SURVIVAL AND MIGRATORY PATTERNS OF CENTRAL VALLEY JUVENILE SALMONIDS

prepared by Klimley, Abbott (Peter) P.

submitted to Science Program 2004

compiled 2005−01−11 12:09:54 PST

Project

This proposal is for the Science Program 2004 solicitation as prepared by Klimley, Abbott (Peter) P..

The submission deadline for this proposal has passed. Proposals may not be changed.

Instructions

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Proposal Title	***SURVIVAL AND MIGRATORY PATTERNS OF CENTRAL VALLEY JUVENILE SALMONIDS***	
Institutions	University of California, Davis NOAA Fisheries, Santa Cruz/Univ. of Calif., Santa Cruz	*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?
− No.
X Yes. Anticipated start date of this effort: ***2005−10−01***

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
X implications of future change on regional hydrology, water operations, and environmental processes
− water management models for prediction, optimization, and strategic assessments
X assessment and monitoring
X salmonid−related projects
− 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
− delta smelt
− longfin smelt
− other species
X 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***
− ***habitat***
− benthos
− channels and sloughs
− flooded islands
− floodplains and bypasses
− oceanic
− reservoirs
− riparian
− rivers and streams
− shallow water
− upland habitat
− vernal pools
− water column
− wetlands, freshwater
− wetlands, seasonal
− wetlands, tidal
− ***human health***
− ***hydrodynamics***
− ***hydrology***
− ***insects***
− ***invasive species / non−native species / exotic species***
− ***land use management, planning, and zoning***
− ***limnology***
− ***mammals***
− large
− small
− ***microbiology / bacteriology***
− ***modeling***
− conceptual
− quantitative
− ***monitoring***
X natural resource management

− ***performance measures***
− ***phytoplankton***
− ***plants***
− ***primary productivity***
− ***reptiles***
− ***restoration ecology***
− ***riparian ecology***
− ***sediment***
− ***soil science***
− ***statistics***
− ***subsidence***
− ***trophic dynamics and food webs***
− ***water operations***
− barriers
− diversions / pumps / intakes / exports
− 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***
− ***water supply***
− demand
− 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.	
− local	ZIP Code:
− regional	ZIP Code: counties:
X system−wide	Survival and migration of juvenile Chinook salmon and steelhead tracked over 500 km along Sacramento River, Grizzly, Suisun, and San Pablo Bays, and along coast both north and south of the mouth of San Francisco Bay.

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.

2004−2006, "Development of a “virtual−cage culture” technology for sea ranching of fishes", PI: Boaz Zion, BARD, $389,000 (Pending).

2004−2000, "Determining the ecological importance of seamounts to pelagic fishes and fisheries in the Gulf of California", Science for Oceans and Coast, David and Lucile Packard Foundation, $41,104.84 (Funded).

2004−2006,"Experimental and field studies to assess pulsed, water−flow impacts on the behavior and distribution of fishes in a Californian river", UC Stream Pulsed Flow Program,$385,529.17 (Funded).

2003−2005, "Biological Assessment of green sturgeon in the Sacramento−San Joaquin watershed", CALFED ERP Program, California, $998,222 (Funded).

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
Tom Quinn, Ph.D.	***University of Washington, School of Aquatic &Fisheries Science***	***(206) 543−9042***	***tquinn@u.washington.edu***	***fish biology, salmon and steelhead***
David Welch, Ph.D.	***Kintama Research***	***(250) 756−7747***	***david.welch@kintamaresearch.org***	***fish biology, salmon and steelhead***
Mary L. Moser, Ph.D.	***NOAA Fisheries, Northwest Fisheries Science Center***	***(206) 860−3351***	***mary.moser@noaa.gov***	***fish biology, salmon and steelhead***
Patrick Rutten	***NOAA Fisheries, Southwest Region***	***(707) 575−6059***	***patrick.rutten@noaa.gov***	***fish management and facilities***

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.)*

We will determine the survival and movement patterns of late−fall Chinook salmon (Oncorhynchus tshawytscha) smolts and steelhead (O. mykiss) smolts as they migrate from the upper Sacramento River, down the mainstem, through the San Francisco Estuary, and into the ocean. These smolts, from Coleman National Fish Hatchery (CNFH) on Battle Creek, will carry individually coded miniature ultrasonic transmitters placed within their peritoneal

cavities. Downstream passage and survival of smolts during outmigration will be recorded by automated, transmitter−detecting monitors placed at sites throughout the watershed and in the coastal ocean to the north and south of the Golden Gate. Data from these monitors will allow us to reconstruct each fish's migratory path and ascertain rates of migration, residence times in specific river segments (reaches), bays, and coastal areas, and ultimately survival (or mortality) rates associated with those locations.

This high−resolution ultrasonic tagging−tracking system will provide a comprehensive evaluation of areas with increased mortality, areas important to the animal's life history (e.g., nursery or holding areas), and changes in survival and movement that may be related to natural factors and water project activities. Data from this project can be used to complete a detailed lifecycle model for Central Valley salmonids, which currently is seriously lacking in knowledge of smolt survival and spatial−temporal migratory patterns. Information on movement and survival of salmonid smolts through the river and Delta is important to many CALFED agencies seeking to improve the biological basis and consequences of water management actions.

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	***University of California, Davis***	*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	***Peter***
Last Name	***Klimley***
Street Address	***2870 Eastman Ln.***
City	***Petaluma***
State Or Province	***CA***
ZIP Code Or Mailing Code	***94952***
Telephone	***(530) 752−5830*** *Include area code.*
E−Mail	***apklimley@ucdavis.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.

Klimley, A. Peter, Ph.D.

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

Full Name	***Klimley, A. Peter, Ph.D.***	example: Wright, Jeffrey R., PhD.
Institution	***University of California, Davis***	*This list comes from the project form.*
Title	***Adjunct Associate Professor***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Task 1a: Will oversee deployment tag−detecting monitors in Sacramento river and San Francisco estuary; Task 3a: Will direct tagging of juvenile steelhead during Yrs 1−3 in headwaters of Sacramento River and analysis of resulting survival and movement data within river, estuary,and ocean environments; Task 4a: Will supervise overall project and ensure proper dissemination of the scientific results of the research project.	
Qualifications		*You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*
Mailing Address	***Dept. Wildlife, Fish, &Cons. Biol., University of California***	
City	***Davis***	
State	***CA***	
ZIP	***95616***	
Business Phone	***(530) 752−5830***	
Mobile Phone	***(707) 481−1547***	
E−Mail	***apklimley@ucdavis.edu***	

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

MacFarlane, R. Bruce, Ph.D.

Full Name	***MacFarlane, R. Bruce, Ph.D.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***NOAA Fisheries, Santa Cruz/Univ. of Calif., Santa Cruz***	*This list comes from the project form.*

Title	***Supervisory Research Fisheries Biologist***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Task 1b: Will deploy array of tag−detecting monitors across the mouth of San Francisco Bay; Task 2b: Will overseee the deployment of three arrays of monitors, two leading offshore north and one leading offshore south of the mouth of San Francisco Bay; Task 3b: Will oversee tagging of juvenile Chinook salmon at headwaters of Sacramento River; Task 4b: Will organize symposium on salmonid survival and movement patterns in North America.	
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.*

Lindley, Steven T., Ph.D.

Full Name	***Lindley, Steven T., Ph.D.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***NOAA Fisheries, Santa Cruz/Univ. of Calif., Santa Cruz***	*This list comes from the project form.*
Title	***Ecologist***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Task 1a: Will deploy array of tag−detecting monitors across the mouth of San Francisco Bay; Task 2b: Will set up three coastal arrays of monitors; Task 3b: Will analyze resulting data from tagged juvenile Chinook salmon on the survival and movement rates within river, estuary, and oceanic environments.	
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.*

Ammann, Arnold J.

Full Name	***Ammann, Arnold J.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***NOAA Fisheries, Santa Cruz/Univ. of Calif., Santa Cruz***	*This list comes from the project form.*
Title	***Research Fisheries Biologist***	*example: Dean of Engineering*
Position Classification	***primary staff***	
Responsibilities	Task 1b: Will deploy array of tag−detecting monitors across the mouth of San Francisco Bay; Task 2b: Will set up three coastal arrays of monitors; Task 3b: Will tag juvenile Chinook salmon in headwaters of Sacramento River.	
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.*

To Be Named (1)

Full Name	***To be named (1)***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Davis***	*This list comes from the project form.*

Title	***Junior Specialist***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Task 1a: Will deploy and maintain tag−detecting monitors in Sacramento River and San Francisco Estuary; Task 3a: Will tag juvenile steelhead trout in headwaters of Sacramento River.	
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.*

To Be Named (2)

Full Name	***To be named (2)***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Davis***	*This list comes from the project form.*
Title	***Graduate Student Researcher I***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Task 1a: Will assist in deployment and maintenance of tag detecting monitors in Sacramento River and San Francisco Estuary; Task 3a: Will assist in tagging juvenile steelhead trout in headwaters of Sacramento River and will analyze data on survival and movement patterns for Ph.D thesis research.	
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.*

Szerlong, Glenn

Full Name	***Szerlong, Glenn***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***NOAA Fisheries, Santa Cruz/Univ. of Calif., Santa Cruz***	*This list comes from the project form.*
Title	***Staff Research Associate III***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities	Task 3b: Will assist in the development of mark−recapture statistical models to assess movement and survival of juvenile salmonids	
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.*

To Be Named (3)

Full Name	***To be named (3)***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***NOAA Fisheries, Santa Cruz/Univ. of Calif., Santa Cruz***	*This list comes from the project form.*
Title	***Lab Assistant III***	*example: Dean of Engineering*
Position Classification	***secondary staff***	
Responsibilities		

	Task 3b: Will be a primary field biologist responsible for tagging juvenile salmonids. Will also assist in the deployment and retrieval of monitors in Tasks 1 &2	
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.*

Kucich, Jennifer L.

Full Name	***Kucich, Jennifer L.***	example: Wright, Jeffrey R., PhD. Leave blank if name not known.
Institution	***University of California, Davis***	*This list comes from the project form.*
Title	***Web Design Engineer***	*example: Dean of Engineering*
Position Classification	***subcontractor***	
Responsibilities	Will create home page, illustrating locations of monitors and enabling viewers to access dates and times of fish detections at these monitors.	
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	University of California, Davis
Submittor	Klimley, Abbott (Peter) P.
Primary Staff	Klimley, A. Peter, Ph.D.
Primary Staff	MacFarlane, R. Bruce, Ph.D.
Primary Staff	Lindley, Steven T., Ph.D.
Primary Staff	Ammann, Arnold J.
Secondary Staff	To be named (1)
Secondary Staff	To be named (2)
Secondary Staff	Szerlong, Glenn
Secondary Staff	To be named (3)
Subcontractor	Kucich, Jennifer L.

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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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
1a	*Maintain inland monitor arrays*	*1*	*36*	*Klimley, A. Peter, Ph.D.* *To be named (1)* *To be named (2)*	Establish and maintain array of tag−detecting monitors in Sacramento River, Grizzly, Suisun, and San Pablo Bay as well in sloughs and rivers flowing into San Francisco Estuary.	Provide records of the passage of juvenile Chinook salmon and steelhead trout every four months; keep database of records.
1b	*Maintain array across mouth of San Francisco Estuary*	*1*	*36*	*MacFarlane, R. Bruce, Ph.D.* *Lindley, Steven T., Ph.D.* *Ammann, Arnold J.*	Establish and maintain array of tag−detecting monitors across the mouth of San Francisco Estuary	Provide records of the passage of juvenile salmonids every six months; keep database of records.
2	*Maintain coastal monitor arrays*	*1*	*36*	*MacFarlane, R. Bruce, Ph.D.* *Lindley, Steven T., Ph.D.* *Ammann, Arnold J.*	Establish and maintain three arrays of tag−detecting monitors north and south of the mouth of the San Francisco Estuary.	Provide records of the passage of juvenile salmonids every six months; keep database of records.
3a	*Tag juvenile steelhead trout*	*3*	*36*	*Klimley, A. Peter, Ph.D.* *To be named (1)* *To be named (2)*	Tag juvenile steelhead trout and analyze data on survival and movement patterns.	Produce scientific publication on survival and movement patterns of juvenile steelhead in San Francisco Estuary.
3b	*Tag juvenile Chinook salmon*	*3*	*36*	*MacFarlane, R. Bruce, Ph.D.* *Lindley, Steven T., Ph.D.* *Ammann, Arnold J.* *Szerlong, Glenn* *To be named (3)*	Tag juvenile Chinook salmon and analyze data on survival of movement patterns	Produce scientific publication on survival and movement patterns of juvenile Chinook salmon in San Francisco Estuary.
4a	*Dissemination of Results*	*1*	*36*	*Klimley, A. Peter, Ph.D.* *Kucich, Jennifer L.*	Prepare seminannual and final reports; maintain web site; and attend local scientific meetings.	Produce seminannual and final reports and either give scientific talks or present posters with results of studies at local meetings.
4b	*Dissemination of Results*	*1*	*36*	*MacFarlane, R. Bruce, Ph.D.* *Lindley, Steven*	Attend local scientific meetings; organize and hold symposium.	Make scientific presentations at local meetings; produce peer−reviewed journal issue devoted to the migratory behavior of salmonids.

				T., Ph.D. *Ammann, Arnold J.*			

Budget

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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 1a, Maintain Inland Monitor Arrays: Labor	Justification	Amount

Klimley, A. Peter, Ph.D.	***422.40 hrs X $37.14 (Yr 1) + 422.40 hrs X $37.14 (Yr 2) + 422.40 hrs X $37.14 (Yr 3)***	***47040***
To Be Named (1)	***844.80 hrs X $14.70 (Yr 1) + 844.80 hrs X $14.70 (Yr 2) + 844.80 hrs X $14.70 (Yr 3)***	***38904***
To Be Named (2)	***422.40 hrs X $13.85 (Yr 1) + 422.40 hrs X $13.85 (Yr 2) + 422.40 hrs X $13.85 (Yr 3)***	***19147***
Task 1a, Maintain Inland Monitor Arrays: Benefits	**Justification**	**Amount**
Klimley, A. Peter, Ph.D.	***26% of salary***	***12230***
To Be Named (1)	***26% of salary***	***10115***
To Be Named (2)	***02% of salary***	***383***
Task 1a, Maintain Inland Monitor Arrays: Travel Expenses	**Justification**	**Amount**
Mileage	***4 trips of 600 miles/trip (2400 miles) for 3 yrs @ $0.37/mile***	***2664***
Meals	***4 trips of 5 days/trip for 3 yrs @ $33.00/day***	***1980***
Lodging	***4 trips of 5 days/trip for 3 yrs @ $70/day***	***4200***
Task 1a, Maintain Inland Monitor Arrays: Supplies And Expendables	**Justification**	**Amount**
Other	***44 X automated tag−detecting monitors @ $1174.39 ea (Yr 1) + 8 X monitors @ $1174.39 ea (Yr 2) + 8 X monitors @ $1174.39 ea (Yr 3)***	***70463***
Other	***44 X temperature loggers @ $127.63 ea (Yr 1) + 8 X loggers @ $127.63 ea (Yr 2) + 8 X loggers @ $127.63 ea (Yr 3)***	***7658***
Other	***34 X river moorings (pyramid anchor, crab−pot buoy, line, ss cable) @ $104.00 ea (Yr 1) + 8 X river moorings @$104.00 ea (Yr 2) + 8 X river moorings @$104.00 ea (Yr 3)***	***5200***
Other	***20 X bay moorings (heavy duty anchor, spherical buoy, line) [2 x yr] @$180 ea (Yr 1) + 20 X bay moorings @$180 ea (Yr 2) + 20 X bay moorings @$180 ea (Yr 3)***	***10800***
Other	***10 X ultrasonic releases for bay moorings @ $1800 ea (Yr 1) + 2 X ultrasonic releases @ $1800 ea (Yr 2) + 2 X ultrasonic releases @ $1800 ea (Yr 3)***	***25200***
Other	***10 X electronic transponders for bay moorings @ $1100 ea (Yr 1) + 2 X ultrasonic transponders @ $1100 ea (Yr 2) + 2 X ultrasonic transponders @ $1100 ea (Yr 3)***	***15400***
Other	***1000 X gal of gasoline+oil for boat operation @$2.50/gal (Yr 1) + 1000 X gal of gasoline+oil @$2.50/gal (Yr 2) + 1000 X gal of gasoline+oil @$2.50/gal (Yr 3)***	***7500***
Other	***Cost share: 40 monitors @ $1174.39 ea ($46,975.60)***	***0***
	Cost share: 44 loggers @ $127.63 ea ($5105.20)	***0***
Task 1a, Maintain Inland Monitor Arrays: Subcontractors	**Justification**	**Amount**
	No subcontractor was assigned to this task.	
Task 1a, Maintain Inland Monitor Arrays: Equipment	**Justification**	**Amount**
20−Ft Design Concepts Patrol/Rescue Boat	***For use deploying and interrogating tag−detecting monitors throughout the San Francisco Estuary***	***38000***
Receiver/Transmitter To Activate Transponder	***Triggers release of buoy and monitor to float to surface for interrogation***	***6000***
Task 1a, Maintain Inland Monitor Arrays: Other Direct	**Justification**	**Amount**
Fee Remission	***3 X quarters tuition fees @ $8406.50 ea (Yr 2) +3 X quarters tuition fees @ $8406.50 ea (Yr 3)***	***27826***
Task 1a, Maintain Inland Monitor Arrays: Indirect (Overhead)	**Justification**	**Amount**
25% Of Salaries, Benefits, Travel, And Supplies10% Of Salaries, Benefits, Travel, And Supplies	***25% X $140,243.91 Yr 1) + 25% X $68,970.12 + 25% X $69,670.25***	***69721***

	Task 1a Total	$420,431
Task 1b, Maintain Array Across Mouth Of San Francisco Estuary: Labor	**Justification**	**Amount**
MacFarlane, R. Bruce, Ph.D.	***Cost Share: 105.6 hr x $51/hr (Yr 1) + 105.6 hr x $53.04/hr (Yr 2) + 105.6 hr x $55.17/hr (Yr 3) = $16813***	***0***
Lindley, Steven T., Ph.D.	***Cost Share: 105.6 hr x $39.42/hr (Yr 1) + 105.6 hr x $41.00/hr (Yr 2) + 105.6 hr x $42.64/hr (Yr 3) = $12996***	***0***
Ammann, Arnold J.	***Cost Share: 105.6 hr x $25.96/hr (Yr 1) + 105.6 hr x $27.00/hr (Yr 2) + 105.6 hr x $28.07/hr (Yr 3) = $8556***	***0***
Task 1b, Maintain Array Across Mouth Of San Francisco Estuary: Benefits	**Justification**	**Amount**
MacFarlane, R. Bruce, Ph.D.	***Cost Share: 24% of salary = $4035***	***0***
Lindley, Steven T., Ph.D.	***Cost Share: 24% of salary = $3119***	***0***
Ammann, Arnold J.	***Cost Share: 24% of salary = $2053***	***0***
Task 1b, Maintain Array Across Mouth Of San Francisco Estuary: Travel Expenses	**Justification**	**Amount**
Mileage	***Cost Share: miles/trip (200 miles) x 2 trips/yr for 3 yrs @ $0.375/mile = z$450***	***0***
Meals	***2 trips of 4 days/trip x 3 people/trip for 3 yrs @ $33.00/day***	***2376***
Lodging	***2 trips of 4 days/trip x 3 people/trip for 3 yrs @ $70/day***	***5040***
Task 1b, Maintain Array Across Mouth Of San Francisco Estuary: Supplies And Expendables	**Justification**	**Amount**
Other	***10 X automated tag−detecting monitors @ $1185.34 ea (Yr 1) + 3 X monitors @ $1185.34 ea (Yr 2) + 3 X monitors @ $1185.34 ea (Yr 3)***	***18965***
Other	***10 X temperature loggers @ $128.82 ea (Yr 1) + 3 X loggers @ $128.82ea (Yr 2) + 3 X loggers @ $128.82 ea (Yr 3)***	***2061***
Other	***20 X bay moorings (heavy duty anchor, spherical buoy, line) [2 x yr] @$180 ea (Yr 1) + 20 X bay moorings @$180 ea (Yr 2) + 20 X bay moorings @$180 ea (Yr 3)***	***10800***
Other	***10 X ultrasonic releases for bay moorings @ $1800 ea (Yr 1) + 2 X ultrasonic releases @ $1800 ea (Yr 2) + 2 X ultrasonic releases @ $1800 ea (Yr 3)***	***25200***
Other	***10 X electronic transponders for bay moorings @ $1100 ea (Yr 1) + 2 X ultrasonic transponders @ $1100 ea (Yr 2) + 2 X ultrasonic transponders @ $1100 ea (Yr 3)***	***15400***
Task 1b, Maintain Array Across Mouth Of San Francisco Estuary: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 1b, Maintain Array Across Mouth Of San Francisco Estuary: Equipment	**Justification**	**Amount**
Receiver/Transmitter To Activate Transponder	***Triggers release of buoy and monitor to float to surface for interrogation***	***6000***
Task 1b, Maintain Array Across Mouth Of San Francisco Estuary: Other Direct	**Justification**	**Amount**
Charter Private Research Vessel To Deploy/Retrieve Monitors	***2 trips/yr x 4 d/trip x 3 yrs x $2000/trip***	***48000***
Task 1b, Maintain Array Across Mouth Of San Francisco Estuary: Indirect (Overhead)	**Justification**	**Amount**
24.4% Of Salaries, Benefits, Travel, Supplies, And Other Direct Costs (UCSC Off−Campus Rate)	***$15668 (Yr 1) + $7763 (Yr 2) + $7763 (Yr 3)***	***31194***
	Task 1b Total	$165,036
Task 2, Maintain Coastal Monitor Arrays: Labor	**Justification**	**Amount**
MacFarlane, R. Bruce, Ph.D.	***Cost Share: 211.2 hr x $51/hr (Yr 1) + 211.2 hr x $53.04/hr (Yr 2) + 211.2 hr x $55.17/hr (Yr 3) = $33627***	***0***

Lindley, Steven T., Ph.D.	***Cost Share: 211.2 hr x $39.42/hr (Yr 1) + 211.2 hr x $41.00/hr (Yr 2) + 211.2 hr x $42.64/hr (Yr 3) = $25991***	***0***
Ammann, Arnold J.	***Cost Share: 316.8hr x $25.96/hr (Yr 1) + 316.8 hr x $27.00/hr (Yr 2) + 316.8 hr x $28.07/hr (Yr 3) = $25669***	***0***
Task 2, Maintain Coastal Monitor Arrays: Benefits	**Justification**	**Amount**
MacFarlane, R. Bruce, Ph.D.	***Cost Share: 24% of salary = $8070***	***0***
Lindley, Steven T., Ph.D.	***Cost Share: 24% of salary = $6238***	***0***
Ammann, Arnold J.	***Cost Share: 24% of salary = $6161***	***0***
Task 2, Maintain Coastal Monitor Arrays: Travel Expenses	**Justification**	**Amount**
Task 2, Maintain Coastal Monitor Arrays: Supplies And Expendables	**Justification**	**Amount**
Other	***30 X automated tag−detecting monitors @ $1185.34 ea (Yr 1) + 6 X monitors @ $1185.34 ea (Yr 2) + 6 X monitors @ $1185.34 ea (Yr 3)***	***49784***
Other	***30 X temperature loggers @ $128.82 ea (Yr 1) + 6 X loggers @ $128.82ea (Yr 2) + 6 X loggers @ $128.82 ea (Yr 3)***	***5410***
Other	***60 X ocean moorings (heavy duty anchor, spherical buoy, line) [2 x yr] @$180 ea (Yr 1) + 60 X ocean moorings @$180 ea (Yr 2) + 60 X ocean moorings @$180 ea (Yr 3)***	***32400***
Other	***30 X ultrasonic releases for ocean moorings @ $1800 ea (Yr 1) + 6 X ultrasonic releases @ $1800 ea (Yr 2) + 6 X ultrasonic releases @ $1800 ea (Yr 3)***	***75600***
Other	***30 X electronic transponders for ocean moorings @ $1100 ea (Yr 1) + 6 X ultrasonic transponders @ $1100 ea (Yr 2) + 6 X ultrasonic transponders @ $1100 ea (Yr 3)***	***46200***
Task 2, Maintain Coastal Monitor Arrays: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 2, Maintain Coastal Monitor Arrays: Equipment	**Justification**	**Amount**
Task 2, Maintain Coastal Monitor Arrays: Other Direct	**Justification**	**Amount**
Charter Private Research Vessel To Deploy/Retrieve Monitors	***2 trips/yr x 14 d/trip x 3 yrs x $2000/trip***	***168000***
Task 2, Maintain Coastal Monitor Arrays: Indirect (Overhead)	**Justification**	**Amount**
24.4% Of Salaries, Benefits, Travel, Supplies, And Other Direct Costs (UCSC Off−Campus Rate)	***$47147 (Yr 1) + $22469 (Yr 2) + $22469 (Yr 3)***	***92085***
	Task 2 Total	$469,479
Task 3a, Tag Juvenile Steelhead Trout: Labor	**Justification**	**Amount**
Klimley, A. Peter, Ph.D.	***633.60 hrs X $37.14 (Yr 1) + 633.60 hrs X $37.14 (Yr 2) + 633.60 hrs X $37.14 (Yr 3)***	***70559***
To Be Named (1)	***1,267.20 hrs X $14.70 (Yr 1) + 1,267.20 hrs X $15.68 (Yr 2) + 1,267.20 hrs X $15.68 (Yr 3)***	***58356***
To Be Named (2)	***897.60 hrs X $13.85 (Yr 1) + 897.60 hrs X $14.93 (Yr 2) + 897.60 hrs X $16.55***	***40688***
Task 3a, Tag Juvenile Steelhead Trout: Benefits	**Justification**	**Amount**
Klimley, A. Peter, Ph.D.	***26% of salary***	***18345***
To Be Named (1)	***26% of salary***	***15173***
To Be Named (2)	***02% of salary***	***814***
Task 3a, Tag Juvenile Steelhead Trout: Travel Expenses	**Justification**	**Amount**
Mileage	***1 trip of 600 miles for 3 yrs @ 0.37/yr***	***666***
	1 trip of 20 days/trip for 3 yrs @ $33.00/day	***1980***

Meals		
Lodging	*1 trip of 20 days/trip for 3 yrs @ $70/day*	*4200*
Task 3a, Tag Juvenile Steelhead Trout: Supplies And Expendables	**Justification**	**Amount**
Other	*200 X coded ultrasonic beacons @ $311.03 ea (Yr 1) + 200 X beacons @ $311.03 ea (Yr 2) + 200 beacons @$311.03 ea (Yr 3)*	*186618*
Other	*Surgical supplies for 3 yrs @ $500/yr*	*15000*
Other	*Graphics and software licenses for 3 yrs @ $1,000/yr*	*3000*
Task 3a, Tag Juvenile Steelhead Trout: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 3a, Tag Juvenile Steelhead Trout: Equipment	**Justification**	**Amount**
Task 3a, Tag Juvenile Steelhead Trout: Other Direct	**Justification**	**Amount**
Task 3a, Tag Juvenile Steelhead Trout: Indirect (Overhead)	**Justification**	**Amount**
25% Of Salaries, Benefits, Travel, And Supplies10% Of Salaries, Benefits, Travel, And Supplies	*25% X $131,774.69 (Yr 1) + 25% X $134,318.25 (Yr 2) + $135,806.02 (Yr 3)*	*100475*
	Task 3a Total	$515,874
Task 3b, Tag Juvenile Chinook Salmon: Labor	**Justification**	**Amount**
MacFarlane, R. Bruce, Ph.D.	*Cost Share: 211.2 hr x $51/hr (Yr 1) + 211.2 hr x $53.04/hr (Yr 2) + 211.2 hr x $55.17/hr (Yr 3) = $33627*	*0*
Lindley, Steven T., Ph.D.	*Cost Share: 422.4 hr x $39.42/hr (Yr 1) + 422.4 hr x $41.00/hr (Yr 2) + 422.4 hr x $42.64/hr (Yr 3) = $51983*	*0*
Ammann, Arnold J.	*Cost Share: 422.4hr x $25.96/hr (Yr 1) + 422.4 hr x $27.00/hr (Yr 2) + 422.4 hr x $28.07/hr (Yr 3) = $34226*	*0*
Szerlong, Glenn	*528.0 hrs X $23.30(Yr 1) + 528.0 hrs X $24.00 (Yr 2) + 528.0 hrs X $24.72 (Yr 3)*	*38027*
To Be Named (3)	*2080 hrs X $14.41 (Yr 1) + 2080 hrs X $14.84 (Yr 2) + 2080 hrs X $15.29 (Yr 3)*	*92653*
Task 3b, Tag Juvenile Chinook Salmon: Benefits	**Justification**	**Amount**
MacFarlane, R. Bruce, Ph.D.	*Cost Share: 24% of salary = $8070*	*0*
Lindley, Steven T., Ph.D.	*Cost Share: 24% of salary = $12476*	*0*
Ammann, Arnold J.	*Cost Share: 24% of salary = $8214*	*0*
Szerlong, Glenn	*25% of salary (UCSC rate)*	*9507*
To Be Named (3)	*25% of salary (UCSC rate)*	*23163*
Task 3b, Tag Juvenile Chinook Salmon: Travel Expenses	**Justification**	**Amount**
Mileage	*1 trip of 600 miles for 3 yrs @ 0.37/yr*	*666*
Meals	*1 trip of 30 days/trip for 2 people for 3 yrs @ $33.00/day*	*5940*
Lodging	*1 trip of 30 days/trip for 2 people for 3 yrs @ $70/day*	*12600*
Task 3b, Tag Juvenile Chinook Salmon: Supplies And Expendables	**Justification**	**Amount**
Other	*200 X coded ultrasonic beacons @ $319.93 ea (Yr 1) + 200 X beacons @ $319.93 ea (Yr 2) + 200 beacons @$319.93 ea (Yr 3)*	*191958*
Other	*Surgical supplies: $1000 yr 1, $500/yr for years 2 &3*	*2000*

Other	***Graphics &analysis software: $1000/yr for 3 yrs***	***3000***
Task 3b, Tag Juvenile Chinook Salmon: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 3b, Tag Juvenile Chinook Salmon: Equipment	**Justification**	**Amount**
Task 3b, Tag Juvenile Chinook Salmon: Other Direct	**Justification**	**Amount**
Task 3b, Tag Juvenile Chinook Salmon: Indirect (Overhead)	**Justification**	**Amount**
24.4% Of Salaries, Benefits, Travel, Supplies, And Other Direct Costs (UCSC Off−Campus Rate)	***$30558 (Yr 1) + $30823 (Yr 2) + $31221 (Yr 3)***	***92602***
	Task 3b Total	$472,116
Task 4a, Dissemination Of Results: Labor	**Justification**	**Amount**
Klimley, A. Peter, Ph.D.	***422.40 hrs X $37.14 (Yr 1) + 422.40 hrs X $37.14 (Yr 2) + 422.40 hrs X $37.14 (Yr 3)***	***47040***
Task 4a, Dissemination Of Results: Benefits	**Justification**	**Amount**
Klimley, A. Peter, Ph.D.	***26% of salary***	***12230***
Task 4a, Dissemination Of Results: Travel Expenses	**Justification**	**Amount**
Mileage	***2 X trips of 200 miles (400 miles) to Santa Cruz for 3 yrs @ $0.37/mile***	***444***
Conferences	***1 X registration for 2 persons for 3 yrs @ $150/registration***	***900***
Task 4a, Dissemination Of Results: Supplies And Expendables	**Justification**	**Amount**
Task 4a, Dissemination Of Results: Subcontractors	**Justification**	**Amount**
Kucich, Jennifer L.	***Create and maintain home page, $2,500 (Yr 1); maintain home page, $1,500 (Yr 2); maintain home page, $1,500 (Yr 3)***	***5500***
Task 4a, Dissemination Of Results: Equipment	**Justification**	**Amount**
Task 4a, Dissemination Of Results: Other Direct	**Justification**	**Amount**
25% Overhead On Subcontract	***$625 (Yr 1) + $375 (Yr 2) + $375 (Yr 3)***	***1375***
Task 4a, Dissemination Of Results: Indirect (Overhead)	**Justification**	**Amount**
25% Of Salaries, Benefits, Travel, And Supplies10% Of Salaries, Benefits, Travel, And Supplies	***25% X $35,884.50 (Yr 1) + 25% X $35,884.50 (Yr 2) + $35,884.50 (Yr 3)***	***26913***
	Task 4a Total	$94,402
Task 4b, Dissemination Of Results: Labor	**Justification**	**Amount**
MacFarlane, R. Bruce, Ph.D.	***Cost Share: 211.2 hr x $51/hr (Yr 1) + 211.2 hr x $53.04/hr (Yr 2) + 211.2 hr x $55.17/hr (Yr 3) = $33627***	***0***
Lindley, Steven T., Ph.D.	***Cost Share: 211.2 hr x $39.42/hr (Yr 1) + 211.2 hr x $41.00/hr (Yr 2) + 211.2 hr x $42.64/hr (Yr 3) = $25991***	***0***
Ammann, Arnold J.	***Cost Share: 422.4hr x $25.96/hr (Yr 1) + 422.4 hr x $27.00/hr (Yr 2) + 422.4 hr x $28.07/hr (Yr 3) = $34226***	***0***
Task 4b, Dissemination Of Results: Benefits	**Justification**	**Amount**
MacFarlane, R. Bruce, Ph.D.	***Cost Share: 24% of salary = $8070***	***0***
Lindley, Steven T., Ph.D.	***Cost Share: 24% of salary = $6238***	***0***
Ammann, Arnold J.	***Cost Share: 24% of salary = $8214***	***0***
Task 4b, Dissemination Of Results: Travel Expenses	**Justification**	**Amount**

Mileage	*2 X trips of 200 miles (400 miles) to Davis for 3 yrs @ $0.37/mile*	*444*
Conferences	*1 X registration for 3 persons for 3 yrs @ $150/registration*	*1350*
Task 4b, Dissemination Of Results: Supplies And Expendables	**Justification**	**Amount**
Task 4b, Dissemination Of Results: Subcontractors	**Justification**	**Amount**
No subcontractor was assigned to this task.		
Task 4b, Dissemination Of Results: Equipment	**Justification**	**Amount**
Task 4b, Dissemination Of Results: Other Direct	**Justification**	**Amount**
International Symposium At UCSC	*To present state−of−the−art salmonid tagging−tracking results; presentations to be published in journal or book*	*9000*
Task 4b, Dissemination Of Results: Indirect (Overhead)	**Justification**	**Amount**
24.4% Of Salaries, Benefits, Travel, Supplies, And Other Direct Costs (UCSC Off−Campus Rate)	*$146 (Yr 1) + $146 (Yr 2) + $2342 (Yr 3)*	*2634*
	Task 4b Total	$13,428
	Grand Total	$2,150,766

− 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 Title: SURVIVAL AND MIGRATORY PATTERNS OF CENTRAL VALLEY JUVENILE SALMONIDS

Co-PIs: A. Peter Klimley, *University of California, Davis*
R. Bruce MacFarlane, Steven T. Lindley, Arnold J. Ammann, *NOAA Fisheries, Santa Cruz* and *University of California, Santa Cruz*

I. Project Goals

A. Purpose

We will determine the survival and movement patterns of late-fall Chinook salmon (*Oncorhynchus tshawytscha*) smolts and steelhead (*O. mykiss*) smolts as they migrate from the upper Sacramento River, down the mainstem, through the San Francisco Estuary, and into the ocean. These smolts, from Coleman National Fish Hatchery (CNFH) on Battle Creek, will carry individually coded miniature ultrasonic transmitters placed within their peritoneal cavities. Downstream passage and survival of smolts during outmigration will be recorded by automated, transmitter-detecting monitors placed at sites throughout the watershed and in the coastal ocean to the north and south of the Golden Gate. Data from these monitors will allow us to reconstruct each fish's migratory path and ascertain rates of migration, residence times in specific river segments (reaches), bays, and coastal areas, and ultimately survival (or mortality) rates associated with those locations.

This high-resolution ultrasonic tagging-tracking system will provide a comprehensive evaluation of areas with increased mortality, areas important to the animal's life history (e.g., nursery or holding areas), and changes in survival and movement that may be related to natural factors and water project activities. Data from this project can be used to complete a detailed lifecycle model for Central Valley salmonids, which currently is seriously lacking in knowledge of smolt survival and spatial-temporal migratory patterns. Information on movement and survival of salmonid smolts through the river and Delta is important to many CALFED agencies seeking to improve the biological basis and consequences of water management actions.

B. Objectives

Our study has two major objectives. The first objective is to describe *reach-specific rates of survival and movement* of juvenile steelhead and Chinook salmon between the upper Sacramento and into the coastal ocean. Our second objective is to explain *variations in these rates in terms of natural and anthropogenic covariates, including reach length, water velocity, water temperature, bank condition and the presence of structures that might attract predators, the magnitude of screened and unscreened water diversions from the reach, and estuarine and ocean conditions (temperature, current velocity, upwelling intensity, etc.).*

II. Project Description

A. Background

1. Central Valley Salmonids

Chinook salmon and steelhead trout were formerly highly abundant and widely distributed throughout the rivers and streams of California's Central Valley. Chinook salmon have been identified as four distinct subpopulations based on differences in spawning run timing, spawning time, former spawning habitat, and the emergence, freshwater residency and ocean entry of juveniles (Fisher, 1994). These Chinook subpopulations have been named as runs based on the season when most adults return to freshwater to spawn: winter, spring, fall, and late-fall (Stone, 1874; Fry, 1961). Of the four salmon runs, the fall run is the most abundant, and heavily supplemented by hatchery production (Fisher, 1994). The late-fall and spring runs exhibit two types of juvenile life-history strategies: ocean-type and stream-type. The ocean-type juveniles spend relatively little time in streams and enter the ocean at a small size [80 mm fork length (FL)]. In contrast, the stream-type juveniles spend several months to over a year in streams and enter the ocean at a large size (120-180 mm FL). These larger stream-type smolts are also called yearlings. Central Valley steelhead are currently recognized only as winter run, although in the past there may have been a summer run of steelhead as well (Needham *et al.*, 1941). Steelhead also vary in freshwater residency and age at ocean entry with some entering the ocean as smaller sub-yearlings and others as larger yearlings or older.

Today, populations are just a fraction of their historical abundance, mainly due to loss of spawning habitat from the construction of dams. Sacramento River winter-run Chinook are classified as endangered under the U.S. Endangered Species Act (ESA) of 1973, with Central Valley steelhead and spring-run Chinook listed as threatened, and Central Valley fall and late-fall run Chinook as candidate species. Current threats to the recovery of these species include continued degradation of remaining spawning and rearing habitat and direct and indirect-mortality caused by water diversions along the Sacramento River and in the Delta.

The San Francisco Estuary is the largest estuary on the west coast of the United States. This estuary drains California's Central Valley from the north by the Sacramento River and from the south by the San Joaquin River. These two rivers converge at the Delta, a freshwater, tidally influenced network of nearly 1,200 km of channels (Kjelson *et al.*, 1982). The Delta is the transfer point of water diversions (exports) from northern California to southern California via two pumping plants; the Central Valley Project (CVP) and the State Water Project (SWP). Downstream of the Delta are a series of three bays, Suisan Bay, San Pablo Bay, and San Francisco Bay. These bays are affected by tidal flows and freshwater outflows. The estuary connects to the ocean at the Golden Gate.

Outmigration Studies. Survival and migration rates of Chinook salmon have been estimated previously in this watershed using mark-recapture data. Marking methods of juveniles included fin clips, spray dye, and coded wire tags (CWT) inserted into nose tissue. As a tagging method CWT have the advantages of being able to tag small fish, the tags are inexpensive, they are retained for the life of the fish, and large numbers of fish can be tagged. *The disadvantages of CWT are that large scale tagging requires expensive specialized equipment, the tagged fish must also have some external mark to alert the surveyor of the presence of the tag (e.g., adipose fin removed), and the tagged fish must be recovered and sacrificed to obtain the information.* Further, CWT can provide information on migration, growth and survival of groups of fish, *but individual fish cannot be followed throughout their migration. And importantly, the time or place of mortality or changes in movement rate cannot be determined.*

Management agencies have mainly used CWT in combination with adipose fin clipping to mark groups of juvenile salmonids released at various locations, then recapture some of these tagged fish through a variety of sampling programs. CWT tagging and recovery efforts have been on going since 1972, with over 40 million individual salmonids tagged. The main focus of these studies has been tests of juvenile release strategies aimed at determining the inland factors most responsible for out-migrant survival (Bailey, 2000).

Juvenile Chinook Survival Rate. Current attempts to generate survival estimates of outmigrating smolts have certain shortcomings. In addition to the drawbacks of CWT methodology described above, two other limitations are the need to sample all possible outmigration pathways and the need to know what proportion of passing smolts are sampled. Survival of outmigrating salmon has been estimated from releases of CWT hatchery-reared juveniles recovered at locations downstream of the release sites (Snider & Titus, 2000; Brandes, 2003). Snider and Titus (2000) estimated survival of hatchery-produced salmonids to Knights Landing ranged from 2.3 to 5.3%. In one study, a total of 854,349 CWT late-fall Chinook juveniles were released from CNFH on Battle Creek, approximately 180 river miles upstream of Knights Landing, with an estimated 19,875 of these juveniles moving past Knights Landing (based on 159 marked fish caught then divided by an estimated trap efficiency of 0.008) for an estimated survival of 2.3%. Unfortunately, these survival estimates are confounded by the fact that during high flow conditions, when most fish are migrating downstream, an unknown proportion of smolts are diverted into the Sutter Bypass upstream of Knights Landing (Snider & Titus, 2000). Also, trap efficiency is variable and affected by factors such as variation in stream discharge. Although this study estimated the sampled proportion of smolts moving past Knights Landing with their gear efficiency experiments, they did not sample all possible outmigration options.

Midwater trawling at Chipps Island does sample at a location where all outmigrating smolts must pass (Brandes, 2003), however, an estimate of the proportion of the migrating smolts caught (i.e., gear efficiency) has not been determined. Thus survival was reported as an index relative to release location. Brandes (2003) compared relative survival of late-fall smolts released at Georgiana Slough (migrating through the central Delta) to those released at Ryde (migrating down the mainstem of the Sacramento) and recovered by midwater trawling at Chipps Island. The survival index was generally lower for those fish that must migrate through the Delta. Brandes and McLain (2001) suggest that the lower survival of Delta-migrating smolts may be due in part to CVP and SWP water export operations in the south Delta, as there is a decrease in survival of CWT smolts released in Georgiana Slough with increasing water exports at the pumping facilities. Although, this study provided valuable information on relative survival rates, it could not provide an estimate of actual survival because of a lack of an estimated of gear efficiency.

Juvenile Chinook Migration Rates. Although some data exist on migration of juvenile Chinook in watersheds north of central California, only two published papers address migration through the Central Valley. The first paper presented a life history description for fall-run juveniles, but emphasis was on fry (<70 mm FL) in the freshwater delta at the head of the estuary (Kjelson *et al.,* 1982). An analysis of CWT data prior to 1980 suggests that smolts move through the Delta quickly, at a rate of 10-18 km/d (Kjelson *et al*., 1981). The second paper (MacFarlane & Norton, 2002) examined physiological development of juvenile Chinook salmon during their migration through the San Francisco Estuary and early residence in the coastal waters of central California. The juvenile Chinook spent about 40 d migrating through the 65 km long San Francisco Estuary (1.6 km/d) based on mean age differences of fish entering the estuary and fish leaving the Golden Gate.

Release and recovery data of CWT salmon can be used to estimate point-to-point migration rates. For example, late-fall CWT smolts released at Battle Creek (river km [rkm] 470) can travel to the Chipps Island recovery site (the eastern end of the San Francisco Estuary; rkm 1) in as little as 5 d or as long as 150 d with an average of 22 d (n = 835, USFWS data 1998-2003, www.delta.dfg.ca.gov/usfws/maps/index.htm). The estimate of mean transit time of 22 d from Battle Creek to the start of the estuary added to the estimate of 40 d through the estuary to the Golden Gate gives a total estimated time of 62 d. This compares well with the very limited ocean recoveries of CWT juvenile late-fall salmon (n = 3) of 73 d to travel from Battle Creek to the Gulf of the Farallones.

Movement data from CWT recoveries can only provide minimum distance traveled estimates. Each fish can only be said to move between two points and the resolution of the points depends on the number and location of recovery sites. Each recovery site requires considerable effort for relatively few recoveries. Individual fish can only be tracked to one recovery site, because fish must be sacrificed to obtain the CWT data. These limitations make application of CWT methodology inappropriate for determining fine-scale migration patterns and for identifying local areas of increased mortality.

Previous tracking of individual smolts fitted with radio-telemetry tags has provided insights into how fish respond to changes in flow caused by water management operations such as the Delta Cross Channel (DCC) or by rapid changes in flow direction caused by tidal influences. A limited study examining these factors tracked radio-tagged Chinook yearling smolts that were released just upstream of the DCC (Okamoto, 2001). Here the DCC gates were open and many fish directly entered the DCC, however, even those fish that migrated past the channel down the river where pulled back into the channel by the effect of the flood tide on flow into the channel. This study demonstrates that fine scale movement patterns are very useful in determining how flows affect movement of fish.

Juvenile Steelhead Survival and Migration Rates. Very little is known about juvenile steelhead survival and migration patterns. Relatively few are caught in juvenile salmon monitoring projects. Steelhead yearlings were collected from Knights Landing rotary screw traps predominantly in January (10%), February (5%) and March (70%) (Snider & Titus, 2000). Data from mid-water trawls at Chipps Island from 1994-1997 show steelhead were caught between October and June, with peak catch in February and March. Length frequency data shows a mode between 160 and 300 mm FL with a peak at 220 mm FL (Brandes *et al.,* 2000). Prior to 1997, it was not possible to distinguish between hatchery and wild produced steelhead, because hatchery steelhead were never marked (Brandes *et al.,* 2000). Since the 1998 mass-marking, adipose fin clipping is now done for most hatchery produced steelhead.

2. Recent Innovations in Tracking Technology

Two recent technological developments have made it feasible to track juvenile salmonids as they migrate throughout watersheds, including rivers, the estuaries, and coastal waters. The first innovation was the development of an individually coded ultrasonic transmitter, miniaturized sufficiently to be implanted within the body cavity of a juvenile salmon and not alter the swimming behavior of the juvenile. The second was the fabrication of low cost and power efficient electronic monitors, which can be moored in a body of water to record the passage of juveniles by detecting an ultrasonic signal propagated by these small internal tags. Throughout the remainder of this proposal we will refer to implanted electronic devices that transmit individually coded signals as tags.

Coded Electronic Tags. Traditionally, radio tags rather than ultrasonic tags have been placed on juvenile salmon. Radio tags were much smaller than ultrasonic tags because less power was needed to transmit a radio versus an ultrasonic signal. The former produce pulse bursts of 1.5 MHz, and these are propagated using little power with an antenna immersed in fresh water. A small battery could confer to the tag an extended life, and this small tag could be carried within the stomach or body cavity of a juvenile salmonid. However, the radio tag has one critical shortcoming, which may eventually be its downfall – the radio signal must be propagated from an antenna, 50-100 mm long, that trails from one end of the tag's cylindrical housing. This antenna either passes out the esophagus (if the tag is implanted within the stomach) or through the epidermis (if the tag is placed within the body cavity) and trails behind the juvenile while swimming. One would expect the tags implanted within the stomach with their antenna passing out the esophagus to hinder food consumption. Indeed,

Fig. 1. V7 tag recently developed by Vemco, Ltd. of Halifax. This miniature tag has a diameter of 7 mm and minimum length of 17.5 mm.

this is true. Forty-eight juvenile Chinook salmon of 114-159 mm FL carrying tags, which were 2.3-5.5% of their body mass, within their stomach grew significantly slower over a period of 54 d than a similar number of salmon carrying tags in their body cavity, as well as fish with surgery but no implanted tags (Adams *et al.*, 1998a). Feeding activity was similar among groups, but the fish with gastrically implanted tags exhibited a coughing behavior and had difficulty retaining swallowed food. Antennas that trail along the side of the body cause additional drag as water flows not only along the sides of the fish but also along the antenna. Tags weighing 2.2-10% of a fish's mass in air were found to decrease the swimming capacity of juvenile Chinook salmon, which were 95-160 cm FL, and these fish were preyed upon nearly three times more often than control fish (Adams *et al.*, 1998b). This result might be expected because the antennas were two to three times the length of the fish. A reduction in antenna length to <1 body length resulted in there being no significant difference between the critical swimming speeds of juveniles with and without radio tags that were 6-12% of their mass, yet the range of the tags was greatly reduced. The mortality of outmigrating juveniles carrying radio tags is characteristically high, and one suspects that this is due to their reduced swimming performance and accompanying vulnerability to predation. For example, radio tags were placed in 46 juvenile Chinook salmon, of which 36 were wild and 10 hatchery-raised, with sizes ranging from 101-117 mm FL that were released in the Stanislaus River during May-July 1998 (Demko *et al.*, 1998). Three of the tagged fish died soon after release, due to the marking procedure, and only five of the remaining 43 juveniles (11.6%) were located 20.5 and 35.3 km downstream of the two release sites. The investigators argued that predators consumed 70% of the smolts.

Ultrasonic tags, conversely, lack an external antenna, and thus are unlikely to influence predation mortality. Yet, until recently, they have been larger than radio tags and their use has been largely confined to adult fishes. The first ultrasonic tags were used on adult salmon (Quinn *et al.*, 1989; Olson and Quinn, 1993), tunas (Holland *et al.*, 1990; Block *et al.*, 1997; Brill *et al.*, 1997, billfish (Holland *et al.*, 1990; Block *et al.*, 1992; Brill *et al.*, 1993), and sharks (Klimley and Nelson, 1984; Carey and Scharold, 1990; Klimley, 1993). The reasons that the tags are larger are twofold. An ultrasonic tag produces a much lower frequency signal than a radio tag, emanating frequencies less than 100 KHz. A piezo-electric transducer (PZT), which is a ceramic ring, must resonate at these lower frequencies to emit periodic pulse bursts. These 'pings' are detected by a hydrophone and receiver. The higher the ultrasonic frequency, the smaller the PZT needed, but at the same time the shorter the range of signal propagation. A PZT with a diameter 25.4 mm resonates at 40 KHz and has a range of 2.5 km at a wave height of zero; a transducer with a 12.7 mm diameter that resonates at 80 kHz has a range of 1.4 km; and a PZT with a diameter of 6.35 mm resonating at 120 kHz has a range of only a few hundred meters (Nelson, 1978; Klimley *et al.*, 1998). Only the smallest PZT could be placed within a juvenile salmon. The solution to this problem has been to drive the PZT off its resonance frequency. The V7 tag developed by Vemco Ltd. of Halifax, Canada, uses a very small PZT with a 6.35 mm diameter that is energized by ultrasonic signals of 69 kHz, a frequency considerably lower than that one's natural resonance, yet the PZT still propagates its signal over a distance of 500 m in water (Fig. 1). The second reason that ultrasonic tags have been larger than radio tags is because more power is required to resonate a PZT than to transmit radio signals from an antenna. This has necessitated the use of larger batteries in ultrasonic tags. However, battery sizes have recently decreased as power density in batteries has increased with the constant improvement of lithium and metal hydride battery technologies. The most important design change, which has resulted in small size, is lengthening the intervals between successive pings. The V7 tag transmits short pulse bursts, which are individually coded, with intervals between pulses ranging from 30- 300 s. The V7 tag is now commonly being implanted into the peritoneum of juvenile salmonids and used in tracking studies worldwide. This tag is being implanted internally in juvenile Chinook to record their migration through the Columbia River estuary (Carl Schreck, pers. commun.) and juvenile sockeye salmon that migrate out of the Fraser River (David Welch, pers. commun.). In the former study, arrays of tag-detecting monitors have been placed across the estuary at multiple sites; in the latter, arrays of monitors have been established across the Straits of Juan de Fuca and extending offshore over the coastal shelf.

Electronic Listening Stations. It is obviously very difficult to follow juveniles, carrying tags, within a boat during their entire migration down the river, through the estuary, and in the coastal waters. The signals of small radio tags are weak, and one would have to drift down the river in a raft, searching for the signal of the radio tags using a receiver and antenna held in air. Similarly, one would follow a similar procedure in searching for an ultrasonic tag, but a hydrophone must be placed underwater to detect the tags. A more viable approach would be to detect the passage of tagged fish by electronic listening devices moored within the river, estuary, and coastal waters. Listening stations are available that receive, de-code, and record ultrasonic as well as radio signals. The advantage of utilizing the former is that ultrasonic monitors are low cost ($1,100 ea) in comparison to radio listening stations ($4,500 ea), and ultrasonic signals can be detected not only in fresh water, but unlike radio signals, also in brackish water of the estuary, and salt water of the coastal zone.

Electronic listening stations (monitors), which detect tags with individually coded ultrasonic signals, have been used mainly to record the tenure of residence of fishes at aggregation sites in the ocean and their propensity to return to these localities (for review, see Klimley *et al.*, 1998). These biotic 'hotspots' are conspicuous geographical features such as seamounts and coral reefs as well as anthropogenic structures such as fish aggregating buoys (FADs). Illustrating this type of relationship is the association of scalloped hammerheads with seamounts, which support large populations of their prey, fish and squid. Multiple hammerhead sharks carrying coded tags could be repeatedly detected during the day by listening devices moored at a seamount, but were not recorded at night (Klimley *et al.*, 1988). Individual sharks were later followed away from the seamount at night and found to forage extensively in the surrounding pelagic waters (Klimley, 1993). Groups of sharks collectively emigrated from the seamount in response to the arrival of cool coastal waters and immigrated upon the return of warm oceanic water (Klimley & Butler, 1988). Monitors were more recently moored at multiple rocky reefs oriented parallel to shore to record the exchange of rockfish between them in order to specify the scale of marine reserves (Starr *et al.*, 2002). The spatial scale, over which these automated monitoring systems are deployed in the ocean, is continuously expanding – the goal of the scientific community is to use them to track the movements of fishes during their long-distance migrations. Monitors have been moored within the last two years along transects leading westward and perpendicular to the shoreline in order to detect juvenile salmon as they migrate along the western coast of North America (David Welch, pers. commun.). Multiple arrays of these monitors now exist in the Straits of Juan de Fuca in British Columbia.

Tag-detecting monitors are now also being used to effectively track the migration of fishes in rivers and lakes. There is an obvious advantage to their use in rivers as the tagged fish often must swim in a narrow channel, and it is forced to swim close to the monitor, well within its detection range. In the last three years, arrays of ultrasonic tag-detecting monitors have been established within rivers along the western coast of North America. Adult green sturgeon are being tracked as they migrate to their spawning grounds in the Rogue (Erickson *et al.*, 2001), Klamath (Turo and McCovey, 2004), and Sacramento Rivers (Klimley, pers. commun), as well as in Willapa Bay

Fig. 2. The VR2 monitor (Vemco Ltd., Halifax) that detects the coded V7 tags, which are small enough to place in juvenile steelhead and late-fall Chinook salmon.

(Langsness, pers. commun.). The movements of adult Chinook salmon (Vincik, pers. commun.) and white sturgeon (Stein, pers. commun) have been tracked with monitors distributed throughout the Delta and the Sacramento River. Finally, juvenile Chinook salmon are being recorded by a cross-wise array of monitors as they move through the mouth of the Columbia. We intend to utilize these electronic monitors placed at strategic locations (nodes) to comprise a large array (network) able to detect the passage of juvenile Chinook salmon and steelhead as they migrate down the Sacramento River, through the San Francisco estuary, and in the coastal waters.

Vemco Ltd. of Halifax, Canada produces a monitor, which is now being widely used by the scientific community (see studies mentioned above). This monitor is capable of identifying V7 tags. The VR2 records the identification number of the tag along with a time stamp. Each monitor consists of a hydrophone, ID detector, data logging memory, and a battery contained in a submersible case (Fig. 2). The monitor is a very small cylinder (60 mm diameter; 340 mm length) that can be easily suspended using a small subsurface buoy from an anchor at the bottom of the river, bay, or nearshore waters. The monitor can remain in place up to 15 months with its lithium D cell power supply before being interrogated of its detections. The data can be removed quickly and easily in the field – without opening its case – by using a magnetic probe and PC interface. A single PC interface can service all monitors, and the system is supplied with Windows compatible software. The unit can record up to 65,000 coded tags, and VR 2 Mbytes of flash memory permits it to record 300,000 detections per deployment. The V7 tags, which are compatible with this monitor, are currently placed on juvenile salmonids in the Columbia River, Washington, and the Fraser River, British Columbia, green sturgeon in the Sacramento, Klamath, and Rogue Rivers and Willapa Bay, and adult Chinook in the Delta Region of the Sacramento/San Joaquin watershed.

A coded V7 tag coming within the range of the VR2 monitor will transmit bursts of pulses of a frequency of 69 kHz and a duration of <3 s that encode the identity of the tag. This is followed by a period of silence (typically 20-45 s) before it repeats. This long silent interval provides ample opportunity for other tags to be detected. The repeat interval is a pseudo random interval so that if the pulse bursts of two tags overlap in time, the next time that they transmit they will be distinct and apart. We have conducted tests to ascertain the distance, at which a monitor will detect a coded tag in the Toe Drain, a canal adjacent to the Yolo Bypass of Sacramento River. Water is passed through this bypass during periods of high flows to keep the water level of the Sacramento low during the winter and spring months. This waterway is 3 m deep and 20 m wide. The monitor was placed within the center of the waterway. We then attached three coded tags to a line suspended from a pole at distances of 0.5, 1.5, and 2.5 m from a knot, which was held at the surface – a weight below the last tag kept the line straight in the water. All three tags were detected at a distance of 150 m, but not at the next distance of 200 m in the center of the channel. The surface and midwater tags were detected along the side of the channel – all three tags were detected at a distance of 100 m.

The number of times that a monitor would detect a tagged juvenile can be determined as it migrates down the river based on the juvenile's rate of speed, the pulse burst interval, and the range of the monitor. Juvenile salmon have a sustained swimming rate of 0.25 m/s (Joe Cech, Jr., person. commun.). It would take the juvenile 800 s to swim over the distance 100 m before and after the receiver, where it is detectable based on the above described range tests -- 200 m / 0.25 m/s. The monitor would be able to detect the juvenile 6.7 times, if the tag were to propagate it signal at the 120 sec, the longest pseudo-random intervals between pulses. Even at speeds of 4-5 knots, the maximum tidal currents in the Bay-Delta system, pulse intervals as long as 120 sec would be easily detected by the monitors. There would be an ample opportunity to detect the juvenile as it passes the monitor during its migration down the river. The range of the monitors in the open ocean is farther because of the greater depth. There is less absorption of the energy as the signals reflect off the bottom and surface and greater range of detection. Range tests have been conducted in the Columbia River for V7 tags, and the monitors detected juveniles at a distance of 500 m from the monitor (Carl Schreck, unpubl. manus.). Given this range, it would take the juvenile 4000 sec to pass through the diameter of the reception sphere – 1000 m / 0.25 – and the tag could be detected 33 times.

B. Proposed Project

1. Conceptual Model of the Study

Our study can be viewed as a classical mark-recapture experiment with multiple marking and recapture locations and complete capture histories (Burnham *et al.,* 1987). Fish are "marked" with uniquely coded ultrasonic transmitters and "recaptured" by the monitors. The pattern of recaptures allows the estimation of reach-specific survival rates and the probabilities of detection at each monitor site with a statistical model of the mark-recapture data set. A schematic representation of the study is shown in Fig. 3, following the notation and conceptualization of Burnham *et al.* (1987). Fish are tagged and released in groups at the upper-most site (spread over several days). They are then detected at the various monitor locations downstream and, in the parlance of mark-recapture models, fish detected at a downstream site are considered recaptured and re-released at that site (importantly, note that the fish are not actually handled in our study, unlike the classical studies based on visual tagging). The data are tabulated in terms of releases by site and the initial capture following release. In our study, we expect the vast majority of initial recaptures to be at the next site downstream because of the high probability of detecting the ultrasonic tags as they pass by.

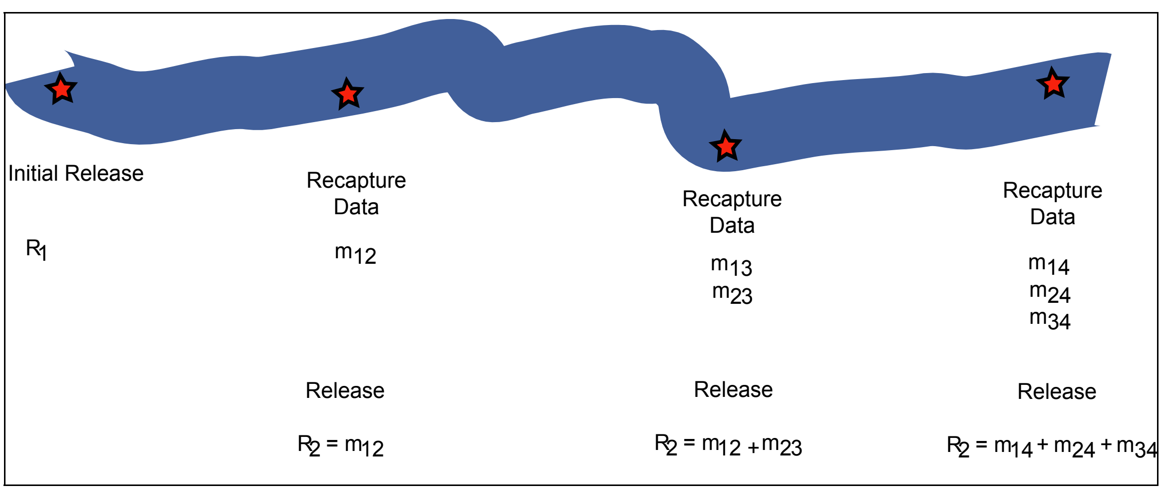

Fig. 3. Conceptual model of study design. The wide blue line represents the river and the stars indicate location of monitors. The actual study has many more receiver locations. The patterns of releases and detections (the R_i's and m_{ij}'s, equivalent in our study design following the initial release) are sufficient (statistically) for estimating survival and detection probabilities.

The river reaches between receiver sites will be characterized in terms of habitat attributes such as amount of riparian cover, the amount of rip-rap along the banks, number of unscreened diversions, and water temperature. The reach-specific survival rates will be modeled as appropriate nonlinear functions of these covariates and the effect of these covariates will be estimated statistically. For example, it is reasonable to expect that survival rate will decline with increasing amounts of rip-rap along river banks because rip-rap displaces cover and attracts predators. If this hypothesis is in fact true, then the parameters describing the relationship between survival and the amount of rip-rap should be significantly different than zero. We will build a family of models ranging from constant survival rate through models including various explanatory variables to explicit reach-specific survival rates. We will use Akaike's information criterion to evaluate these alternative models (Burnham and Anderson, 1998) and rank them in order of their explanatory power.

2. Scope of Work

Task 1. Expansion and Maintenance of Array of Tag-detecting Monitors in Sacramento River and San Francisco Estuary

We have established an array of tag-detecting monitors within the Sacramento River to detect the migratory movements of green sturgeon (Klimley, pers. commun.). Thirty-two monitors are currently in place at the junctions between the mainstem and tributaries over a 500 km reach of the Sacramento River from Rio Vista at the mouth of Grizzly Bay to the headwaters at the base of Keswick Dam (Fig. 4). We will be placing eight more monitors during fall 2004 at additional sites along the river such as along the Yolo Bypass and at the junction to the San Joaquin River. A goal of this grant proposal is to expand the geographic extent of this array and increase the density of monitors to enable us to describe the migration of juvenile Chinook salmon and steelhead down the Sacramento River and through the San Francisco Estuary. We will upgrade the array of monitors in the following ways. More monitors will be installed at critical points in the Sacramento River, where juvenile salmon may be diverted from their normal migratory route, such as entrances and exits to the Delta, Sutter Bypass, and the Deep Water Ship Channel, at the Glenn Colusa Irrigation Ditch intake, and at the two water project intakes. Secondly, monitors, each separated by 250 m, will be installed at the mouth of the Sacramento River at the northernmost end of Grizzly Bay to detect the arrival of juveniles to Grizzly and Suisun Bays. Thirdly, monitors separated by a similar distance will be installed across the Carquinez Straits to detect the arrival of juveniles at the entrance to San Pablo Bay. Fourthly, monitors will be placed at the mouths of the sloughs and rivers leading into Grizzly, Suisun, San Pablo, and San Francisco Bays to ascertain whether juveniles might stray from their path directly through the bay, and become stranded in rivers during the strong reverse flows occurring from slack to high tide during the periods of full and new moons. Finally, monitors will be placed across the mouth of San Francisco Bay at the Golden Gate to detect the egress of juveniles from the San Francisco Estuary.

The river monitors will be deployed 1.5 m above the bottom in the main channel (Fig 5). Each river mooring will consist of an 18 kg, pyramid-shaped, lead anchor with a galvanized eye at the vertex of the pyramid. Attached to the eye will be a 1.5 m nylon line leading to a subsurface buoy. A steel plate, holding the monitor, will be affixed to the line using plastic tie wraps and its signal-detecting PZT will be oriented upward in the water column. Attached to the monitor will be a small temperature logger (Onset, HOBO). These low-cost devices can be programmed to record water temperature at hourly intervals during the deployment period of the monitor. Also attached to eye is a 10-m length of ¼" stainless steel cable, which is unraveled so that it lies on the river bottom and leads to the bank where the cable is looped and attached to itself with a stainless steel crimp. These

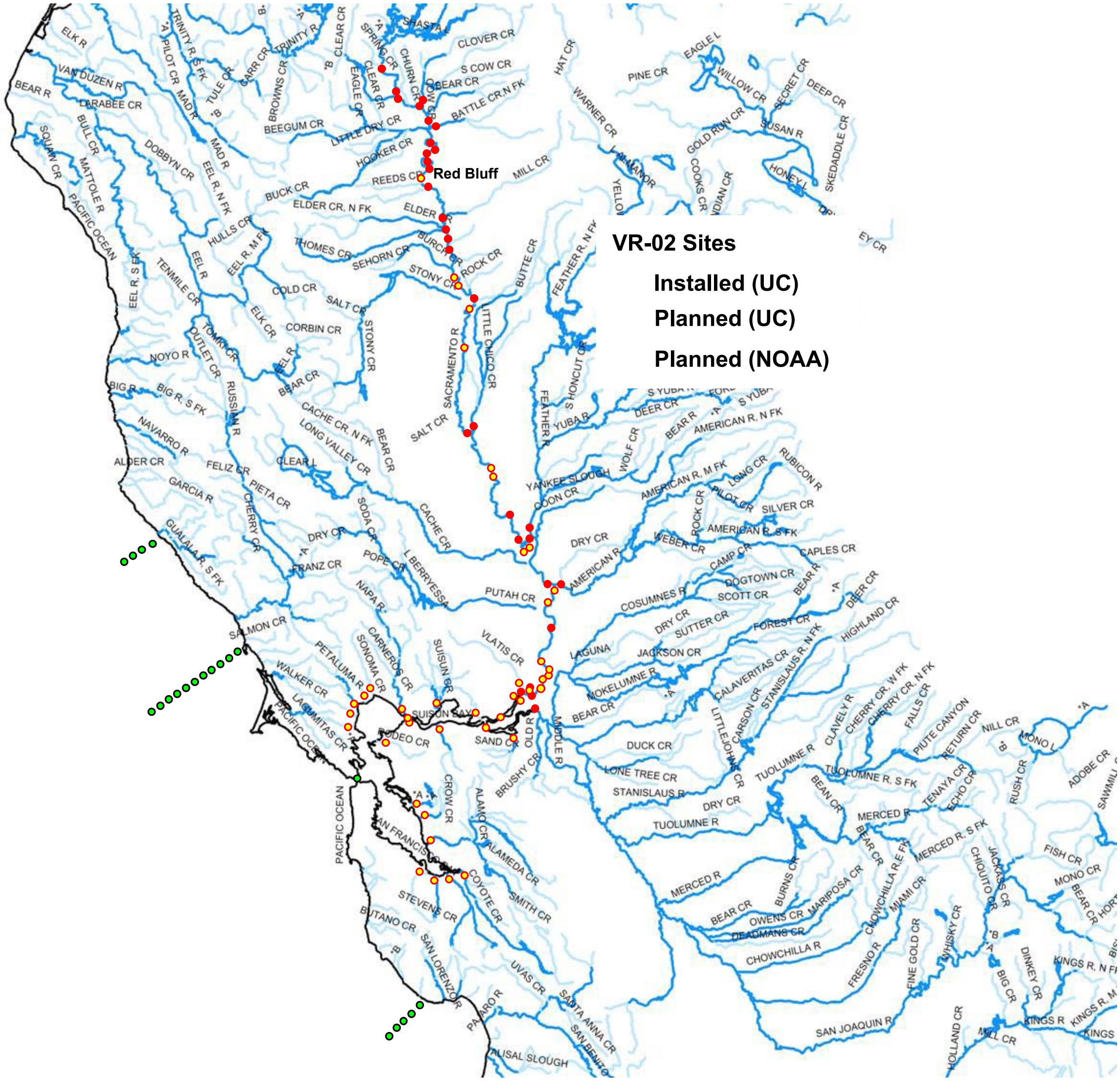

Fig. 4. Sites of VR-02 monitors installed by investigators from UC Davis (red circles), to be installed by the same researchers (clear circles), and to be installed by investigators of NOAA (green circles).

moorings are small and inconspicuous with all of the components being underwater, and hence there should be little loss of equipment due to vandalism or theft. All of the monitors, to which we have returned to interrogate as part of the green sturgeon study, have remained in place. Recently, 29 of 30 monitors were relocated after a deployment period of six months by biologists of the Department of Fish and Game studying the migratory behavior of white sturgeon in the Delta region of Sacramento/San Joaquin watershed (Derek Stein, pers. commun.). The monitors within the bays will be of similar design to the river monitors, but will not be connected to a structure on shore. Instead, they will be connected to each other by a lead line that will lie along the bottom. Attached to the eyes of the pyramid anchors at the beginning and end of each lead line will be a polypropylene line with a buoy at its end that will release from the bottom when activated by a signal from an ultrasonic transducer.

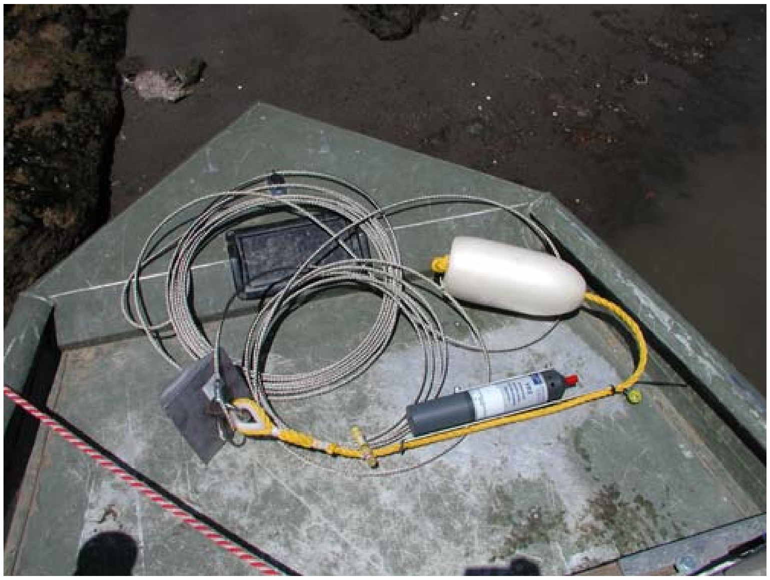

Fig. 5. Mooring for VR-02 used to deploy monitors in the channel of the Sacramento River.

We will interrogate all monitors every four months. We will purchase on the grant a 22-foot skiff, which will have a small cabin in which the monitors can be downloaded away from rain and brackish environment of the bay. The boat will have a semi-displacement hull and use an outboard jet drive, which will permit it to be used both in the river and bay environments.

Task 2. Establishment and Maintenance of Monitor Arrays in Coastal Waters

Salmonid smolts leaving the San Francisco Bay will be recorded by an array of monitors just east of the Golden Gate Bridge (in Task 1). Based on seven years of ocean trawling surveys north and south of the Golden Gate, our data strongly indicate that the vast majority of Chinook salmon smolts will move northward on the continental shelf near shore over depths less than 100 m (MacFarlane, unpubl. data). We cannot make any predictions about steelhead ocean movements as they are rarely caught in ocean surveys and no data exist on their distribution on the California coast. To determine the critical early ocean-phase mortality and migratory rates, we propose placing two lines of monitors north of the Golden Gate and one line to the south (Fig 4). We will limit the offshore extent of the line to the 100m-depth contour and the lines will be orientated perpendicular to shore and in areas where the shelf is narrow.

We will use the same monitors as described above, the Vemco VR-02. Detection range in the coastal ocean will be tested in the field at one location using V7 tags. At each location the number and spacing of monitors will be set by this experimentally estimated detection radius and the estimated swimming speed of the tagged fish. Based on these factors, the geometry of the monitoring array will be designed according to methods of Welch *et al.* (2003). Previous work using Vemco VR-02 monitors and low power output tags suggests a detection radius of 500 m with a resulting receiver spacing of 995 m (Welch *et al.,* 2003). Using this spacing, a preliminary design for the three coastal arrays would require eight monitors for the southern line at Davenport (8 km across), ten monitors at the first northern line at Bodega Head (11 km across), and six monitors at the second northern line near Gualala (5 km across) (Fig. 4). These monitors will be attached to subsurface moorings consisting of a weighted anchor, acoustic release device, 7 m of nylon line, and a 12" diameter trawl float. The floats for these moorings are subsurface to eliminate the vulnerability of a surface float to vessel traffic and fishing activities. We will use independent moorings rather than a series of monitors connected by a horizontal lead line because of the increased risk of a long lead line being snagged by trawling or crab pot gear. These considerations require the use of acoustic releases for each monitor; however, the increased probability of recovering the monitors outweighs the extra cost. Each mooring will have a temperature logger attached to it. Mooring deployment and retrieval will be performed using a contracted 52' research vessel (R/V *Shana Rae*). The fully assembled mooring will be lowered to the bottom using the ships winch cable fitted with a mechanical release. Once close to the bottom the mooring will be detached by tripping the release with a messenger. The monitors will be retrieved, downloaded, fresh batteries installed, and returned to their location every 6 months (the maximum battery life of the instruments is about 12-15 months), by activating the acoustic release with the remote command module. At each visit, only the anchor and a short length of line will need to be replaced.

Task 3. Monitoring Outmigration of Late-Fall Run Juvenile Chinook Salmon and Steelhead Trout

Implanting ultrasonic tags and releasing fish. Each year for three years (2006-2008), we will implant coded ultrasonic tags into 200 late-fall Chinook salmon smolts (about 150 mm FL) and 200 steelhead smolts (about 190 mm FL). The fish will be released during January into the headwaters of the Sacramento River to monitor rate of movement and mortality during their downstream migration. The fish will be raised at the Coleman National Fish Hatchery (CNFH), situated on Battle Creek, and released into the reach below the hatchery. The CNFH raises late-fall juveniles spawned from adults migrating up to CNFH in December and January. Some of these juveniles are kept for one year, after which they are 130-150 mm FL and released into the river during January (Hamelberg, pers. commun.). The CNFH also raises juvenile steelhead (160-200 mm FL) spawned from adults that migrate up Battle Creek in January to February of the previous year (Hamelberg, pers. commun.). We have made formal request to CNFH to provide us with the above-mentioned number of juveniles. Scott Hamelberg, the Hatchery Manager, and Kevin Niemela, U.S. Fish & Wildlife Service Hatchery Evaluation Program Leader, have approved our request.

We chose to use late-fall run Chinook salmon and steelhead because *(1) they are candidates for listing (late-fall Chinook) or listed as threatened (steelhead) under the U.S. Endangered Species Act, (2) are important ecological and socioeconomic resources to California and (3) are large enough at the time of smolt outmigration to carry an ultrasonic tag.* In addition, late-fall run Chinook yearlings can be considered as surrogates for the ESA-listed threatened spring-run because of their overlapping early life history. Fish from CNFH were selected because of (1) availability, (2) ease of conducting the tagging and evaluation of tagged fish, and (3) the hatchery's location at the northern end of the Sacramento River system, thus encompassing the entire migratory corridor for anadromous salmonids. Although we would prefer to also implant tags into wild late-fall Chinook salmon and steelhead juveniles, they are not caught in enough numbers at juvenile monitoring sites, due to their size and ability to avoid traps, to make statistically valid comparisons – less than six fish/year are captured in January at Red Bluff Diversion Dam Rotary Screw Traps (Bill Poytress, pers. comm.).

When using any experimental technique to monitor animal behavior it is essential that the technique itself does not modify behavior or affect survival (Moore *et al.*, 1990). With respect to implantation of a tracking device into a fish, the main consideration is the size of the device that can be implanted into a fish without modifying that fish's behavior. Several technical advances in electronic miniaturization and transmitter configuration (pulsed and coded signals) have resulted in very small tags with extended battery life and the ability to monitor many tags in the same area. Some very small ultrasonic tags are available (~0.5 g), but the tradeoff in reducing tag size is reduced battery life and power output. The estimated transit time of up to 60 days from Battle Creek to the Golden Gate for juvenile late-fall Chinook salmon (see section II above) requires a tag with battery life at least that long and preferable much longer so that monitoring in the ocean will also be possible.

Several studies have examined the effect of implanted radio or ultrasonic tags on swimming performance, growth, and vulnerability to predation of juvenile salmonids. These studies comprise experiments with juveniles of various sizes and tags of various sizes, both with and without an external antenna. The characteristic that seems to best indicate the magnitude of effect in these studies is the tag weight to fish weight ratio. Studies that implanted a tag that weighed less than 8.0% of the fish's weight did not find any significant difference in swimming performance between tag, sham tag (if done), or control treatments (Moore *et al.,* 1990; Peake *et al.,* 1997; Adams *et al.,* 1998b; Brown *et al.,* 1999; Robertson *et al.,* 2003; Anglea *et al.,* 2004; Lacroix *et al.,* 2004).

In studies that examined growth rates, three studies using surgically implanted tags of less than 6% of the fish's weight found no effect on growth rates compared to controls (Moore *et al.,* 1990; Adams *et al.,* 1998a; Martinelli *et al.,* 1998). Another study demonstrated a negative effect of surgically implanted tags on growth rates compared to controls, but the tag weighed about 8.5% of the fish's weight (Lacroix *et al.,* 2004). Two studies suggested that surgical intraperitoneal tag implantation was superior to gastric implantation (Adams *et al.,* 1998a; Martinelli *et al.,* 1998). Two studies that tested predator avoidance had contrasting results. Juvenile Chinook salmon implanted with tags representing 4.6-10.4% of the fish's weight and having a 31 cm long trailing antenna were eaten in significantly greater numbers than controls, probably because of the affect of the antenna (Adams *et al.,* 1998b). In contrast, predation on juvenile Chinook salmon implanted with tags representing 4.2% of the fish's weight and not having an antenna was not significantly different from controls (Anglea *et al.,* 2004). The results of these studies indicate that the *optimum methodology would be surgical intraperitoneal implantation of tags without antennae (i.e., ultrasonic) and keeping the tag weight to less than 8% of the fish's weight.*

Given our requirement of tag battery life of at least 60 d (to at least migrate through the Golden Gate) and an approximate fish weight of 37 g for a 150 mm FL Chinook smolt and 78 g for a steelhead smolt (Fig. 6), the most appropriate tag under the 8% limit is the Vemco V7-4L. This tag is

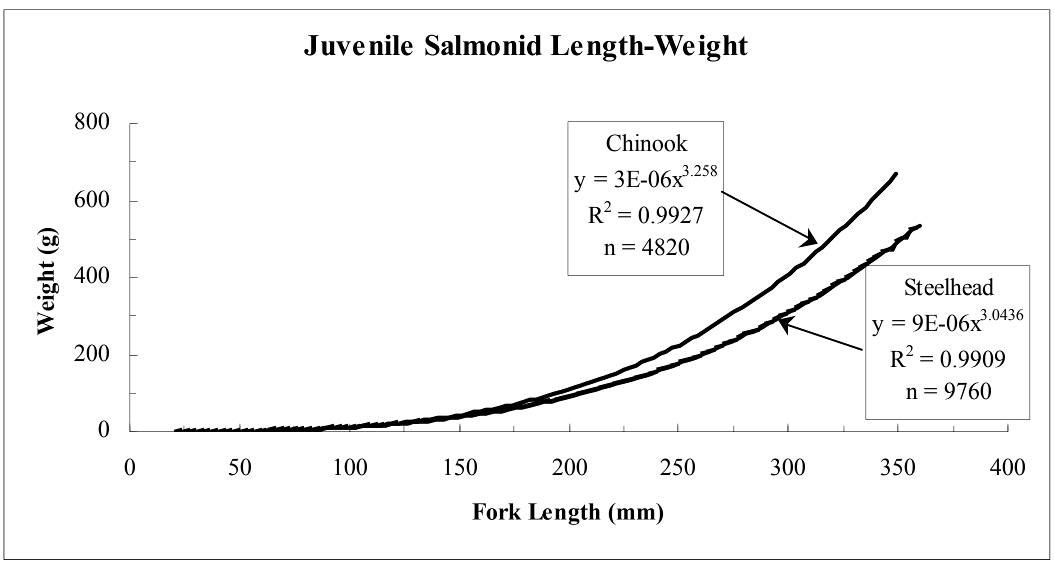

Fig. 6. Fork length – weight relationships for Central Valley Chinook salmon and central California coastal steelhead. Chinook were collected in San Francisco Estuary. From daily length criteria, Chinook were mostly fall run, but run identification is imprecise for fish caught in San Francisco Estuary. Data from MacFarlane (unpublished).

7 mm dia by 20.5 mm in length and weighs 1.8 g in air. The tag would comprise 4.9% of juvenile Chinook weight and 2.3% of juvenile steelhead weight. With an average pulse interval of 60 s (range 30-90 sec) and R4K coding, this tag will have an estimated minimum 160 d of life according to

Vemco Ltd. Data from Vemco for battery life is typically conservative; it is expected that the tags will be substantially longer than 160 d, perhaps twice as long.

We will tag individuals following the procedure of Moore *et al.* (1990) as modified by Lacroix *et al.* (2004). Each juvenile will be held initially in a 40-liter cooler with river water and anesthetized with CO_2 (150 g of sodium bicarbonate, a trace of sodium chloride, and acetic acid; for concentration versus fish size, see Peake, 1998). The individual will be removed from the anesthetic solution when it loses equilibrium. The fish's weight and fork length will be recorded. The fish will be placed ventral side up on a surgery cradle, its head covered by wet toweling, and its gills flushed by water of half-strength anesthetic passed through vinyl tubing from a container using a submersible pump. A short incision (10 mm) will be made parallel to and 3 mm to the side of the ventral midline and 3 mm anterior to the pelvic girdle. We will insert a sterilized, individually coded, cylindrical ultrasonic tag into the peritoneum of the fish. The tag will be positioned so it is lying just under the incision. The incision will be closed with two simple interrupted sutures using 3-0 silicon treated silk. The fish will then be placed into a 40-liter cooler to recover from anesthesia and surgery. Once fully recovered and swimming normally the fish will be transferred to a holding tank for three days. The implanted tag will be checked for proper function using Vemco VR60 manual tracking receiver, then the fish will be released into the river. There will be a VR-02 monitor in place at the release site, which will record when individuals leave the reach and begin their downstream migration.

Tags will be implanted into 10 late-fall Chinook salmon smolts and 10 steelhead smolts each day, 5 days per week, for four weeks in January. Each group will be released after the post-implant holding period. Ten fish of both species will be released each day, 5 days per week, until 200 fish have been released. Releasing fish over a 30 d period will minimize the number of fish moving together through the river system thus reduce potential "tag collisions" (multiple fish pinging at the same time at a given monitor) and increase detection rate. Furthermore, spreading out releases through time will allow for comparisons with varying environmental variables, such as flow rate.

Analysis of tracking data. The basic data produced by our study are detections of tagged fish at various locations between the upper river and ocean monitors. Each fish has a unique "mark" given by its ultrasonic pinger code, and we "recapture" the fish by detecting it with the data-logging hydrophones. We will use standard mark-recapture modeling to reduce the receiver detection data set to estimates of survival (see Burnham *et al.,* 1987, Cormack, 1964), and extend these models to include explanatory variables.

Each fish either exits the study area after completing its migration, or it dies en route to the sea. Along the way, it can be detected as it passes locations where monitors are moored with probability p_i at the i'th location. At several places, the fish can take either of two paths with probability t_i and $1 - t_i$, circumventing the monitors on the other path. Between the i'th and i'th +1 hydrophone locations, the fish survives with probability ϕ_i. It is these survival rates and turning probabilities that are of interest in our study. Using the terms of Burnham *et al.* (1987), the study results can be represented as a capture history matrix or an *m*-array. The likelihood of the data set is the product of $2k-3$ independent binomial distributions (where k is the number of monitor locations + 1 [for the initial release location]), allowing estimation of the unknown parameters p_i , t_i, , and ϕ_i with the maximum likelihood method.

It is a fairly simple extension to treat the reach-specific survival probabilities as functions (logistic, complementary log-log) of various explanatory variables. The analysis proceeds as above, except that rather than finding the maximum likelihood estimates (MLEs) of the survival probabilities, we find the MLEs of the parameters that relate the explanatory variables to the survival probabilities, which in turn influence the expected capture histories.

In addition to reach-specific survival estimates, the data will allow determination of movement rates between monitors. *This analysis will be useful in identifying areas of importance to juvenile salmonids, such as holding/nursery areas, etc. that can be subsequently afforded protection to improve recovery. Further, analysis of the data in relation to sites of water projects, diversions, bypasses and Delta entrances, and other anthropogenic structures will provide knowledge on the impacts of these factors to survival and movement rates.* Interannual comparisons of survival and movement patterns in relation to hydrologic variables, including flow dynamics and water temperature, will improve understanding of their effects on survival and migratory patterns. By gathering data in the coastal ocean, the influence of oceanographic conditions on migratory dynamics and survival can be assessed, which will improve the ability to resolve impacts of water projects on the animals.

Task 4. Project Management and Dissemination of Results

The principle investigator (APK) will manage the project. This will involve frequent inspection of the work in progress. He will work with the co-investigators to coordinate completion of tasks, will supervise graduate students, give scientific presentations, and prepare jointly authored publications. He will assemble the semiannual reports, based on reports from the co-principle investigators of the tasks described in this proposal. In addition to conducting the research, the co-investigators will prepare semiannual progress reports, analyze the data, present results in peer-reviewed journals and at national scientific meetings.

We will make a concerted effort to communicate the results of this study to the scientific community, interest and stakeholder groups, and the public concerned with the health of the salmonid runs in the Central Valley. We will present posters, describing the planned studies for juvenile Chinook and steelhead at the beginning of Year 1 of the grant at the 7th Biennial State of the Estuary Conference, which will be held in October 2005. This meeting is attended by academic and agency scientists, consultants, and the general public. The results of Year 1's studies will be reported at the 4th Biennial CALFED Bay-Delta Conference, which will be held during October 2006. Year 2's results will be presented during the following year at the 8th Biennial State of the Estuary Conference.

We plan to organize and hold an international symposium at the NOAA Fisheries Santa Cruz Laboratory/UCSC Long Marine Laboratory during September 2008 on survival and migratory patterns of salmonids in North America. This meeting will serve to publicize the results of our studies, and place them in the context of other studies being conducted on the western and eastern coasts of North America. We will invite presentations from scientists, conducting similar studies, from elsewhere in California, Oregon, Washington, Alaska, Maine, and Canada. This meeting will be open to scientists, resource managers, and the interested public. The presenters at this meeting would be asked to produce scientific articles for a book or dedicated journal issue. The contributions would be peer-reviewed, whether they are published in a book or journal.

A website will be created for the research study. The internet site would have two functions. It will make the public aware of our studies of juvenile salmonids and update them on the latest findings. Secondarily, it will provide a coordination interface with other tagging-tracking studies, through which other researchers can learn of our tag codes and the locations of our tag-detecting monitors. They will be able to learn whether one of our tagged fish has been detected by one of their monitors or one of their tagged fish has been detected by our monitors. The potential for collaboration between research groups in this tagging study is very high, increasing the overall benefit of the project for resource management.

3. Chronology of Study

Task	2005 O	2005 N	2005 D	2006 J	F	M	A	M	J	J	A	S	O	N	D
1. Expansion & Maintenance of Monitors in Sacramento River & San Francisco Estuary															
a. Order & place monitors	X	X	X												
b. Retrieve data & replace monitors			X				X				X				X
2. Establishment & Maintenance of Monitors in Coastal Ocean															
a. Place monitors	X	X	X												
b. Retrieve data & replace monitors									X						X
3. Monitor Migration of Juvenile Steelhead & Late-Fall Chinook Salmon															
a. Implant ultrasonic tags & release fish				X											
b. Data analysis				X	X	X	X	X	X	X	X	X	X	X	X
4. Project Management & Dissemination of Results															
a. Semiannual report									X						X
b. Website updates			X								X				
c. State of Estuary & CALFED Science Conf	X												X		
d. Symposium on salmon tagging & tracking															
e. Final report															

Task	2007 J	F	M	A	M	J	J	A	S	O	N	D
1. Expansion & Maintenance of Monitors in Sacramento River & San Francisco Estuary												
a. Order & place monitors												
b. Retrieve data & replace monitors				X				X				X
2. Establishment & Maintenance of Monitors in Coastal Ocean												
a. Place monitors												
b. Retrieve data & replace monitors						X						X
3. Monitor Migration of Juvenile Steelhead & Late-Fall Chinook Salmon												
a. Implant ultrasonic tags & release fish	X											
b. Data analysis	X	X	X	X	X	X	X	X	X	X	X	X
4. Project Management & Dissemination of Results												
a. Semiannual report						X						X
b. Website updates		X						X				
c. State of Estuary & CALFED Science Conf										X		
d. Symposium on salmon tagging & tracking												
e. Final report												

Task	2008 J	F	M	A	M	J	J	A	S	O	N	D	2009 J	F
1. Expansion & Maintenance of Monitors in Sacramento River & San Francisco Estuary														
a. Order & place monitors														
b. Retrieve data & replace monitors				X				X				X		
2. Establishment & Maintenance of Monitors in Coastal Ocean														
a. Place monitors														
b. Retrieve data & replace monitors						X						X		
3. Monitor Migration of Juvenile Steelhead & Late-Fall Chinook Salmon														
a. Implant ultrasonic tags & release fish	X													
b. Data analysis	X	X	X	X	X	X	X	X	X	X	X	X	X	X
4. Project Management & Dissemination of Results														
a. Semiannual report						X						X		
b. Website updates		X						X						X
c. State of Estuary & CALFED Science Conf										X				
d. Symposium on salmon tagging & tracking									X					
e. Final report														X

III. Justification

A. Uncertainties Resolved in Salmonid Life Histories

Several critical areas of salmonid life histories are poorly understood. These knowledge gaps are typical for difficult to observe and highly migratory aquatic organisms. With respect to the objectives of the CALFED program, the most important components of the salmonid life history are those that are vulnerable to the effects of water operations in the Sacramento/Bay-Delta. The two most important questions are: (1) what are their migratory patterns, and by extension, important habitat areas, and (2) where are the areas of increased mortality? Outmigrating salmonids travel through a wide variety of river habitats with many hazards of both natural and of human origin. The answers to these questions have not been provided by coded-wire tagging studies because the fish can only be captured once and at widely separated geographical locations (see Section IIA1). *In contrast, juveniles bearing coded-ultrasonic tags, will be detected by automated monitors at nearly 50 locations along the 500 km length of the river, and at the mouth of the river at Grizzly Bay, at the Carquinez Straits, at the mouth of San Francisco Bay, at sloughs and rivers leading into the estuary, and in the ocean at three cross-shelf transects. This fine spatial scale will greatly enhance our understanding of the distribution of juvenile salmonids.* A detailed understanding of reach-specific and bay-specific movement and mortality is required to determine the effect of water management operations and environmental conditions on salmon and steelhead smolts.

Current monitoring programs have been successful in estimating within-year and among-year patterns in relative abundance and generalized seasonal migration patterns (Brandes *et al.,* 2000). Although details about survival have been more difficult to obtain, with the exception of data suggesting that juveniles migrating through the Delta have decreased relative survival rates compared to those avoiding the Delta (Brandes & McLain, 2001). However, more specific information on where these fish are experiencing increased mortality is still missing.

In 2000, the Interagency Ecological program (IEP) and CALFED sponsored a multi-disciplinary team to study the effect of flow and fish movement at the Delta Cross Channel (DCC) (Okamoto, 2001). This study provided data that suggests that the previous conceptual model of how smolts move through the system was too simplistic and that the study provided a more mechanistic understanding of smolt movement (Brown & Kimmerer, 2003). Although this study was considered a major contribution to the understanding of fish and water movement in the DCC area, the team has yet to published any of its findings. Brown and Kimmerer (2003) go on to say, “The studies to date only provide snapshots – a more comprehensive approach using different techniques may be needed.” We believe that miniaturized ultrasonic tags along with an extensive system of automated monitors is one such comprehensive approach that can provide high-resolution spatial-temporal information on survival and movement of salmonids.

B. Relevance to Objectives of CALFED Science Program

The information obtained from this proposed project will address all three priority topic areas defined by the Science Program of the California Bay-Delta Authority: 1) water operations and their affect on at-risk species, 2) ecological processes and their relationships to water management and the success of key species, and 3) performance assessment by development of new tools. Analysis of the movement and survival data from our project will address how these factors are affected by water operations, such as the proportion and fate of smolts diverted into bypass channels or mortality rates in areas with modified stream beds or in-stream structures. Our project will be able to address how ecological processes such as variation in water flow affect juvenile salmonid movement and survival.

Our project will put in place a system of monitors that will generate new information on salmonid movement and survival at such a fine spatial and temporal scale, as to allow assessment of how specific areas and events affect salmonids. Further, the establishment of the monitor arrays will allow other investigations to assess movement and survival of other species in a cost effective manner. Of the specific study topics identified in the CALFED Science program Proposal Solicitation Package, Attachment 1, we believe our proposal will address the following:

Life Cycle Models and Population Biology of Key Species. Our project will provide methodology and data that will be used to address several objectives of the CALFED Science Program. This research will provide information to fill knowledge gaps in life-cycle modeling and population biology for both steelhead and late-fall Chinook salmon. Since many of the life history attributes of late-fall run Chinook salmon are shared by spring-run as well, our data can be used to improve knowledge and understanding of this ESA-listed threatened species. *In particular, data on steelhead are critical; virtually nothing is known of their survival rates or migratory patterns in the Central Valley.* Our approach will provide previously unavailable information on movement rates and patterns, putative nursery areas, vulnerability to pumping and other water diversions, habitat use and survival in a high-resolution, spatial-temporal design. We intend to model the migratory and survival data along with water project and environmental data to determine the interactions between the salmonids and these variables.

Environmental Influences on Key Species and Ecosystems. Our study will assess the influence of environmental factors, such as water flow, temperature, and fine- and large-scale habitat types, on survival and movement patterns of salmonid smolts at within-year and among-year scales. We will be able to compare movement and survival of salmonids at varying river flows, because we will be releasing tagged salmonids during the month of January, which typically has highly variable river flow rates. Available maps of habitat types along the migration route will allow us to analyze survival in relationship to habitat type. Additionally, this project will determine relative survival rates among the riverine migratory corridor, the estuary, and the early ocean phase of the salmonid's lifecycles. Because CALFED is interested in implications of water operations and management occurring in the Bay-Delta ecosystem, it will be useful to put Bay-Delta survival rates in the context of early ocean survival. This information may help development of a more complete life-cycle model that will improve understanding of how water management decisions affect the population biology of Central Valley salmonids. The experimental approach will quantify for the first time survival rates in defined reaches and specific locations along the migratory pathway of late-fall Chinook salmon and steelhead smolts. Although we will not be measuring predation directly, we will be able to quantify survival rates in areas (between successive monitors) that include habitat that is believed to contain, or be associated with, predators of juvenile salmonid smolts, such as striped bass, black bass, catfish, and pike minnows.

Direct and Indirect Effects of Diversions on At-Risk Species. Numerous unscreened water diversions have been suspected as a significant source of mortality for salmonid smolts. We will analyze the survival data from our project with respect to areas with varying numbers and sizes of these diversions. Large-scale diversions such as the Delta Cross Channel are thought to divert smolts from their intended migratory pathway (the Sacramento River) into the Delta. The Delta is considered to have a negative effect on survival, thus causing increased mortality for those fish entering the DCC. With our project design we can follow the fate of salmonids migrating down either pathway.

Export pumping has long been considered to be a serious threat to at-risk species. Our approach will allow us to calculate what proportion of tagged fish released at Battle Creek enter the Clifton Court Forebay, approach the intakes of the state or federal pumping facilities, and become entrained and end up in the salvage facilities. Ultrasonic monitors at these locations will provide this information. This information will provide a second independent measure of loss rates that can be compared to the existing program of measuring loss rates of salmonid smolts at the pumping facilities. Our project may also provide more information on behavior of smolts as they approach the pumping facilities. For example, we may be able to determine if a smolt approaches the pumps but does not enter the pumps, then swims away and is detected at another location.

Assessment and Monitoring. In addition to monitoring juvenile salmonids of diverse life histories, our project will create an extensive array of ultrasonic monitors extending from the upper Sacramento River through the Golden Gate and into the coastal ocean that can be used by other researches to track other species of interest, such as sturgeon and striped bass. Vemco manufactures the equipment we will use and is the most widely used supplier of ultrasonic tags and monitors for fishes. Demonstration by our study that data on movement and survival can be effectively and efficiently obtained using ultrasonic tagging and monitoring will prove beneficial to CALFED objectives and may result in retention of the array for future studies.

Salmonid-related Projects. Our project will provide information relevant to CALFED agencies concerned with juvenile salmonid movement and survival throughout the Sacramento River and Bay-Delta system. Results from our study will greatly improve understanding of segment-specific mortality rates; use of specific habitats; movement patterns and transit routes; influences of river and tidal flows; losses from diversions and other anthropogenic activities, and the effects of natural factors on survival and movement patterns. Although projects using CWT generate gross estimates of migration and survival, they do not provide the high spatial and temporal resolution of movement and survival that is necessary to make management decisions; the proposed ultrasonic tagging and monitoring design will accomplish that in a cost effective manner.

C. Other Planned Fish Migration Studies in Watershed using Monitor Arrays

There are several ongoing and planned studies of fishes using individually coded tags and tag-detecting monitors in the Sacramento/San Joaquin watershed. Investigators conducting the following studies are employing the V series tags (Vemco Ltd.), which are detectable by the VR-02 monitors to be used our proposed study. Intermediate-sized fish such as the striped bass and splittail minnow are being tagged with V13 tags, which have a much larger 13 mm diameter than the 7 mm V7 tags, and for this reason have a longer life, yet transmit signals of the same frequency and coding scheme, and are thus detectable by our monitors. The largest fishes, white and green sturgeon, may be tagged with V22 tags, which are even longer lived (five years) and have a diameter of 22 mm, yet also propagate signals of the same frequency and coding. By establishing our monitor network, we will be effectively increasing the area of detection for these studies. Likewise, their monitors will allow us to determine juvenile salmonid movement in areas adjacent to our study area.

1. Migration of Adult Chinook Salmon through Delta Region of Sacramento/San Joaquin Watershed (R. Vincik, Department of Fish and Game[CDFG])

R. Vincik, Fisheries Biologist with CDFG, placed coded tags on approximately 100 adult fall-run Chinook salmon during September 2003 and 2004 to assess their ability to utilize fish passage facilities within the sloughs and rivers of the Delta region. Once these marked individuals exited the Delta in October and November 2004, they migrated up the Sacramento River and were detected by multiple monitors, moored in the channel of the mainstem of the river at the confluences of major tributaries on the Sacramento River. The monitors were deployed in a study of upriver migration of green sturgeon (see study described below). The usefulness of this technology– an array of monitors that detect individually coded tags placed in different species – to multiple investigators is well illustrated by this record of the detections of >50 tagged fish from the monitor in Sacramento River downstream of the confluence with the American River (Fig. 7).

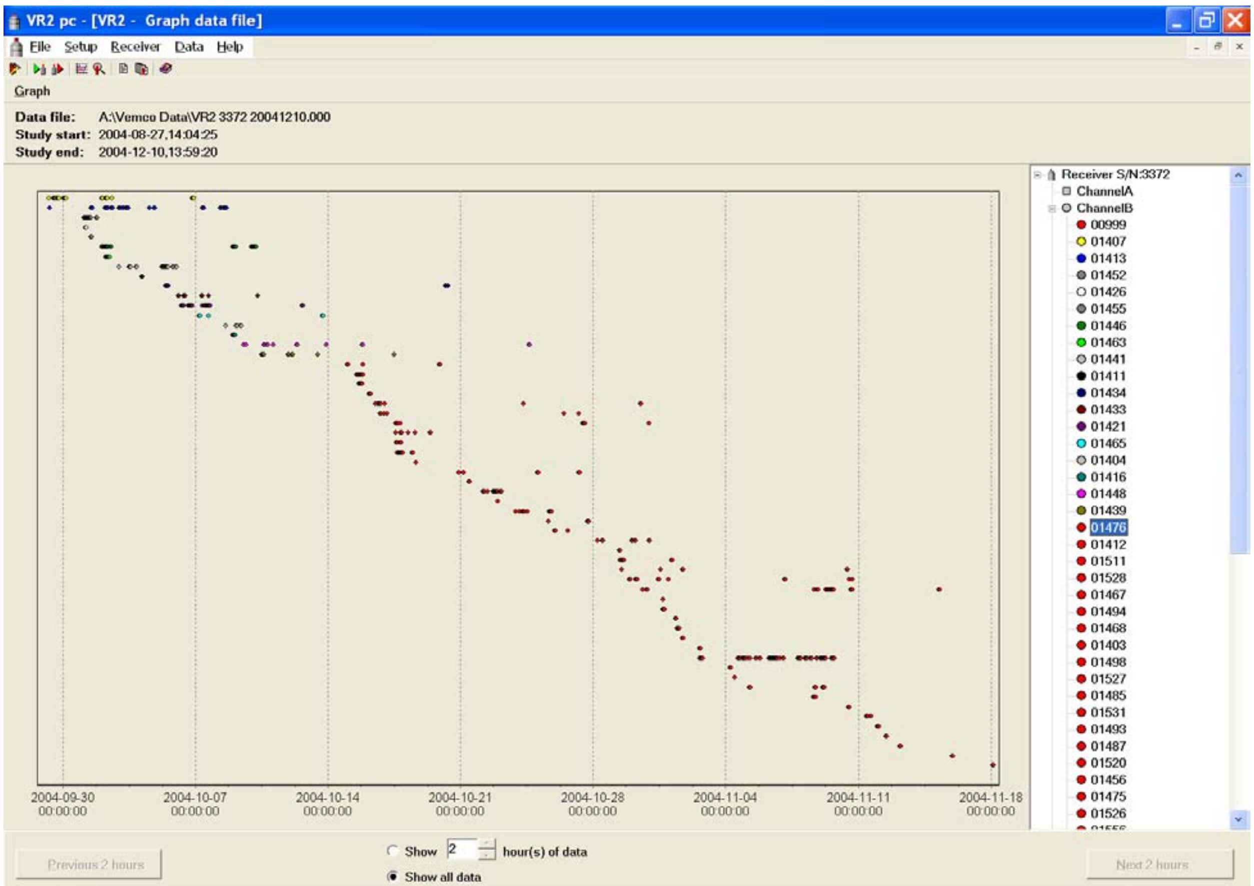

Fig. 7. Graphic image captured from the screen of a laptop with colored symbols in successive rows designating the passage of individual adult salmon by an automated monitor moored in the channel of Sacramento River from 30 September to 18 November 2004. The tags are identified in key to right of abscissa of graph that can be scrolled to reveal the rest of the tag identities

2. Movements of White Sturgeon, Striped Bass, and Splittail Minnow in Delta (Z. Matica, Department of Water Resources [DWR])

Z. Matica, Fisheries Biologist for DWR, has placed an array of VR-02 monitors in the Yolo Bypass and Toe Drain, by which water is diverted away from the city of Sacramento during periods of high rain fall. He and his colleagues are interested in tracking the movements of white sturgeon, striped bass, and splittail minnow. His monitors will be capable of detecting the juvenile Chinook and steelhead tagged in our study. We will likewise be able to detect the fish that he has tagged as they move upstream in the Sacramento River and downstream into Grizzly Bay and the San Francisco Estuary.

3. Movements of Green Sturgeon in Sacramento River (A.P. Klimley, UC Davis)

A.P. Klimley, Adjunct Associate Professor at UCD, will be maintaining the existing array of monitors from 2004-2005 to track green sturgeon tagged during Phase 5 of the CALFED-sponsored biological assessment of green sturgeon in the Sacramento/San Joaquin watershed. Sixty green sturgeon were captured, tagged, and released within San Pablo Bay during April-May and Sept-Aug 2004 of Year 1 of that study; and 100 additional green sturgeon will be tagged during the same two periods during Year 2. The V22 coded tags on the green sturgeon have an active life of five years. The array of monitors in the Sacramento River will be checked periodically during the following year to determine where up-migrating adults spawn. Individuals will be located based on appearing on the record of a downstream monitor and absence on the record of an upstream monitor. They will then be located with a portable tracking system, operated from a boat with an outboard jet drive, and their physical environment characterized by measuring water temperature, dissolved oxygen, flow rate and mapping the geomorphology of the river reach.

Klimley and his co-investigators at UC Davis are likely to submit a proposal to complete a population viability model based on data collected during Phases 1-5 of the biological assessment. This will extend the period of time that monitors are deployed on the river, and ensure that adult sturgeon are detected during their upward migrations in the river to spawn. This will be a collaborative proposal with investigators of the Department of California Fish and Game, situated at Red Bluff, and their role will be to place longer-term coded tags on spawning adults above and below the diversion dam in order to ascertain their spawning periodicity, an essential input to any population viability model for the species.

4. Movements of Steelhead Juveniles in San Joaquin River (D. Demko, S.P Cramer and Associates)

D. Demko , a Biologist at S.P Cramer and Associates, may propose to CALFED to establish and maintain monitors in the San Joaquin River. He intends to catch, tag, and release juvenile wild steelhead in the Stanislaus River and tag and release hatchery raised juvenile steelhead in the Mokelumne River. The migration of these individuals, carrying V7 tags, downstream will be recorded by VR2 monitors placed at the junctions between tributaries and the mainstem of the San Joaquin River.

D. Multiple Use of Monitor Arrays

Randall Brown of the California Department of Water Resources emphasized during the 4th Biennial CALFED Bay-Delta Conference that there was an imperative need for collaboration among scientists studying fishes in the Sacramento/San Joaquin watershed. Academic, agency, and consulting scientists need to come together and collaborate to produce a comprehensive understanding of the biology of fishes in this watershed. We believe the establishment and maintenance of a monitoring array by multiple parties is vital step in this direction. This array will be established by scientists at the (1) University of California, Davis, (2) NOAA Fisheries, Santa Cruz, (3) Department of Water Resources, and (4) S.P. Cramer and Associates. It would be very difficult for one organization to service the extensive network of these monitors, but is quite feasible when the effort is shared among multiple groups. Scientists from each of these organizations will be placing tags on different species of fishes (of particular interest to their organizations), yet their separate monitoring systems are compatible, and will record the identity of any fish that passes within their range. Thus, the range over which fish can be detected by a monitor is increased four fold – over the 500 km long watershed from the mouth of San Francisco Bay to Keswick Dam.

Arrays of compatible monitors have been established elsewhere and are being maintained in the Klamath River, California (Turo, Yurok Tribe); Rogue River, Oregon (Erickson, Wildlife Conservation Society); Willapa Bay, Washington (Langsness, Washington Department of Fish and Game); and Columbia River (Schreck, Oregon State University); Straits of Juan de Fuca, Canada (Welch, Kintama Research). We will be able to detect their tagged Chinook salmon and green sturgeon with monitors within the Sacramento River, San Francisco Estuary, and Californian coast. They will be conversely be able to record our tagged fish, assuming sufficient battery life, with their monitors. There is a growing distribution of the VR-02 monitors along the entire west coast and the geographic extent over which these monitors are deployed will only increase with time. We will establish a coordinated effort to ensure tag detections among the various programs are distributed among the appropriate researchers.

IV. Literature Cited

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Vincik, R. 2004. Fish passage studies at the Suisun Marsh salinity control gates in Montezuma Slough. Abstract, 3rd Biennial CALFED Bay-Delta Program.

Welch, D.W., G.W. Boehlert & B.R. Ward. 2003. POST - the Pacific Ocean salmon tracking project. *Oceanologica Acta*, 25: 243-253.

(ABBOTT) PETER KLIMLEY

Professional Address	*Residential Address*
DEPARTMENT OF WILDLIFE, FISH, & *CONSERVATION BIOLOGY* *1334 ACADEMIC SURGE* *UNIVERSITY OF CALIFORNIA* *DAVIS, CALIFORNIA 95616*	*2870 EASTMAN LN.* *PETALUMA, CA 94952* *TEL: (707) 765-6516 (HOME)* *TEL: (707) 752-5830 (OFF.)*

EDUCATION

1982 Doctor of Philosophy (Ph.D.), Marine Biology.
Scripps Institution of Oceanography, UC San Diego, California.
1976 Master of Science (M.Sc.), Biological Oceanography.
Rosenstiel School of Marine and Atmospheric Science, Univ. of Miami, Florida.
1970 Bachelor of Science (B.S.), Zoology.
State University of New York, Stony Brook, New York.

EMPLOYMENT

1999-Pres. Adjunct Associate Professor, Department of Wildlife, Fish, & Conservation Biology, University of California, Davis.
2001-2002. Senior Fisheries Ecologist, H.T. Harvey & Associates, San Jose.
1996-2001 Associate Research Behaviorist, Bodega Marine Laboratory, UC Davis.
1987-1995 Assistant Research Behaviorist, Bodega Marine Laboratory, UC Davis.

RESEARCH ASSOCIATE

1997-Pres. Research Associate, Institute of Marine Science, Univ. of Calif., Santa Cruz.
1993-Pres. Adjunct Faculty Member, Centro de Investigaciones de Biologicas, La Paz, Mexico.

RESEARCH INTERESTS

Animal behavior and behavioral ecology of marine vertebrates; conservation, marine fisheries biology, ecology, and oceanography, development of behavioral and environmental sensors, computer-decoded telemetry, automated data logging, archival tags.

SOCIETIES

American Association for the Advancement of Science, American Elasmobranch Society, American Society of Ichthyologists and Herpetologists, Association for the Study of Animal Behavior, Sigma Xi , Member.

EDITOR

1997-Pres. *Oecologia*, Off-board Editor.
1995-Pres. *American Scientist*, Consulting Editor, Animal Behavior & Marine Biology.

REVIEWER

African Journal of Marine Science (South Africa), *Animal Behavior* (U.S.A.), *Australian Journal of Marine and Freshwater Research* (Australia), *Canadian Journal of Zoology* (Canada), *Ciencias Marinas* (Mexico), *Copeia* (U.S.A.), *Environmental Biology of Fishes* (Canada), *Experimental Marine Biology and Ecology (U.K.)*, *Fisheries Bulletin* (U.S.A.), *INTERFACE*, The Royal Society (U.K.), *Journal of Fish Biology* (U.K.), *Journal of Fisheries Management* (U.S.A.), *Marine Biology* (Germany), *Marine Ecology Progress Series* (U.S.A.), *Naturwissenschaften* (Germany), *Oecologia* (U.S.A.),*Transactions of the American Fisheries Society* (U.S.A.)

HONORS

1998 Certificate of Excellence in recognition of "excellence in concept, design and manufacture" for *Great White Sharks: The Biology of Carcharodon carcharias*, Bookbuilders West Book Show.
1995 SNAP EXCEL Silver Award, Magazines: Feature Article, "The predatory behavior of the white shark," *American Scientist*.
1994 Presidential Nomination, American Elasmobranch Society.

INTERNET

2004-Present Biotelemetry Laboratory, Biographies of APK and graduate students with project descriptions (http://wfcb.ucdavis.edu/www/faculty/Pete).
1997-Present Dr. Hammerhead, NOVA/PBS Web Page, research featured and questions about shark biology answered [see www.pbs.org/wgbh/nova/sharks/masters/hammerhead.html].

SYMPOSIUM

1992. Biology of the White Shark, Bodega Marine Laboratory, UC Davis, organized with D.G. Ainley.

BOOK

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51. Kihslinger, R.L. and A.P. Klimley. 2002. Species identity and the temporal characteristics of fish acoustic signals. *Journal of Comparative Psychology,* 116: 210-214.

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39. Klimley, A.P. and S.D. Anderson. 1996. Residency patterns of white sharks at the South Farallon Islands, California. Pp. 365-373 *in* Klimley, A.P. and D.G. Ainley (Eds.), IBID.

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37. Klimley, A.P., P. Pyle, and S.D. Anderson, 1996. Is the Tail Slap an agonistic display among white sharks? Pp. 241-255 *in* Klimley, A.P. and D.G. Ainley (Eds.), IBID.

36. Anderson, S.D., A. P. Klimley, P. Pyle, and R.H. Henderson. 1996. Tidal height and white shark predation at the South Farallon Islands. Pp. 275-279 *in* Klimley, A.P. and D.G. Ainley (Eds.), IBID.

35. Goldman, K.J., S. D. Anderson, J.E. McCosker, and A.P. Klimley. 1996. Temperature, swimming depth, and diel movements of a white shark at the South Farallon Islands, Central California, with comments on thermal physiology. Pp. 111-120 *in* Klimley, A.P. and D.G. Ainley (Eds.), IBID.

34. Mollet, H., G.M. Cailliet, A.P. Klimley, D.A. Ebert, A.T. Testi, and L.J.V. Compagno. 1996. A review of length validation methods for large white sharks. Klimley, A.P. and D.G. Ainley (Eds.), IBID.

33. Pyle, P., S.D. Anderson, A.P. Klimley, and R.P. Henderson. 1996. Environmental factors affecting the occurrence and behavior of white sharks at the South Farallon Islands, California. Pp. 281-291 *in* Klimley, A.P. and D.G. Ainley (Eds.), IBID.

32. Klimley, A.P. 1995. Hammerhead city, *Natural History,* 104:32-39.

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22. Cigas, J. and A.P. Klimley. 1987. A microcomputer interface for decoding telemetry data and displaying them numerically and graphically in real time. *Behavioral Research Methods, Instruments, and Computers*, 19:19-25.

21. Klimley, A.P. 1987. The determinants of sexual segregation in the scalloped hammerhead, *Sphyrna lewini*. *Environmental Biology of Fishes*, 18:27-40.

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16. Klimley, A.P. and S.T. Brown. 1983. Stereophotography for the field biologist: measurement of lengths and three-dimensional positions of free-swimming sharks. *Marine Biology*, 74:175-185.
15. Klimley, A.P. and S.T. Brown. 1983. A stereophotographic technique for the determination of lengths of free-swimming sharks. *CIBCASIO Transactions*, 11:110-137.
14. Klimley, A.P. 1982. Social organization of schools of scalloped hammerhead shark, *Sphyrna lewini* (Griffith and Smith), in the Gulf of California. *Dissertation*, University of California, San Diego, 341 pp.
13. Klimley, A.P. 1981. Grouping behavior in the scalloped hammerhead. *Oceanus*, 24:65-71.
12. Klimley, A.P and D.R. Nelson 1981. Schooling of scalloped hammerhead, *Sphyrna lewini*, in the Gulf of California. *Fishery Bulletin*, 79:356-360.
11. Klimley, A.P. 1980. Observations of courtship and copulation in the nurse shark, *Ginglymostoma cirratum*. *Copeia*, 1980:878-882.
10. Klimley, A.P. and A.A. Myrberg, Jr. 1979. Acoustic stimuli underlying withdrawal from a sound source by adult lemon sharks, *Negaprion brevirostris* (Poey). *Bulletin of Marine Science*, 29:447-458.
9. Myrberg, Jr., A.A., C.R. Gordon, and A.P. Klimley. 1978. Rapid withdrawal from a sound source by open ocean sharks. *Journal of the Acoustical Society of America*, 64:1289-1297.
8. Klimley, A.P. 1978. Nurses at home and school. *Marine Aquarist,* 8:5-13.
7. Myrberg, Jr., A.A., C.R. Gordon, and A.P. Klimley. 1976. Attraction of free-ranging sharks by low frequency sound, with comments on its biological significance. Pp. 205-239 *in* A. Schuijf and A.D. Hawkins (Eds.), Sound Reception in Fishes. Elsevier Press, New York.
6. Klimley, A.P. 1976. Analysis of acoustic stimulus properties underlying withdrawal in the lemon shark, *Negaprion brevirostris* (Poey). *Thesis*, Rosenstiel School of Marine and Atmospheric Science, 80 pp.
5. Klimley, A.P. 1976. The white shark: a matter of size. *Sea Frontiers,* 22:2-8.
4. Myrberg, Jr., A.A., C.R. Gordon, and A.P. Klimley. 1975. Rapid withdrawal from a sound source by sharks under open ocean and captive conditions. *Technical Report*, University of Miami, 24 pp.
3. Myrberg, Jr., A.A., C.R. Gordon, and A.P. Klimley. 1975. Attraction of free-ranging sharks by acoustic signals in near-subsonic range. *Technical Report*, University of Miami, 32 pp.
2. Klimley, A.P. 1975. A new look at shark attack. *Triton*, 1975:11-15.
1. Klimley, A.P. 1974. An inquiry into the causes of shark attacks. *Sea Frontiers*, 20:66-75.

GRADUATE GROUP MEMBERSHIPS

1999-Pres. Membership, Graduate Group in Ecology, UC Davis.
1998-Pres. Membership, Animal Behavior Graduate Group, UC Davis.

*Articles relevant to ultrasonic tagging technology are in bold font.

R. BRUCE MACFARLANE

Professional Address	*Residential Address*
NOAA Fisheries *Southwest Fisheries Science Center* *Santa Cruz Laboratory* *110 Shaffer Road* *Santa Cruz, CA 95060*	*4380 Lucy Way* *Soquel, CA 95073* *TEL: (831) 477-7638 (HOME)* *TEL: (831) 420-3939 (OFF.)*

EDUCATION

1980 Doctor of Philosophy (Ph.D.), Biological Oceanography.
Florida State University, Tallahassee, Florida.
1970 Master of Science (M.Sc.), Biological Oceanography.
Florida State University, Tallahassee, Florida.
1968 Bachelor of Science (B.S.), Zoology.
Pennsylvania State University, University Park, Pennsylvania.

EMPLOYMENT

1980-Pres.	Supervisory Research Fishery Biologist (1989-present), Research Biological Oceanographer (1980-1989), NOAA Fisheries, Santa Cruz and Tiburon, CA
1999-Pres.	Research Associate, Institute of Marine Sciences, University of California, Santa Cruz, Santa Cruz, CA
1978-1980	Instructor, Department of Oceanography, Florida State University, Tallahassee, FL
1979	Graduate Lecturer, Department of Biological Sciences, Florida State University, Tallahassee, FL
1975-1980	Research and Teaching Assistant, Department of Biological Sciences, Florida State University, Tallahassee, FL
1970-1975	Pilot, U.S. Air Force
1968-1970	Research Assistant, Department of Oceanography, Florida State University, Tallahassee, FL
1967-1968	Research Assistant, Department of Food & Dairy Sciences, Pennsylvania State University, University Park, PA

RESEARCH INTERESTS

Ecology, physiology, and biochemistry of marine and estuarine fishes; salmonid biology; conservation biology; stress physiology; contaminant effects on fishes; fisheries oceanography

SOCIETIES

American Association for the Advancement of Science, American Fisheries Society, American Chemical Society, Sigma Xi, Society of Comparative and Integrative Biologists

REVIEWER

Aquatic Toxicology, Archives of Environmental Contamination and Toxicology, Canadian Journal of Fisheries and Aquatic Sciences, Canadian Journal of Zoology,
Comparative Biochemistry and Physiology, Fish Physiology and Biochemistry,
Fishery Bulletin, Fisheries Oceanography, ICES Journal of Marine Science, Marine Biology, Marine Ecology - Progress Series, Transactions of the American Fisheries Society

HONORS

2003	U.S. Department of Commerce Bronze Medal
2002	Best Publication in 2002, Fishery Bulletin
1998-pres.	National Research Council Post-doctoral Fellow Advisor
2002, 2001, 2000,1999, 1998, 1997, 1995, 1994, 1990, 1984	Outstanding Performance Award, NOAA Fisheries, Southwest Fisheries Science Center
1998, 1990	Quality Step Increase, NOAA Fisheries, Southwest Fisheries Science Center National Marine Fisheries Service,
1985 - 1986	Sustained Superior Performance Award, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center
1985	Commendation for Technical Advice, Aquatic Habitat Program, Resolution Number 85-16, San Francisco Bay Regional Water Quality Control Board, Oakland, California
1977	Society of Sigma Xi Doctoral Assistance Grant, Florida State University

SCIENTIFIC ARTICLES

MacFarlane, R.B., S. Ralston, C. Royer, and E.C. Norton. Juvenile chinook salmon (*Oncorhynchus tshawytscha*) growth on the central California coast during the 1998 El NiZo and 1999 La NiZa. Fisheries Oceanography (In press)

Hayes, S.A., M.H. Bond, C.V. Hanson, and R.B. MacFarlane. 2004. Interactions between endangered wild and hatchery salmonids; can the pitfalls of artificial propagation be avoided in a small coastal stream? Journal of Fish Biology (In press)

Norton, E.C. and R.B. MacFarlane. Interannual variability of juvenile shortbelly rockfish growth and lipids in relation to environmental conditions off the California coast. (In prep)

Lindley, S.T., R. Schick, B.P. May, J.J. Anderson, S. Greene, C. Hanson, A. Low, D. McEwan, R.B. MacFarlane, C. Swanson, and J.G. Williams. 2004. Population structure of threatened and endangered Chinook salmon ESUs in California's Central Valley basin. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-370, 66p.

Eldridge, M.B., E.C. Norton, B.M. Jarvis, and R.B. MacFarlane. 2002. Energetics of early development in the viviparous yellowtail rockfish. Journal of Fish Biology 61:1122-1134.

MacFarlane, R.B., S. Ralston, C. Royer, and E.C. Norton. 2002. Influences of the 1997- 1998 El NiZo and 1999 La NiZa on juvenile chinook salmon in the Gulf of the Farallones. PICES Scientific Report No. 20:25-29.

MacFarlane, R.B. and E.C. Norton. 2002. Physiological ecology of juvenile chinook salmon (*Oncorhynchus tshawytscha*) at the southern end of their distribution, the San Francisco Estuary and the Gulf of the Farallones, California. Fishery Bulletin 100:244-257.

Norton, E.C., R.B. MacFarlane, and M.S. Mohr. 2001. Lipid class dynamics during development in early life stages of shortbelly rockfish and their application to condition assessment. Journal of Fish Biology 58:1010-1024.

MacFarlane, R.B. 2000. Use of the San Francisco Estuary by juvenile chinook salmon. In *Fish migration and passage*, (J. Cech, Jr., S. McCormick, and D. MacKinlay, eds.) International Congress on the Biology of Fish, American Fisheries Society, pp. 41-45.

Norton, E.C. and R.B. MacFarlane. 1999. Lipid class composition of the viviparous yellowtail rockfish over a reproductive cycle. Journal of Fish Biology 54:1287-1299.

MacFarlane, R.B. and E.C. Norton. 1999. Nutritional dynamics during embryonic development in the viviparous genus *Sebastes* their application to the assessment of reproductive success. Fishery Bulletin, U.S. 97:273-281.

MacFarlane, R.B. and E.C. Norton. 1996. Lipid and protein changes during egg and embryo development in the viviparous genus *Sebastes*: application to the assessment of reproductive success. In *The fish egg: its biology and culture*, (D. MacKinley and M. Eldridge, eds.) International Congress on the Biology of Fishes, American Fisheries Society, pp. 95-102.

MacFarlane, R.B. and M.J. Bowers. 1995. Matrotrophic viviparity in the yellowtail rockfish *Sebastes flavidus*. Journal of Experimental Biology 198:1197-1206.

Norton, E.C. and R.B. MacFarlane. 1995. Nutritional dynamics of reproduction in viviparous yellowtail rockfish, *Sebastes flavidus*. Fishery Bulletin, U.S. 93:299-307.

MacFarlane, R.B., E.C. Norton, and M.J. Bowers. 1993. Lipid dynamics in relation to the annual reproductive cycle in yellowtail rockfish (*Sebastes flavidus*). Canadian Journal of Fisheries and Aquatic Sciences 50:391-401.

MacFarlane, R.B., R. Harvey, M.J. Bowers, and J.S. Patton. 1990. Serum lipoproteins in striped bass (*Morone saxatilis*): effects of starvation. Canadian Journal of Fisheries and Aquatic Sciences 47:739-745.

Setzler-Hamilton, E.M., J.A. Whipple, and R.B. MacFarlane. 1988. Striped bass populations in Chesapeake and San Francisco Bays: two environmentally impacted estuaries. Marine Pollution Bulletin. 19:466-477.

Whipple, J.A., R.B. MacFarlane, M.B. Eldridge, and P. Benville, Jr. 1987. The impacts of estuarine degradation and chronic pollution on populations of anadromous striped bass (*Morone saxatilis*) in the San Francisco Bay-Delta, California: A summary. In *San Francisco Bay: Issues, resources, status, and management*, (D.M. Goodrich, ed.) NOAA Estuary-of-the- Month Seminar Series No. n6. U. S. Dept. Commer., National Oceanic and Atmospheric Administration, NOAA Estuarine Programs Office, Washington, D. C. pp. 77-106.

MacFarlane, R.B. and P.E. Benville, Jr. 1986. Primary and secondary stress responses of striped bass (*Morone saxatilis*) exposed to benzene. Marine Biology 92:245- 254.

MacFarlane, R.B. 1984. Determination of corticosteroids in fish plasma by high performance liquid chromatography: evaluation of the method using striped bass (*Morone saxatilis*). Canadian Journal of Fisheries and Aquatic Sciences 41:1280-1286.

Whipple, J.A., M. Jung, R.B. MacFarlane, and R. Fischer. 1984. Histopathological manual for monitoring health of striped bass in relation to pollutant burdens. NOAA Technical Memorandum NMFS, SWFC-46. 81 pp.

MacFarlane, R.B. and R.J. Livingston. 1983. Effects of acidified water on the locomotor behavior of the Gulf killifish, *Fundulus grandis*: a time series approach. Archives of Environmental Contamination and Toxicology 12:163-168.

MacFarlane, R.B. 1982. A fisheries view of the drain. Fremontia 10:37.

MacFarlane, R.B. and J.A. Whipple. 1982. The striped bass (*Morone saxatilis*) as an indicator of water quality in the San Francisco Bay-Delta system. In *Proceedings of the State of the Bay Conference*, (M. Herz and S. McCreary, eds.). The Oceanic Society, San Francisco, California . pp. 81-134.

MacFarlane, R.B. 1981. Alterations in adenine nucleotide metabolism in the Gulf killifish (*Fundulus grandis*) induced by low pH water. Comparative Biochemistry and Physiology 68B:193-202.

MacFarlane, R.B. 1980. Effects of low pH water on the adenine nucleotide pool and locomotor activity of the Gulf killifish, *Fundulus grandis*. Ph.D. Thesis. Florida State University, Tallahassee, Florida. 111 pp.

MacFarlane, R.B. 1978. Molecular weight distribution of humic and fulvic acids of sediments from a North Florida estuary. Geochimica et Cosmochimica Acta 42: 1579-1582.

MacFarlane, R.B., C.J. Byrne, and R.C. Harriss. 1978. Problems of measuring and predicting the impact of persistent anthropogenic chemicals on plankton. In NATO Workshop on Ecotoxicology. University of Surrey, England. 55 pp.

MacFarlane, R.B., W.A. Glooschenko, and R.C. Harriss. 1972. The interaction of light intensity and DDT concentration upon the marine diatom, *Nitzschia delicatissima* Cleve. Hydrobiologia 39:373-382.

MacFarlane, R.B. 1970. The effects of DDT on photosynthesis and chlorophyll *a* content in the marine diatom *Nitzschia delicatissima* Cleve. under conditions of variable light intensity. M.S. Thesis. Florida State University, Tallahassee, FL. 49 pp.

Harriss, R.C., D.B. White, and R.B. MacFarlane. 1970. Mercury compounds reduce photosynthesis by plankton. Science 170:736-737.

STEVEN T. LINDLEY

Professional Address

NOAA FISHERIES
110 SHAFFER ROAD
SANTA CRUZ, CA 95060
TEL: (831) 420-3921 (OFF.)

Residential Address

408 COLUMBIA ST.
SANTA CRUZ, CA 95060
TEL: (831) 429-1848 (HOME)

EDUCATION

1994 Doctor of Philosophy (Ph.D.), Oceanography.
Duke University, Durham, North Carolina.
1989 Bachelor of Arts (B.A.), Aquatic Biology (with Honors and Distinction in the Major).
University of California, Santa Barbara, California.

EMPLOYMENT

1996-Pres. Ecologist, NOAA Fisheries, Santa Cruz and Tiburon Laboratories.
1995-1996 Research Associate, Duke University Marine Laboratory, Beaufort, North Carolina.
1994-1995 Postdoctoral Fellow, Stanford University and Carnegie Institution of Washington, Stanford, California.

ADJUNCT APPOINTMENT

1997-Pres. Adjunct Assistant Professor, Nicholas School for the Environment, Duke University, Durham, North Carolina.
2001-Pres. Research Associate, University of California, Santa Cruz, California.

RESEARCH INTERESTS
Landscape, ecosystem, community and population ecology of aquatic organisms, numerical and statistical modeling, time series analysis, stable isotopes, telemetry.

SOCIETIES
Society for Conservation Biology

REVIEWER

Journals: *Fishery Bulletin* (U.S.A.), *Canadian Journal of Fisheries and Aquatic Science, Deep Sea Research, Conservation Biology, North American Journal of Fisheries Management, Estuaries.*
Granting Agencies: *NASA SIMBIOS Program, NOAA Salston-Kennedy, NOAA Candidate Species, National Fish and Wildlife Foundation.*

HONORS

2003 Dept. of Commerce, Bronze Medal, "For expeditiously reassessing the status of all twenty-six West Coast salmon and steelhead populations listed under the Endangered Species Act."

PUBLICATIONS

Newman, K. B., S. T. Buckland, S. T. Lindley, L. Thomas, and C. Fernandez. In press. Hidden process models for animal population dynamics. Ecological Applications.

Lindley, S. T. In press. California Central Valley steelhead. *In* Updated status of Federally listed ESUs of West Coast salmon and steelhead. West Coast Salmon Biological Review Team, NOAA Fisheries, NOAA Technical Memorandum. pp. B123–B133.

Lindley, S. T. In press. Central Valley spring-run Chinook salmon. *In* Updated status of Federally listed ESUs of West Coast salmon and steelhead. West Coast Salmon Biological Review Team, NOAA Fisheries, NOAA Technical Memorandum. pp. A131–A142

Lindley, S. T. In press. Sacramento River winter-run Chinook salmon. *In* Updated status of Federally listed ESUs of West Coast salmon and steelhead. West Coast Salmon Biological Review Team, NOAA Fisheries, NOAA Technical Memorandum. pp. A124–A130

Lindley, S. T., R. Schick, B. P. May, J. J. Anderson, S. Greene, C. Hanson, A. Low, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2004. Population structure of threatened and endangered chinook salmon ESUs in California's Central Valley basin. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-SWFSC-360.

Lindley, S. T. 2003. Estimation of population growth and extinction parameters from noisy data. Ecological Applications 13: 806–813.

Lindley, S. T., and M. S. Mohr. 2003. Modeling the effect of striped bass (*Morone saxatilis*) on the population viability of Sacramento River winter-run chinook salmon (*Oncorhynchus tshawytscha*). Fishery Bulletin 101: 321–331.

Adams, P. B., C. B. Grimes, S. T. Lindley, and M. L. Moser. 2002. Status review for North American green sturgeon, *Acipenser medirostris*. National Marine Fisheries Service, Santa Cruz, California. 50 p.

Lindley, S. T., M. S. Mohr, and M. H. Prager. 2000. Monitoring protocol for Sacramento River winter chinook salmon, *Oncorhynchus tshawytscha*: application of statistical power analysis to recovery of an endangered species. Fishery Bulletin 98: 759–766.

Brodeur, R. D., W. T. Peterson, G. W. Boehlert, E. Casillas, M. H. Schiewe, M. B. Eldridge, S. T. Lindley, J. H. Helle, and W. R. Heard. 2000. A coordinated research plan for estuarine and ocean research on Pacific salmon. Fisheries 25: 7–16.

Chai, F., S. T. Lindley, J. R. Toggweiler, and R. T. Barber. 2000. Testing the importance of iron and grazing in the maintenance of the high nitrate condition in the equatorial Pacific Ocean: a physical-biological model study. *In* The Changing Ocean Carbon Cycle: a midterm synthesis of the Joint Global Ocean Flux Study. *Edited by* R. B. Hanson, H. W. Ducklow, and J. G. Field. International

Geosphere-Biosphere Programme Book Series 5. Cambridge University Press. pp. 155–186.
Bender, M., J. Orchardo, M. Dickson, R. Barber, and S. Lindley. 1999. In vitro O_2 fluxes compared with ^{14}C production and other rate terms during the JGOFS Equatorial Pacific experiment. Deep-Sea Research Part I: Oceanographic Research Papers 46: 637–654.
Lindley, S. T., and R. T. Barber. 1998. Phytoplankton response to natural and experimental iron addition. Deep-Sea Research Part II: Topical Studies in Oceanography 45: 1135–1150.
Myers, J. M., R. G. Kope, G. J. Bryant, D. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grant, F. W. Waknitz, K. Neely, S. T. Lindley, and R. S. Waples. 1998. Status review of chinook salmon from Washington, Idaho, Oregon, and California. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-35, 443 p.
Foley, D. G., T. D. Dickey, M. J. McPhaden, R. R. Bidigare, M. R. Lewis, R. T. Barber, S. T. Lindley, C. Garside, D. V. Manov, and J. D. McNeil. 1997. Longwaves and primary productivity variations in the equatorial Pacific at 0E, 140EW. Deep-Sea Research Part II: Topical Studies in Oceanography 44: 1801–1826.
Landry, M. R., R. T. Barber, R. R. Bidigare, F. Chai, K. H. Coale, H. G. Dam, M. R. Lewis, S. T. Lindley, J. J. McCarthy, M. R. Roman, D. K. Stoecker, P. G. Verity and J. R. White. 1997. Iron and grazing constraints on primary production in the central equatorial Pacific: An EqPac synthesis. Limnology and Oceanography 42: 405–418.
Lindley, S. T. 1997. Estimating escapement of the Sacramento River winter-run chinook: a review of methods. NMFS SWFSC Administrative Report T-97-02. 19 p.
Chai, F., S. T. Lindley, and R. T. Barber. 1996. Origin and maintenance of a high nitrate condition in the equatorial Pacific. Deep-Sea Research Part II: Topical Studies in Oceanography 43: 1031–1064.
Barber, R.T., M. P. Sanderson, S. T. Lindley, F. Chai, J. Newton, C. C. Trees, D. G. Foley, and F. P. Chavez. 1996. Primary productivity and its regulation in the equatorial Pacific during and following the 1991–1992 El Nino. Deep-Sea Research Part II: Topical Studies in Oceanography 43: 933 –969.
Lindley, S. T., R. R. Bidigare, and R. T. Barber. 1995. Phytoplankton photosynthesis parameters along 140EW in the equatorial Pacific. Deep-Sea Research Part II: Topical Studies in Oceanography 42: 441–463.
Barber, R. T., F. Chai, S. T. Lindley, and R. R. Bidigare. 1994. Regulation of equatorial primary production. *In*: Global Fluxes of Carbon and its Related Substances in the Coastal Sea-Ocean-Atmosphere System. *Edited by* S. Tsunogai, K. Iseki, I. Koike, and T. Oba. Proceedings of the 1994 IGBP Symposium, Sapporo, Japan. pp. 294–300.
Kolber, Z. S., R. T. Barber, K. H. Coale, S. E. Fitzwater, R. M. Greene, K. S. Johnson, S. Lindley, and P. G. Falkowski. 1994. Iron limitation of phytoplankton photosynthesis in the equatorial Pacific Ocean. Nature 371: 145–149.
Martin, J. H., K. H. Coale, K. S. Johnson, S. E. Fitzwater, R. M. Gordon, S. J. Tanner, C. N. Hunter, V. A. Elrod, J. L. Nowicki, T. L. Coley, R. T. Barber, S. Lindley, A. J. Watson, K. Van Scoy, C. S. Law, M. I. Liddicoat, R. Ling, T. Stanton, J. Stockel, C. Collins, A.

Anderson, R. Bidigare, M. Ondrusek, M. Latasa, F. J. Millero, K. Lee, W. Yao, J. Z. Zhang, G. Friederich, C. Sakamoto, F. Chavez, K. Buck, Z. Kolber, R. Greene, P. Falkowski, S. W. Chisholm, F. Hoge, R. Swift, J. Yungel, S. Turner, P. Nightingale, A. Hatton, P. Liss, and N. W. Tindale. 1994. Testing the iron hypothesis in ecosystems of the equatorial Pacific Ocean. Nature 371: 123–129.

Henley, W. J., S. T. Lindley, G. Levavasseur, C. B. Osmond, and J. Ramus. 1992. Photosynthetic response of *Ulva rotundata* to light and temperature during emersion on an intertidal sand flat. Oecologia 89: 516–523.

Henley, W. J., G. Levavasseur, L. A. Franklin, S. T. Lindley, J. Ramus, and C. B. Osmond. 1991. Diurnal responses of photosynthesis and fluorescence in *Ulva rotundata* acclimated to sun and shade in outdoor culture. Marine Ecology Progress Series 75: 19–28.

ARNOLD J. AMMANN

Professional Address

NOAA Fisheries
Southwest Fisheries Science Center
110 Shaffer Rd.
Santa Cruz, CA 95060
TEL: (831) 420-3968
Email: Arnold.Ammann@noaa.gov

Residential Address

803 Skyline Dr.
Felton, CA 95018
TEL: (831) 335-4902

EDUCATION

2001 Master of Arts in Biology
University of California Santa Cruz
1994 Bachelor of Arts, Aquatic Biology
University of California, Santa Barbara

EMPLOYMENT

2002-Pres. Research Fishery Biologist, NOAA Fisheries, Santa Cruz, CA.
2002-2002 Post-graduate researcher, Partnership for Interdisciplinary Studies of Coastal Oceans, UC Santa Cruz
1998-2002 Research Assistant, Partnership for Interdisciplinary Studies of Coastal Oceans, UC Santa Cruz
1995-1998 Laboratory Technician II, Ecology of fish on natural reefs and oil/gas production platforms, Marine Science Institute, Santa Barbara
1995 Research Assistant, Long Term Ecological Research Program, Antarctica
1994 Research Technician GS-5, Kelp Forest Monitoring Project, Channel Islands National Park Service, Ventura, CA

RESEARCH INTERESTS

Behavior ecology and Physiology of Salmonids; Population and recruitment dynamics of fishes; biological oceanography

SOCIETIES

Western Society of Naturalist

HONORS

Friends of the Long Marine Laboratory Award 2000 and 2001
Myers Oceanography and Marine Biology Trust Award 1999

SCIENTIFIC ARTICLES

Ammann, A.J. 2003 SMURFs: standard monitoring units for the recruitment of temperate reef fishes. J. Exp. Mar. Bio. Ecol. 299:135-154.

Ammann, A.J. and Carr, M.H. 2000. In: *Ecosystem Observations for the Monterey Bay National Marine Sanctuary:* Contrasting effects of La Nina and El Nino on recruitment of juvenile rockfish. pp. 11-12

Ammann, A.J.; Shroeder D.M.; and Love M. In: *Ecological role of natural reefs and oil and bas production platforms on rocky reef fishes in southern California*: Abundance, biomass, and egg production of kelp bass (*Paralabrax clathratus*) inside and outside marine reserves at Santa Catalina Island, California. USGS/BRD/CR 1999-0007 pp. SB-1 to SB-3

JUNIOR SPECIALIST

A job search will be carried out at the University of California, Davis to hire a person, who will be qualified to deploy tag-detecting monitors within the Sacramento River and San Francisco Estuary and place coded tags on juvenile steelhead trout at the headwaters of the river.

GRADUATE STUDENT RESEARCHER

A student will be accepted into the Ph.D. program of the Ecology Graduate Group at University of California, Davis, and that person will conduct his (or her) doctoral research on the survival and movement patterns of steelhead trout in the Sacramento River. That person will also assist the Junior Specialist in deploying and maintaining tag-detecting monitors within the Sacramento River and San Francisco Estuary and placing coded tags on juvenile steelhead trout at the headwaters of the river.

Glenn Szerlong has a Master's of Science degree in biostatistics from the University of Idaho

Laboratory Assistant III

A Laboratory Assistant III will be hired to accomplish the tagging of juvenile salmonids, and to assist in the deployment and retrieval of monitors. This individual will meet the requirements of a Laboratory Assistant III at the University of California, Santa Cruz. He/she will have a Bachelor's degree in Biology or other Life Science and will have knowledge of fish biology and experience dissecting or operating on fishes.

SURVIVAL AND MIGRATORY PATTERNS OF CENTRAL VALLEY JUVENILE SALMONIDS: Signature

This proposal is for the Science Program 2004 solicitation as prepared by Klimley, Abbott (Peter) P..

The submission deadline is approximately 30 hours from now.

Proposal updates will be disabled immediately after the deadline. All forms, including the signature form, must be completed, compiled and acknowledged in order to be eligible for consideration and review. Allow at least one hour for Science Program staff to verify and file signature pages after they are received.

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 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: SURVIVAL AND MIGRATORY PATTERNS OF CENTRAL VALLEY JUVENILE SALMONIDS
Proposal Number: 2004.01-0313
Submitter: Klimley, Abbott (Peter) P. (apklimley@ucdavis.edu)

A. Peter Klimley René Domino, CRA 01/05/05

Applicant Signature **Date**

A. PETER KLIMLEY THE REGENTS OF THE UNIVERSITY OF CALIFORNIA UNIV. OF CALIF., DAVIS

Printed Name Of Applicant René H. Domino, CRA
Contracts & Grants Analyst **Applicant Organization**

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

We care about the data we collect. Please read our privacy policy.

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René H. Domino, CRA, Contracts and Grants Analyst
Office of Research
One Shields Avenue
Davis, California 95616-8671

Sponsored Programs, 118 Everson Hall
Telephone: (530) 752-6065
Fax: (530) 754-9233
e-mail: rhdomino@ucdavis.edu

January 6, 2005

Ms. Kate Marie, Grant Manager
Science Program
California Bay-Delta Authority
650 Capitol Mall, 5th Floor
Sacramento CA 95814

Dear Ms. Marie:

Letter in Support of Project #2004-01-0313 Entitled: **"Survival and Migratory Patterns of Central Valley Juvenile Salmonids"**
UCDavis Principal Investigator- Dr. Peter Klimley

It is our pleasure to forward institutional support and approval of the collaboration by UCD's Dr. Klimley on the referenced research project to the California Bay-Delta Authority Science Program.

Please note as outlined in Attachments 3 and 6 of the Solicitation we would like to address the Compliance with Standard Terms and Conditions section in order to provide notification that UCD takes exception to the following proposed "standard" clauses:

Exhibit C – Section 12 – State Travel & Per Diem Expenses Guidelines (Delete)
Exhibit C – General Terms and Conditions for ERP Grants (Replace with GIA 101)
Exhibit C – Special Terms and Conditions for ERP Grants (Replace with UC IP Clause)
Exhibit D – Section 13. Rights In Data - UC reserves the right to negotiate the Terms and Conditions regarding Rights in Data to align with the policies of The Regents of the University of California.

Please note the above has previously been negotiated with CALFED/GCAPS on behalf of the University of California and agreeable language has been included in the following current ERP agreements with UC Davis (ERP-02D-P31, ERP-02D-P32, ERP-02D-P33, ERP-02D-P35, and ERP-02D-P51).

Should the Department make an award to the University, we would anticipate negotiating terms that comply with University and federal guidelines as they pertain to the higher learning institutions and retention of intellectual property rights.

Please contact the principal investigator for scientific information. Administrative questions may be directed to me by telephone, facsimile or electronic mail at the numbers cited above.

Sincerely,

René Domino, CRA

René H. Domino, CRA
Contracts & Grants Analyst

cc: Dr. P. Klimley