent organic contaminants
− pesticides
− salinity
− sediment and turbidity
− selenium
− trace metals
− ***database management***
− ***economics***
− ***engineering***
− civil
− environmental
− hydraulic
− ***environmental education***
− ***environmental impact analysis***
− ***environmental laws and regulations***
− ***environmental risk assessment***
X fish biology
− bass and other centarchids
X delta smelt
− longfin smelt
− other species
− salmon and steelhead
− splittail
− striped bass
− sturgeon
− ***fish management and facilities***
− hatcheries
− ladders and passage
− screens
− ***forestry***
− ***genetics***
− ***geochemistry***
− ***geographic information systems (GIS)***
− ***geology***
− ***geomorphology***
− ***groundwater***
X habitat
− benthos
X channels and sloughs
− flooded islands
− floodplains and bypasses
− oceanic
− reservoirs
− riparian
− rivers and streams
− shallow water
− upland habitat
− vernal pools
X water column
− wetlands, freshwater
− wetlands, seasonal
− wetlands, tidal
− ***human health***
X hydrodynamics
− ***hydrology***
− ***insects***
X invasive species / non−native species / exotic species
− ***land use management, planning, and zoning***
− ***limnology***
− ***mammals***
− large
− small

− ***microbiology / bacteriology***
X modeling
X conceptual
X quantitative
− ***monitoring***
− ***natural resource management***
− ***performance measures***
− ***phytoplankton***
− ***plants***
− ***primary productivity***
− ***reptiles***
− ***restoration ecology***
− ***riparian ecology***
− ***sediment***
− ***soil science***
X statistics
− ***subsidence***
− ***trophic dynamics and food webs***
X water operations
X barriers
X diversions / pumps / intakes / exports
X gates
− levees
− reservoirs
− ***water quality management***
− ag runoff
− mine waste assessment and remediation
− remediation
− temperature
− urban runoff
− water quality assessment and monitoring
− ***water resource management***
X water supply
− demand
X environmental water account
− water level
− water storage
− ***watershed management***
− ***weed science***
− ***wildlife***
− ecology
− management
− wildlife−friendly agriculture
− ***zooplankton***
− ***administrative***

Indicate whether your project area is local, regional, or system−wide. If it is local, provide a central ZIP Code. If it is regional, provide the central ZIP Code and choose the counties affected. If it is system−wide, describe the area using information such as water bodies, river miles, and road intersections.	
X local	ZIP Code: ***94920***
− regional	ZIP Code: counties:
− system−wide	

Does your project fall on or adjacent to tribal lands?
No.

(Refer to California Indian reservations *to locate tribal lands.)*
If it does, list the tribal lands.

Has a proposal for this effort or a similar effort ever been submitted to CALFED for funding or to any other public agency for funding?
No.

If yes, complete the table below.

Status	Proposal Title	Funding Source	Amount	Comments

Has the lead scientist or principal investigator of this effort ever submitted a proposal to CALFED for funding or to any other public agency for funding?
Yes.

If yes, provide the name of the project, when it was submitted, and to which agency and funding mechanism if was submitted. Also describe the outcome and any other pertinent details describing the proposal's current status.

I list here only CALFED funding. Please contact me at Kimmerer@sfsu.edu if you really want information on proposals to “any other public agency”

Kimmerer has received ERP and Science Program funding as listed below. In addition, Kimmerer is a member and Co−Chair of the ERP Science Board, and had ERP support for completion of the “Open Water Processes” white paper (Kimmerer 2004). Kimmerer is also co−advisor to the CBDA Lead Scientist on the Environmental Water Account.

ERP−00−F10 “Determining the Biological, Physical and Chemical Characteristics of Ballast Water Arriving in the San Francisco Bay/Delta Estuary”, in progress. One paper has been submitted for publication, one Masters thesis has been completed and being prepared for publication, and work is proceeding toward two other publications. A spin−off project has been funded by the National Science Foundation, providing leverage for the original project. This project has also benefited from collaboration with Dr. Greg Ruiz of the Smithsonian Environmental Research Center, a recognized expert on introduced species. A request for additional funding to expand sampling of ballast water is being processed; this extension will enable us to investigate the larval forms that arrive in ballast water, and the viability of various planktonic organisms in ballast water.

ERP−00−E109 “Effects of Introduced Clams on the Food Supply of Bay−Delta Fish Species.” This modeling/data analysis study has been completed. Three papers have been published, one with partial funding and two with full funding from the ERP. Two additional papers have been submitted for publication and a final report has been submitted.

(With W. Bennett and S. Bollens): ERP 99−N09: “Effects of Introduced Species of Zooplankton and Clams on the Bay−Delta Food Web.” This experimental study has supported one Ph.D. dissertation and two Masters’ theses, one of which is completed and the other has been delayed somewhat (the student took a job) and is now scheduled for completion in early 2005. In addition, numerous presentations and newsletter articles have been completed, and several journal articles are in various stages of completion. A synthesis of the information has been submitted as a final report.

Proposals submitted:

ERP (Nov 2004): Monitoring Responses Of The Delta Smelt Population To Multiple Restoration Actions In The San Francisco Estuary (Sub to UC Davis)
Science Program, Jan 2005: Foodweb Support for the Threatened Delta Smelt and other Estuarine Species in Suisun Bay and the Western Delta (with USGS and U. of Connecticut)

Science Program, Jan 2005: Ecological Consequences of Elevated Salinity in the Sacramento−San Joaquin Delta (with USGS and Department of Water Resources)

Science Program, Jan 2005: Ecological Consequences of Elevated Salinity in the Sacramento−San Joaquin Delta (with Louisiana State University, UC Davis, and Stanford University

Science Program, Jan 2005: Model−Based Guidance For Restoring Chinook Salmon: River, Estuary, And Ocean Influences On Populations Spawning In The Sacramento And San Joaquin Basins. (Sub to Oak Ridge National Labs, with CDFG, University of Tennessee)

Science Program, Jan 2005: Long−Term Trends in Benthic Macrofauna Biomass in the Upper San Francisco Estuary (Sub to DWR with USGS)

All applicants must identify all sources of funding other than the funds requested through this solicitation to support the effort outlined in their proposal. Applicants must include the status of these commitments (tentative, approved, received), the source, and any cost−sharing requirements. Successful proposals that demonstrate multiple sources of funding must have the commitment of the non−Science Program PSP related funding within 30 days of notification of approval of Science Program PSP funds. If an applicant fails to secure the non−Science Program PSP funds identified in the proposal, and as a result has insufficient funds to complete the project, CBDA retains the option to amend or terminate the award. The California Bay−Delta Authority reserves the right to audit grantees.

Status	Proposal Title	Funding Source	Period Of Commitment	Requirements And Comments

Are you specifically seeking non−federal cost−share funds for this proposal?
No.

In addition to the general funds available, are you targeting additional funds set aside specifically for collaborative proposals?
Yes.

List people you feel are qualified to act as scientific reviewers for this proposal and are not associated with CALFED.

Full Name	Organization	Telephone	E−Mail	Expertise
John Quinlan	***Rutgers University***	***732−932−6555 ext. 549***	***quinlan@marine.rutgers.edu***	***modeling, quantitative***
Larry Crowder	***Duke University Marine Lab***	***252−504−7637***	***lcrowder@duke.edu***	***modeling, quantitative***
Roger Nisbet	***University of California, Santa Barbara***	***(805) 893−7115***	***nisbet@lifesci.ucsb.edu***	***modeling, quantitative***
Edward D. Houde	***Chesapeake Biological Laboratory***	***410−326−7224***	***ehoude@cbl.umces.edu***	***fish biology***

Executive Summary

Provide a brief but complete summary description of the proposed project; its geographic location; project objective; approach to implement the proposal; hypotheses being tested; expected outcomes; and relationship to Science Program priorities. The Executive Summary should be a concise, informative, stand−alone description of the proposed project. *(This information will be made public on our website shortly after the closing date of this PSP.)*

The threatened delta smelt is arguably the most important species for management and restoration in the San Francisco Estuary. Singularly dependent on the Sacramento−San Joaquin Delta and Suisun Bay, delta smelt is highly vulnerable to entrainment in export pumping facilities. The management attention to this fish has led to some important advances in our understanding of its population dynamics, and to improvements in how this species is monitored. However, we lack population models necessary to extend and test the scope of our present knowledge, and to quantitatively explore management alternatives. It is therefore timely to develop and apply computer models to the delta smelt population. Such models can be useful in organizing the available information and placing it in a population context, pointing out key information gaps, and investigating the implications of alternative management strategies.

The proposed project will develop, test, and apply three classes of computer models for delta smelt: particle−tracking models, an individual−based model, and matrix projection models. These models have very different spatial and temporal scales, and different objectives. Particle−tracking models (PTMs) are useful for exploring short−term transport and movement over fine−scale spatial variability. PTMs are especially useful in the Sacramento−San Joaquin Delta where a major concern is the transport towards and entrainment of delta smelt in the south Delta water export facilities. Individual−based models (IBMs) focus on life−history characteristics of individual fish, building the population response from the summed interactions of the individuals. IBMs require substantial knowledge of the physiology and behavior of the species and are most useful for exploring the population responses to complex combinations of alternative environmental (e.g., food, water temperature) and management scenarios. Matrix projection models take a more broad−brush approach to modeling population dynamics by lumping individuals into age or stage groups and following the numbers in each stage, rather than individuals. The mathematics and analysis of matrix projection models is well developed. Matrix projection models also allow for the easy investigation of hypotheses, quick mathematical analysis of population responses, and determination of the relative importance of various life stages and population processes (e.g., fecundity, survival) to the predicted responses.

These three types of models will be developed in a collaborative arrangement among San Francisco State University, the University of California at Davis, Stanford University, and Louisiana State University. The PTM will be applied at Stanford University by Monismith and colleagues. The IBM will be developed based upon a preliminary IBM assembled for the 2003 EWA delta smelt workshop, which in turn is based on previous modeling work by Rose and colleagues. As part of this proposed project, we will hire a postdoctoral research associate to do most of the coding, testing, and analysis under Kimmerer's supervision, with advice and assistance from Rose and Bennett. The matrix projection models will be developed by Bennett and a Ph.D. student, with advice and assistance from Rose and Kimmerer.

Feasibility of such an ambitious project as the one proposed here depends on the capabilities of the scientists involved, as well as on the organization of the project. The investigators on this project have many years of experience individually, each of the investigators has worked extensively with at least one of the other investigators, and the responsibilities and interactions specifically for this proposed project are clearly laid out in this proposal. Development of all three model types will also take advantage of the collective knowledge of the community of scientists in the region, through workshops and presentations as well as personal contact.

Give additional comments, information, etc. here.

Applicant

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All information on this page is to be provided for the agency or institution to whom funds for this proposal would be awarded.

Applicant Institution	***San Francisco State University***	*This list comes from the project form.*
Applicant Institution Type	***public institution of higher education***	

Institution Contact

Please provide information for the primary person responsible for oversight of grant operation, management, and reporting requirements.

Salutation	***Dr.***
First Name	***Kenneth***
Last Name	***Paap***
Street Address	***1600 Holloway Avenue; ADM 469***
City	***San Francisco***
State Or Province	***CA***
ZIP Code Or Mailing Code	***94132***
Telephone	***(415) 338−7091*** *Include area code.*
E−Mail	***kenp@sfsu.edu***

Additional information regarding prior applications submitted to CALFED by the applicant organization or agency and/or funds received from CALFED programs by applicant organization or agency may be required.

Personnel

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Instructions

Applicants must provide brief biographical sketches, titles, affiliations, and descriptions of roles, relevant to this effort, of the principal and supporting project participants by completing a Personnel Form. This includes the use of any consultants, subcontractors and/or vendors; provide information on this form for all such people.

Information provided on this form will automatically support subsequent forms to be completed as part of the Science PSP submission process. Please be mindful of what information you enter and how it may be represented in the Task and Budget forms.

Information regarding anticipated subcontractor services must be provided regardless if the specific service provider has been selected or not. If the specific subcontractor has not been identified or selected, please list TBD (to be determined) in the Full Name field and the anticipated service type in the Title field (example: Hydrology Expert).

Please provide this information before continuing to those forms.

Kimmerer, Wim J.

*This person is the **Lead Investigator**. Contact information for this person is required.*

Full Name	***Kimmerer, Wim J.***	example: Wright, Jeffrey R., PhD.
Institution	***San Francisco State University***	*This list comes from the project form.*
Title	***Research Professor***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Project direction, supervision of postdoctoral associate doing the IBM work, coordination with other participant.	
Qualifications		*You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*
Mailing Address	***3152 Paradise Drive***	
City	***Tiburon***	
State	***CA***	
ZIP	***94920***	
Business Phone	***4103383515***	
Mobile Phone	***510 555 1212***	
E−Mail	***kimmerer@sfsu.edu***	

Describe other staff below. If you run out of spaces, submit your updates and return to this form.

Bennett, William A.

Full Name	***Bennett, William A.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California at Davis***	*This list comes from the project form.*
Title	***Assistant Research Scientist***	*example: Dean of Engineering*

Position Classification	***primary staff***	
Responsibilities	Principal responsibility for the matrix modeling, participant in the IBM development.	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Rose, Kenny

Full Name	***Rose, Kenny***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***Louisiana State University***	*This list comes from the project form.*
Title	***Professor***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Oversight of IBM work, advice and consultation on matrix modeling.	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Postdoctoral Associate

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***San Francisco State University***	*This list comes from the project form.*
Title	***Postdoctoral associate***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Develop the IBM	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Graduate Research Assistant

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California at Davis***	*This list comes from the project form.*
Title	***Graduate research assistant***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Assist with development of matrix models.	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Monismith, Stephen

Full Name	***Monismith, Stephen***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***Stanford University***	*This list comes from the project form.*
Title	***Professor***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Lead application of particle tracking model	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Fong, Derek

Full Name	***Fong, Derek***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***Stanford University***	*This list comes from the project form.*
Title	***Senior Research Associate***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Application of particle tracking model	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Hench, James

Full Name	***Hench, James***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***Stanford University***	*This list comes from the project form.*
Title	***Research Associate***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Application of particle tracking model	
Qualifications		***This is only required for primary staff.*** *You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Technical Assistant

Full Name		example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***San Francisco State University***	*This list comes from the project form.*
Title	***Technical Assistant***	*example: Dean of Engineering*

Position Classification	***secondary staff***	
Responsibilities	Assist with gathering data	
Qualifications		***This is only required for primary staff.*** *Upload a PDF version of this person's resume that is no more than five pages long. To upload a resume, use the "Browse" button to select the PDF file containing the resume.*

Conflict Of Interest

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Instructions

To help Science Program staff manage potential conflicts of interest in the review and selection process, we need some information about who will directly benefit if your proposal is funded. We need to know of individuals in the following categories:

- Applicants listed in the proposal who wrote the proposal, will be performing the tasks listed in the proposal, or who will benefit financially if the proposal is funded;
- Subcontractors listed in the proposal who will perform some tasks listed in the proposal and will benefit financially if the proposal is funded.

Applicant	San Francisco State University
Submittor	Kimmerer, Wim J.
Primary Staff	Kimmerer, Wim J.
Primary Staff	Bennett, William A.
Primary Staff	Rose, Kenny
Secondary Staff	*Postdoctoral associate
Secondary Staff	*Graduate research assistant
Primary Staff	Monismith, Stephen
Primary Staff	Fong, Derek
Primary Staff	Hench, James
Secondary Staff	*Technical Assistant

Are there other persons not listed above who helped with proposal development?
No.

If there are, provide below the list of names and organizations of all individuals not listed in the proposal who helped with proposal development along with any comments.

Tasks

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Instructions

Utilize this Task Table to delineate the tasks identified in your project description. Each task and subtask must have a number, title, brief description of the task (detailed information should be provided in the project description), timeline, list of personnel or subcontractors providing services on each specific task, and list of anticipated deliverables (where appropriate). When creating subtasks, information must be provided in a way that avoids duel presentation of supporting tasks within the overall task (i.e. avoid double counting). Information provided in the Task Table will be used to support the Budget Form. Ensuring information regarding deliverables, personnel and costs associated with subtasks are only provided once is imperative for purposes of avoiding double counting of efforts within the Budget Form.

For proposals involving multiple institutions (including subcontractors), the table must clearly state which institutions are performing which tasks and subtasks.

Task ID	Task Name	Start Month	End Month	Personnel Involved	Description	Deliverables
1	***Particle tracking modeling***	*1*	*36*	***Monismith, Stephen*** ***Fong, Derek*** ***Hench, James***	Apply the DSM2 particle tracking model to the movements of delta smelt	At least one paper in the scientific literature One talk at the CALFED Science Conference Presentations at the Estuarine Ecology Team. Report discussing capabilities and limitations of alternative modeling approaches, submitted to CALFED upon project completion.
2	***Individual−Based Modeling***	*1*	*36*	***Kimmerer, Wim J.*** ***Rose, Kenny*** ****Postdoctoral associate*** ****Technical Assistant***	Develop, test, and run the individual−based model	At least one paper in the scientific literature One talk at the CALFED Science Conference Presentations at the Estuarine Ecology Team.
3	***Matrix modeling***	*1*	*36*	***Bennett, William A.*** ****Graduate research assistant***	Develop, test, and run the matrix models	At least one paper in the scientific literature One talk at the CALFED Science Conference Presentations at the Estuarine Ecology Team

Budget

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Instructions

All applicants must complete a budget for each task and subtask. The Budget Form uses data entered in the Task Form, thus tasks should be entered before starting this form. Failure to complete a Budget Form for each task and/or subtask will result in removal of the application from consideration for funding.

CBDA retains the right to request additional information pertaining to the items, rates, and justification of the information presented in the Budget Form(s).

Supporting details on how costs were derived for each line item must be included in the justification section for each item. The cost detail for each item should include the individual cost calculations associated with each line item to provide the basis for determining the total amount for each budget category.

Following are guidelines for completing the justification section of this form:

Labor (Salary &Wages)

Ensure each employee and associated classification is correctly identified for each task and subtask. This information will automatically be provided once the Staff Form has been completed. Provide estimated hours and hourly rate of compensation for each position proposed in the project.

Employee Benefits

Benefits, calculated as a percentage of salaries, are contributions made by the applicant for sick leave, retirement, insurance, etc. Provide the overall benefit rate and specify benefits included in this rate for each employee classification proposed in the project.

Travel

Travel includes the cost of transportation, subsistence, and other associated costs incurred by personnel during the term of the project. Provide purpose and estimated costs for all travel. Reoccurring travel costs for a particular task or subtask may be combined into one entry. The number of trips and cost for each occurrence must be clearly represented in the justification section for reoccurring travel items of this nature.

Any reimbursement for necessary travel and per diem shall be at rates specified by the California Department of Personnel Administration for similar employees (www.dpa.ca.gov/jobinfo/statetravel.shtm).

Equipment

Equipment is classified as any item of $5,000 or more and has an expected life of three years or more. Equipment purchased in whole or in part with these grant funds must be itemized. List each piece of equipment and provide a brief description and justification for each.

Supplies

Provide a basic description and cost for expendable research supplies. Costs associated with GIS services, air photos, reports, etc. must be listed separately and have a clear justification associated with each entry. Postage, copying, phone, fax and other basic operational costs associated with each task and subtask may be combined unless the cost associated with one particular service is unusually excessive.

Subcontractor Services

Subcontractor services (Professional and Consultant services) include the total costs for any services needed by the applicant to complete the project tasks. Ensure the correct organization is entered in the Personnel Form so that it appropriately appears on the Budget Form. The applicant must provide all associated costs of all subcontractors (i.e. outside service providers) when completing this form. Applicants must be able to demonstrate that all subcontractors were selected according to an applicant's institutional requirements for the selection of subcontractors (competitive selection or sole source justification).

CBDA retains the right to request that a subcontractor provide cost estimates in writing prior to distribution of grant funds.

CBDA retains the right to request consultant, subcontractor, and/or outside service provider cost estimates in writing prior to distribution of grant funds.

Indirect Costs (Overhead)

Indirect costs are overhead expenses incurred by the applicant organization as a result of the project but are not easily identifiable with a specific project. The indirect cost rate consists of a reasonable percentage of all costs to run the agency or organization while completing the project. List the cost and items associated with indirect costs. (These items may include general office expenses such as rent, office equipment, administrative staff, operational costs, etc. Generally these items are represented by the applicant through a predetermined percentage or surcharge separate from other specific costs of items necessary to complete a specific task or subtask.)

If indirect cost rates are different for State and Federal funds, please identify each rate and the specific items included in the calculation for that rate.

Task 1, Particle Tracking Modeling: Labor	Justification	Amount
Monismith, Stephen	*0.5 mo. summer salary in years 1,2,3*	*24433*
Fong, Derek	*years 1,2,3: 1 month*	*26855*
Hench, James	*years 1,2: 4 months, year 3: 1 month*	*84474*
Task 1, Particle Tracking Modeling: Benefits	**Justification**	**Amount**
Monismith, Stephen	*30.5% of salary*	*7452*
Fong, Derek	*30.5% of salary*	*8191*
Hench, James	*30.5% of salary*	*25765*
Task 1, Particle Tracking Modeling: Travel Expenses	**Justification**	**Amount**
Other	*Meetings at RTC/Sacramento/Bodega Bay/LSU*	*13000*
Conferences	*Conference travel (yrs 2 and 3)*	*2500*
Task 1, Particle Tracking Modeling: Supplies And Expendables	**Justification**	**Amount**
	Materials, supplies and software, etc. ($2k/yr, 3 yrs)	*6000*
Task 1, Particle Tracking Modeling: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 1, Particle Tracking Modeling: Equipment	**Justification**	**Amount**
	workstation dedicated to project	*8000*
Task 1, Particle Tracking Modeling: Other Direct	**Justification**	**Amount**
Task 1, Particle Tracking Modeling: Indirect (Overhead)	**Justification**	**Amount**
	56% SU indirect costs	*111256*
	Task 1 Total	$317,926
Task 2, Individual−Based Modeling: Labor	**Justification**	**Amount**
Kimmerer, Wim J.	*($7800/mo x 100% time for 3 mos x 3 yrs*	*73769*
Rose, Kenny	*2 mos/year x 3 yrs*	*54204*
*Postdoctoral Associate	*100% time for 6 mos in Year 1, 100% time in Years 2 &3*	*112500*
*Technical Assistant	*$3000/mo x 100% time for 1 mo/year*	*9000*
Task 2, Individual−Based Modeling: Benefits	**Justification**	**Amount**
Kimmerer, Wim J.	*fringe benefits (medical, dental, vision, social security, etc.) @ 48%*	*35409*
Rose, Kenny	*fringe benefits (medical, dental, vision, social security, etc.) @ 23.5%*	*12738*
*Postdoctoral Associate	*fringe benefits (medical, dental, vision, social security, etc.) @ 48%*	*54000*
*Technical Assistant	*fringe benefits (medical, dental, vision, social security, etc.) @ 48%*	*4320*
Task 2, Individual−Based Modeling: Travel Expenses	**Justification**	**Amount**
Air/Train	*Kimmerer: airfare for collaborative meetings and annual scientific meetings*	*6000*
Conferences	*Kimmerer: conference fees for annual scientific meetings*	*300*
Meals	*Kimmerer: per diem rate of $46/day*	*1380*
Lodging	*Kimmerer: hotel accommodations for collaborative work and annual scientific meetings*	*3544*
Mileage	*Kimmerer: mileage rate of $0.345/mi*	*1500*
Parking/Tolls	*Kimmerer: parking and local bridge tolls*	*676*

Air/Train	*Rose: two 4−day trips to SF (2 x $460)*	*2760*
Lodging	*Rose: two 4−day trips to SF (2 x 4 x $120)*	*2880*
Meals	*Rose: two 4−day trips to SF (2 x 4 x $40)*	*960*
Task 2, Individual−Based Modeling: Supplies And Expendables	**Justification**	**Amount**
Other	*Laptop Computer and Computer Software*	*5500*
Reproduction	*Publication Costs*	*1500*
Task 2, Individual−Based Modeling: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 2, Individual−Based Modeling: Equipment	**Justification**	**Amount**
Task 2, Individual−Based Modeling: Other Direct	**Justification**	**Amount**
Task 2, Individual−Based Modeling: Indirect (Overhead)	**Justification**	**Amount**
Indirect Costs − LSU	*Indirect Cost Rate of 34% on Direct Costs*	*25005*
Indirect Costs − SFSU	*Indirect Cost Rate of 25% on Direct Costs + 25% on first $25,000 of LSU subaward*	*96099*
	Task 2 Total	$504,044
Task 3, Matrix Modeling: Labor	**Justification**	**Amount**
Bennett, William A.	*100% time for 4 mos/yr*	*57031*
***Graduate Research Assistant**	*100% time for 12 mos/yr*	*92230*
Task 3, Matrix Modeling: Benefits	**Justification**	**Amount**
Bennett, William A.	*fringe benefits (medical, dental, vision, social security, etc.)*	*14828*
***Graduate Research Assistant**	*fringe benefits (medical, dental, vision, social security, etc.)*	*23980*
Task 3, Matrix Modeling: Travel Expenses	**Justification**	**Amount**
Air/Train	*airfare*	*7500*
Lodging	*hotel accommodations*	*3000*
Meals	*per diem*	*1500*
Conferences	*fees for annual scientific conferences*	*1500*
Task 3, Matrix Modeling: Supplies And Expendables	**Justification**	**Amount**
Reproduction	*Publication Costs*	*3500*
Other	*Laptop Computer and Computer Software*	*3500*
Task 3, Matrix Modeling: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 3, Matrix Modeling: Equipment	**Justification**	**Amount**
Task 3, Matrix Modeling: Other Direct	**Justification**	**Amount**
Student Fees	*Tuition for Graduate Student Assistant*	*25221*
Task 3, Matrix Modeling: Indirect (Overhead)	**Justification**	**Amount**
Indirect Costs − UCD	*Indirect Cost Rate of 25% on Direct Costs*	*51267*

	Task 3 Total	$285,057
	Grand Total	$1,107,027

− The indirect costs may change by more than 10% if federal funds are awarded for this proposal.

What is the total of non−federal funds requested?

PROJECT PURPOSE

Introduction

The thorniest problem in managing and restoring the San Francisco Estuary is what to do about delta smelt. These threatened fish are now the principal focus of actions taken under the Environmental Water Account (EWA; Kimmerer 2002) in the Sacramento-San Joaquin Delta. Export pumping in the Delta is often reduced because of concerns over take (entrainment and mortality of delta smelt by the pumping facilities). Even scientific sampling programs, which take a minuscule fraction of the population each year, can be curtailed or stopped because of concern over killing these fish. Furthermore, numerous actions in the CALFED Ecosystem Restoration Program (ERP) have invoked protection of delta smelt as one of their rationales.

At the same time, and a result of this attention, a great deal continues to be learned about the biology of delta smelt. Delta smelt abundance is monitored by several programs administered by the Interagency Ecological Program (IEP) that target different life stages. Rearing studies have provided much useful information on the basic biology of the early life stages of delta smelt. Field-based studies involving otolith aging and microchemistry, as well as histopathology, are providing new insights into the key environmental influences on delta smelt, and new field-based studies are being proposed. These advances in knowledge about delta smelt biology have been summarized in a recently submitted monograph (Bennett 2005).

While the accumulation of information on delta smelt is critical and encouraging, the information would benefit greatly from a systematic evaluation. To date, there has not been a quantitative framework available in which to synthesize, evaluate, and compare the different types of information in a common context or to examine how alternative hypotheses about processes and management actions might affect population dynamics. Modeling provides such a systematic framework, and we believe that several alternative modeling approaches are needed to deal with the multiple temporal and spatial scales involved in delta smelt population dynamics. We also believe that the time is ripe for the development of these models; the information available now and in the next few years will support an effective modeling effort. We expect that this modeling effort can then form the basis for designing future studies, revising management actions, and possibly even aid in designing experimental actions using the Environmental Water Account.

We propose to further develop, test, and apply several complementary models of the delta smelt population. The purpose of these models is not to answer detailed questions about water allocation or specific restoration actions. Rather, inputs to these models consist of information on environmental conditions and population vital rates (growth, reproduction, and mortality), which then influence how the modeled population responds. Our proposed suite of models should be initially conceived as research models, but these models can be applied to management problems by first specifying how a particular action will affect vital rates and then using the models to predict population responses to these altered vital rates.

Relatively simple matrix projection models of delta smelt have already been developed to explore the importance of mortality factors and the contribution of various life stages to the population's sensitivity to environmental influences (Bennett 2005). We propose to expand on those efforts to take into account nonlinear effects, interannual and spatial variability, and the effects of water management options. We propose to also develop an individual-based model (IBM) as a complementary tool to the matrix projection models. The IBM allows exploration of population responses to simultaneous variation in multiple environmental factors and management actions. Matrix projection models and IBMs are a powerful combination that enables evaluation of a broad suite of hypotheses and management actions. In addition, we propose to expand and investigate the use of existing particle-tracking models to investigate how behavior and hydrodynamics interact to result in the transport and movement of early life stages. These three types of models will provide a complementary and interacting set of analytical tools, each with a different purpose and a different level of resolution.

Research Objectives

The ultimate goal of this modeling effort is to better understand the ecology of delta smelt and their vulnerability to export flows in the south Delta, as well as to improve how we manage the ecosystem to benefit these fish. Our proposed project has the following specific objectives:

1. To test and apply the DSM2 particle tracking model and investigate how alternative flow conditions and larval behaviors influence the movement of delta smelt.
2. To develop, test, and explore an individual-based model (IBM) of delta smelt population dynamics.
3. To further develop, test, and explore the behaviors of stage-based matrix projection models of delta smelt.
4. To investigate some key hypotheses concerning delta smelt biology and the influence of environmental factors, such as food supply, on delta smelt population dynamics.
5. To investigate short- and long-term implications of various management scenarios, such as EWA and the Vernalis Adaptive Management Program, on the delta smelt population.
6. To investigate how alternative scenarios of export pumping can affect delta smelt population abundance.

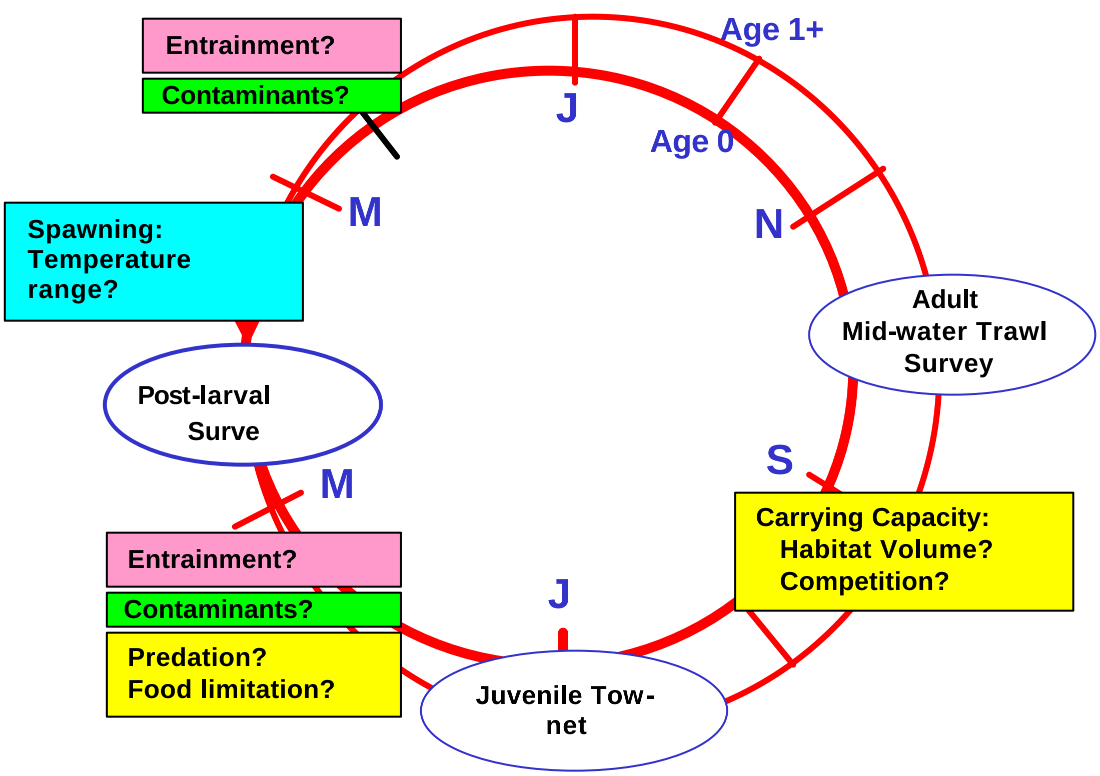


Figure 1. Conceptual model of delta smelt life-cycle and factors influencing abundance (boxes) at key periods. Thick red circle represents one-year cycle, and thin red circle reflects the small proportion of adults that survive 2 years. Ovals show the timing of the primary monitoring surveys.circle reflects the small proportion of adults that survive 2 years. Ovals show the timing

The Life History of Delta Smelt: a Conceptual Model

Our conceptual model for the delta smelt population is derived from considerable research and monitoring by resource agencies and academic researchers, summarized in the recently-submitted review paper (Figure 1, Bennett 2005). Monitoring conducted by the IEP collects delta smelt during almost all life stages, with ancillary data on environmental conditions (e.g., temperature, salinity) also measured at each station. These monitoring data provide a valuable foundation upon which we can develop our models.

Spawning: Delta smelt are primarily an annual species with a small number of individuals potentially spawning at two years of age (Figure 1). Adult delta smelt spawn in freshwater during the spring when water temperatures are between about 15 and 20ºC. Adult fish are monitored by the spring Kodiak trawl survey from March to May, and fish are identified as to their reproductive state (Table 1). Spawning distribution, inferred from the transition of the fish from pre-spawned (ripe) to spawned condition, varies from year-to-year with hydrologic conditions. In dry years, delta smelt spawn primarily in the North Delta (Figure 2), while in wet years spawning is more evenly distributed among spatial regions. Delta smelt spawn in the Napa River (Figure 2) only under wet (high inflow) conditions. Pesticides that enter the habitat with freshwater runoff from agricultural fields in late winter may impair egg or sperm development in many regions of the delta smelt habitat (Thompson 2000, Bennett 2005).

Delta smelt spawn adhesive eggs, but little is known of their spawning habitat other than that delta smelt probably utilize shallow-water or shoreline areas, as does their closest relative the surf smelt (*Hypomesus pretiosus*), a marine species that sometimes frequents the estuary. Only one egg has been found in the field (K. Fleming, CDFG, personal communication). Laboratory tests of spawning have shown that delta smelt will spawn on gravel (J. Lindberg, UCD, personal communication); however, gravel is not a common substrate in any of the spawning areas.

Post-larval stage: Delta smelt hatch as yolk-sac larvae and then grow and develop on endogenous energy supplies until they begin to feed at about 5 mm total length (TL). At about 15 to 20mm TL delta smelt are considered post-larvae; they have finished developing a functional swim bladder and fin-folds. The post-larval life-stage is monitored by the 20mm survey from April to June. The initial distribution of post-larvae is generally similar to that of adults during the spawning season, but the post-larvae move seaward so that they are in the Low-Salinity Zone (LSZ) by July (Bennett et al. 2002). As in many fishes, survival through the post-larval stage is influenced by multiple factors (Figure 1). Feeding success and exposure to toxic pesticides may be especially important, either directly causing mortality or, more likely, by impairing growth and reducing stage survival. Rapid growth during early life history is an essential feature of recruitment success in fishes because losses to predation tend to decrease with increasing body size (Houde 1987).

Feeding success at first feeding and later may be particularly poor for delta smelt because the composition of their zooplankton prey has been changed dramatically by the introduction of several exotic species over the last few decades (Kimmerer et al. 1994, Kimmerer and Orsi 1996, Orsi and Ohtsuka 1999, Nobriga 2002). Since 1987, biomass of calanoid copepods, which are the principal prey of delta smelt (Nobriga 2002, Lott 1998), has been lower during spring in and near the LSZ, including the western Delta. Total copepod biomass has been supplemented since 1993 by the introduced cyclopoid copepod *Limnoithona tetraspina*, but this copepod is apparently too small to be readily consumed by delta smelt (Lott 1998, Bouley 2004).

Table 1. Data sources to be used for modeling the delta smelt population. Data related to delta smelt are shown first, followed by the other various environmental and biological data needed for modeling.

Data	Method (institution*)	Years	Months (frequency)	Locations (stations)	Life stages / variables
CPUE, length, temperature, turbidity, gonadal maturity (SKT only)	Kodiak trawl (SKT, CDFG)	2001-present	March-May (bi-weekly)	Suisun Bay-Delta(~30)	Adult / spawning
	Plankton nets (ELS, CDFG)	1990 - 1993	April - June (weekly)	Suisun Bay - Delta(~30)	Larvae
	Mid - water trawl (MWT, CDFG)	1967 - present	Sep - Mar (monthly)	San Pablo Bay - Delta (53 - 113)	Juvenile - adult
	Tow - net (TNS, CDFG)	1959 - present	June - August (bi - weekly)	Suisun Bay - Delta(~30)	Juvenile - adult
	Plankton nets (20mm, CDFG)	1995 - present	April - June (bi - weekly)	Suisun Bay - Delta (~30)	20mm post - larvae - juvenile
	Bay Study MWT (CDFG)	1980 - present	Jan - Dec(monthly)	So. SF Bay - W. Delta (42)	Juvenile - adult
	Mid - water trawl (USFWS)	1976 - present	April - June (~weekly)	Chipps Island (1)	Juvenile - adult
	Beach seine (USFWS)	1977 - present	Jan - Jun (~2 weeks)	Delta-Sac. River (23)	Juvenile - adult
Catch per volume of export flow, fish length	Export facilities (CDWR, USBR)	1979 - present	Jan – Dec (daily)	South Delta (2)	20mm post larvae - adult
Daily growth rates, natal origin, and somatic condition	Otoliths, histopathology (Bennett, UCD)	1999 - 2000	May - October (~monthly)	20mm, TNS and MWT stations	Post - larvae - adult
Vertical migration	Studies in the LSZ (Bennett, UCD)	1994, 1996	May - June	Suisun Bay	Vertical & horizontal dist.
Competition / predation with exotic fishes	Lab/Field studies Bennett, UCD)	Various	Various	Delta and Suisun Marsh	Larvae - juvenile
Physiological tolerances, swimming performance	Lab experiments (Cech, UCD)	Various			Juvenile - adult
Reproductive biology and physiology	Lab (Baskerville - Bridges, UCD)	1997 - present	Continuous since 1997	Delta export facility	All
Striped bass abundance	Striped bass tagging study	1969 – present	Annual (2 yr since 1994)	Entire estuary	Adult striped bass
Catch per unit effort of striped bass	Mid - water trawl (MWT, CDFG)	1967 - present	Sep - Mar (monthly)	San Pablo Bay - Delta (53 - 113)	Piscivorous age - 0 striped bass
Zooplankton abundance	Zooplankton, 20mm surveys	1972 – present	Mar-Nov (monthly)	San Pablo – Delta (15 - 60)	Copepods and other food
Zooplankton biomass	From abundance (Kimmerer, SFSU)				
Co - occurrence of smelt with zooplankton	Field (Kimmerer, Bennett)	1994, 1996	May - June	Suisun Bay	Distribution
Zooplankton population dynamics	Various studies (Kimmerer, SFSU)	1994 – present	Various	San Pablo Bay to Delta	Growth, mortality
Salinity, temperature	Water Quality (CDWR)	Various	Daily (continuous)	N. estuary (increasing #)	Environmental conditions
Freshwater flow, X2	Dayflow program (CDWR)	1955 – present	Daily	Inflow, export flow, outflow	Environmental conditions

* California Department of Fish and Game (CDFG); University of California, Davis (UCD); California Department of Water Resources (CDWR); U.S. Bureau of Reclamation (USBR); U.S. Fish and Wildlife Service (USFWS).

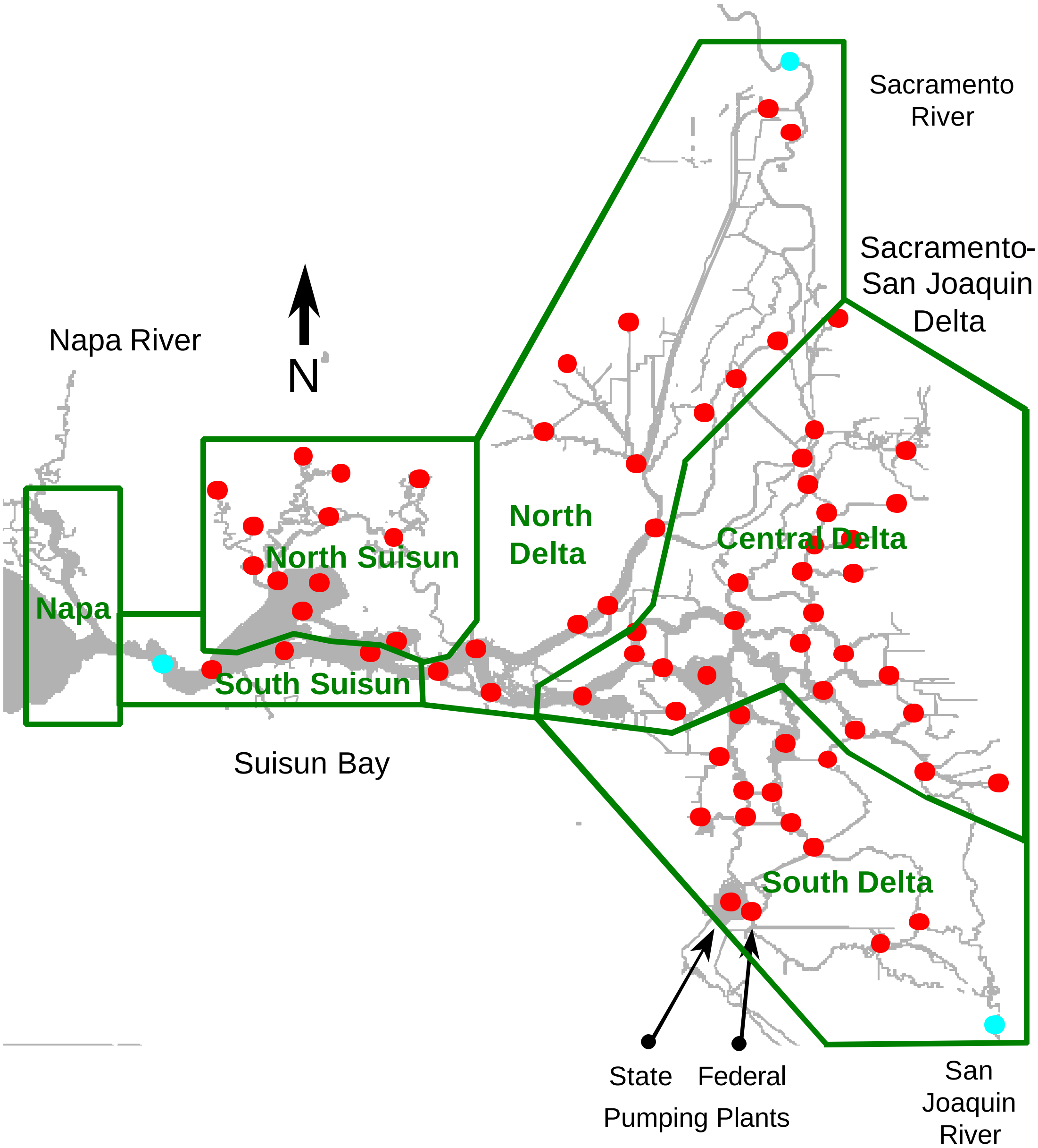


Figure 2. Map of the northern San Francisco Estuary including Suisun Bay and the Sacramento-San Joaquin Delta. Areas outlined in green indicate one possible division of the system in the IBM. Exact boundaries will be determined from initial runs of the PTM. Circles indicate 73 key nodes in the DSM2 hydrodynamic model (out of a total of 482); the light blue circles indicate the terminal nodes at which boundary conditions are specified.

Pesticides are known to occur in the regions occupied by larval and post-larval delta smelt (Kuivila and Foe 1995, Moon et al. 2000, Thompson et al. 2000, Bennett 2005). We previously detected growth impairments in delta smelt post-larvae due to poor feeding and toxic exposure (summarized in Bennett 2005).

Entrainment of larvae in the freshwater export facilities also causes considerable mortality during early life stages. However, fish shorter than about 20mm in length are not collected by the export fish facilities, presumably because these fish go through the screening louvers. Furthermore, the screening efficiency for fish longer than 20mm in length is unknown. Therefore, entrainment mortality is estimated only for fish longer than 20mm, and even that estimate may be in error. The extent that entrained delta smelt reflect only those spawned in the South Delta versus those that have arrived there from other areas of the Delta is a topic of considerable importance and uncertainty.

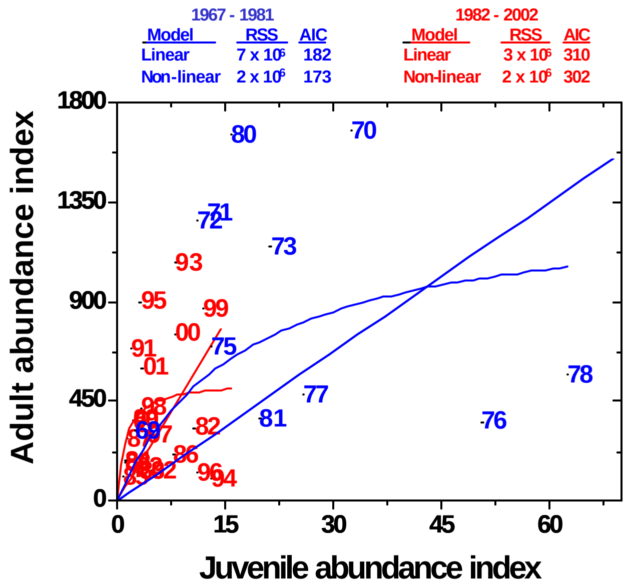


Figure 3. Stock-recruit relationships comparing a Beverton-Holt curve with a linear model for two time periods, pre-decline (blue) and post-decline (red). Statistics show the residual sums of squares and the Akaike Information Criterion, for which a lower value represents a better fit to the data. Numbered data points indicate years.

Juvenile to adult stage: The juvenile stage of delta smelt is monitored primarily by the summer tow-net survey from June to August. The fall mid-water trawl survey monitors juveniles and immature adults during September to December. Our previous work showed that a recruitment bottleneck may occur in late summer as juveniles transition into the adult stage. A stock-recruit model indicated that survival during the juvenile to adult transition may be density-dependent in some years (Figure 3). Approximately 60% of the juveniles examined in our previous study had growth impairments due to poor feeding success (Bennett 2005). Food limitation is commonly associated with density-dependent survival (Houde 1987, 1989, Cowan et al. 2002).

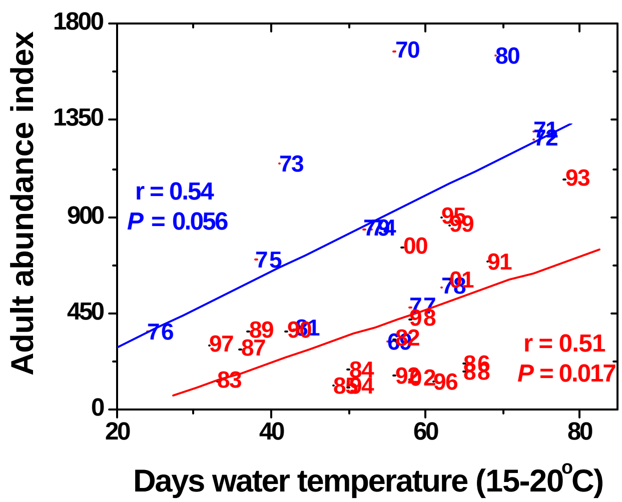


Figure 4. Delta smelt indices from the fall midwater trawl survey, which captures pre-adult and adult delta smelt. Relationships between abundance index and the duration of the spawning season as indexed by the number of days that water temperature was in the range of 15-20°C during the previous spawning season. Fitted lines are linear regressions. Numbered data points indicate years.

Potential limits on abundance: As indicated above, a variety of factors may limit delta smelt abundance. A positive relationship between the number of potential spawning days, as determined by water temperature and adult abundance, suggests that higher spawning success generally leads to higher abundance (Figure 4). However, this relationship has considerable variability, indicating the importance of other mechanisms. These mechanisms can operate during a variety of life stages, interact with each other, and vary in importance among years (Bennett and Moyle 1996). Population modeling offers a framework for quantitatively understanding the cumulative influence of these mechanisms on population abundance. In many instances where population modeling has been applied to fishes, combinations of factors rather than any single factor has been shown to limit abundance (Rose et al. 1993, Cowan et al. 1996). Understanding these complexities is critical for developing sound management strategies for delta smelt.

Management and Restoration for Delta Smelt

Delta smelt is a prime focus of both the Ecosystem Restoration Program and the Environmental Water Account. The first of the Ecosystem Restoration Program's goals is to "Achieve recovery of at-risk native species dependent on the Delta and Suisun Bay…." (CALFED 1999). The species most dependent on the Delta and Suisun Bay is delta smelt, and the only management action to date that is tailored to delta smelt is reduced export pumping in the south Delta.

The Environmental Water Account (EWA) is described as "a cooperative management program whose purpose is to provide protection to the fish of the Bay–Delta estuary through environmentally beneficial changes in SWP [State Water Project] and CVP [federal Central Valley Project] operations…." (CALFED 2000). By virtue of its spatial distribution focused in the Delta and its listing as an endangered species, delta smelt is arguably the most in need of environmental protection, and many of the actions taken under the EWA in the past four years have been on behalf of delta smelt (see presentation by J. Johns, http://science.calwater.ca.gov/pdf/ewa/presentations_110804/EWA_presentation_jjohns_pm_110804.pdf).

The EWA has been operating on the basis of reasonably complete knowledge of water flows and costs, regulations, and numbers of fish salvaged at the export pumping plants, and a limited understanding of the ecology of the fish being protected. Protection of delta smelt using EWA water has taken the form of reductions in export flow at times when the fish are expected to be vulnerable to entrainment. This expectation is based on a decision tree developed from agency scientists' understanding of the biology and movement patterns of delta smelt. Although extensive analysis and gaming have been used to design and refine EWA decision-making, the target of EWA actions in the Delta has generally been reduction in take (entrainment) at the export facilities. To date there has been no quantitative assessment of the likely results of alternative decision processes or the potential population-level effects of EWA actions. Furthermore, there has not been an analysis of the probabilistic nature of risk, nor of the uncertainties involved in the decision tree. Our proposed suite of models offers a methodology for population-level assessment of EWA-like actions on delta smelt.

The need for models

CALFED itself, and the scientific and management community in the CALFED geographic area, have embraced the use of conceptual models as a means of making assumptions, beliefs, and expectations explicit (CALFED 1999). However, progress has been slow in extending these conceptual models into quantitative models. Ecological simulation models in general can be very useful for planning and evaluating restoration actions. Adaptive Management requires the use of models to explore the consequences of alternative actions, and to make predictions of likely outcomes that are then tested in the real world (Walters 1986). Life-cycle models, such as matrix projection models and IBMs, can be useful for placing restorative actions in a population context, and for exploring the benefits of alternative actions. In addition, models have a wide variety of uses in research, such as extending the scope of inference available from field or laboratory data, exploring the consequences of alternative hypotheses, and synthesizing information from multiple studies.

This is an opportune time to develop population models of delta smelt for two reasons. First, the amount of data and knowledge on delta smelt has been accumulating and is now sufficient to build both matrix projection models and IBMs, and to expand and integrate the use of particle-tracking models into these population models. Second, our research team has the expertise and experience to get this modeling effort off the ground and to be successful.

The 2003 EWA delta smelt workshop in Santa Cruz, CA focused on various modeling approaches applicable to delta smelt. Key points of agreement in the workshop included (http://www.science.calwater.ca.gov/pdf/EWA_Delta_Smelt_Workshop.pdf):

1. Knowledge about delta smelt biology is sufficient to proceed with the development of models, and this knowledge would benefit from the organization that the process of modeling brings to bear.
2. It is worthwhile to continue to develop all of the types of models that were discussed at the workshop, including decision trees, particle tracking models, matrix projection models, and IBMs.
3. Modeling is needed in order to evaluate of the population-level effects of EWA and other management actions.

Because delta smelt is a focal point of management, both the modeling and the presentation of analyses of delta smelt biology are subject to intense scrutiny and review. In such a situation, mistrust can arise when some parties are not informed of developments, and are not involved in decisions about what needs to be done. Therefore, a key objective of the 2003 delta smelt workshop was to build trust among various participants and stakeholders. Such trust can develop from creating a transparent process, ensuring collaboration, and maintaining ongoing communication. It is essential for the results of future analytical and modeling efforts to become part of the commonly-held conceptual model of delta smelt and, in particular, of how EWA actions may benefit delta smelt.

Key points where workshop participants did not agree, or agreed that the knowledge is incomplete or inconsistent:

1. The degree and importance of density dependent growth and mortality.
2. The importance of 2-year-old fish to population dynamics and population persistence.
3. The nature of the relationship of delta smelt abundance to freshwater flow.

Modeling provides a systematic framework so that differences are clearly understood, thereby providing a forum for resolving key scientific issues.

The three types of models we propose to develop have a long history of use and are well established as tools for the analysis of populations. Particle tracking models are most useful for investigating spatially-specific processes on short time scales (i.e., those most influenced by the behavior of fish and the actions of managers). Because of their relative simplicity and well-known mathematical properties, matrix projection models have the advantage of compactness and ease of analysis; matrix projection models have long history of development and wide application (e.g., Lefkovitch 1965, Crouse et al. 1987, Caswell 2001). IBMs are a natural extension of matrix projection models in which age or stage classes are further subdivided into individuals. IBMs allow for a natural link between processes at the individual level (e.g., growth) and population characteristics and trajectories (e.g., DeAngelis et al. 1979, Rose and Cowan 1993, DeAngelis and Gross 1995, Rose et al. 1993, 1999a, 1999b). IBMs are especially useful in spatially-explicit situations because of their ease in simulating movement and when local interactions among individuals are important.

PROJECT DESCRIPTION

Our proposed project comprises the development and use of three distinct, but closely linked, types of models that each operate at different levels of resolution (Figure 5). Each model type, which can be a single model or its own suite of models, focuses on a distinct aspect of the modeling domain:

- A particle-tracking model (PTM) will use fine-scale spatial and temporal resolution within a single season (late spring-summer) to examine the movements of delta smelt larvae. The PTM focuses on larvae because of the importance of physical transport to these early life stages (Bennett 2005). The PTM will allow for a detailed examination of movement and vulnerability of delta smelt larvae to export entrainment, and PTM predictions will provide inputs to the matrix projection model and IBM in terms of pumping-related entrainment rates and realistic probabilities of movement from one spatial box to another.
- An individual-based model (IBM) will use a relatively coarse spatial resolution and an intermediate temporal resolution to simulate the long-term (multi-generational) population dynamics of delta smelt. The IBM will focus very closely on the biological details of delta smelt during all of its life stages.
- A series of stage-based matrix projection models will operate at the coarsest scales in time and space to predict critical population-related parameters of delta smelt (e.g., population growth rate). The matrix projection models will allow for easy exploration of the long-term consequences of a large number of alternative management scenarios and alternative assumptions about delta smelt population ecology.

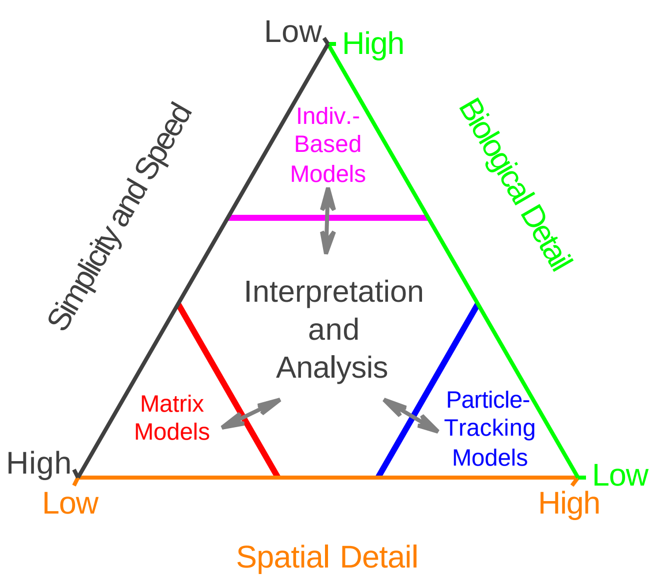


Figure 5. Diagram representing characteristics of the three classes of models included here. As is true of any tool, no model is best at all tasks; therefore the models that maximize each of these characteristics are very different. Thus, the particle-tracking models excel in spatial detail, the IBM in biological detail, and the matrix models in simplicity and speed. The intersection of these models occurs at the level of interpretation and analysis. As computer capabilities and our understanding of the system improve, each of these models can move toward higher levels of organization on all three axes, but the "High" end of each axis will also keep increasing.

Why develop these models separately? That is, why not imbed individual-based models in the particle-tracking model, and run all scenarios with the full model? The answer is that the models are best developed separately, but in close collaboration, because they address different questions and therefore they appropriately operate at different levels of temporal and spatial resolution. Forcing these models into single computer code would hinder their individual development, and potentially raise new numerical and scaling issues about how to simultaneously solve these models. Advances, such as extending the particle tracking model to three spatial dimensions and adding more biology to the IBM as information becomes available, can become cumbersome if the models are imbedded into a single code. Development and testing of any one of our models requires considerable work independent of the details of the other models. Thus, the models will initially be developed as separate codes, and will be linked through the information flow between the modeling groups through a process of collaboration in model development and exploration (Figure 6). Each of the modeling groups requires information from each of the other groups, and from the available external data on delta smelt and on hydrodynamic and other environmental conditions (Table 1, Bennett 2005, Kimmerer 2004). Ultimately, if the models iterate to fairly stable configurations, software is available that could provide a user shell around the separate model codes.

The proposed models will not, and cannot, replace the field investigations needed to determine the proximate effects of management actions. The development of these models will, in fact, result in specific recommendations for future field data collection efforts needed to improve the precision and accuracy of each of these models and to fill in critical data-gaps about delta smelt population biology. Our proposed models will provide useful tools for comparing among alternative conceptual models of delta smelt ecology, placing expected outcomes of management actions in a population context, and comparing outcomes of selected actions to those of alternative actions within the context of natural variation.

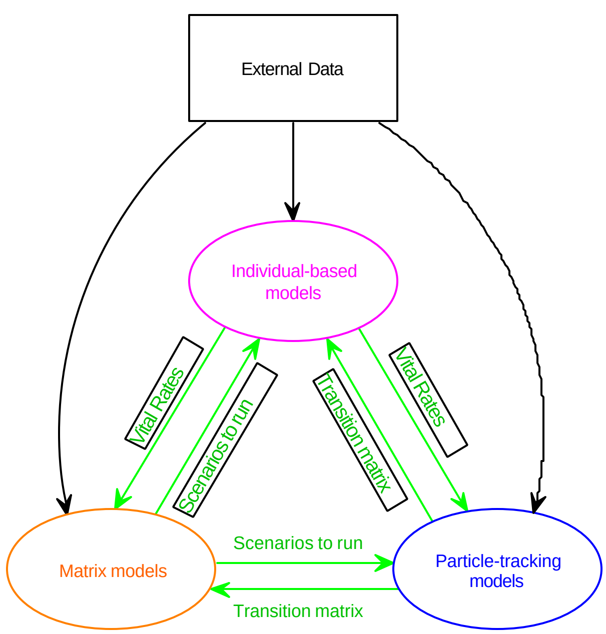


Figure 6. Information flow between modeling components. Each arrow indicates the flow of some information, the most prominent of which is labeled next to the arrow. External data supplies information for use in all models, depending on the degree of specificity of each model.

Particle-tracking models

A fundamental issue underlying the effects on delta smelt of freshwater diversions in the Delta and the value of environmental water (e.g., EWA, VAMP) is how these actions affect changes in water flow patterns. Indeed, the conceptual model of entrainment of delta smelt based on subtidal water balances has formed an important part of the development of flow standards such as those incorporated into the 1994 delta smelt biological opinion. Recent efforts at protecting delta smelt and chinook salmon, using coordinated freshwater releases and pumping reductions paid for by the Environmental Water Account, have assumed that increasing flows seaward across the Delta promote transport of larval fish and eggs into Suisun Bay (Figure 2). We propose to model these transport processes using the Department of Water Resources' (DWR) model called DSM2 (Dynamic Simulation Model [version] 2) and the associated Particle Tracking Model (PTM). We will use the DSM2 and PTM to simulate the transport-related movement of delta smelt larvae in response to freshwater flows and tides. Model predictions will be used to estimate entrainment losses and movement rules for use in the matrix projection models and the IBM.

The key reason for using a spatially-detailed hydrodynamic model like DSM2 to simulate the movement of larval delta smelt is that the combination of energetic tides and the complex braided and multiply-connected geometry of the Delta means that transport by mean flows is strongly altered by dispersion (Fischer et al 1979). The geometry of the Delta varies at spatial scales smaller than a tidal excursion, implying that the dominant dispersion mechanism is likely to be tidal stirring. Tidal stirring is an advective process that must be modeled explicitly, rather than simply parameterized with simple dispersion coefficients (Zimmerman 1986).Thus, sufficient spatial resolution, such as is possible in DSM2, is needed to represent the dispersive process and tidal stirring. A PTM is appropriate because simply inferring long-term transport from Eulerian residual flows can be misleading. Transport over multiple tidal cycles must be modeled as a time-dependent Lagrangian process, for which PTMs are ideally suited. In terms of larval fish transport, it seems likely that these complex circulation patterns yield a form of Lagrangian chaos (Ridderinkhof and Zimmerman 1992) wherein the fate of a given particle (larval fish) is highly sensitive to its initial position and tidal phase.

We note that PTMs have been used previously in the Delta. For example, Arthur et al (1991) carried out modeling studies of striped bass egg and larval transport through the Delta using a hydrodynamic model that assumed that the channels could each be represented by one-dimensional sections joined to one another. This work, which the authors considered preliminary, showed that large changes in inflows and outflows could cause significant changes in the transport of particles through the Delta. More recently, one of the PIs on this proposed project (Kimmerer) has been working with Matt Nobriga of DWR using DSM2 to study the likelihood of entrainment of larval fish (represented purely as passive particles) by the pumping facilities, given a set of hydrologic conditions and the starting location of the particle. We propose to use a similar PTM analysis, but with model configuration and analyses preformed to directly integrate with the matrix projection models and the IBM of delta smelt.

The DSM2 model is a hydrodynamic code developed by DWR that is based on two USGS codes: the 4-Point hydrodynamic code (DeLong 1986, Nader 1993) and the Branched Lagrangian Transport model (Jobson and Schoellhamer 1987). The 4-Point hydrodynamic code is a model for a network of 1-dimensional channels based on the well-known Preissman scheme (e.g., Vreugdenhil 1989). The Branched Lagrangian Transport model uses a Lagrangian scheme identical to that used in a previous PTM applied to the Delta (see Fischer 1979, Gartrell 1993).

Significant effort has already been invested in the calibration of DSM2 to the Delta by variation of the friction and mixing coefficients and by recent upgrading of the bathymetry. The domain of the DSM2 model extends from Benicia in the west and landward to Sacramento on the Sacramento River, and to Vernalis on the San Joaquin River (Figure 2). The DSM2 model now demonstrates an impressive ability to represent tidal stage, flows, and salinities in the Delta (see http://modeling.water.ca.gov/delta/models/dsm2/calval/). The application of the DSM2 to the Delta has been recently published (Culberson et al 2004), the Bay-Delta modeling community has extensive experience with the DSM2 model, and the DSM2 model was recently reviewed by the California Water Environment Forum (see http://www.cwemf.org/1-DReview/default.htm).

In addition to extensive calibration, another advantage of the DSM2 model is that DWR has also developed a particle tracking model (PTM) that moves particles around in the Delta using DSM2-computed velocities (Smith and Bogle 1996, Wilbur 2000). Each particle's position is computed within its channel cross-section based on the effects of turbulent mixing, transverse and vertical velocity variations in a given channel, and prescribed biological behavior (swimming, sinking, or floating). Turbulent mixing is modeled using a random displacement (see Visser 1997), although vertical variations in mixing are not accounted for in the existing version of the model. Vertical and transverse shear are accounted for using simple analytical representations (Bogle 1997). In combination with turbulent mixing, shears lead to enhanced longitudinal dispersion within channel segments via the Taylor shear flow dispersion mechanism (see Fischer et al 1979). Finally, the particles can develop (change from larva to post-larva), changing their physical properties, or they can die.

In our proposed application of the DSM2 model with the PTM we will keep track of two classes of particles: yolk-sac larvae and larger (but shorter than 20mm) feeding larvae. Yolk-sac larvae will be given phototactic behavior, and feeding larvae will be allowed to engage in tidal vertical migration (Kimmerer et al 2002, Bennett et al 2002, Bennett 2005). Typical vertical swimming speeds are unknown, because they depend on the orientation as well as the forward speed of the fish. Various speeds will be tested by comparing predicted vertical distributions with observed vertical distributions (Bennett et al. 2002). Based on our experience with particle tracking models of zebra mussel larvae in the St. Lawrence estuary (Simons 2004, Simons et al submitted), we anticipate using on the order of 10^5 particles. We will attempt to hindcast observed spatial distributions of delta smelt larvae based on the 20 mm larval fish survey (http://www.delta.dfg.ca.gov/data/20mm/) for the 4 years for which the EWA has operated (2001 to 2004). To assess the sensitivity of the modeled spatial distributions to the assumption of a locally uniform vertical mixing coefficient, we will also model vertical distributions of particles with behavior using a 1-dimensional version of the particle tracking code (Simons et al submitted). If the vertical variation in mixing is significant, then we will attempt to modify the PTM to better represent vertical mixing..

We plan on simulating six different hydrologic year-types. Rather than simply using the standard water-year type designations (e.g., critical, dry), we will develop appropriate inflow and export scenarios based on an analysis of the historical data for delta smelt. We will choose year-types defined by flow variations based specifically on the observed responses of the delta smelt population. For each of those 6 hydrologic year-types, we will look at the effects of the Head of Old River Barriers (open or closed) and the VAMP enhancement of San Joaquin flows (on or off), resulting in a total of 24 possible combinations. Additionally, for each of these 24 possible combinations of year-type, open or closed barriers, and on or off VAMP, we will explore the effects of a small set of possible larval behaviors (swimming speeds and relative strength of phototaxis and tidal migration). Based on the initial results of the PTM simulations, we will also use the PTM to simulate alternative operational patterns by the pumping facilities for some or all of these hydrological year-types.

The PTM results will be synthesized in three ways. For use in the matrix models and the IBM, we will first develop estimates of entrainment losses of larval delta smelt due to pumping, and secondly, we will develop transition matrices (i.e., daily probabilities that a yolk-sac and early feeding larva would move between spatial boxes). We note that these estimated probabilities will be adjusted to counter numerical dispersion that can arise from the coarse spatial resolution of the IBM. The third synthesis approach, one that will guide the other two, is that we will construct a Matlab shell with a graphical user interface that will run both the DSM2 model and the PTM and graphically display the results.

In the long-term, we expect that 3-dimensional hydrodynamic models and associated PTMs will eclipse the DSM2 model. Three-dimensional models will evolve as our knowledge increases because the real physics underlying transport is truly 3-dimensional. For example, there is evidence that stratification (e.g., Stacey et al 1999) and channel curvature (Lacy and Monismith 2001) can lead to significant flow variations in all three spatial dimensions. Unfortunately, a 3-dimensional model is not feasible at this time because the needed data are just becoming available and the analyses needed as inputs to the population models would require a significant computational effort. We anticipate that eventually similar analyses as proposed here will be performed using a fully-functional 3-dimensional hydrodynamics and particle-tracking models.

Individual-based models

The IBM will simulate the entire life cycle of the delta smelt. Individual fish will be tracked on a daily basis through the processes of growth, development, mortality, reproduction, and movement (Figure 7). The spatial resolution of the IBM grid will be much coarser than that of the PTM grid, with the IBM using approximately six spatial boxes to represent the estuary (Figure 2). One-year and multi-year simulations of the IBM will be performed for model calibration, corroboration, evaluation of hypotheses and management actions, as well as for comparison to the matrix projection models. Primary model prediction variables include annual values of life stage-specific survival rates, annual egg production, number surviving to 20-mm, total population abundance, population growth rate, and snapshots of delta smelt spatial distributions in the estuary.

The IBM will be formulated starting from the results and suggestions from the 2003 EWA delta smelt workshop that included presentation of a much-simplified initial IBM. We will deal with both structural and parametric uncertainty. For some of the key processes, alternative formulations will be included in the model, and these alternatives will propagated through model simulations resulting in alternative versions of the model. Uncertainty in parameter values will then be superimposed on each version of the model using Monte Carlo methods, resulting in model predictions for each version of the model being expressed as probability distributions. This will allow the effects on model predictions of alternative beliefs about processes and contradictory evidence from field data to be assessed in an objective and quantitative manner.

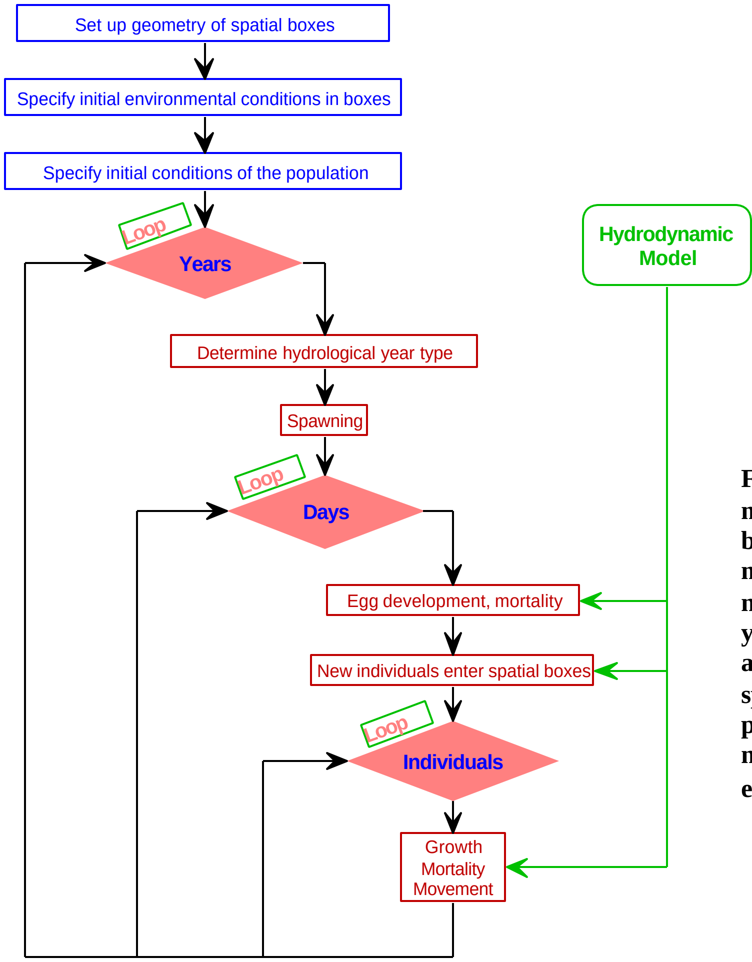


Figure 7. Flow diagram for individual-based model. Boxes in blue are processes that occur before the main model run (but within the model program). Boxes in red occur within the nested set of loops over years, days within years, and individuals. The innermost loop across individuals also encompasses the various spatial boxes. Input from the hydrodynamic / particle-tracking model, shown in green, are not automatic; rather these features will be entered as model parameters.

Processes throughout the life cycle of the delta smelt will developed from available data (Bennett 2005), and from our previous experience developing IBMs of other fish species (e.g., Rose et al. 1999a, b; Letcher et al. 1996; Jager and Rose 2003; Tyler and Rose 1994). Daily growth rates will either be assigned to individuals and then modified by spatial cell (habitat) specific multipliers, or be dynamically simulated using a bioenergetics submodel with an individual's consumption dependent on zooplankton densities. Ontogenetic development will be based on accumulated temperature exposure for the early life stages, and the attainment of certain triggering sizes and ages for older individuals. Daily mortality rate will be specified for each life stage, and then modified by the habitat type of the spatial cell and any assumed changes in external mortality sources (e.g., pumping). Reproduction will involve evaluation of adult smelt at the appropriate time of the year to assess their maturity status and recent growth history. Fecundity will then be determined from body size, and the exact timing and location of the releases of eggs determined by day of the year, hydrological conditions, and water temperatures.

Movement will be a mix of fixed rules and transition probabilities from the simulations of the PTM. Fixed rules will be used to move individuals when physical transport is not the driving force (e.g., migration to spawning grounds, juveniles). The transition probabilities derived from the PTM simulations will be used to move early life stages (yolk-sac and early feeding larvae) around the IBM spatial grid. The PTM and IBM groups together will investigate alternative ways to use the output of the PTM simulations for transition probabilities, as the coarser IBM spatial grid can result in artificial numerical dispersion of individuals in IBM simulations. Some possible alternatives include having a finer spatial grid imbedded in each of the IBM spatial cells strictly for movement tracking, or using a probabilistic approach and the past history of the individuals to modify the transition probabilities from the PTM.

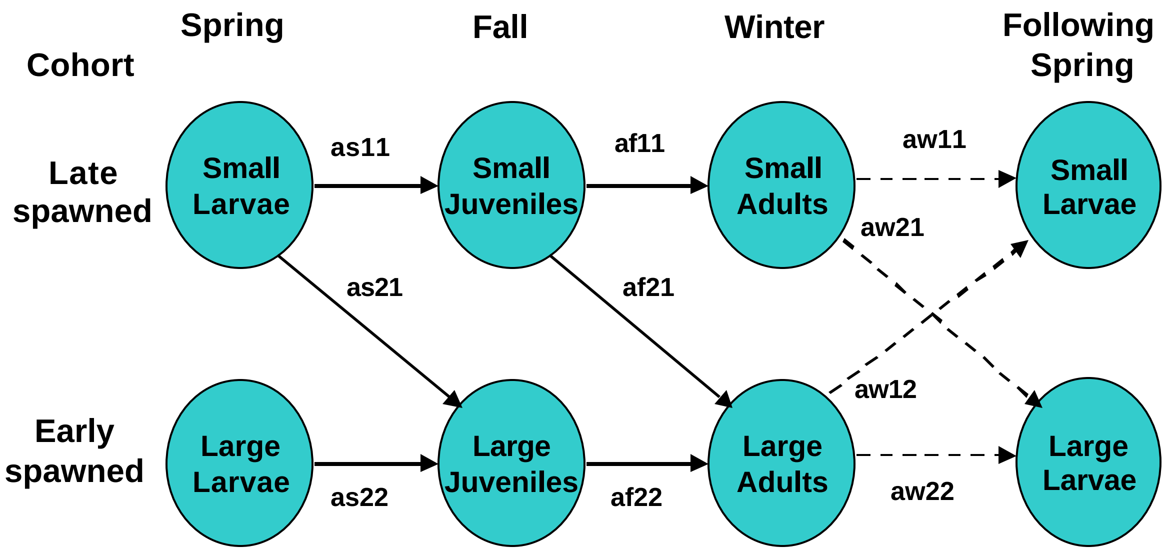
Model calibration, corroboration, and management evaluation will use a mix of one-year and multi-year simulations. Hydrological year types used in the IBM will be discrete, using single hydrological years or synthesized sequences of different hydrological years from those combinations that were simulated by the PTM. We have some evidence for differential year-class success and first-year survival of delta smelt from the ongoing field monitoring data. Model calibration would try as closely as possible to qualitatively replay these conditions using one-year simulations, and we will manually adjust model parameters as needed to obtain the same predicted patterns of survival as observed in the field data. For example, we could simulate the effects of a short and long spawning season (number of days between 15 and 20ºC) to ensure the model predicts similarly higher survival with a longer spawning season as observed in the field data (e.g., 1993 versus 1983, Figure 4). In our model calibration and corroboration we will be looking for general agreement, at least in terms of direction of the responses, between the model and the field data.

Once calibrated and corroborated, the IBM would then be used with multi-year simulations to investigate how changes in life-stage-specific growth, mortality, and movement of delta smelt might affect long-term population dynamics. Model forecasts will include uncertainty due to alternative representations of processes (e.g., density-dependence), due to imprecise parameter values, and due to likely sequences of uncontrollable events (e.g., successive warm summers). IBM simulations will also be performed under conditions that allow comparison of long-term population responses to those predicted by the matrix projection models. IBM model output can be aggregated spatially and over individuals, and averaged over time, to be directly comparable to the predictions of the more aggregated matrix projection models.

As with the matrix projection models, evaluation of management actions would be entered in the IBM as changes in reproduction, growth, movement, or mortality rates. The IBM would not contain explicit inputs with labels that map directly to EWA actions, export flow, or other commonly used management variables. We think that requiring management actions to first be pre-processed and translated into changes in vital rates will reduce the chances for misinterpretation of model predictions. The IBM (and matrix models) is well-suited to predict the effects of changes in vital rates on population dynamics, and thus management simulations are best labeled in terms of changes in vital rates.

Stage-based models

Stage-based matrix projection models (Caswell 2001) will be developed at three different temporal and spatial scales to address several major questions concerning the entire life cycle of delta smelt. These models operate over coarser scales of resolution than the IBM, and examine population responses to survival and fecundity parameters assuming that all individuals in a life-stage are identical and that the vital rates remain constant over time (Caswell 2001). Matrix projection models are relatively easy to construct and allow for rapid evaluation of large number of alternative models and scenarios. Initially, a general model will be scaled to address questions concerning the biology of delta smelt over its entire habitat. A preliminary version of that model has already been developed (Bennett 2005). Second, spatial complexity will be added by dividing this general model into a south Delta-Suisun Bay component and a north Delta-Suisun Bay component, linked by transition probabilities developed from the PTM simulations and by fixed rules. Movement rules will be developed that will be consistent with the movement rules in the IBM. Finally, several versions of these spatially-explicit matrix projection models will be used to examine the effects on long-term population responses due to alternative life history strategies (e.g. a biennial life cycle), density-dependent mortality, and export pumping.



$$\begin{pmatrix} as11 & 0 \\ as21 & as22 \end{pmatrix} \cdot \begin{pmatrix} af11 & 0 \\ af21 & af22 \end{pmatrix} \cdot \begin{pmatrix} aw11 & aw12 \\ aw21 & aw22 \end{pmatrix} = A$$

Figure 8. Periodic stage-based population model composed of three seasonal matrices that follow the fate of two cohorts; a large cohort (spawned early in spring) and a small cohort (spawned later). The model projects these cohorts to the following spring by multiplying the individual seasonal matrices into an aggregate matrix (A).

This sequence of model designs is appropriate for a variety of questions concerning delta smelt ecology and management, and is also useful for guiding the development of the IBM. Stage-based matrix models track the number of individuals in the various life stages. The rates at which individuals move from one life stage to the next will be estimated from information on development, growth, and different sources of mortality (e.g. entrainment, contaminants, poor growth) (Bennett 2004, Table 1). The sensitivity of these models to a range of values for these rates will identify their relative influence on population growth rates, and thus reflect how key life stages may respond to management alternatives. Therefore, once these sensitivities have been established, it will be possible to develop scenarios reflecting events from past years to understand the potential influences of entrainment mortality and use of EWA water on the delta smelt population.

In our proposed project, we will first refine the preliminary stage-based model developed by Bennett (2005). The preliminary model (Figure 8) used a periodic stage-based approach (Caswell 2001) because delta smelt are primarily an annual species for which seasonal processes dominate. This model projects population abundance among years based on the dynamics of three seasonal matrices that roughly represent the spring, fall, and winter periods, tracking the relative survival of early-spawned and late-spawned cohorts. Fish that hatched early were larger than those that hatched later, and survival was assumed to vary in time and to increase with fish size. Initial results showed that population growth rate was relatively robust to changes in export mortality of larvae, but was highly sensitive to small changes in mortality rate of older life stages. These results suggest that export mortality may be easily offset or masked by very small changes in mortality at other life stages. Because of the implications of these results for water export management, they will be carefully reexamined.

Refinement and expansion of the preliminary periodic version of the matrix projection model will involve re-examination of all survival parameter estimates and an exploration of model sensitivity to alternative assumptions about delta smelt biology. In the preliminary model, individuals from the early-spawned cohort were assumed to transition into large juveniles and large adults, and individuals from the late-spawned cohort were assumed to transition into 25% large and 75% small juveniles and adults. Large adults were then assumed to spawn primarily early in the season producing 75% large and 25% small larvae, whereas small adults spawn evenly throughout the season producing 50% large and 50% small larvae. Large adults were also assumed to produce more eggs than small adults. In addition, losses to water export operations were assumed to affect only large (early-spawned) individuals. As many of these model features were based mainly on best judgment, they will be reexamined and alternative configurations will be simulated to understand their consequences for long-term delta smelt population dynamics and the likely magnitude of responses to changes in export mortality.

Approach

We propose this as a 3-year project to allow adequate time to develop and explore behavior of the individual models involved, and to ensure adequate time for investigation of ways to link the models. Products from each component of the project (Table 2) will include papers submitted for publication to professional journals, interim reports in the IEP Newsletter, and oral presentations at the CALFED Science Conference and other national conferences. The principal outcome, however, will be an improved, population-level understanding of the ecology of delta smelt, and a framework for organizing future investigations.

The general scheme calls for parallel work on all three models, with information flowing between the three components as needed (Figure 6). This information flow will be facilitated by frequent meetings of project participants, as well as periodic telephone and email conferences to investigate results and resolve issues.

The development of these models will require contact with the scientists and managers involved with delta smelt management and monitoring to keep them informed of model development and to continually challenge the assumptions of the models. To this end we propose to hold workshops at two points during model development; the first workshop will be held early in the process, and the second workshop will occur after initial formulation and exploration of the models. To the extent possible these workshops will be part of the annual EWA-sponsored workshops on delta smelt.

Table 2. Key personnel, deliverables, and data anticipated by task.

Task	Description	Key Personnel	Deliverables	Data
Each			At least one scientific paper **per task** One paper synthesizing modeling results. One talk per task at the CALFED Science Conference Presentations at other venues.	All data to be provided to the IEP online database within 1 year after submission of papers to scientific journals.
1	Particle Tracking model	Monismith, Hench, Fong	As listed above, plus Report discussing capabilities and limitations of alternative modeling approaches, submitted to CALFED upon project completion, and the MATLAB shell to DSM2.	PTM output summarized as arrays of model output.
2	IBM	Kimmerer, Rose, post-doc	As listed above. The model will be made available.	Data used as input to model
3	Matrix models	Bennett, student	As listed above	Data used as input to model

Task 1: Particle-tracking modeling:

The particle tracking model will be applied by Monismith, Fong, and Hench, with advice from Kimmerer, Bennett, and Rose. Since both the particle tracking and hydrodynamics codes exist, initial efforts will focus on familiarization of the project investigators with the codes, and assembly of appropriate data sets for model development and testing. This includes adapting (if necessary) the PTM to handle the transition of yolk-sac larvae to feeding larvae that have directed movement. We will also develop the appropriate software to map particle positions to exchanges among the spatial boxes represented in the IBM. As part of this effort, we will develop a Matlab shell needed to facilitate viewing of PTM results. We will examine the differences in transport of larvae across the Delta under various combinations of the six different hydrological year-types, on or off barrier operations, on or off VAMP activities, different export pumping levels, and alternative larval behaviors. PTM predictions will be viewed in terms of entrainment losses and transition probabilities of movement for use in the IBM and matrix projection models. The development and analysis of the PTM will be done in close collaboration with Rose, Bennett, and Kimmerer to ensure easy integration of the PTM results with the IBM and matrix projection models.

Task 2: Individual-based modeling:

The IBM will be developed and evaluated by Kimmerer, a post-doctoral student, and Rose, with advice from Bennett and Monismith. The modeling will extend the preliminary IBM presented at the 2003 EWA delta smelt workshop. The data leads and suggestions from the 2003 workshop will be pursued. Depending on the skills of the post-doctoral student, computer coding of the IBM will be done in C, C++, Fortran, or Visual-Basic. Initially, Kimmerer, the post-doctoral student, and Rose will meet to specify a work plan for keeping track of data acquisitions, data analyses, model process formulations and parameter values, and model coding. This work plan will be adapted to changing conditions (e.g., new data, results from other components) as the modeling process proceeds. Model development will be an iterative process that involves repeatedly revisiting the model and continually challenging the assumptions and data interpretations underlying its process formulations.

Task 3: Matrix projection modeling:

The majority of the matrix projection modeling will be done by Bennett and a graduate student, with advice from Rose, Kimmerer, and Monismith. Modeling will extend the preliminary three-season model developed by Bennett (2005). Parameter estimates and model structure will be reexamined using newly available data and information. Particular emphasis will be given to refining the mortality rates assigned to each life stage by careful analysis of available field data. Alternative model structures will be developed by incorporating additional life-history attributes such as a two-year life cycle, density dependent mortality, and environmental stochasticity. Modeled abundances will be projected forward in time to examine long-term dynamics and to compare model sensitivities among life stages and among alternative model structures. A subset of these models will then be further expanded to include explicit spatial regions in order to better accommodate the sources of mortality that are restricted to different areas of the delta smelt habitat (e.g. export pumping by the south Delta facilities). Once these models and their sensitivities have been evaluated, we will develop scenarios reflecting recruitment from past years to understand the potential influences of entrainment mortality and use of EWA water on the delta smelt population. Our overall modeling approach will also be iterative, incorporating refinements to model parameters as new information becomes available, and incorporating information from the PTM (transition probabilities, losses to entrainment) and the IBM (model results, vital rates).

Synthesis:

Synthesis has not been identified as a separate task; rather, we consider it an essential part of each task. We have planned for extensive interactions, both in person and through electronic communications, which will facilitate mutual understanding, information flow, and an ongoing synthesis of results. This synthesis will culminate in a paper to be written jointly by at least one member of each research team, which will likely focus most heavily on the management implications of our modeling results.

Feasibility

The models will be developed as a team effort led by Kimmerer, Bennett, Monismith, and Rose. Wim Kimmerer will be the lead PI, and will have primary responsibility for hiring and supervising a postdoctoral researcher, who will conduct most of the IBM testing and development. Stephen Monismith will direct the particle tracking model work. Bill Bennett will focus mainly on the matrix projection models, supervising a graduate student assistant. Kenneth Rose will work with all of the research teams to provide guidance and help with interpretation, focusing mainly on the IBM.

The feasibility of a research project such as this depends on the capabilities of the participants. All four investigators have experience in modeling fish populations. Rose has extensive experience in quantitative analysis of fish population dynamics and in the development and use of individual-based models Monismith has extensive experience with hydrodynamic modeling and, more specifically, with modeling the interaction between hydrodynamics and the behavior of organisms. Bennett has been constructing matrix projection models of delta smelt and other fish, and is extremely knowledgeable about the biology of the delta smelt. Kimmerer has conducted statistical modeling of various fish populations including delta smelt, has developed several simulation models of Chinook salmon including an IBM, and has synthesized a vast amount of information on the ecology of the San Francisco Estuary. The project team, including research associates at Stanford as well as a post-doctoral associate and student to be identified, is ideally suited to develop this suite of modeling tools.

The bulk of the work will be done at the Bodega Marine Laboratory (Bennett, graduate student), the Romberg Tiburon Center (Kimmerer, post-doctoral student), and Stanford University (Monismith). However, an essential element of a collaborative project such as this is periodic working sessions in which team members can directly interact on developing the models and the products. We request funding to support four meetings at Louisiana State University (Rose) during the course of the project. Two of these meetings will involve everyone, while the other two meetings will involve the postdoctoral student and graduate student traveling to Louisiana State University to work with Rose in model development and interpretation. In addition, we request funds for Rose to meet with the project team four times during the course of the project; additional meetings will be arranged when Rose is in California for other events.

Relation to other projects, current and pending This project does not depend on other projects for successful completion, but one current project and two proposed projects would greatly benefit this one. Bennett has submitted a review paper on delta smelt to San Francisco Estuary and Watershed Science (Bennett 2005); when published, that paper will form much of the basis for the development of the models described in this proposal. Bennett and Kimmerer have submitted a proposal to the ERP for a substantial monitoring effort that emphasizes the feeding, growth, and condition of individual delta smelt. If funded, that project would provide substantial new information about delta smelt dynamics and individual variability that would greatly improve our ability to model the population. In addition, Kimmerer and colleagues are submitting a proposal for work on foodweb support for delta smelt. That project would enable us to extend the description in the IBM of the feeding environment of delta smelt.

Data management

Products will be made available as indicated below; computer codes and files will be made available upon request to any of the project team members. In addition, input and output files will be provided to the IEP data web page no later than 1 year after completion of the manuscripts (Table 2).

Expected Products/Outcomes

Anticipated products include:

1. Developed computer codes will be made available for public use.
2. A report to the CALFED Science Program describing the technological status of models used for the delta smelt, and possibly recommending further model development in future projects.

3. Presentations at the Estuarine Ecology Team, CALFED Science Conference, and at least one national conference during the project.
4. Presentations at annual delta smelt or EWA workshops to apprise the management community of progress. This will also be accomplished through presentations to the Water Operations Management Team and through informal contacts (e.g., during EWA-related meetings).
5. Articles in the IEP Newsletter describing progress.
6. At least four manuscripts submitted to peer-reviewed journals. One of these will be a synthesis of modeling results to be submitted to the online journal San Francisco Estuary and Watershed Science.

PROJECT ORGANIZATION

Management plan

Table 2 lists the tasks and personnel assigned to each task, along with expected deliverables for each task. To an extent the three components are independent, and therefore the leader for each component will be responsible for ensuring that component meets its goals. However, we have also proposed a synthesis paper combining the results of all three components. We believe this is an essential part of the project, in that the synthesis should lead to insights not available from any one component.

Each of the three sub-projects (tasks) is linked to the others through the passing of specific information (Figure 6). In terms of process, this linkage will be largely informal (through email), with meetings of the entire project team at least twice yearly.

The geographic separation of participants in this project does not present any difficulties in project management. The reason is that all PIs are in frequent contact anyway, and we have allocated enough travel time and effort to allow for frequent project meetings.

<u>Note regarding conflicts</u>: Kimmerer is a member of the Ecosystem Restoration Program Science Board, and an advisor on the Environmental Water Account. Rose and Monismith are both on the EWA Review Panel, and Rose is on the CALFE Independent Science Board. None of the participants in this proposal have been involved in development of the PSP or of any of its content, nor will any be involved in evaluation of proposals.

Schedule

The schedule for this project is based on an assumed start date of 1 January 2006. However, our past experience suggests that actual start dates could be greatly delayed (i.e., over a year) by contracting difficulties. Since this project has no seasonal component, it can start at any time, so the scheduled events will be shifted according to the actual start date. Principal milestones are listed in Table 3.

Task 1.- Particle tracking model: We expect to have the hydrological year-types identified, our evaluation of the DMS2 model coupled with the PTM completed, and an initial MATLAB shell developed by the end of year 1 (Table 3). Year 2 will be devoted to simulations of the various combinations of hydrological year-types, export pumping, barrier and VAMP operations, and larval behaviors. Year 3 will allow for improvements to the DMS2 model and the PTM, manuscript preparation, and additional simulations identified by the IBM and matrix projection modeling.

Task 2. -Individual-based model**:** We expect to have a prototype IBM by the end of year 1 of the project, and a 2nd or 3rd generation version (calibrated and corroborated) that reflects significant input and critique of the delta smelt scientific community and a preliminary set of management action simulations by the end of year 2. Year 3 will allow further refinement of the model and model simulations, and final preparation of manuscripts.

Task 3. – Matrix projection models: We expect to have several alternative models by the end of year 1 of the project. In year 2, we will expand a subset of these models to include spatial regions and begin developing scenarios reflecting recruitment from past years. These models will be further refined in year 3, and then manuscripts will be prepared.

Table 3. Schedule based on a start date of 1 January 2006. Dates of events are approximate

Date	All	Task 1: PTM	Task 2: IBM	Task 3: Matrix
1/06	Initial project meeting (CA)	Begin work with DSM2/PTM. Test turbulent mixing effects.	Begin work plan on IBM development and data needs	Begin refinement of seasonal matrix model, and development of alternative models
7/06	Workshop with managers and agency scientists	Draft report of PTM evaluation	Initial IBM description based on the preliminary IBM	Description of progress to refine seasonal matrix model
8/06	Project meeting (LA)	Begin formulation of GUI/output from PTM to bio models.		
12/06	Project meeting (CA)		Complete the coding and code testing of the first generation of the new and updated IBM	Complete set of alternative models to be expanded in year 2.
1/07	First annual report			
3/07	Project meeting (CA)	Complete first iteration of PTM integration with bio models.	Complete calibration and corroboration of the IBM	Begin expanding alternative models to include spatial components
7/07	Workshop with managers and agency scientists	Complete Matlab shell/PTM outputs to bio models. Start production runs of model.	Complete the next generation versions of the IBM based on model performance, workshops, and meetings	Complete set of spatial matrix models
1/08	Second annual report	Complete production runs	Perform a complete set of initial model simulations	Complete model scenarios reflecting past years.
6/08	Project meeting (CA)		Refine and revise the IBM for final simulations	Complete final matrix models
6/08	Draft papers for internal review			
12/08	Papers submitted			

Justification

Delta smelt is now the principal canary in the Delta coal mine. Its listing as an endangered species is unlikely to change soon, given that the latest fall abundance index (2004) was the lowest on record. Much of the protective activity in the Delta, including the EWA and south Delta barriers, focuses largely on delta smelt. At present, these actions are evaluated and selected ad hoc; the effects of these actions are not placed in a population context. Thus, the model proposed here, and other models, are needed to help us make sense of the large amount of data on delta smelt, and to put long-term management on a more secure scientific footing.

The 2003 EWA delta smelt workshop in Santa Cruz focused on modeling needs and approaches. The principal outcome was a strong, consensus recommendation to continue and expand current modeling efforts, including the decision tree model used to guide EWA allocations, particle-tracking modeling in the Delta, matrix projection models, and an IBM.

Our proposed modeling effort combines models that operate at three levels of detail (Figure 5): particle tracking, individual-based, and matrix projection models. These models differ in how they use available data, make different although often overlapping assumptions, and provide different kinds of information to the scientific and management community. The PTM will be used to explore the spatial details of movement, abundance patterns, and entrainment risk of delta smelt larvae, and provide a suitable match to the spatial detail available from the monitoring studies. The matrix projection models will be used to explore numerous scenarios about the effects on long-term population responses of possible alternative assumptions about delta smelt biology. IBM's will be used to explore how various assumptions about the fundamental biology of delta smelt may play out in terms of their population dynamics under changing and multi-factor environmental conditions. We see these models not as competing, but as a complementary suite of tools that together provide a framework for quantitatively examining and synthesizing the population biology of delta smelt. These models are also complementary to the decision tree models presently being used to manage environmental water to benefit delta smelt.

Finally, we reiterate the co-occurring conditions that led us to propose this effort. First is the immense level of expenditure related to delta smelt in terms of money, work, and water, with much less effort devoted to quantifying the biological benefits or the population responses of delta smelt to these management actions. Second is the need for models in order to make maximum use of the huge quantity of data on delta smelt and their habitat; the cost of gathering those data is measured in the tens to hundreds of millions of dollars, and it is appropriate to make the most of them. Last, our project team has the right combination of experience in modeling, investigation of delta smelt biology, and data synthesis to make the most of this opportunity.

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Current Position

Research Professor, Romberg Tiburon Center for Environmental Studies, San Francisco State University.

Education

University of Hawaii, Ph.D. 1980, Biological Oceanography
U.S. Navy Nuclear Power School, 1968.
Purdue University, B.S. 1967, Chemistry

Research and Professional Experience

1994-present	Senior Research Scientist and Research Professor, Romberg Tiburon Center
1986-1995	Senior Scientist, BioSystems Analysis Inc.
1982-1985	Research Fellow, University of Melbourne (Australia), Zoology Dept.
1980-1982	Research Associate/Assistant Director, Hawaii Institute of Marine Biology
1976-1980	Research Assistant, University of Hawaii
1973-1980	Graduate student, University of Hawaii
1972-1973	Flight instructor
1967-1972	U.S. Navy submarine force, final rank Lieutenant

Research Interests

The ecology of estuaries and coastal waters, with emphasis on the San Francisco Estuary. Influence of physical environment including freshwater flow, tidal currents, and turbulence on behavior, movement, and population dynamics of plankton and fish. Predatory control of species composition and abundance of plankton populations. Modeling of ecosystems, populations, and material cycling. Modeling and analyzing salmon populations in California's Central Valley. Human impacts on aquatic ecosystems and the interaction of science and management.

Other Professional Activities

- Member, Strategic Planning Core Team, CALFED Bay-Delta Program, 1998-99
- Co-Chair, Independent Science Board, CALFED Bay-Delta Ecosystem Restoration Program, 2000-present
- Co-founder and President-Elect, California Estuarine Research Society, the newest affiliate society of the Estuarine Research Federation.

- Chair, Estuarine Ecology Team, Interagency Ecological Program for the San Francisco Estuary.
- Member of organizing committee, State of the Estuary Conference, 1997 through 2001
- Advisor to the CALFED Lead Scientist for the Environmental Water Account
- Advisory committee, Georgia Coastal Estuaries LTER Program, J.T. Hollibaugh, PI.
- Invited participant in workshops at the University of Rhode Island (effects of freshwater flow on estuaries), Louisiana Universities Marine Consortium (coastal restoration), and the University of British Columbia (science needs for coastal management).
- Member, Journal Working Group for the Estuarine Research Federation, working to improve the quality of the international journal Estuaries.
- Reviewer for professional journals including Limnology and Oceanography, Marine Biology, Marine Ecology Progress Series, Estuaries, Estuarine, Coastal, and Shelf Science, ICES Journal of Marine Science, Hydrobiologia, Environmental Biology of Fishes.
- Reviewer of grant proposals for the National Science Foundation, EPA, and numerous Seagrant offices.
- Steering committee, Bay-Delta Modeling Forum, 1995-2001
- Co-convenor, CALFED Ecosystem Restoration Program workshop on adaptive management, 2002
- Co-convenor, CALFED Environmental Water Account workshops on salmonids and delta smelt, 2001 and 2003.
- Co-convenor, CALFED workshop on hatchery impacts on Battle Creek, California, 2003.

Recent and Current Students

Keun-Hyung Choi (research associate), Diego Holmgren (post-doc); Heather Peterson, Lenny Grimaldo, Jena Bills, Paola Bouley, John Durand, Renny Talianchich, Allegra Briggs, and Debbie Marcal (all Masters' students).

Selected Publications

Kimmerer, W.J., and A.D. McKinnon. 1987. Growth, mortality, and secondary production of the copepod *Acartia tranteri* in Westernport Bay, Australia. Limnol. Oceanogr. 32:14-28.

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Kimmerer, W., D. Murphy, and P. Angermeier. A landscape-level model of the San Francisco Estuary and its watershed. In press, San Francisco Estuary and Watershed Science

Kimmerer, W.J. Long-term changes in apparent uptake of silica in the San Francisco Estuary. In press, Limnology and Oceanography.

Submitted

Choi, K-H., W. Kimmerer, G. Smith, G.M. Ruiz, and K. Lion. Post-exchange zooplankton in ships ballast water coming to the San Francisco Estuary. Submitted, Biological Invasions

Holmgren, D., K.A. Hieb, and W.J. Kimmerer. Interannual variability in abundance of fish and crustaceans in the San Francisco Estuary. Submitted, Estuaries

Grimaldo, L., W. Kimmerer, and A.R. Stewart. Diets and carbon sources of fishes from open-water, intertidal edge, and SAV habitats in restored freshwater wetlands of the San Francisco Estuary. Submitted, Estuaries

* Available in pdf format at http://online.sfsu.edu/~kimmerer/Files/

In preparation

Kimmerer, W.J. Regime change in an estuarine foodweb responding to an invasive bivalve. In preparation, Proceedings of the National Academy of Sciences

Kimmerer, W.J. S. Bollens, C. Peñalva, and S. Avent. Decade-scale shifts in abundance patterns of the zooplankton of the lower San Francisco Estuary: introductions, floods, and benthic competitors.

Kimmerer, W.J., M.H. Nicolini, N. Ferm, and C. Peñalva. Chronic food limitation in estuarine copepod populations. In preparation, Limnology and Oceanography.

Selected Presentations

Kimmerer, W.J. 2003. Yogi Berra was right: Predicting the effects of climate change on the San Francisco Estuary. Invited, CALFED Science Conference, Sacramento, January 2003.

Kimmerer, W.J. 2003. Ecological lessons from a non-coevolved assemblage of estuarine zooplankton. Third International Symposium on Marine Zooplankton. Gijon, Spain, May 2003.

Kimmerer, W.J. 2003. Physical, Biological, and Management Responses to Variable Freshwater Flow and Diversions in the San Francisco Estuary. Invited, Coastal Restoration and Enhancement through Science and Technology program (CREST) Symposium. Thibodaux, Louisiana, July 2003.

Kimmerer, W.J. 2003. Estuarine zooplankton as ecological filters. Invited, American Fisheries Society Early Life History symposium, Santa Cruz, CA, August 2003.

Kimmerer, W.J. 2003. Paradoxes in the response of zooplankton to freshwater flow in the San Francisco Estuary. Invited, Estuarine Research Federation, Seattle, September 2003.

Kimmerer, W.J. 2004. Ecosystem-level changes following disruption of lower trophic levels by an introduced clam in the San Francisco Estuary. California Estuarine Research Society second annual conference, Bodega Bay, March 2004.

Kimmerer, W.J. 2004. Ecosystem-level changes following foodweb disruption by an introduced clam in the San Francisco Estuary. CALFED Science Conference, Sacramento, October 2004.

Kimmerer, W.J. 2004. Population trends and the influence of restoration actions on winter-run Chinook salmon. Invited, CALFED Science Conference, Sacramento, October 2004.

Kimmerer, W.J. 2004. Assessing the CALFED Bay-Delta Ecosystem Restoration Program: Racing to Catch Up. Invited plenary talk, First National Conference on Ecosystem Restoration, Orlando

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Current Position

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Education

University of California, Davis, Ph.D. 1994, Ecology
University of Massachusetts, Boston, MS 1984, Population Biology
University of Massachusetts, Boston, BS 1980, Biology

Research and Professional Experience

1999-present	Assistant Research Ecologist, U.C. Davis
1994-1999	Post-doctoral Researcher, U.C. Davis
1995	Environmental Protection Specialist, U.S.E.P.A, San Francisco, CA
1991-1994	Post-graduate Researcher, UC-Davis.
1987-1991	Research Assistant, UC-Davis.
1985	Teaching Fellow, Harvard University.
1984-1985	Lecturer, University of Massachusetts, Boston
1982-1984	Teaching Assistant, University of Massachusetts, Boston.
1980-1982	Research Assistant, Harvard University.
1975-1986	Carpenter, Self-employed

Research Interests

The ecology of estuaries and near-shore marine systems, with emphasis on the San Francisco Estuary. Environmental and biological factors influencing the population dynamics and community ecology of fishes. Understanding the population ecology of delta smelt. Distinguishing the relative influences of climate change and human activities on the population dynamics of estuarine and marine fisheries. Applying interdisciplinary approaches to diagnose individual condition and their use in establishing the relative importance of diverse mechanisms on fish populations using qualitative and projection-matrix modeling. Understanding the effects of invasive species on native populations and food webs.

Other Professional Activities

- Scientific Technical Advisor, CALFED Bay-Delta Program
- Member, Estuarine Ecology Team, Interagency Ecological Program for the San Francisco Estuary

Publications

Bennett, W.A. 1990. Scale of investigation and the detection of competition: an example from the house sparrow and house finch introductions in North America. American Naturalist 135: 725-747.

Brown, L.R., P.B. Moyle, W.A. Bennett, and B.D. Quelvog. 1992. Implications of morphological variation among populations of California roach *Lavinia symmetricus* (Cyprinidae) for conservation policy. Biological Conservation 62:1-10.

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Rogers-Bennett, L., W.A. Bennett, H.C. Fastenau, and C.M. Dewees. 1995. Spatial variation in red sea urchin reproduction and morphology: implications for harvest refugia. Ecological Applications 5:1171-1180.

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Rogers-Bennett, L., D.W. Rogers, W.A. Bennett, and T.A. Ebert. 2003. Modeling red sea urchin growth using six growth functions. U.S. Fishery Bulletin 101: 614-626.

Bennett, W.A., K. Roinestad, L. Rogers-Bennett, L. Kaufman, D. Wilson-Vandenberg, B. Heneman. Inverse regional responses to climate change and fishing intensity by the recreational rockfish (*Sebastes*, spp.) fishery in California. In press, Canadian Journal of Fisheries and Aquatic Sciences.

Fujiwara, M., B.E. Kendall, R.M. Nisbet, and W.A. Bennett.. Analysis of size trajectory data using an energetic-based growth model. In press, Ecology

Bennett, W.A. 2004. The Population Ecology of Delta Smelt in the San Francisco Estuary. Submitted to San Francisco Estuary and Watershed Science.

Hobbs, J.A. and J. Burton-Hobbs, and W.A. Bennett. The application of otolith strontium isotope ratios Using MC-LA-ICPMS to determine natal areas for delta smelt (*Hypomesus transpacificus*) in the San Francisco Estuary, USA. Submitted to Journal of Freshwater and Marine Research; 3rd International Otolith Symposium Proceedings.

In preparation

Bennett, W.A., S.J. Teh, S.L. Anderson, J.A. Hobbs. Assessing multiple stressors influencing recruitment of a threatened fish in a modified estuary. MS for Ecological Applications

Kenneth A. Rose

Personal:

Date of birth	27 December 1957
Place of Birth	Oceanside, NY
Nationality	United States
Martial status	Married, 3 children
Address	Coastal Fisheries Institute and Department of Oceanography and Coastal Sciences Louisiana State University Baton Rouge, LA 70803-7503 (225) 578-6346; E-mail: karose@lsu.edu

Education: Ph.D., Fisheries Science, University of Washington, 1985.
M.S., Fisheries Science, University of Washington, 1981.
B.S., Biology and Mathematics, University at Albany, NY, 1979.

Professional Experience:

2001-Present Professor, Coastal Fisheries Institute and Department of Oceanography and Coastal Sciences, Louisiana State University.
1998-2001 Associate Professor, Coastal Fisheries Institute and Department of Oceanography and Coastal Sciences, Louisiana State University.
1987-1998 Scientist, Environmental Sciences Division, Oak Ridge National Lab.
1983-1987 Scientist, Martin Marietta Environmental Systems (now Versar), Columbia, MD.

Adjunct Faculty: Department of Ecology and Evolutionary Biology, University of Tennessee
School of Natural Resources and Environment, University of Michigan
Department of Marine Sciences, University of South Alabama

Selected Professional Activities:

Associate Editor (past and ongoing): Transactions of the American Fisheries Society, Ecological Applications, Environmetrics.
Fellow of the American Association for the Advancement of Science (AAAS).
Speaker of over 35 invited presentations; co-author on over 120 presentations made by others.
Ad-hoc reviewer for over 25 journals.
Current member of: Reef Fish Stock Assessment Panel (Gulf of Mexico Fisheries Management Council), Science Review Panel of the Environmental Water Account (CALFED), Independent Science Board of the CALFED, over 30 graduate student committees.

Recent Research Support (PI or co-PI):

2001-04 Hypoxia and Estuarine Nursery Habitat Quality: An Experimental and Modeling Approach Linking Low Dissolved Oxygen With Fish Survival and Growth, Grant from Joint Delaware, North Carolina, and Louisiana Sea Grant Programs (Regional), $450K ($52K to LSU)

2001-05 Modeling Water Quality Effects on Estuarine Fish Populations. Component of a larger EPA Project entitled "Consortium for Estuarine Ecoindicator Research for the Gulf of Mexico", 5.9 million ($188K to LSU)

2001-04 Comparison of Population Modeling Methods and Development of Life History-Based Screening Criteria. Electric Power Research Institute, $240K

2001-04 Utilizing Bioenergetics and Matrix Projection Modeling to Quantify Population Fluctuations in Long-lived Elasmobranchs. Joint Graduate Fellowship Program in Population Dynamics and Marine Resource Economics, National Sea Grant and National Marine Fisheries Service, $31K (support for a graduate student)

2004-06 Using a Combined Measurement-Modeling Approach to Study Movement and Inshore Nursery Areas by Louisiana Brown Shrimp. Louisiana Sea Grant, $177K

Selected Publications (from a total greater than 90):

Jaworska, J.S., **K.A. Rose**, and L.W. Barnthouse. 1997. General response patterns of fish populations to stress: an evaluation using an individual-based simulation model. *Journal of Aquatic Ecosystem Stress and Recovery* 6:15-31.

Breitburg, D., **K. Rose**, and J. Cowan. 1999. Linking water quality to larval survival: predation mortality of fish larvae in an oxygen-stratified water column. *Marine Ecology Progress Series* 178:39-54.

Rose, K.A., J.H. Cowan, M.E. Clark, E.D. Houde, and S-B Wang. 1999. Individual-based modeling of bay anchovy population dynamics in the mesohaline region of Chesapeake Bay. *Marine Ecology Progress Series* 185:113-132

Railsback, S.F., and **K.A. Rose**. 1999. Bioenergetics modeling of stream trout growth: temperature and food consumption effects. *Transactions of the American Fisheries Society* 128:241-256.

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Rose, K.A. 2000. Why are quantitative relationships between environmental quality and fish populations so elusive? *Ecological Applications* 10: 367-385.

Kimmerer, W., J.H. Cowan, L.W. Miller, and **K.A. Rose**. 2000. Analysis of an estuarine striped bass population: influence of density-dependent mortality between metamorphosis and recruitment. *Canadian Journal of Fisheries and Aquatic Sciences* 57: 478-486.

Cowan, J.H., **K.A. Rose**, and D. DeVries. 2000. Is density-dependent growth in young-of-the-year fishes a question of critical weight? Reviews in Fish Biology and Fisheries 10: 61-89.

Jager, H.I., W.W. Hargrove, C.C. Brandt, A.W. King, R.J. Olson, J.M.O. Scurlock, and **K.A. Rose**. 2000. Constructive model validation on a regional scale. *Ecosystems* 3: 396-411.

Sutton, T.M., **K.A. Rose**, and J.J. Ney. 2000. A model analysis of strategies for enhancing stocking success of landlocked striped bass populations. *North American Journal of Fisheries Management* 20: 841-859.

Clark, M.E., **K.A. Rose**, D.A. Levine, and W.W. Hargrove. 2001. Predicting climate change effects on brook and rainbow trout populations in southern Appalachian streams: combining GIS and individual-based modeling. *Ecological Applications*. 11: 161-178.

Clark, J.S., S. Carpenter, M. Barber, S. Collins, A. Dobson, J. Foley, D. Lodge, M. Pascual, R. Pielke, W. Pizer, C. Pringle, W. Reid, **K. Rose**, O. Sala, W. Schlesinger, D. Wall, and D. Wear. 2001. Ecological forecasts: an emerging imperative. *Science* 293: 657-660.

Rose, KA., J.H. Cowan, K.O. Winemiller, R.A. Myers, and R. Hilborn. 2001. Compensatory density-dependence in fish populations: importance, controversy, understanding, and prognosis. *Fish and Fisheries* 2: 293-327.

Kimmerer,W., J.H. Cowan, L.W. Miller, and **K.A. Rose**. 2001. Analysis of an estuarine striped bass population: effects of environmental conditions during early life. *Estuaries* 24: 557-575.

Rose, K.A., and J.H. Cowan. 2003. Data, models, and decisions in US marine fisheries management: lessons for ecologists. *Reviews for Ecology, Evolution, and Systematics* 34:127-151.

Breitburg, D.L., A. Adamack, **K.A. Rose**, S.E. Kolesar, M.B. Decker, J.E. Purcell, J.E. Keister, JH. Cowan. 2003. The pattern and influence of low dissolved oxygen in the Patuxent River, a seasonally hypoxic estuary. *Estuaries* 26(2A): 280-297.

Jager, Y., and **K.A Rose**. 2003. Designing optimal flow patterns for fall chinook salmon in a Central Valley, California river. *North American Journal of Fisheries Management* 23: 1-21.

Rose, K.A., C.A. Murphy, S.L. Diamond, L.A. Fuiman, and P. Thomas. 2003. Using nested models and laboratory data for predicting population effects of contaminants on fish: a step towards a bottom-up approach for establishing causality in field studies. *Human and Ecological Risk Assessment* 9:231-257.

Haas, H.L., **K.A. Rose**, B. Fry, T.J. Minello, and L.P. Rozas. 2004. Brown shrimp on the edge: linking habitat to survival using an individual-based simulation model. *Ecological Applications* 14:1232-1247.

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Academic History

1977 B.S., Civil Engineering, University of California at Berkeley
1979 M.S., Civil Engineering(Hydraulic Eng.), University of California at Berkeley
1983 Ph.D., Civil Engineering (Hydraulic Eng.), University of California at Berkeley

Professional Experience:

9/99 - present **Professor**, Dept. of Civil and Env Eng., Stanford University.
9/98–6/02 **Resident Fellow**, Robinson House, Stanford University.
9/96-present **Director,** Environmental Fluid Mechanics Laboratory
9/93 – 9/99 **Associate Professor**, Dept. of Civil Eng., Stanford University.
1/87 - 9/93 **Assistant Professor**, Dept. of Civil Eng., Stanford University.
8/83 - 12/86 **Postdoctoral Research Fellow**, Center for Water Res., Univ. of Western Australia. (Supervisor: Prof. J. Imberger)

Honors, Awards and Professional Societies:

Einstein Memorial Fellowship, academic year 1981-1982
NSF Presidential Young Investigator, 1989
Invited Participant, 1991 International Technical Exchange on Hydraulics and Hydrology, Hokkaido, Japan, July 1991.

Professional Service (selected):

Member, Elkhorn Slough Tidal Wetlands Restoration Science Panel 2004-
Member, NOAA SFO Runways Panel 1999
Member CALFED EWA Science Panel 2001-present
Hydrodynamics group chair – CALFED Comprehensive Management and Research Program (CMARP) 1998-1999
Associate Editor (hydrodynamics) Limnology and Oceanography, 1997-2003
Member of Interagency Ecological Program (SF Bay/Delta) Science Advisory Group 1995-
Chair Interagency Ecological Program (SF Bay/Delta) Science Advisory Group 2002-
Member,. Steering Committee, NSF APROPOS workshop to define research directions in Physical Oceanography 1997-1998

Publications (Last Five Years)

Gross, E.S., Koseff, J.R. Koseff, and S.G. Monismith, "Evaluation of advective schemes for estuarine salinity simulations," J. Hyd. Div. ASCE , 125(1), pp. 32-46, 1999.

Gross, E.S., Koseff, J.R. Koseff, and S.G. Monismith, "Three-dimensional salinity simulations in South San Francisco Bay," J. Hyd. Div. ASCE , 125(11), pp. 1199-1209, 1999.

Lucas, L., J.E. Cloern , J.R. Koseff, S.G. Monismith, and J.K. Thompson "Processes governing phytoplankton blooms in estuaries: Part I: The local production-loss balance" Mar Ecol. Prog. Ser.186, pp.1-15, 1999.

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Stacey, M.T., S.G. Monismith, and J.R. Burau "Observations of turbulence in a partially stratified estuary," J. Phys. Oceanog. 29 pp. 1950-1970, 1999.

Stacey, M.T., S.G. Monismith, and J.R. Burau, "Measurements of Reynolds stress profiles in unstratified tidal flow," J. Geophys. Res. (Oceans), 104 (C5) pp. 10933-10949, 1999.

Stacey, M.T.,E.A. Cowen, T.M. Powell, E. Dobbins, E., S.G. Monismith, and J.R.Koseff, ,"Plume dispersion in a stratified, near-coastal flow: measurements and modeling," Cont. Shelf Res., .20, pp.637-663, 2000.

Garg, R.P, J.H. Ferziger, S.G. Monismith and J.R. Koseff, "Stably stratified channel flows. I Stratification regimes and turbulence suppression mechanism," Phys. Fluids. 12(10), 2000.

Stacey, M.T. J.R. Burau, and S.G. Monismith "Creation of residual flows in a partially stratified estuary," J. Geophys. Res (Oceans) 106 (C4) pp. 17013-17038, 2001.

Lacy, J. and S.G. Monismith, "Secondary currents in a curved, stratified channel," J. Geophys. Res (Oceans) 106(C12): 31,283-31,302, 2001.

Brennan, M.L., Schoellhamer, D.H., Burau, J.R. and Monismith, S.G. 2002. "Tidal asymmetry and variability of cohesive sediment transport at a site in San Francisco Bay, California". In: INTERCOH-2000: Fine Sediment Dynamics in the Marine Environment / Ed. by J.C. Winterwerp, C. Kranenburg. Amsterdam u.a.: Elsevier (Proceedings in Marine Science; 5), pp. 93-108.

Ferziger, J.H., J.R. Koseff, and S.G. Monismith , 2002 "Numerical simulation of geophysical turbulence," Computers and Fluids 31: 557-568

Genin, A., G. Yahel, M.A. Reidenbach, S.G. Monismith, and J.R. Koseff (2002) "Intense benthic grazing on phytoplankton in coral reefs revealed using the control voilume approach," Oceanography, 15(2), pp. 90-97.

Monismith, S.G., W. Kimmerer, M.T. Stacey, and J.R. Burau, (2002) "Structure and Flow-Induced Variability of the Subtidal Salinity Field in Northern San Francisco Bay" J. Phys. Ocean, 32(11): 3003-3019.

Monsen, N.E., J.E Cloern, L.V. Lucas, and S.G. Monismith (2002), "A comment on the use of flushing time, residence time, and age as transport time scales," Limnol. Oceanog. 47(5), 1543-1553.

Rueda, F., S.G. Schladow, S.G. Monismith, and M.T. Stacey, "The internal dynamics of a large polymictic lake. Part I: Field observations." J. Hydraulic Eng. 129(2): 82-91, 2003.

Lacy, J. R. and S.G. Monismith "The interaction of lateral baroclinic forcing and turbulence in an estuary" J. Geophys. Res (Oceans) 108(C3) 10.1029/2001JC001105, 2003.

Labiosa, R.G.,K.R. Arrigo, A Genin, S.G. Monismith, and G. van Dijken, "The interplay between upwelling and deep convective mixing in determining the seasonal phytoplankton dynamics in the Gulf of Aqaba: Evidence from SeaWiFS and MODIS." Limnol. Ocean. **48**(6) 2355-2368, 2003

Fong, D.A., and S.G. Monismith, "Evaluation of the accuracy of a ship-mounted, bottom-tracking ADCP in a near-shore coastal flow," J, Atmos. Ocean. Tech., **21**(7): 1121-1128, 2004

Monismith, S.G., and D.A. Fong, "A note on the transport of scalars and organisms by surface waves," Limnol. Ocean. **49**: 1214-1219, 2004

Monismith, S.G. and A. Genin "Tides and sea level in the Gulf of Aqaba (Eilat)" J. Geophys Res (Oceans) 109, C04015, doi:10.1029/2003JC002069, 2004

Holtzman, R., R.Yahel, G.Yahel, M.A. Reidenbach, S.G. Monismith, J.R. Koseff and A. Genin. "Near-bottom depletion of zooplankton over a coral reef: bottom avoidance or actual predation?" Coral Reefs (in press)

Law, A K.W. Ho, W.F. and S.G. Monismith "Double diffusive effect on desalination discharges" ASCE J. Hyd Eng. (in press)

Bricker, J.D., S. Inagaki, and S. G. Monismith. "Bed drag coefficient variability under wind waves in a tidal estuary, ASCE J. Hyd Eng. (in press)

Rueda, F., S.G. Schladow, S.G. Monismith, and M.T. Stacey, "On the effects of topography on wind and the generation of currents in a large multi-basin lake," Hydrobiologica (in press)

Lowe, R.J., J.L. Falter, M.D. Bandet, G. Pawlak, M.J. Atkinson, S.G. Monismith, and J.R. Koseff, Spectral wave dissipation over a barrier reef," J. Geophys. Res. (in press)

Horner-Devine, A.R., D.A. Fong, S.G. Monismith, and T. Maxworthy, "Laboratory experiments simulating a coastal river inflow," submitted to J. Fluid Mech.

Monismith, S.G., A, Genin, M.A. Reidenbach, G. Yahel, and J.R. Koseff, Thermally driven exchanges between a coral reef and the adjoining ocean," submitted to J. Phys. Ocean.

Pidgeon, E.J., S.G. Monismith, and E.A Cowen, "The structure of turbulence induced by a breaking wave," submitted to J. Fluid Mech.

Reidenbach, M.A., J.R. Koseff, S.G. Monismith, J.V. Steinbuck, and A, Genin, "Effects of waves, unidirectional currents, and morphology on mass transfer in branched reef corals", submitted to Limnol. Oceanog

Reidenbach, M.A., S.G. Monismith, J.R. Koseff, G. Yahel , and A, Genin, "Boundary layer turbulence and flow structure over a fringing coral reef", submitted to Limnol. Oceanog

R. Simons, S. Monismith, F. Saucier, L. Johnson, and G. Winkler, "Tidal and Residual Circulation in the Estuarine Transition Zone of the St. Lawrence Estuary: Part 1 Observations", J. Geophys. Res. (in prep)

R. Simons, S. Monismith, F. Saucier, L. Johnson, and G. Winkler, "Tidal and Residual Circulation in the Estuarine Transition Zone of the St. Lawrence Estuary: Part 2 Three Dimensional Modeling", J. Geophys. Res. (in prep)

R. Simons, S. Monismith, F. Saucier, L. Johnson, and G. Winkler, "Zooplankton Retention in the Estuarine Transition Zone of the St. Lawrence Estuary", Limnol. Oceanog. (in prep)

Students

PhD students (finished): Heidi Nepf, Cathy O'Riordan, Mark Stacey, Todd Cowen, Rajat Garg (with J. Ferziger), Lisa Lucas (w. J Koseff), Ed Gross (w. J. Koseff), John Crimaldi (w. J. Koseff), Jenny Zhou (w. J. Ferziger), Emily Pidgeon, Jessica Lacy, Nancy Monsen, Jeremy Bricker, Alex Horner, Matt Brennan,, Rachel Simons, and Matt Reidenbach (w. J. Koseff)
PhD students (current) Jon Burau, Jonah Steinbuck, Sandy Chang, Nicole Jones, Kristen Davis, and Nick Nidzieko
Engineers degree students: Brian McDonald, Shari Kimmel, Satoshi Inagaki, Greg Shellenberger
Postdoctoral students: Todd Cowen, Derek Fong, Jessica Lacy, Alex Horner, Cary Troy, and Jim Hench

Advisors:

Thesis advisor: Hugo B. Fischer (dec.)

Postdoctoral advisor: Jorg Imberger

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RESEARCH INTERESTS

Dynamics of freshwater plumes; mixing processes; transport and mixing processes in stratified estuaries; estuarine and coastal circulation; coastal exchange processes; physical/biological interactions in geophysical flows.

EDUCATION

1998	Ph. D. Physical Oceanography, Massachusetts Institute of Technology/Woods Hole Oceanographic Institution Graduate Joint Program in Oceanography. Thesis: The dynamics of freshwater plumes: observations and numerical modeling of the wind-forced response and alongshore transport of freshwater Advisor: Dr. W. Rockwell Geyer
1992	M. S. Water Resources Engineering, Stanford University. Advisors: Dr. Jeffrey Koseff and Dr. Stephen Monismith.
1991	B. S. Civil Engineering, Stanford University; with distinction.

RESEARCH EXPERIENCE

2001-present	Engineering Research Associate, Stanford University
1998-present	Postdoctoral Research Fellow, Faculty Sponsor: Dr. Stephen Monismith, Stanford University.
1994-1998	Graduate Research Assistant, Advisor: Dr. W. Rockwell Geyer, Woods Hole Oceanographic Institution.
1993	Graduate Research Assistant, Advisor: Dr. Nelson Hogg, Woods Hole Oceanographic Institution.
1991-92	Research Assistant, Advisor: Dr. Stephen Monismith, Stanford University.

TEACHING EXPERIENCE

1999-present	Lecturer, Department of Civil and Environmental Engineering, Stanford University. Taught undergraduate and graduate classes: *Mechanics of Fluids Laboratory*,*Open Channel and Pipe Flows*,*Transport and Mixing in Surface Waters*, *Mechanics of Stratified Fluids*, *Geophysical Fluid Dynamics*.

TEACHING EXPERIENCE (continued)

1999	Senior Lecturer: *Coastal Geophysical Fluid Dynamics*, Friday Harbor Laboratories, University of Washington.
1992	Teaching Assistant: *Open Channel Flows*, Professor Jeffrey Koseff, Stanford University.
1991	Laboratory Instructor: *Laboratory in Engineering Fluid Mechanics*, Department of Civil Engineering, Stanford University.
1989-1990	Course Assistant: *Calculus and Analytic Geometry, Ordinary Differential Equations*, Professor Gregory Brumfiel, Stanford University.

ENGINEERING EXPERIENCE

1991	Civil Engineer, Supervisor: Dr. Ralph Cheng, United States Geological Survey.
1989-1990	Engineering Assistant, Supervisor: Mr. Allen Cuenca, Alameda County Water District.
1991	Passed Engineer-in-Training (EIT) Licensing Exam (California).

PROFESSIONAL SERVICE

Manuscript Reviewer for:

Continental Shelf Research
Dynamics of Atmospheres and Oceans
Estuarine, Coastal, and Shelf Science
Journal of Geophysical Research (Oceans)
Journal of Marine Research
Journal of Marine Systems
Journal of Physical Oceanography
Limnology and Oceanography

Session convener for:

AGU Ocean Sciences, 2004

Proposal Reviewer for:

National Science Foundation
Sea Grant Program

PROFESSIONAL ORGANIZATIONS

Sigma Xi
Tau Beta Pi

HONORS AND AWARDS

1999	Invited Speaker, American Geophysical Union Spring Meeting
1992-1995	National Science Foundation Graduate Fellowship
1992	Brian Kangas Foulk Writing Award
1991	W.B. Dickman Prize for Technical Writing
1991	Frederick E. Terman Engineering Award
1991	Earth Systems Consultants Writing Award
1988-89	William W. Carson Honor Scholarship
1987-1991	National Honor Society Scholarship

REVIEWED PUBLICATIONS

Fong, D.A., and S.G. Monismith, 2004. Evaluation of the accuracy of a ship-mounted, bottom-tracking ADCP in a near-shore coastal flow, *Journal of Atmospheric and Oceanic Technology*, **21**(7), 1121-1128.

Fong, D.A. and M.T. Stacey, 2004. Horizontal disperion of a near bed coastal plume. *Journal of Fluid Mechanics*, **489**,239-267.

Fong, D.A. and W.R. Geyer, 2002. The alongshore transport of freshwater in a surface-trapped river plume. *Journal of Physical Oceanography*,**32**, 957-972.

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Fong, D.A., Geyer, W.R., and R.P. Signell, 1997. The wind-forced response of a buoyant coastal current: Observations of the western Gulf of Maine plume. *Journal of Marine Systems* **12**, 69-81.

Geyer, W.R., Signell R.P., Fong D.A., Wang J., Anderson D.M., Keafer B.P, 2004. The freshwater transport and dynamics of the western Maine coastal current, *Continental Shelf Research*, **24**, 1339-1357.

Horner-Devine, A.R., and D.A. Fong, 2005. The dependence of river plume dynamics and transport on inflow angle, *Journal of Physical Oceanography*, in prep.

Horner-Devine, A.R., D.A. Fong, S.G. Monismith, and T. Maxworthy, 2005. Laboratory experiments simulating a coastal river inflow, *Journal of Fluid Mechanics*, submitted.

Horner, A.R., D.A. Fong, J.R. Koseff, T. Maxworthy, and S.G. Monismith, 2000. The control of coastal current transport. 5th International Symposium on Stratified Flows, International Association of Hydraulic Research, **2**, 865-870.

Monismith, S.G., and D.A. Fong, 2004. A note on the potential transport of scalars and organisms by surface waves, *Limnology and Oceanography*, **49**, 1214-1217.

Monismith, S.G. and D.A. Fong, 1996. A simple model of vertical mixing in a stratified tidal flow, *Journal of Geophysical Research*, **101**, 28583-28595.

REVIEWED PUBLICATIONS (continued)

Monismith, S.G., Fong, D.A., and M.T. Stacey, 1993. A model of mixing in a stratified tidal flow. In Shen, H.W., Su, S.T., and F. Wen, editors, *Hydraulic Engineering '93*, **2**, 725-730.

Musiak, J.D., M.T. Stacey, D. Sereno, T.M. Powell, S.G. Monismith, D.A. Fong, and M. Purcell, 2000. Vertical mixing and horizontal transport in stratified flow at a near coastal site. 5th International Symposium on Stratified Flows, International Association of Hydraulic Research, **2**, 989-994.

Palmarsson, S.O., S. G. Schladow, and D.A. Fong, 2004. Salvaging velocitymeasurements corrupted by nearby instruments, *Limnology and Oceanography: Methods*, accepted for publication

Warrick, J.A. and D.A. Fong, 2004. Dispersal scaling from the world's rivers. *Geophysical Research Letters*, **31**, L04301, doi: 10. 1029/2003GL019114.

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Students: Alex Horner-Devine (with S. Monismith)

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EDUCATION:

Ph.D., Physical Oceanography, University of North Carolina at Chapel Hill, 2002
M.S., Civil Engineering, Stanford University, 1992
B.S., Civil Engineering, North Carolina State University, 1991

PROFESSIONAL EXPERIENCE:

2004 - pres. Post-doc., Environmental Fluid Mechanics Laboratory, Stanford University
2003 - 2004 Post-doc., Institute of Marine Sciences, University of North Carolina at Chapel Hill
1995 - 2002 Res. / Teach. Assist., Dept. Marine Sciences, University of North Carolina at Chapel Hill
1994 - 1995 Teaching Assist., Department of Civil Engineering, University of Washington
1993 - 1994 Research Tech., Institute of Marine Sciences, University of North Carolina at Chapel Hill
1992 - 1993 Research Tech., Civil Engineering Department, North Carolina State University
1991 - 1992 Research Assist., Department of Civil Engineering, Stanford University
1989 - 1991 Research Assist., Civil Engineering Department, North Carolina State University

PUBLICATIONS: (18 total, 15 refereed)

Carr, S. D., J. L. Hench, R. A. Luettich, Jr., R. B. Forward Jr., and R. A. Tankersley, in press. Spatial patterns in the ovigerous blue crab spawning migration: results from a coupled behavioral-physical model. Accepted 06 December 2004 to *Marine Ecology Progress Series*.

Hench, J. L., R. B. Forward Jr., S. D. Carr, D. Rittschof, and R. A. Luettich, Jr., 2004. Testing a selective tidal-stream transport model: observations of female blue crab (*Callinectes sapidus*) vertical migration during the spawning season. *Limnology and Oceanography*, 49 (5): 1857-1870.

Carr, S. D., R. A. Tankersley, J. L. Hench, R. B. Forward Jr., and R. A. Luettich, Jr., 2004. Movement patterns and trajectories of ovigerous blue crabs *Callinectes sapidus* during the spawning migration. *Estuarine Coastal and Shelf Science*, 60 (4): 567-579.

Brix, H., J. L. Hench, H. L. Johnson, T. M. S. Johnston, J. Polton, M. Roughan, and P. Testor, 2003. An international perspective on graduate education in physical oceanography. *Oceanography*, 16 (3): 128-133.

Hench, J. L., and R. A. Luettich, Jr., 2003. Transient tidal circulation and momentum balances at a shallow inlet. *Journal of Physical Oceanography*, 33 (4): 913-932.

Hench, J. L., B. O. Blanton, and R. A. Luettich, Jr., 2002. Lateral dynamic analysis and classification of barotropic tidal inlets. *Continental Shelf Research*, 22 (18/19): 2615-2631.

Moisander, P. H., J. L. Hench, K. Kononen, and H. A. Paerl, 2002. Small-scale shear effects on heterocystous cyanobacteria. *Limnology and Oceanography*, 47 (1): 108-119.

Hench, J. L., and R. A. Luettich, Jr., 2000. Tidal inlet circulation: observations, model skill and momentum balances. *Proc. 6th Conference on Estuarine and Coastal Modeling*, M. L. Spaulding and H. L. Butler (eds.), ASCE, pp. 811-826.

Hench, J. L., J. T. Bircher, and R. A. Luettich, Jr. 2000. A portable retractable ADCP boom-mount for small boats. *Estuaries*, 23 (3): 392-399.

Blanton, J. O., J. Amft, R. A. Luettich, Jr., J. L. Hench, and J. H. Churchill, 1999. Tidal and subtidal fluctuations in temperature, salinity and pressure for the winter 1996 larval ingress experiment - Beaufort Inlet, NC. *Fisheries Oceanography*, 8 (Suppl. 2): 134-152.

Churchill, J. H., R. B. Forward, R. A. Luettich, J. L. Hench, W. F. Hettler, L. B. Crowder, and J. O. Blanton, 1999. Circulation and larval fish transport through a tidally dominated estuary. *Fisheries Oceanography*, 8 (Suppl. 2): 173-189.

Luettich, Jr., R. A., J. L. Hench, C. W. Fulcher, F. E. Werner, B. O. Blanton, and J. H. Churchill, 1999. Barotropic tidal and wind-driven larval transport in the vicinity of a barrier island inlet. *Fisheries Oceanography*, 8 (Suppl. 2): 190-209.

Churchill, J. H., J. O. Blanton, J. L. Hench, R. A. Luettich, Jr., and F. E. Werner, 1999. Flood tide circulation near Beaufort Inlet, North Carolina: implications for larval recruitment. *Estuaries*, 22 (4): 1057-1070.

Hench, J. L., and R. A. Luettich, Jr., 1998. Analysis and application of Eulerian finite element methods for the transport equation, *Proc. 5th Conference on Estuarine and Coastal Modeling*, M. L. Spaulding and A. F. Blumberg (eds.), ASCE, pp. 138-152.

Luettich, Jr., R. A., J. L. Hench, C. D. Williams, B. O. Blanton, and F. E. Werner, 1998. Modeling circulation and larval transport through a barrier island inlet, *Proc. 5th Conference on Estuarine and Coastal Modeling*, M. L. Spaulding and A. F. Blumberg (eds.), ASCE, pp. 849-863.

Benton, S. B., C. J. Bellis, M. F. Overton, J. S. Fisher, J. L. Hench, and R. Dolan, 1997. *North Carolina long term average annual rates of shoreline change: methods report 1992 update.* North Carolina Department of Environment, Health, and Natural Resources, Division of Coastal Management, Raleigh, NC, 42 pages and 14 plates.

Hench, J. L., R. A. Luettich, Jr., J. J. Westerink, and N. W. Scheffner, 1995. ADCIRC: An advanced three-dimensional circulation model for shelves, coasts, and estuaries: Report 6, Development of a Tidal Constituent Database for the Eastern North Pacific. *Technical Report DRP-92-6*, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 60 pages.

Overton, M. F., J. S. Fisher, J. L. Hench and R. Dolan, 1993. 1992 Update of North Carolina annual average shoreline change rates. *Proc. Hilton Head Int. Coastal Sym.*, Per Bruun (ed.), Hilton Head, SC, 249-254.

UNPUBLISHED TECHNICAL REPORTS:

Hench, J. L., 2004. Circulation in Paopao Bay, Moorea, French Polynesia. Annual report for Richard B. Gump South Pacific Research Station, 11 pp. (in French).

Hench, J. L., and R. A. Luettich, Jr., 2000. ADBED: advanced sediment bed change model. Numerical formulation and user's manual. Institute of Marine Sciences, University of North Carolina at Chapel Hill, 20 pp.

Hench, J. L., and R. A. Luettich, Jr., 1999. ADTRANS 2DDI user's manual. Institute of Marine Sciences, University of North Carolina at Chapel Hill, 11 pp.

TEACHING EXPERIENCE:

Spring 2005: Instructor, Fluid Mechanics Laboratory, Stanford University (mostly juniors in engineering)
Spring 1997: TA, Tidal Inlet Circulation, University of North Carolina at Chapel Hill (graduate seminar)
Spring 1996: TA, Modeling Systems Modeling, University of North Carolina at Chapel Hill (mostly first year graduate students)
Spring 1995: TA, Introduction to Fluid Mechanics, University of Washington (mostly juniors in engineering)
Fall 1994: TA, Introduction to Fluid Mechanics, University of Washington (mostly juniors in engineering)

CONFERENCES AND WORKSHOPS ATTENDED: (16 total, plus 1 abstract accepted)

February 2005: ASLO Aquatic Sciences, Salt Lake City, UT (talk, abstract accepted)
October 2004: 3rd CALFED Science Conference, Sacramento, CA (poster)
November 2003: Estuarine and Coastal Modeling VIII, Monterey, CA (talk)
September 2003: Estuarine Research Federation, Seattle, WA (poster)
June 2002: NSF/ONR Physical Oceanogr. Dissertation Sym. I, Breckenridge, CO (talk)
February 2002: AGU/ASLO Ocean Sciences Meeting, Honolulu, HI (talk)
February 2001: ADCIRC Users' Group Meeting, Stennis Space Center, MS (talk)
October 2000: 10th Physics of Estuaries and Coastal Seas, Norfolk, VA (talk)
June 2000: Coastal Inlets Research Program Workshop, Vicksburg, MS (talk)
November 1999: Estuarine and Coastal Modeling VI, New Orleans, LA (talk)
June 1999: 1st Gordon Res. Conf. Coastal Ocean Modeling, Waterville, ME (poster)
October 1997: Estuarine and Coastal Modeling V, Alexandria, VA (talk)
June 1997: 2nd Gordon Research Conf. Coastal Ocean Circulation, Waterville, ME
June 1997: QUODDY Users' Group Meeting, Hanover, NH (talk)
September 1996: 25th International Conference on Coastal Engineering, Orlando, FL
September 1993: Estuarine and Coastal Modeling III, Chicago, IL
June 1993: International Coastal Symposium, Hilton Head, SC (talk)

SEMINARS: (5 total)

January 2005: United States Geological Survey, Menlo Park, CA
July 2004: Gump South Pacific Research Station, University of California, Berkeley

May 2004: Department of Civil and Environmental Engineering, Stanford University
March 2003: Marine Science Institute, University of Texas at Austin
November 2002: Department of Marine Sciences, University of North Carolina at Chapel Hill

PROFESSIONAL AFFILIATIONS, HONORS AND ACTIVITIES:

- Member, American Geophysical Union, 1994 - present
- Member, Estuarine Research Federation, 2000 - present
- Associate Member, American Society of Civil Engineers, 1990 – present
- Member, American Society of Limnology and Oceanography, 2004 – present
- Member, American Shore and Beach Preservation Association, 1995 - present
- Member, Society for Industrial and Applied Mathematics, 1996 - present
- AAUS scientific diver certification (100 ft depth rating), 2001 - present
- Patricia Dortch Memorial Fellowship, 1998
- Ocean Science Bowl (high school students), science judge or moderator, 2000, 2001, 2002, 2003
- Groundhog Day Shadow Mentor (eighth grade students), 2000, 2001
- Supervised summer research project for one high school senior, 1999
- Carteret County Career Fair (Physical Oceanography representative), 1997, 1998

MANUSCRIPTS, BOOKS AND PROPOSALS REVIEWED: (17 total)

Continental Shelf Research, *Estuaries*, *Fisheries Oceanography*, *International Journal for Numerical Methods in Fluids*, *Journal of Coastal Research*, *Journal of Waterway, Port, Coastal, and Ocean Engineering*, *Proc. 5th-8th Conference on Estuarine and Coastal Modeling*, *Association of Southeastern Biologists Bulletin* (book review, Vol. 45 (4): 209-210), Sea Grant, National Science Foundation, Physical Oceanography,

COLLABORATORS:

Rick Luettich (UNC), Hans Paerl (UNC), Harvey Seim (UNC), Niels Lindquist (UNC),
Jack Blanton (SkIO), Jim Churchill (WHOI), Dick Forward (Duke),
Hunter Lenihan (UCSB), Stephen Monismith (Stanford), Jim Leichter (Scripps)

ADVISORS:

Ph.D. advisor: Rick Luettich (UNC)
Post-doc advisor: Stephen Monismith (Stanford)

Modeling The Delta Smelt Population Of The San Francisco Estuary: Signature

The applicant for this proposal must submit this form by printing it, signing below, and faxing it to +1 877-408-9310.

Failure to sign and submit this form will result in the application not being considered for funding. The individual submitting this proposal will receive e-mail confirmation as soon as this signature page has been processed.

The individual signing below declares that:

- all representations in this proposal are truthful;
- the individual signing the form is authorized to submit the application on behalf of the applicant (if applicant is an entity or organization);
- the applicant has read and understood the conflict of interest and confidentiality discussion under the Confidentiality and Conflict of Interest Section in the main body of the PSP and waives any and all rights to privacy and confidentiality1 of the proposal on behalf of the applicant, to the extent provided in this PSP; and
- the applicant has read and understood all attachments of this PSP.

Proposal Title: Modeling the Delta Smelt Population of the San Francisco Estuary
Proposal Number: 2004.01-0106

K Paap 1/06/05

Applicant Signature **Date**

Kenneth R. Paap, Ph.D.
Associate Vice President for Research

SaanFrancisco State University

Printed Name Of Applicant **Applicant Organization**

Help is available: help@solicitation.calwater.ca.gov, +1 877 408-9310

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