Proposal submission for the CALFED 2007 Supplemental PSP

Name of PI: Peter Klimley
Institution: University of California, Davis

Title of Supplemental Proposal: Supplement: Survival and Migratory Patterns of Central Valley Juvenile Salmonids

Funding Amount Requested: $ 256,676

Original Proposal Title: Survival and Migratory Patterns of Central Valley Juvenile Salmonids

Year of Original Proposal Submission: 2004

Proposal to:

CALFED Science Program
650 Capitol Mall, 5th Floor
Sacramento, CA 95814

Submitting Organization:

The Regents of the University of California
Sponsored Programs, 118 Everson Hall
One Shields Avenue
University of California
Davis, California 95616-8671

Title of Proposed Research:

SUPPLEMENT: SURVIVAL AND MIGRATORY PATTERNS OF CENTRAL VALLEY JUVENILE SALMONIDS

Total Amount Requested:	**Proposed Duration:**	**Desired Starting Date:**
$259,676	12 months	03/01/08
Principal Investigator:	**Department:**	**Phone Number:**
A. Peter Klimley, Ph.D.	Watershed Center	752-5830

Checks Made Payable to:

The Regents of the University of California

Send Checks to:

Cashier's Office
1200 Dutton Hall
One Shields Avenue
University of California
Davis, California 95616

Send Award Notice to:

Office of the Vice Chancellor for Research
Sponsored Programs, 118 Everson Hall
One Shields Avenue
University of California
Davis, California 95616-8671
(530) 752-2075 / FAX (530) 752-5432

Approvals:

A. Peter Klimley 01/03/08
Principal Investigator Date

Cheryl Smith 1/3/08
Department Chair Date

Dean, College/School (if required) Date

Other Endorsement (optional) Date

Danielle Neff
Official Signing for Organization Date

Danielle Neff
Contracts and Grants Analyst

Project Title: SUPPLEMENT: SURVIVAL AND MIGRATORY PATTERNS OF CENTRAL VALLEY JUVENILE SALMONIDS

PI: A. Peter Klimley, University of California, Davis
Co-PI: R. Bruce MacFarlane, NOAA Fisheries, Santa Cruz and University of California, Santa Cruz

I. Project Goals

A. Purpose

We will continue to determine the survival and movement patterns of hatchery raised, steelhead (*Oncorhynchus mykiss*) and late-fall Chinook salmon (*O. tshawytscha*), but will in addition determine the same for wild fall and late-fall Chinook smolts, > 115 mm fork length, as they migrate from the upper Sacramento River, down the mainstem, through the San Francisco Estuary, and into the ocean. These smolts will carry individually coded miniature ultrasonic transmitters placed within their peritoneal cavities. The number of hatchery raised smolts, tagged at the Coleman Hatchery, will be increased from 200 to 300 for each species, and they will be released at three locations along the mainstream to reduce the confidence intervals of survival estimates. The same number of wild smolts, captured in screw traps at the Red Bluff Diversion Dam, Glen Colusa, Knight's landing, and tagged at the Center for Aquaculture and Aquatic Biology of UC Davis, will be released at the three sites so that the rates of movement and survival of hatchery raised fish can be compared with that of wild fish. 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 group'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. Introduction

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.

Investigators from UC Davis and NMFS determined the reach-specific, survival rates of 200 late-fall run Chinook and 200 steelhead smolts, released from Coleman Hatchery into Battle Creek during January 2007, in the Sacramento River and San Francisco Estuary. These rates were determined using a large-scale array of automated monitors throughout the Sacramento/San Joaquin watershed, which is capable of detecting the migratory movements of fish carrying coded ultrasonic beacons. Roughly 200 automated, tag-detecting monitors are now situated along the mainstem of the Sacramento and San Joaquin Rivers, throughout the Delta, and within Grizzly, Suisun, San Pablo, and San Francisco Bays. Monitors downstream of Suisun Bay are provided by partners in our study, including the U.S. Army Corps of Engineers and the Bay Planning Coalition. These monitors are continuously active and able to detect tagged salmonids (and other species of fish tagged with similar transmitters, such as green sturgeon) as they pass through their ranges of detection. The data collected from the individual-specific, coded signals of the beacons are stored in the memory of the monitors. Not only are single and paired monitors situated between successive reaches of the river, averaging roughly one monitor moored every 10 river kilometers, but arrays of monitors, each monitor separated from another by <300 m, exist across the waterway at Chipps Island, across the Benicia and Carquinez straits, parallel to the Richmond-San Rafael and Bay Bridge, and the Golden Gate.

The total number of monitors deployed is likely to increase by 50-100 as part of 1) a Directed Action funded by the California Department of Fish and Game to study the movements of juvenile green sturgeon, 2) additional grants to unspecified organizations, and 3) studies conducted by the Army Corps of Engineers to determine the potential effect of dredging in the San Francisco Estuary on endangered fish species. The ability of the monitors to detect a diversity of tags of varying sizes and tag lives placed on multiple species has lead to the formation of the California Fish Tracking Consortium, which includes UC Davis/UC Santa Cruz-NMFS, other state and federal agencies (US Fish & Wildlife Service, US Army Corps of Engineers., CA Water Resources, CA Fish & Game), local government (Bay Planning Coalition, East Bay Municipal District) and private consultants (ECORP, Hanson Environmental). An internet site (see http://www. californiafishtracking/), created with CALFED funds provides project descriptions and

personal biographies of participating scientists, and it is currently maintained on the server of the Watershed Center of the University of California, Davis. At three-month intervals, the data from all fish tagged within the Central Valley are retrieved from the monitors by the various participating organizations. The data are entered into a database (using Microsoft Access software) by scientists of the National Marine Fisheries Service. These data can be obtained through the internet site using user-friendly software, provided permission is granted by the participants. This project was drawn together for one common objective – the elucidation of the movement and mortality patterns of fishes in the context of environmental variables, both natural and anthropogenic.

B. Progress to Date

1. Results of Year 1

The first year (of three) of the CALFED-funded project entitled "Survival and migratory patterns of Central Valley juvenile salmonids," has been very successful and validated our ability to provide high-resolution spatial and temporal estimates of movement and survival. In January 2007, we implanted ultrasonic tags, each with a unique signature code, within the peritoneal cavity of 200 Chinook salmon and 200 steelhead smolts. These tagged fish were released into Battle Creek and the Sacramento River, respectively, over a four-week period and the monitors recorded them as they swam through the range of each monitor during their migration throughout the watershed to the ocean (Fig. 1). It is apparent that the

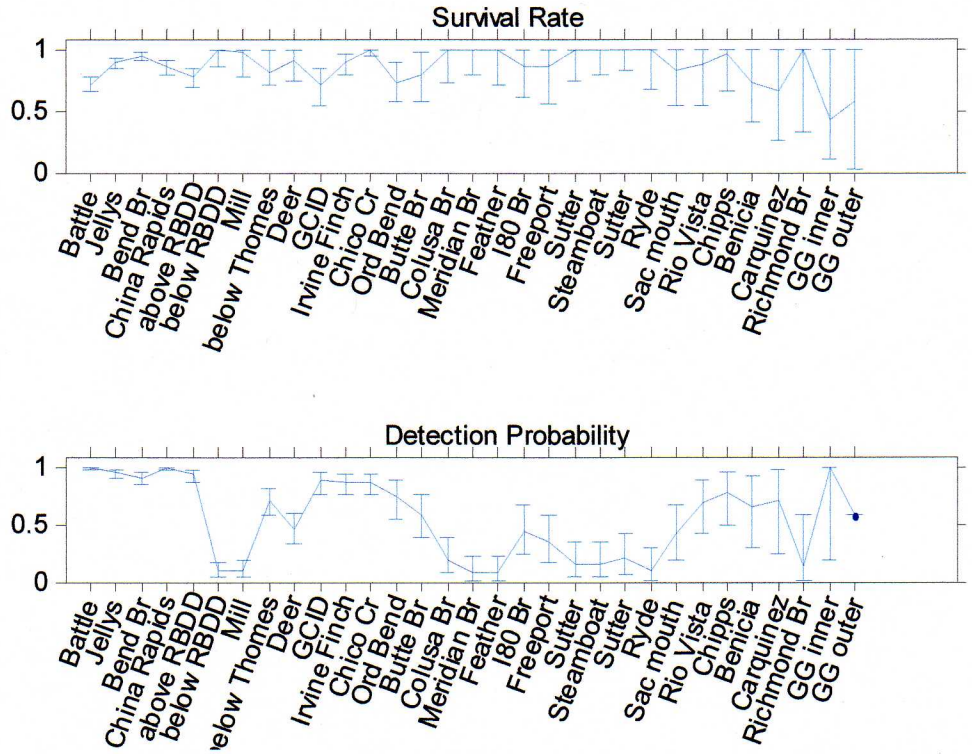

Fig. 1. Estimated survival and detection probabilities for late-fall-run Chinook salmon. Error bars represent 95% confidence intervals.

survival of both juvenile Chinook salmon and steelhead decreases rapidly within the river, with only roughly 10-15% of the smolts reaching the Delta. Mortality appears to lessen within the Delta and Bay. However, the number of tagged fish was greatly reduced by the time the fish entered the lower river and estuary, with few tagged fish being detected by the monitors situated between Sacramento and the Golden Gate.

Our initial analysis of 202 late-fall-run Chinook smolts released from CNFH in January 2007 shows that survival was quite low—only about 5 of the released fish are estimated to have made it downstream to the Golden Gate bridge. Because survival was poor, there are too few fish to estimate survival with good precision below Red Bluff Diversion Dam—the width of 95% confidence intervals begins to exceed 20% of the estimated survival rate, and intervals continue to grow until they span 0.1-1.0 at the inner Golden Gate line (the survival and detection rates are confounded at the outer Golden Gate line) [see Fig. 1]. Detection rates were excellent on the upper river (with the exception of a few sites with known problems), but declined to rather low levels between the mouth of Butte Creek and the mouth of the Sacramento River. It may be necessary to add one or more monitors to these locations to improve detection rates. Better detection rates would improve survival estimates for these reaches to some extent, although the small number of fish that survive to these reaches is a greater issue.

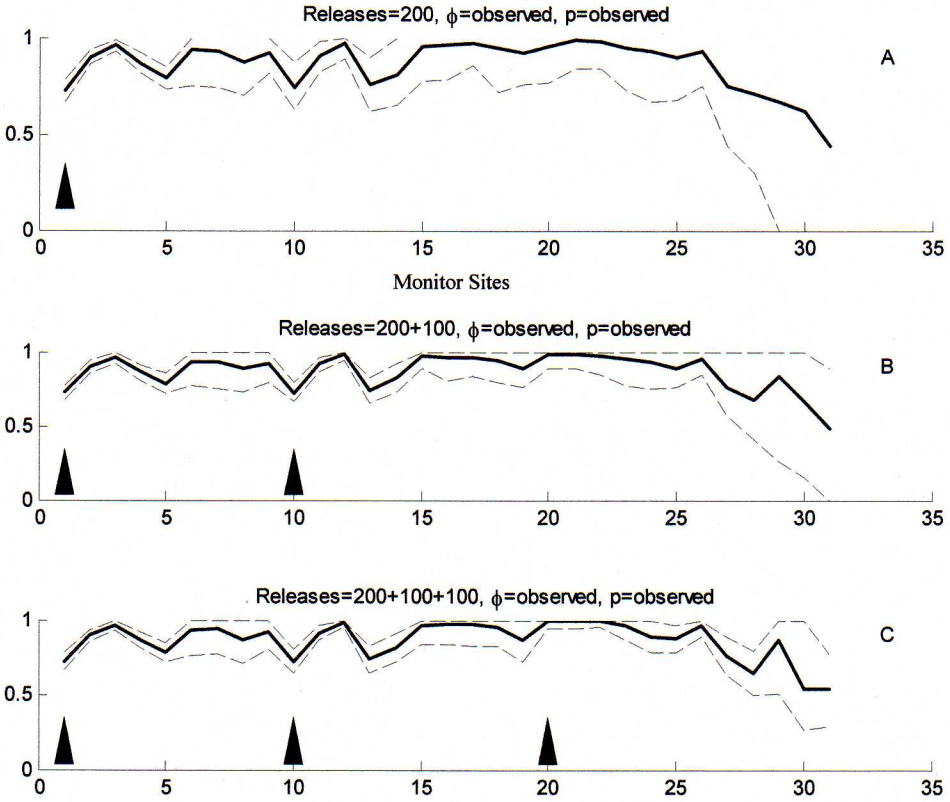

Fig. 2. Simulated effects of releasing additional groups of Chinook smolts downstream of Battle Creek. Panel A: estimate survival rates (solid line) and 95% CI (dashed lines) for 200 fish released at CNFH, survival rates and detection probabilities = 2007. Panel B & C: same as in A but additional fish released at GCID, entrance of Steamboat Slough, and at the base of estuary.

We can significantly improve the precision of survival estimates at downstream reaches by increasing the number of fish that reach those locations. The most effective way to achieve this is to release additional groups of fish at intermediate locations. Simulations can show the effects of releasing more fish at various locations. Assuming 2007's detection rates, releasing additional fish at three sites downstream of Battle Creek would greatly improve the precision of survival rate estimates (Fig. 2). Even more consistent and reasonably tight CI's can be achieved by releasing multiple groups of 100 fish at three evenly distributed points along the river and increasing the probability of detection (Fig. 3). Increasing the probability of detection would further decrease the confidence intervals. The simulations assuming good detection probabilities show significant improvement over what would be expected with

detection probabilities equal to what was observed in the 2007 experiment, especially on the lower river and through the Bay, where there were few surviving fish and detection rates were low to moderate. In conclusion, releasing additional tagged fish at multiple sites throughout the watershed would likely increase the number of tagged smolts transiting both the river and the estuary and result in significantly higher accuracy of mortality estimates and movement patterns. The value of this ongoing study would be enhanced greatly and the study would provide results of greater utility to resource managers in decision-making relative to ESA-listed species within the river and estuary. David Woodbury, who oversees compliance with the Endangered Species Act in this region by NMFS, will be corresponding with you in support of our request.

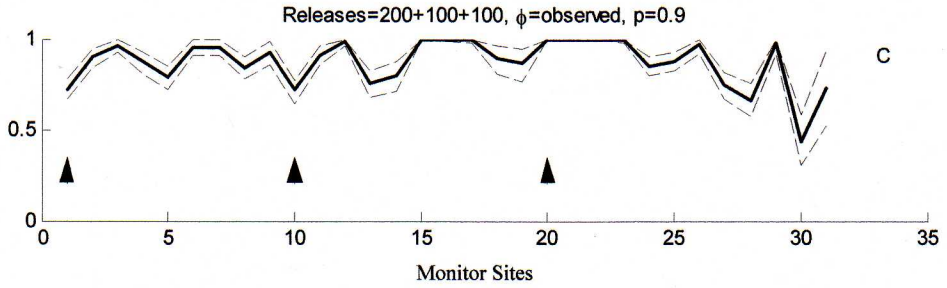

Fig. 3. Simulated effects of releasing additional groups of Chinook smolts downstream of Battle Creek with a higher level of probability.

1. Ongoing Effort during Year 2

The tagging procedures were modified on the basis the results of the January 2007 releases of late-fall run Chinook and steelhead smolts, and the simulations carried out to provide insight into how to reduce the confidence limits of the survival estimates throughout the Sacramento River and San Francisco Estuary. Firstly, the number of release sites was increased from one to three, and the number of smolts of each species released was increased by 300 per site NMFS in Seattle provided the funds to NMFS in Santa Cruz to acquire an additional 86 coded tags for Chinook smolts with the rationale that given a sufficient sample site, the reach-specific survival estimates determined along the mainstem of the Sacramento River could be compared with similar estimates, using the same technology, in the Columbia River in Washington and the Fraser River in British Columbia. The Army Corps of Engineers provided 14 more coded tags for Chinook (now totaling 300) and 100 for steelhead smolts to be released at the lowermost release site on the river, from where a sufficient fraction of the release would enter the bay and their distribution could be determined relative to dredge removal and deposition sites. Fifty smolts of each species were released during successive weeks in December and January at three reaches: 1) Jelly's Ferry, 2) Irvine Finch, and 3) Ord Bend. These three release sites were chosen because they were upstream of three separate sections of the watershed, which were shown in our 2007 studies to have consistent but different rates of survival. The rate of survival was least between Battle Creek to Red Bluff, slightly higher between Red Bluff and Ord Bend, and greatest from Ord Bend to the Golden Gate (Fig. 4). The smolts were released at nighttime to reduce predation on them as they acclimated to the river environment.

Secondly, a concerted attempt has been made to increase the probability of tag detection. The pseudorandom interval between the train of pulses, indicating the tags numerical identity, has been decreased so that it varies between 45-60 s to ensure the tag's detection as it passes downriver within range of the monitors. Two monitors have been deployed 100 m apart so that their ranges of reception, determined to equal 50 m in the shallowest reaches, are abutting, providing a 200 m range of detection.

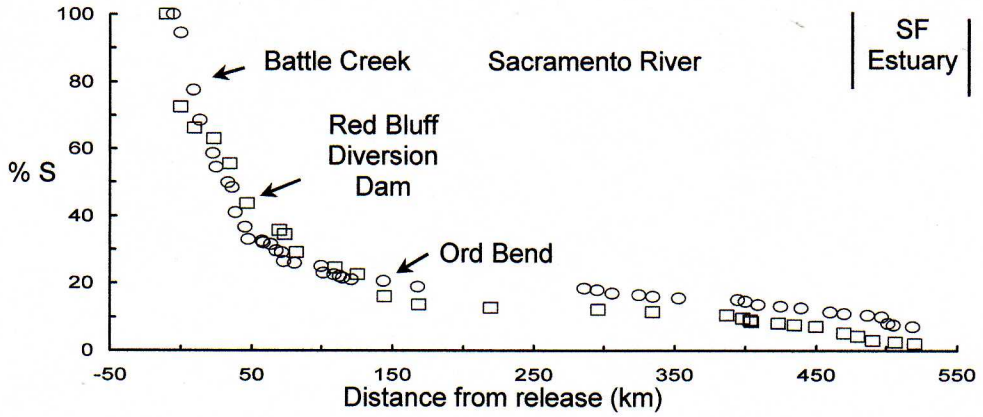

Fig. 4. Cumulative percent decrease in survival (%S) with increasing distance from release site.

B. Proposed Supplementary Research

We will continue to determine the survival and movement patterns of hatchery raised, steelhead (*Oncorhynchus mykiss*) and late-fall Chinook salmon (*O. tshawytscha*), during Year 3. Supplementary funding is sought from CALFED to increase the number of hatchery raised smolts, tagged at the Coleman Hatchery from 200 to 300 for each species, and they will again be released at the three sites, Jelly's Ferry, Red Bluff Diversion Dam, and Ord Bend along the mainstream to reduce the confidence intervals of survival estimates. The contributions from NMFS, Seattle, and ACE for additional tags during 2007 were a one-time matching contribution to the project. It is essential that we release the same number of tags during 2007 and 2008 as during the prior years so that our methodology is consistent between years.

In addition, we request funds from CALFED to purchase 300 additional tags to place on wild fall and late-fall Chinook smolts, as they migrate from the upper Sacramento River, down the mainstem, through the San Francisco Estuary, and into the ocean. Biologists of the United States Fish and Wildlife Service captured 91 wild smolts, <115 mm fork length, in their rotary screw trap deployed downstream of the Red Bluff Diversion Dam during Oct-Nov 2005, 136 during 2006, and 61 in 2007 (Poytress, USFWS, pers. commun). Similar rotary screw traps are deployed along the length of the Sacramento River such as at Glen Colusa and Knight's Landing. We will supply the biologists operating these traps with large, 120 qt coolers with aeration, into which they will place wild smolts upon capture. We will remain on-call, and will drive to these sites to fetch the wild smolts immediately upon capture, and will transport them to the Center for Aquaculture and Aquatic Biology of UC Davis, where they will kept and fed until enough individuals have been collected to tag and release them into the river. They will be released at the three sites mentioned earlier so that the rates of movement and survival of hatchery raised fish can be compared with that of wild fish. It is essential to determine the rates of movement and survival of wild smolts as the main criticism directed at this project in the past has been that we have been tagging hatchery reared smolts. It is true that the majority of fish in the watershed are likely hatchery reared, but it is important to also understand the life history properties of the wild late-fall run Chinook as well as the hatchery reared fish.

The increase in the number of fish tagged will necessitate the hiring of additional seasonal help to remain on call to collect fish from the rotary screw traps and tag fish. We are requesting two months during Dec and Jan for a Fisheries Specialist I at UC Davis and a Fishery Biologist I at UC Santa Cruz (and NMFS). We will also need to build an additional tagging apparatus, and purchase additional surgical supplies for the additional tagging of fishes. In addition, we request funds for (1) the purchase a portable receiver and portable hydrophone, which will enable us to drift downstream through reaches between the monitors and detect the presence of tagged smolts, and (2) the improving the home page of the California Tracking Consortium (http://ww.california fishtracking.ucdavis.edu) so that it is programmed using

Dreamweaver software, and provides an easy menu to collaborators, which will enable them to search for all monitors that detect given tags or to search for all tags detected by a single monitor.

Downstream passage and survival of both the hatchery reared and wild smolts during outmigration will be recorded by automated, transmitter-detecting monitors placed at the many sites throughout the watershed, and the survival rates will be determined as in the past using the program Mark. Data from these monitors will allow us to reconstruct each group's migratory path and ascertain rates of migration, residence times in specific river segments (reaches) and regions of the bay, and ultimately survival (or mortality) rates associated with those locations. In the original objectives of the project, we indicated an interest in comparing rates of survival along reaches of the river, for which habitat information is available. Currently, the Landscape Ecology Group at NMFS under the direction of Steven Lindley is relating reach-specific survival rates to habitat variables recorded in various GIS datasets. Our hope is that the effectiveness of anthropogenic improvements to the banks of the river can be determined by identifying an increase in the survival of outmigrating smolts in such areas after levee improvements.

There is likely to be an opportunity to work in such an effort during Year 3 of this study. The California Department of Water Resources (DWR) is in negotiations with HT Harvey and Associates as well as UC Davis (Klimley and Thompson, PIs) to provide environmental monitoring services for critical erosion repairs at 57 sites along the Sacramento and Bear Rivers, Steamboat, Cache, and Sutter Sloughs, and Cache Creek, California. The California Department of Water Resources undertook repairs at 21 of the sites, and the US Army Corps of Engineers, Sacramento District undertook repairs at 36 of the sites. These sites were identified in the Corps' 2005 and 2006 Field Reconnaissance Memo, Sacramento River Erosion Site inventory, Ayres Associates, as critical whereby erosion into the banks at these sites required immediate work to prevent future levee failure. As described further in the BOs, monitoring requirements include evaluations of habitat features including seasonally inundated benches, anchored instream woody material (IWM), the planting of riparian vegetation, and other fish habitat protection and enhancement measures. Direct fisheries monitoring is also required to validate that the project habitat features effectively avoid jeopardy and minimize adverse effects to listed fish species.

UC Davis (likely in conjunction with NMFS biologists) will monitor the response of steelhead smolts to levee repairs by implanting coded ultrasonic beacons within the peritoneum of 100 steelhead smolts and releasing them upstream of the erosion repair sites and record their passage both by five experimental sites, each characterized with a form of erosion repair, and five control sites, consisting of unaltered levee. Tag-detecting monitors would be placed immediately upstream and downstream of the sites, and this will permit us to record the duration of their tenure at the sites, their rate of passage, and whether they succeed in transit and do not succumb to predation. DWR would provide the funds to purchase tags, additional monitors, and salary support for personnel working on this study. These funds may be considered matching funds for this supplement, increasing the monitor coverage and sample size of tagged fish.

III. Literature Cited

Fisher, F.W. 1994. Past and Present Status of Central Valley Chinook Salmon. *Conservation Biology*, 8: 870-873.

Fry, D.H. 1961. King Salmon spawning stocks of the California Central Valley, 1949-1959. *California Fish and Game*, 47: 55-71.

Needham, P.R., O.R. Smith & H.A. Hanson. 1941. Salmon salvage problems in relation to Shasta Dam, California, and notes on the biology of the Sacramento River salmon. Abstract, *Transactions of the American Fisheries Society*, 17th annual meeting.

Stone, L. 1874. Report of operations during 1872 at the United States salmon hatching establishment on the McCloud River. Pp. 168-215 *in* U.S. Commission on Fish and Fisheries, Report for 1872 and 1873, Part II, Washington, D.C.

UC Davis supplement for "Survival and migratory patterns of Central Valley juvenile salmonids" (U-05-SC-047)

Salaries

Time (mo)	Staff	Salary	Row Total
2	Fisheries Specialist I	2,808	5,616
0.5	Financial Manager	6,324	3,162

Total Labor 8,778

Benefits

Time (mo)	Staff	Rate	Benefits	Total
2	Fisheries Specialist I	0.44	2471	2,471
0.5	Financial Manager	0.30	949	949

Total Benefits 3,420

Total Labor (Salary & Benefits) 12,198

Travel

Time	Staff	# Days	Lodging rate	Per Diem rate	Total
2 mo (December-January)	1	32	82	64	4,672

# Trips	Miles/trip	Rate/mile	Total
8	400	0.485	1,552

Total travel 6,224

Supplies

Item	Quantity	Cost/each	Total
Vemco V9 acoustic tags	250	320	80,000
Material for surgery table	1	500	500
Surgery supplies	1	2,800	2,800

Total Supplies 83,300

Equipment

Item	Quantity	Cost/each	Total
Vemco VR100 portable receiver	1	6,353	6,353
Total Equipment			6,353

Miscellaneous

Item	Cost	Total
Website upgrade	5,000	5,000
Total Miscellaneous		5,000

Subcontract

Item	Cost	Total
UCSC/NMFS Subcontract (UCSC_NMFS)	1 119,921	119,921
Total Subcontract		119,921
Total Direct Costs		232,996
Indirect Costs (25%)		26,680
Total UCD		259,676

UCSC/NMFS Subcontract for UC Davis supplement for "Survival and migratory patterns of Central Valley juvenile salmonids" (U-05-SC-047)

Salaries

Time (mo)	Staff	Salary	Row Total
	2 Lab Asst III	2,668	5,336
Total Labor			5,336

Benefits

Time (mo)	Staff	Rate	Benefits	Total
	2 Lab Asst III	0.35	1868	1,868
Total Benefits				1,868
Total Labor (Salary & Benefits)				7,204

Travel

Time	Staff	# Days	Lodging rat	Per Diem rat	Total
2 mo (December-January)	1	32	82	64	4,672
Total travel					4,672

Supplies

Item	Quantity	Cost/each	Total
Vemco V7 acoustic tags	250	320	80,000
Material for surgery table	1	500	500
Surgery supplies	1	2,800	2,800
Total Supplies			83,300
Total Direct Costs			95,176
Indirect Costs (26%)			24,746
Total UCSC/NMFS			119,921