Proposal to:

DFG Water Branch
830 S Street
Sacramento, CA 958114

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:

SURVIVAL AND MIGRATORY PATTERNS OF JUVENILE SPRING AND FALL RUN CHINOOK SALMON IN SACRAMENTO RIVER AND DELTA

Total Amount Requested:	**Proposed Duration:**	**Desired Starting Date:**
$1,729,280	3 years	10/1/10
Principal Investigator:	**Department:**	**Phone Number:**
A. Peter Klimley	Wildlife, Fish, & Conserv. Biology	(530) 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 02/28/11
Principal Investigator Date

[illegible] 28 Feb 11
Department Chair Date

Dean, College/School (if required) Date

Other Endorsement (optional) Date

May A. Turner 2/28/11
Official Signing for Organization Date
May Turner
Contracts and Grants Analyst

Table of Contents

Peter Klimley

From: Dave Zezulak [DZezulak@dfg.ca.gov]
Sent: Friday, February 25, 2011 4:27 PM
To: Peter Klimley
Cc: jmerz@fishsciences.net; Kevin_Niemela@fws.gov; Robert_Null@fws.gov; arnold.ammann@noaa.gov; Bruce.Macfarlane@noaa.gov; Cyril.Michel@noaa.gov; 'Hays Sean'; Steve.Lindley@noaa.gov; Singer Gabriel; May Turner
Subject: Re: FW: (P02) Klimley, A - Proposal Receipt - Acceptance (Project #201118571)

May Turner - Peter Klimley has asked for confirmation that the Department of Fish and Game Ecosystem Restoration Program has requested that he resubmit his proposal originally submitted to the Delta Science Program, as written - with addendum to address reviewers comments. The format requested by Delta Science Program and the Ecosystem Restoration Program for their proposal solicitation is similar and the peer review process is carried out under a shared resource. We will evaluate this proposal compared to the merits of all proposals submitted.

There are 3 other proposals being considered using this format, including one by Nann Fangue. If you have any questions please contact me. Have a great weekend.

from the desk of:
=====================
David S. Zezulak, Ph. D.
EPM I - Water Branch
Ecosystem Restoration Program
Department of Fish and Game
830 S Street
Sacramento, California 95811-7023
dzezulak@dfg.ca.gov
phone:916.445.3960
cell: 916.838.9671
fax:916.445.1768
=====================

>>> On 2/25/2011 at 3:33 PM, in message <002e01cbd544$7754f520$65fedf60$@edu>, Peter Klimley <apklimley@ucdavis.edu> wrote:

Hi Dave:

May Turner is the contract analyst assigned to our proposals submission. She will assist me in the proposal submission.

She would like a short note from you saying that it is OK for us to submit the CALFED proposal, which I have obtained from CALFED compiled in pdf form, with a new cover page specifying DFG as the sponsor, the comments from the reviewers, and our addendum. This will save us a huge output of time and labor.

My co-PI Sean Hayes of NMFS has run the power analysis specifying our tag and monitor needs as specified by the reviewer, and I should have a finalized addendum later today or Monday at latest. We completed range tests of the miniature JSAT tags yesterday and found that they had an extraordinary range (=100 m) even in strong flows, wind, and rain at Knight's Landing.

Nann Fangue, who submitted a proposal to CALFED on green sturgeon that was forwarded to your agency, is also following this procedure as advised last week.

Cheers,

Pete

<*{{{{{<   <*{{{{{<   <*{{{{{<
     <*{{{{{<   <*{{{{{<

A. Peter (Pete) Klimley, Ph.D.
Adjunct Professor
Director, Biotelemetry Laboratory
Department of Wildlife, Fish, & Conservation Biology
1334 Academic Surge
University of California, Davis, CA 95616

Phone: (530) 752-5830 (Office)
(707) 481-1547 (Cellular)

Biotelemetry Laboratory: http//wfcb.ucdavis.edu/www/faculty/Pete
Dr. Hammerhead: www.pbs.org/wgbh/nova/sharks/masters/hammerhead.html

-----Original Message-----
From: ktfischer@ucdavis.edu [mailto:ktfischer@ucdavis.edu]
Sent: Friday, February 25, 2011 2:01 PM
To: apklimley@ucdavis.edu
Cc: ogomez@ucdavis.edu; maturner@ucdavis.edu; ORSPO-teama-proposals-us@ad3.ucdavis.edu; ktfischer@ucdavis.edu
Subject: (P02) Klimley, A - Proposal Receipt - Acceptance (Project #201118571)

Dear Dr. Klimley:

We have received your proposal/pre-proposal/supplement entitled, "Survival and Migratory Pattersn of Juvenille Spring and Fall Run Chinook Salmon in Sacramento River and Delta," due to the CA FISH AND GAME on March 1, 2011, 5:00 PM. We have assigned SPO Project Number 201118571 to your proposal. We very much appreciate your timely submission.

The assigned analyst is:

Name: May Turner
Telephone: 530-754-8112
Email: maturner@ucdavis.edu

The analyst will contact you if there are questions—and will notify you when your proposal has been submitted or is ready for pick up. In the meantime, if you have questions regarding your proposal, please contact the analyst directly.

Katherine Fischer
Administrative Services
Sponsored Programs
Telephone 530-754-7700

Please reference the Project Number in any correspondence.

cc: Orbelina Gomez
cc: Team A Proposals

SURVIVAL AND MIGRATORY PATTERNS OF JUVENILE SPRING AND FALL RUN CHINOOK SALMON IN SACRAMENTO RIVER AND DELTA

submitted to Science Program 2010 Solicitation

compiled 2010-08-27 14:38:03 PST

Primary Investigator: Abbott (Peter) Klimley

Project Information and Executive Summary

Proposal Title	SURVIVAL AND MIGRATORY PATTERNS OF JUVENILE SPRING AND FALL RUN CHINOOK SALMON IN SACRAMENTO RIVER AND DELTA
Primary Contact Organization Name	University of California, Davis
Primary Contact Organization Type	public institution of higher education
Salutation of Primary Contact	Dr.
First Name	A. Peter
Last Name	Klimley
Street Address	One Shields Ave.
City	Davis
State or Province	CA
Mailing Code	95616
Telephone	(530) 752-5830
E-mail Address	apklimley@ucdavis.edu
Total Amount Requested	$1,746,955
Primary Topic Area	Native Fish Biology and Ecology
Secondary Topic Area(s)	Food Webs of Key Delta Species and their Relationship to Water Quality and other Drivers; Coupled Hydrologic and Ecosystem Models; Water and Ecosystem Management Decision Support System Development
Descriptive Keywords	**adaptive management**; **fish biology**: salmon and steelhead; **fish management and facilities**: hatcheries; **habitat**: rivers and streams; **levees**
Compliance statement	One of the two principal investigators, Sean Hayes, has a NMFS-granted permit to place acoustic tags on juvenile spring run, a run judged threatened by the ESA. Smolts of the fall run of Chinook salmon are not listed, but tagging of them is also authorized through his permit.

Staff and/or subcontractors received funding for at least one project *not* listed above:

Project Title:	SURVIVAL AND MIGRATORY PATTERNS OF CENTRAL VALLEY JUVENILE S
Amount Funded:	$1,499,858.74
Date Awarded:	04/03/06
Lead Organization:	
Project Number:	U-05-SC-047

Project Title:	SUPPLEMENT: SURVIVAL AND MIGRATORY PATTERNS OF...SALMONIDS
Amount Funded:	$259,676.00
Date Awarded:	04/22/08
Lead Organization:	
Project Number:	U-05-SC-047

Project Title:	SUPPLEMENT: MIGRATORY PATTERNS OF...SALMONIDS
Amount Funded:	$218,016.00
Date Awarded:	07/01/09
Lead Organization:	
Project Number:	U-05-SC-047

Recommend Reviewers

Full Name	Organization	Telephone	E-Mail	Expertise
Ferguson, John W., Director of the Fish Ecology Division	Northwest Fisheries Science Center	(206) 860-3270	john.w.ferguson@noaa.gov	fish biology, tagging
McMichael, Geoffrey A., Principal Investigator	Pacific Northwest National Laboratory, Batelle		Geoffrey.Mcmichael@pnl.gov	fish biology, tagging
Skalski, John, Professor of Fisheries Science	School of Fisheries, University of Washington	(206) 616-4851	jrs@cbr.washington.edu	modeling, quantitative
Noakes, David, Professor of Fisheries Ecology	School of Fisheries, Oregon State University	(541) 737-1953	David.Noakes@oregonstate.edu	fish biology, salmon and steelhead

Ferguson: Lead some of the initial studies conducted by NMFS using Juvenile Salmon Acoustic Telemetry System (JSATS) on salmon ecology in the Columbia River. McMichael: Involved in the development by and application of a new acoustic telemetry system for use on small fish (e.g., < 100 mm). He is a Project Manager and Principal Investigator for many acoustic telemetry projects using JSATS conducted by scientists of the Pacific Northwest National Laboratory. Skalski: Estimated salmonid smolt survival using passive and radio-tag methodologies in the Columbia River Basin. Noakes: Authority on the behavior of anadromous fishes; editor of Environmental Biology of Fishes

Executive Summary

Recent advances in acoustic telemetry technology have resulted in acoustic transmitters which are small enough to be implanted in previously untaggable critical life stages of the fall, winter and spring races of Chinook salmon (Oncorhynchus tshawytscha). We will use this technology to tag and track hatchery-raised and wild fall and spring smolts released annually over a period of three years. This will enable us to evaluate the effect of natural and anthropogenic changes in flow and related water project operations on their survival and movement patterns within the Sacramento River and Delta. This study will provide resource managers in California with a more comprehensive understanding of the response of juvenile salmon outmigration under a wide variety of flow conditions and Delta water management practices. There are two specific objectives of this research program. The first is to establish a network of acoustic receivers capable of monitoring the migratory movements of juvenile fall and spring run Chinook salmon. Secondly, we will apply miniature coded transmitters to members of four groups of Chinook salmon: 1) hatchery spring run, 2) wild spring run, 3) hatchery fall run, and 4) wild fall run at or near their source points to assess reach specific survival rates in the river. Hatchery spring and fall run will also be released at the entrance to the Delta to determine movement and survival in this key region, when the cross channel gates are open and closed.

Contacts and Project Staff

Primary Contact

E-Mail	apklimley@ucdavis.edu
Last Name	Klimley
First Name	A. Peter
Organization	University of California, Davis
Work Telephone	(530) 752-5830

Primary Investigator

E-Mail	apklimley@ucdavis.edu
Last Name	Abbott (Peter)
First Name	Klimley
Organization	None
Work Telephone	None
Qualifications	See Appendix for complete CV of this Participant.

Co-PI Sean Hayes

Salutation	Dr.
Last Name	Hayes
First Name	Sean
Title	Research Fisheries Biologist
Organization	Southwest Fisheries Center, National Marine Fisheries Center
Position	Co-PI
Responsibilities	Dr. Sean Hayes will be joining the team, taking over the responsibilities held by Dr. Bruce MacFarlane on the previous effort. Hayes is a NMFS Research Fisheries Biologist and an Adjunct Assistant Professor at UCSC. Hayes has been working for Dr. MacFarlane since 2002 and for the past year has been sharing administrative responsibilities with him on such projects. He will assume the administrative responsibilities of the NOAA and UCSC portions of this project and serve as the faculty sponsor for the UCSC graduate student on this project. Hayes has extensive experience in marine acoustics and using electronic tag technology having tagged and tracked everything from birds and blue whales, to seals and salmon. He will contribute technical expertise to project planning and logistics and participate in tagging efforts. In addition he has considerable expertise with central California coast salmonids, particularly steelhead and coho salmon, as well as experience with Columbia River Chinook salmon focusing on issues such as life history diversity, predator prey interactions, freshwater, estuarine and marine habitat use and marine survival. This proposal already has many of the best experts on Central Valley Chinook salmon, as such Hayes will be providing an outside perspective with the potential to bring new insights to what is known about Central Valley stocks. In particularly, while river habitat issues, water diversions and changing ocean conditions have been identified as mechanistic/proximate reasons for declines in Central Valley Stocks, it is held by many that the ultimate cause for such declines lies in the loss of life history diversity and subsequent lack of resilience in the stocks to respond to changing conditions. Using the multiple combination's of run types and hatchery versus wild origins in this project, Hayes will apply his expertise in life history diversity to explore how this natural and anthropogenic variation

	in life histories influence survival, in ways that can provide insights to management. Finally, Hayes comes from an agricultural background, providing a unique combination of scientific and agricultural insights on the demands growing human populations are placing on resource requirements. As such he will be focused on finding management solutions that look for a practical balance between fisheries, ecosystem and anthropogenic needs.
E-mail	sean.hayes@noaa.gov
Qualifications	See Appendix for complete CV of this Participant.

Co-PI Lindley Stephen

Salutation	Dr.
Last Name	Stephen
First Name	Lindley
Title	Senior Fisheries Biologist
Organization	Southwest Fisheries Center, National Marine Fisheries Servic
Position	Co-PI
Responsibilities	Dr. Stephen Lindley will oversee the statistical analysis of our reach-specific estimates of survival within the Sacramento River and Delta. He will likely serve on the doctoral committees of the two graduate students, one at UC Davis whose dissertation research will focus on fall run Chinook smolts and another at UC Santa Cruz whose dissertation research will focus on spring run smolts.
E-mail	Steve.Lindley@noaa.gov
Qualifications	See Appendix for complete CV of this Participant.

Co-PI Arnold Ammann

Salutation	Mr.
Last Name	Ammann
First Name	Arnold
Title	Research Fisheries Biologist
Organization	Southwest Fisheries Center, National Marine Fisheries Servic
Position	Co-PI
Responsibilities	Mr. Arnold Ammann will serve as leader of a team of NMFS and UC Davis biologists, who annually implant JSATS on hatchery-raised, spring-run Chinook smolts released downstream of the Feather River Hatchery, on wild fall and spring run smolts captured at a screw trap at Mill Creek, and on hatchery fall and spring run fish released at the base of the Delta. He will conduct experiments to test the range of the receivers and the effects of tags on growth and swimming performance of smolts implanted with tags. He will maintain a SQL Server database that will contain the detections of Chinook salmon smolts carrying JSATs and associated receiver, tag, and fish metadata.
E-mail	arnold.ammann@noaa.gov
Qualifications	See Appendix for complete CV of this Participant.

Co-PI Joseph Merz

Salutation	Dr.
Last Name	Merz
First Name	Joseph
Title	Principal Restoration Ecologist

Organization	Cramer Fish Sciences
Position	Co-PI
Responsibilities	Dr. Joseph Merz will be responsible for providing training to the rest of the NMFS, UCSC and UC Davis tagging teams for tag deployment as well as technical advice on managing and analyzing data output from JSATS receivers. In addition Joe will take the lead on the hatchery fall-run Chinook salmon tagging component of this project in collaboration with USFWS and be responsible for maintaining the portion of monitors deployed on the upper section of the Sacramento River. Joe will take the lead on interpreting movement and survival patterns for the hatchery fall-run component of this study and serve as a committee member and scientific adviser for the graduate students on this project.
E-mail	jmerz@fishsciences.net
Qualifications	See Appendix for complete CV of this Participant.

Co-PI Robert Null

Salutation	Mr.
Last Name	Null
First Name	Robert
Title	Supervisory Fish Biologist
Organization	Red Bluff Office, U.S. Fish and Wildlife Service
Position	Co-PI
Responsibilities	Mr. Robert Null will provide historical data from past releases of salmon from the Coleman National Fish Hatchery. He will actively participate in tagging fall run Chinook released from the hatchery.
E-mail	Robert_Null@fws.gov
Qualifications	See Appendix for complete CV of this Participant.

Co-PI Cyril Michel

Salutation	Mr.
Last Name	Michel
First Name	Cyril
Title	Staff Research Assistant
Organization	University of California, Santa Cruz
Position	Co-PI
Responsibilities	Mr. Cyril Michel will serve with Mr Ammann as part of the team from NMFS, UCSC biologists, who will annually implant JSATS on hatchery-raised, spring-run Chinook smolts released downstream of the Feather River Hatchery, on wild fall and spring run smolts captured at a screw trap at Mill Creek, and on hatchery fall and spring run fish released at the base of the Delta. He will conduct experiments to test the range of the receivers and the effects of tags on growth and swimming performance of smolts implanted with tags. He will maintain a SQL Server database that will contain the detections of Chinook salmon smolts carrying JSATs and associated receiver, tag, and fish metadata.
E-mail	
Qualifications	See Appendix for complete CV of this Participant.

Conflict of Interest

Primary Investigator Abbott (Peter) Klimley

To assist Science Program staff in managing potential conflicts of interest as part of the review and selection process, we requested applicants provide information on who will directly benefit if their proposal is funded, that were not listed on the Contacts and Project Staff Form.

Co-PI(s)

Subcontractor

Individuals who helped with proposal development

Last Name	First Name	Organization	Role
MacFarlane	R. Bruce	NMFS	Advisor

Task and Budget Summary

Task #	Task Title	Start Month	End Month	Personnel Involved	Description	Task Budget
1	Project Management and Dissemination of Results	1	36	Abbott (Peter) Klimley	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 first results from our studies for juvenile fall- and spring run at the Biennial State of the Estuary Conference. During the following year, we will organize a session of talks at the Biennial CALFED Bay-Delta Conference. An international symposium will be organized at the end of the study, which would be the second symposium on tracking studies held at the Bodega Marine Laboratory.	$79,949
2	Expanding and Maintaining Acoustic Monitor Array	1	36	Abbott (Peter) Klimley	We have established an array of over 300 tag-detecting monitors (VR2W, Vemco Ltd.) within the Sacramento and San Joaquin Rivers, Delta, San Francisco Bay, and the coastal waters off Point Reyes. This is currently being used to detect the migratory movements of late-fall run Chinook salmon and steelhead smolts, adult green sturgeon, striped bass, cow sharks, and other species. This array will be expanded by a Junior Specialist and Graduate Student Researcher at UC Davis by placing JSATS monitors at strategic points throughout the river and Delta. Range tests will be conducted to ensure a high detection probability of	$189,525

					migrating salmon smolts at all monitor sites. A total of 28 (funding requested for 22) monitors will be needed along the mainstem and tributaries from Battle Creek (fall run release point) to the head of the Delta. This will include monitors in the Feather River below the Feather River Hatchery for estimating reach-specific survival within that tributary and monitors at the mouth of Deer and Mill Creek to record successful emigration from tagging sites for wild fall and spring run smolts. A total of 15 monitors will need to be deployed to cover the four migration routes previously observed for late-fall Chinook salmon within the Delta. Eight more monitors will be used in a linear array at the base of the Delta at Chipps Island. The Lotek JSATS monitors will be attached to the same moorings holding the Vemco VR2W monitors. Attached to the monitor will be a small temperature logger (Onset, HOBO). We will interrogate all monitors every three months over a period of three years. The files of tag detections will transferred to the database at the Southwest Fisheries Science Center in Santa Cruz, California.	
3	Determining Survival of Hatchery Fall-Run	1	36	Abbott (Peter) Klimley; Dr. Joseph Merz; Mr. Robert Null	Fall-run smolts are typically released by the CNFH in two large batches, one in early April and another in late April of each year. The survival of smolts differs greatly between these two releases each year (Robert Null, pers. comm.) This discrepancy is based on the difference in the rates of capture of outmigrating smolts with coded wire tags in trawls by the United States Fish and Wildlife Service in the mainstem of the river near Chipps Island. Furthermore, fewer adults return to the hatchery to spawn from one release versus the other release. There is considerable interest in finding out what factors contribute to the less or greater success of one release so that the hatchery might carry out future releases during benign environmental conditions promoting maximum outmigration success. Hence, Biologists of Cramer Fish Sciences and a Junior Specialist and Graduate Student Researcher at UC Davis will tag and release with each larger (untagged) release group 150 hatchery-raised fall run smolts during early and 150 smolts during late April of	$277,726

					each of three years. Separating the releases in time will allow for comparisons with varying environmental variables such as water temperature and flow rate. Included in this task are the following: 1) a subcontract to NMFS/NOAA to purchase 300 JSAT transmitters(this avoids an overhead charge assessed on these supply purchases) and 2)a subcontract to Cramer Fish Sciences for salary support to place JSATs on the fall run smolts during the three years of the study. They will be assisted by biologists from UC Davis.	
4	Determining Survival of Hatchery Spring-Run	1	36	Dr. Sean Hayes; Mr. Arnold Ammann; Mr. Cyril Michel	Biologists of NMFS/NOAA and UC Davis will tag and release 200 spring-run smolts raised by the Feather River Hatchery, 100 during early April and 100 during late April each year with two of the general releases of untagged fish from the hatchery (A Kastner pers. comm.). Separating the releases in time will allow for comparisons with varying environmental variables such as water temperature and flow rate. Furthermore, this will provide information on a different run, with different temporal migration patterns and mortality estimates from the Feather River as opposed to the mainstem of the upper Sacramento River. Included in this task are the following: 1) a subcontract to NMFS/NOAA to purchase surgical supplies and 200 JSAT transmitters and 11 JSAT automated monitors and mooring hardware(this avoids an overhead charge assessed on these supply purchases and 2) a subcontract to UC Santa Cruz for salary funds for a Staff Research Associate and Graduate Student Researcher to lead the tagging effort.	$231,270
5	Determining Survival of wild Fall and Spring-Run	1	36	Dr. Sean Hayes; Mr. Arnold Ammann; Mr. Cyril Michel	It is desirable to determine baseline rates of survival for wild fall- and spring- run as they may differ from hatchery fish, and come from different source points. Wild (i.e., naturally produced) fall- and spring-run smolts are captured each year by rotary screw traps in Mill and Deer Creeks. We will tag 200 smolts with FL >80mm between October and May of each year. While there is some overlap in fall and spring run emigrate times, by using the date of capture and size in combination, it is possible to select representatives from both races. Fish >80mm FL caught in the fall and winter are likely	$255,252

					spring run, whereas those captured in April and May could be either fall or spring run. Small fin clips will be taken from all tagged fish for post-hoc analysis and genotyped to race at the NOAA Fisheries genetics laboratory in Santa Cruz. That lab has an on-going, large-scale program genotyping Chinook salmon samples from the ocean fishery for the Pacific Fisheries Management Council. Wild fish will be held until deemed fully recovered from tag implant and released at the place of capture after dark. Included in this task are the following: 1) a subcontract to NMFS/NOAA to purchase surgical supplies and 200 JSAT transmitters and 11 JSAT automated monitors and mooring hardware and 2) a subcontract to UC Santa Cruz for salary funds for a Staff Research Associate and Graduate Student Researcher to lead the tagging effort.	
6	Determining Delta Survival of Hatcher Fall and Spring Run	1	36	Abbott (Peter) Klimley; Dr. Sean Hayes; Mr. Arnold Ammann; Mr. Cyril Michel	We will conduct specific releases into the Sacramento River at the head of the Delta, replicating the protocols of Perry et al. (2010). He described four pathways, through which late-fall and spring Chinook smolts passed through the Delta, and recorded reach-specific survival throughout each route. Hatchery fall run and spring run juveniles will be tagged and released at a site near Sacramento. Seventy five fall and 75 spring run juveniles (Perry et al., 2010 released 64-80/group) will be tagged and released before the Delta cross-channel gates are open; another 75 juveniles of each run will be tagged and released after the Delta cross-channel gates are open during the normal downstream migration time window for each group. Included in this task are the following: 1) a subcontract to NMFS/NOAA to purchase surgical supplies and 200 JSAT transmitters and 11 JSAT automated monitors and mooring hardware and 2) a subcontract to UC Santa Cruz for salary funds for a Staff Research Associate and Graduate Student Researcher to lead the tagging effort. These two individuals will be joined by the Junior Specialist and Graduate Student Researcher from UC Davis during tagging activities.	$334,992
7	Data management and Analysis	1	36	Abbott (Peter) Klimley;	Data management- Project data will be held in a relational database hosted at the NMFS lab in Santa Cruz. Data will be provided to	$378,241

Dr. Sean Hayes; Dr. Lindley Stephen; Mr. Arnold Ammann; Dr. Joseph Merz; Mr. Robert Null; Mr. Cyril Michel	project collaborators via an ODBC connection that allows remote ODBC-compliant programs (e.g., Microsoft Access) to link to the live tables such that the programs always have access to the most recent data. The database will be modelled after the existing California Fish Tracking Consortium’s database, modified as necessary accomodate and to account for the differences in JSATS technology. Analysis of Tracking Data. The basic data produced by our study are detections of tagged fish by acoustic monitors at various locations from the upper Sacramento River through the Delta to Chipps Island (river and delta exit). 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, and extend these models to include explanatory variables, particularly those characterizing natural water flow dynamics and water management manipulations by pumping and gate positions in the Delta. 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 increase survival. 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. Inter-annual 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. Gathering data in the river and the delta will allow the parsing of mortality between the two ecosystems, thus improving the knowledge of the relative contributions to factors in the two systems to juvenile salmon mortality, which will improve the ability to resolve impacts of water projects on the animals, and reduce the amount of hearsay.

Included in this task are the following: 1) a subcontract to NMFS/NOAA to purchase surgical supplies and 50 JSAT transmitters for tests of swimming performance and tag retention to be conducted at the Southwest Fisheries Science Center, 2) a subcontract to UC Santa Cruz for salary funds for a Staff Research Associate and Graduate Student Researcher to enter files of tag detections and metadata on the fish tagged and locations of tagging as well as to analyze the results of the tagging of spring run in the Sacramento River and Delta, and 3) a subcontract to Cramer Fish Sciences for their staff biologists to determine reach-specific survival estimates of fall run in the Sacramento River and Delta. The Junior Specialist and Graduate Student Researcher of UC Davis will work closely with the staff biologists of Cramer in analyzing the results of the fall run tagging. The Ph.D. research of the graduate student at UC Davis will focus on determining the natural and anthropogenic effects on reach specific survival of fall run juveniles in the Sacramento River and Delta under the mentorship of Klimley and Merz. The M.Sci. research of the Graduate Student Researcher from UC Santa Cruz will focus n determining the natural and anthropogenic effects on reach specific survival of spring run juveniles in the Sacramento River and Delta under the mentorship of Hayes and Merz.

Budget total	$1,746,955

Schedule of Deliverables

Each Science Program 2010 Solicitation grant recipient must provide the required minimum deliverables (listed below) for each project.

Required minimum deliverables

- Semi-annual Progress Reports (due July 15 and January 15)
- Final Progress Report (Due at end of project)
- One page project summary for public audience at beginning of project
- One page project summary for public audience upon project completion
- Management implications of project findings
- Project closure summary report or copy of draft manuscript
- Presentation at Bay-Delta Science Conference
- Presentations at other events at request of Delta Science Program staff
- Copy of all published material resulting from the grant

Additional deliverables	Description	Start Month	End Month
(1) "Survival of fall run Chinook in river and Delta"	Article in scientific journal	1	36
(2) "Survival of spring run Chinook in river and Delta"	Article in scientific journal	1	36
(3) "Passage of smolts relative to Cross Delta Canal"	Article in scientific journal	1	36
(4) "Effect of hatchery release time on survival of smolts"	Article in scientific journal	1	36
(5) "Effect of levee repairs on salmon outmigration"	Article in scientific journal	1	36

Project Title: SURVIVAL AND MIGRATORY PATTERNS OF JUVENILE SPRING AND FALL RUN CHINOOK SALMON IN SACRAMENTO RIVER AND DELTA

Table of Contents

I. Project Purpose

A. The Problem-Chinook salmon (*Oncorhynchus tshawytscha*) were once highly abundant and widely distributed throughout the rivers and streams of California's Central Valley. Today, Chinook salmon runs are just a fraction of their historical abundance, mainly due to loss of spawning habitat from the construction of dams. Chinook salmon have been identified as four distinct life history groups or races 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 salmon races have been named as runs based on the season when most adults return to freshwater to spawn: winter, spring, fall, and late-fall (Fry 1961; Stone 1874). Of the four salmon runs, the fall run is the most abundant and heavily supplemented by hatchery production (Fisher 1994). The population size of fall run Chinook has until the recent stock collapse (Lindley et al, 2009) exceeded the three other runs (late fall, spring, and winter) by almost an order of magnitude. Adult fall-run Chinook salmon migrate up the mainstem of the Sacramento River often before the first rains, spawn in low elevation areas of the mainstem and tributaries. Juveniles emigrate from the watershed during the spring when flows are high. Historically, spring-run Chinook salmon were the most abundant race of Central Valley salmon but are now much less common than fall run with abundances slightly less than those of late-fall run. They migrate into the upper reaches of a few tributaries of the Sacramento River that haven't been blocked by dams. They exhibit a more diverse life history pattern than the fall run because smolts emigrate both during the spring as subyearlings and during the following fall-to-spring as yearlings. Thus, the timing of emigration of spring and fall Chinook salmon differ from each other and from late-fall Chinook, so we expect survival to differ among the runs due to drastically different environmental conditions during the emigration period (Yoshiyama *et al.*, 1998).

The fall run, which drives the $255 million California salmon fishery, is managed by the National Marine Fisheries Service and affiliated agencies according to the Magnuson-Stevens Fishery Conservation and Management Re-authorization Act of 2006 (MSA) which mandates research to understand stock challenges under MSA Title IV 104-297 SEC. 404. FISHERIES RESEARCH (16 U.S.C. 1881c). Sacramento River winter-run Chinook are classified as endangered under the U.S. Endangered Species Act (ESA) of 1973, with Central Valley spring-run Chinook listed as threatened, and Central Valley fall and late-fall run Chinook as candidate species with research activities to aid understanding and recovery of these stocks mandated under ESA sec 4(b)(3)(C)iii. Current threats to the recovery of these species include continued access limitations and degradation of remaining spawning and rearing habitat and direct and indirect-mortality caused by water diversions along the Sacramento River and in the Delta. This is 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). Very little is known about the survival and movement patterns of emigrating Central Valley Chinook salmon juveniles less than 140 mm in length. Critical unknowns include the following. What proportion of the populations emigrate through the mainstem Sacramento River versus the interior Delta? Are survival rates different with different pathways? Are there areas of increased mortality and is this due to anthropogenic influences? Is mortality affected by bank habitat type?

B. Goals/Objectives-Recent advances in acoustic telemetry technology have resulted in acoustic transmitters which are small enough to be implanted in previously untaggable critical life stages of juvenile Chinook salmon from the fall, winter and spring races. We will use this technology to release acoustically-tagged hatchery-raised and wild fall and spring-run Chinook salmon smolts over a period of three years. This will enable us to evaluate the effect of natural and anthropogenic changes in flow and related water project operations on their survival and movement patterns within the Sacramento River and Delta. This will provide resource managers in California with a more comprehensive understanding of the response of juvenile salmon outmigration under a wide variety of flow conditions and Delta water management practices. The specific goals and objectives of this proposal are to:

1. Establish a network of acoustic receivers in the Sacramento River and Delta capable of monitoring the migratory movements of juvenile fall and spring run Chinook salmon. (The current network of receivers is not compatible with new tag technology)
2. Tag four groups of Chinook salmon- hatchery spring run (HS), wild spring run (WS), hatchery fall run (HF) and wild fall run (WF) at or near their source points to assess reach specific survival rates from their source to the delta and beyond. While technology permits the tagging of all four races, fall run were prioritized due to their commercial importance, and spring run due to their ESA listing and the belief that the remaining wild stocks are the least impacted by hatchery practices. Winter run Chinook could be tagged as well but were excluded due to budget limitations.
3. Tag additional HS and HF run Chinook and release at the entrance to the Delta to measure movement and survival in this key region in two release groups when the Delta Cross Channel (DCC) gates are open and closed.

C. Hypotheses:

1. Fall and spring-run Chinook salmon juveniles will experience significant mortality during downstream migration from source location through the Delta to the entrance to San Francisco Bay and the mortality rates are likely to be higher than previously observed for larger late-fall Chinook salmon and steelhead (*O. mykiss*).
2. Mortality rates will vary between the four groups as a function of fish size, hatchery versus wild origin, environmental conditions, and source location.

3. Mortality rates and variability in movement patterns of juvenile HF and HS Chinook salmon will be higher when the DCC gates are open for the purposes of water diversion/withdrawal.

D. Relevant studies-During the past four years, acoustically-tagged late-fall run Chinook salmon and steelhead smolts from the Coleman National Fish Hatchery have been released by researchers from UCD, NOAA, the U.S. Fish & Wildlife Service, and the U.S. Army Corps of Engineers into the mainstem of the Sacramento River. The reach-specific survival of these smolts has been determined using an array of approximately 300 tag-detecting monitors deployed along the Sacramento River, throughout the Delta, and in the San Francisco Estuary. Mean survival of late-fall run smolts to the Golden Gate averaged 6% with a range 2-12% between 2007 and 2009. Survival on a spatial reach by reach basis was quite variable. Through the three years of the study, the upper river (Jelly's Ferry to Butte City) seemed to have low survival, the lower river seemed to have relatively high survival (Butte City to Freeport), and finally, the delta and estuary had low survival (Michel 2010). Survival through the Delta varied substantially depending upon which migration pathway was used by the smolts, and there were significant differences in pathway used if the Delta cross-channel gate was open or closed (Perry et al., 2010). This study provided unprecedented insight into locations, sources, and rates of mortality of yearling steelhead and Chinook salmon. Reach-specific survival of these species has been related to the effects of hydrology, time of day, and land-use patterns. This information has been used by management to interpret population fluctuations. The results of these studies were presented in talks recently given at the "Salmon Tracking Symposium", held at the Bodega Marine Laboratory (20-21 May 2010). The information from these talks will be published in the next year in a Special Issue of *Environmental Biology of Fishes*.

One of the purposes of the previous work was a proof of concept to evaluate tracking techniques and develop analysis protocols, with a long term goal of applying this technology to smaller size classes/races of juvenile Chinook salmon once sufficiently miniaturized. Recent advances in tag miniaturization have occurred on the Columbia River, where the U.S. Army Corps of Engineers (USACE) initiated development of the Juvenile Salmon Acoustic Telemetry System (JSATS) [McMichael *et al.*, 2010] for the purposes of tagging juvenile spring run Chinook and associated species/runs.

II. Background and Conceptual Models

A. Background- Central Valley Chinook Salmon and Technology

1. Status of Fall-Run Chinook

The abundance of fall Chinook salmon in the Central Valley of California was the smallest on record in 2009 and continues the declining population trend that began in 2007. The recent and sudden collapse of Central Valley fall Chinook salmon has resulted in the most restrictive harvest regulations in the history of the West Coast salmon fisheries. The commercial and recreational marine fisheries and the freshwater sport fishery were either closed or greatly reduced in California and most of Oregon during both 2008 and 2009 resulting in an economic impact estimated at $255 million dollars with a loss of 2,263 jobs per year. The Secretary of Commerce declared the fishery collapse a federal disaster, paving the way for Congress to appropriate $170 million in disaster relief funds to fishermen and related businesses affected by the closure of the salmon fishing in the states of California, Oregon, and Washington. Lindley *et al.* (2009) found that unfavorable conditions in the coastal ocean were most likely the cause of the poor catches and returns in 2007 and 2008, but noted that in-river survival estimates would have been extremely valuable in determining the cause of the collapse and recommended that such studies be undertaken in order to reduce uncertainties in future crises.

The Coleman National Fish Hatchery (CNFH) releases approximately 12 million fall Chinook salmon annually, and historically these fish have contributed substantially to the commercial and recreational marine fisheries and the freshwater sport fishery. Numbers of CNFH fall Chinook salmon harvested in the ocean troll (commercial) fisheries of Washington, Oregon, and California averaged 45,158 annually from 2000 through 2004. An average of 16,204 additional CNFH fall Chinook salmon were harvested annually in the Washington, Oregon, and California recreational ocean fisheries during those years. Fall Chinook salmon released from the Coleman NFH represented as much as 13.1% of the combined commercial fisheries and 19.6% of the recreation fisheries off of the Washington, Oregon, and California coasts. However, since 2007, numbers of fall Chinook salmon returning to the CNFH have experienced declines similar to or greater than the rest of the Central Valley. The reduction or closure of the commercial and recreational fisheries in recent years was implemented in part due to the low abundance of fall Chinook returning to the CNFH. The causes for the recent decline in abundance of fall Chinook salmon are not completely understood, but multiple factors likely contributed to the low numbers of salmon in recent years. One of these factors that may have reduced the survival of fall Chinook salmon was poor in-river and/or delta conditions; however, little information is currently available to assess this.

2. Status of Spring-Run Chinook

Spring-run Chinook were once a major component of the Central Valley Chinook stock, with annual catches of over a half million fish in the 1880's exceeding the fall run complement. They are defined by the timing of adult return historically between April and August, where adults moving in to the cool head waters of primarily west-slope streams above 500 m, where they would spawn during the fall months. The smallest juveniles begin emigrating in November of the same year. However this run is known to exhibit two types of juvenile life-history strategies: ocean-type and stream-type. The ocean-type juveniles spend a few months in streams and enter the ocean at a small size [~80 mm fork length (FL)]. In contrast, the stream-type juveniles spend roughly one year in streams and enter the ocean at a large size (120-180 mm FL). Today wild populations of spring run are now represented by just three small populations in Mill, Deer, and Butte Creeks, which are minor tributaries to the Sacramento River (Lindley *et al.*, 2007, Yoshiyama *et al.*, 1998), and are classified as threatened under the ESA. Spring run are reported in additional Sacramento tributaries, and are supplemented by Feather River Hatchery (FRH), but these additional stocks are believed to have been hybridizing with fall run stocks since the 1960's due to constraints on previously separate spatial distribution created by dams. Spring run were extirpated from the San Joaquin drainage in the 1940s with the construction of Friant Dam (Yoshiyama *et al.*, 1998). In the Sacramento Drainage spring run Chinook have also declined in recent years along with fall Chinook, perhaps because of their similar time of juvenile migration (at least for the large subyearling portion), although the declines have been less severe. Interestingly, Butte Creek spring Chinook have been relatively resilient during the recent period of decline. One notable thing about Butte Creek is that there has been extensive restoration of floodplain and river channel habitat in lower Butte Creek; it is likely that this productive habitat boosts the in-river survival of Butte Creek spring Chinook. Another difference between spring and fall Chinook is that the wild populations of spring Chinook in the Mill, Deer, and Butte Creek tributaries have been little influenced by hatchery practices, unlike fall Chinook which move frequently between natural areas and hatcheries (Yoshiyama *et al.*, 1998). Our study will help elucidate whether apparent differences in productivity among different populations of Chinook are related to differences in in-river survival, and whether these survival differences are associated with certain habitats or conditions.

3. Recent Innovations in Tracking Technology

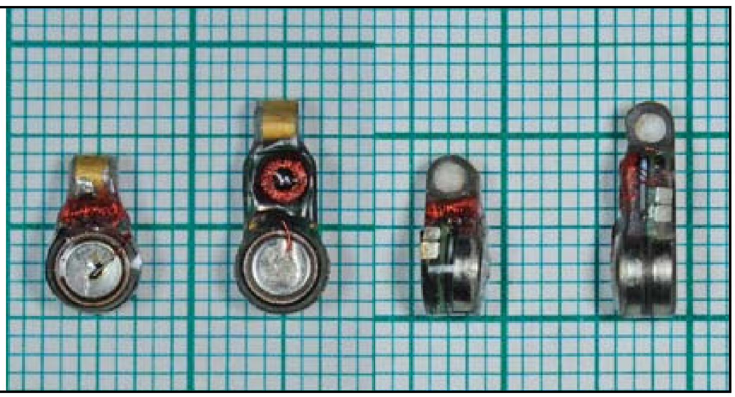
Two recent technological developments have made it feasible to track juvenile salmonids as they migrate throughout watersheds, including rivers, the estuaries, and coastal waters. The first innovation was the development of an individually coded ultrasonic transmitter, miniaturized sufficiently to be 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.

During the past four years, we have released late-fall run Chinook salmon and steelhead smolts carrying coded ultrasonic transmitters from the CNFH into the mainstem of the Sacramento River. The reach-specific survival of these smolts has been determined using an array of approximately 300 tag-detecting monitors deployed along the Sacramento River, throughout the Delta, and in the San Francisco Estuary. The two miniature tags used in this study, the Vemco® V7 and V9, weighed 1.4 and 1.6 g in air. The former were implanted within the peritonal cavity of late-fall run Chinook smolts from 150 to 180 mm fork length (FL) (μ=160 mm, FL), while the latter was implanted in steelhead from 155-270 mm FL (μ=215 mm FL). During the previous study we conducted tag effects studies on late-fall Chinook salmon
We examined the effect of surgically implanted transmitters on growth rate and tag shedding during two trials of captive hatchery raised late-fall Chinook salmon (mean fork length 150 and 160 mm). For both trials, we found no significant difference in growth rate between tag and control groups and no tag shedding in the tag group out to 221 and 160 days respectively (Ammann *et al.*, in prep.). In another trial using the same type of fish we found that swimming performance was reduced in fish surgically implanted with transmitters one day and 21 days after implantation compared to controls (Ammann *et al.*, in prep)

The tags were not placed on smaller smolts because the tag's mass must be no greater than ~8% of the tagged salmon body mass in order to avoid a negative impact in the outmigration behavior of the smolts (Peake and McKinley, 1997). However, in 2001, the Portland District of the U.S. Army Corps of Engineers (USACE) initiated development of the Juvenile Salmon Acoustic Telemetry System (JSATS) [McMichael *et al.*, 2010]. The objective for the development of this system was to provide an active transmitter small enough for implantation in the majority of the size distribution of juvenile Chinook salmon emigrating seaward through the Columbia River hydropower network. Such a system would ultimately enable researchers to answer many of the management questions related to the effect of modifications of the river on salmonids managed under ESA and MSA. This system consists of miniature, ultrasonic transmitters, receiving systems, and data management and processing software. The minimal effect of these miniature beacons on the outmigration behavior of the smolts has been demonstrated by comparing the reach-specific survival probabilities of migrating smolts carrying these transmitters to those carrying only passive integrated transponder (PIT) tags (McMichael *et al.*, 2010).

Micro-ultrasonic Transmitters: The JSATS used in the Columbia River weigh 0.433 g in air. They were 5.21 mm wide, 12.00 mm long, and 3.77 mm high (thick). Each tag transmitted a unique code at a frequency of 416.7 kHz and a mean source level of 155.6 dB (relative to 1 μPascal at 1 m). The coded signal is transmitted over 744 μs. These signals, which do not involve amplitude modulation, are relatively immune to corruption in noisy environments. Tags transmitted one pulse every 5 s and had a battery life of 30 days. The pulse rate on these tags is programmable, enabling the user to select pulse rate intervals (PRI) from 2 to 10 seconds, with an estimated tag life of 20 to 70 days, respectively. Using this system, they were able to implant JSATS within fish with minimum sizes ranging from 93-113 mm FL (McMichael *et al.*, 2010), individuals considerably smaller than the late-fall run smolts tagged in the Sacramento River (Michel *et al.*, 2010). One of our investigators (J. Merz) has successfully placed the Columbia River JSATS with a mass of 0.433 in Sacramento River spring run smolts of 85 mm TL, confirming our ability to place these tags in both fall and spring run smolts in the Sacramento River. An even smaller version of the JSATS transmitter, the L-AMT 1.1 fabricated by Lotek Wireless will be available early during fall of 2010 (Fig. 1). This coded ultrasonic transmitter will by 5.0 mm wide, 8.8 mm long, 3.6 mm high and weigh only 0.300 g in air The source level of this tag is 150 dB re: 1 μPa @ 1 m and given a pulse rate interval of 15 s would have a life exceeding 70 days.

Fig. 1. Front (left) and side (right) views of the ultra-miniature L-AMT 1.1 and the L-AMT 2.1 coded transmitters soon to be available from Lotek Wireless. The latter is comparable in size to the beacons used in the Columbia River studies; the former is considerably smaller than the Columbia River beacon. Square = 1 mm.



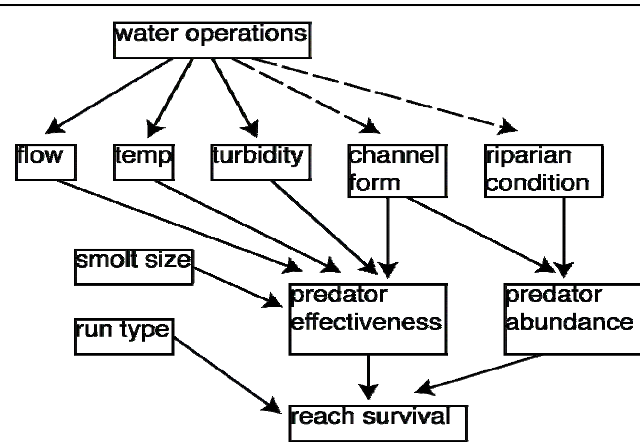
Automated Monitors: The second technological advance is the fabrication of a low cost automated receiver (WHS 4000, Lotek Wireless). Available early this fall will be a JSATS receiver that will cost roughly $2,000-2,500 per unit depending upon quantity purchased for a study. We will be able to deploy these less expensive receivers at a significant fraction of the nodes, at which are located our current Vemco VR2 receivers. The WHS 4000 receivers are positively-buoyant self-contained devices containing a hydrophone, which detects the signal, electronic logic within for decoding the signal to produce a unique code for each transmitter, compact flash media for storing the file of tag-detections, and lithium batteries providing a life of 90 days. A graphical user interface (GUI) developed for use with the receiver enables the user to view and record decoded tag signals. The files of tag detection from autonomous receivers contain records of fish detections recorded in a text file with an individual tag code, time stamp, receive signal strength indicator and a calculated level of noise. A post-processing program has been developed to eliminate false detections from these files. This consists of filtering criteria where detections must match a the list of tags released, the detection date and the release date, requires a minimum of four detections over an interval of 60 seconds, and match the time spacing between the intervals to the known tag pulse rate.

The monitors currently in use for the Sacramento River array rely on a different pulse scheme; specifically they encode tag identity by pulse-interval coding (PIC). This enabled the vendor (Vemco Ltd., Halifax) to produce an economical receiver, costing $1,450 each, but requires that the beacon be within the range of the receiver a pseudo-random interval averaging 60 s to detect an identifying pulse bursts and these, consists of eight pulses with varying intervals over a period of three to five seconds. In the former case, the individual may pass through the range if currents are strong without being detected; in the latter case, another transmitter's pulse burst can collide with the identifying pulse burst preventing its full detection. A JSATS transmitter with a pulse rate interval (PRI) of 5 s and a decode range of 300 m would transmit 40 signals if it passed through the center of a receiver's cylindrical range at a movement rate of 3 m/s. A Vemco transmitter with a mean PRI of 60 seconds and an assumed decode range of 600 m would transmit approximately six pulse bursts separated anywhere from 30 to 90 s apart while passing its detection zone at 3 m/s.

B. Conceptual Model of the Study

The purpose of our study is to measure reach-specific survival rates and determine whether they differ between spring and fall Chinook. Figure 2 illustrates conceptually how water management actions, such as releasing water from reservoirs, directly and indirectly influences reach-specific survival in the broader context of the river ecosystem. We hypothesize that reach-level survival is directly controlled by predation, with different runs and different size fish being differentially susceptible to predators. The ability of a given predator to kill a smolt is directly affected by temperature (through effects on predator metabolic activity), flow (which moves prey past the predator) and turbidity (which limits predator's the range of perception). These factors can be directly affected by how water is released form reservoirs. Also important to the level of predation is the abundance of predators, which is partly influenced by the size of hatchery release groups, channel form (e.g., depth and bank conditions, in-stream structure that determine how predators and prey may interact) and riparian cover. These factors are also influenced by water operations, but over longer time scales through geomorphic processes.

Fig. 2. Conceptual model of how water management actions affect survival of juvenile salmon migrating through a reach. Dashed line indicate long-term influences, solid lines indicate immediate influences.



Due to the costs, we are not proposing in this study to directly measure predator activity and abundance (although if other groups are funded to do this we would want to coordinate with them). Rather, we will relate measured survival at reaches to the factors that we hypothesize affect predator abundance and activity, namely flow, temperature, turbidity, channel form, riparian cover and timing of large hatchery releases. Survival estimates will be made using a mark-recapture framework, 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 then released in a manner such that they are representative of the population being characterized. 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.

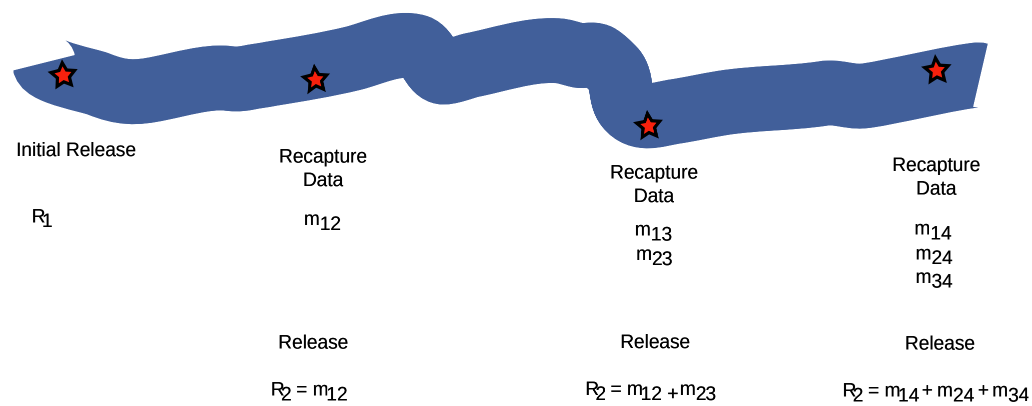


Figure 3. Conceptual model of study design. The wide blue line represents the river and the stars indicate location of monitors. The actual study has many more receiver locations. The patterns of releases and detections (the R_i's and m_{ij}'s, equivalent in our study design following the initial release) 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 could be hypothesized 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.

III. Approach and Scope of Work

Task 1: 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, and 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 first results from our studies for juvenile fall- and spring run at the Biennial State of the Estuary Conference. During the following year, we will organize a session of talks at the Biennial CALFED Bay-Delta Conference. An international symposium will be organized at the end of the study, which would be the second symposium on tracking studies held at the Bodega Marine Laboratory. The first symposium was a great success. The subject matter of this meeting would be broadened to include tagging studies of all species within the Sacramento/San Joaquin watershed. 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.

Task 2: Expanding and Maintaining Acoustic Monitor Array to Detect Tagged Fall- and Spring-Run Chinook Salmon Smolts

We have established an array of over 300 tag-detecting monitors (VR2W, Vemco Ltd.) within the Sacramento and San Joaquin Rivers, Delta, San Francisco Bay, and the coastal waters off Point Reyes. This is currently being used to detect the migratory movements of late-fall run Chinook salmon and steelhead smolts, adult green sturgeon, striped bass, cow sharks, and other species. This array will be expanded by placing JSATS monitors at strategic points throughout the river and Delta. A total of 28 (funding requested for 22) monitors will be needed along the mainstem and tributaries from Battle Creek (fall-run release point) to the head of the Delta (Fig. 4). This will include monitors in the Feather River below the Feather River Hatchery for estimating reach-specific survival within that tributary and monitors at the mouth of Deer and Mill Creek to record successful emigration from tagging sites for wild fall and spring run smolts. A total of 15 monitors will need to be deployed to cover the four migration routes previously observed for late-fall Chinook salmon within the Delta (Fig. 4) [see Perry *et al.*, 2010]. Eight more monitors will be used in a linear array at the base of the Delta at Chipps Island. Detection probabilities at the last receiver line (Chipps Island) will be estimated using methods of Melnychuk and Waters (2010).

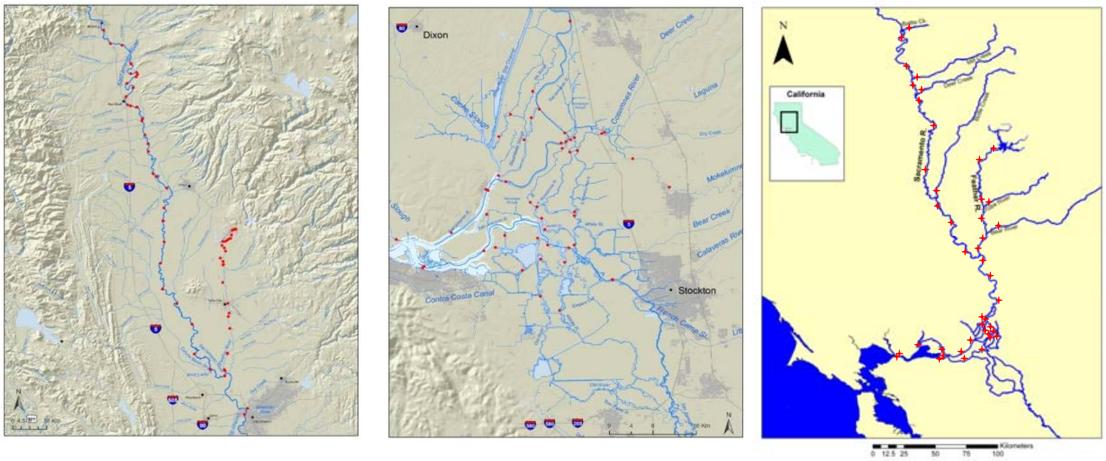


Fig.4 Existing array of VR2W monitors within the Sacramento River (left) the Delta (middle), which will be upgraded by the addition of JSATS monitors capable of detecting tagged fall and spring run Chinook smolts (right)

The Lotek JSATS monitors will be attached to the same moorings holding the Vemco VR2W monitors. Each river mooring will consist of two 10 kg weight plates held together by a galvanized eye bolt. 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 the 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 moorings are small and inconspicuous with all of the components being underwater, and hence there has been little loss of equipment due to vandalism or theft. We will interrogate all monitors every three months. We now have available two research skiffs, a 22-foot and 27-foot skiff, which will have small cabin in which the monitors can be downloaded away from rain and brackish environment of the bay. One of these boats has a semi-displacement hull and a jet drive ideal for working in the shallow reaches of the Sacramento River; the other has a displacement hull and an outboard jet drive that makes it ideal for servicing the monitors in the bay.

Task 3: Determining Reach-Specific Survival of Hatchery Fall-Run Chinook Salmon

Let us first discuss the feasibility of tagging members of the fall run released by the CNFH on Battle Creek. We have calculated the percentage the two tag masses would comprise of the total body mass of Chinook smolts of increasing body masses and fork lengths (Table 1). Joseph Merz (Cramer Fish Sciences) has successfully implanted the larger 0.433 g tag in smolts with a body mass of 5.1 g and FL of 85 mm – resulting in a tag to body mass ratio in percent of 8.4%. This is only a slightly larger 'transmitter burden' of 7.6% found not to affect the survival in juvenile salmonids (Brown *et al.*, in press). The smaller, 0.300 tag would have a tag to body mass ratio of 6.8% of a smolt with a 4.4 g body mass and 80 mm FL. Hence, we believe that we will be able to implant the smaller tag within individuals of 80 mm FL, maybe even 75 mm FL with considerable practice in implantation during the study.

Table 1.Typical Lengths and Weights for Pacific Chinook Salmon and percentage body weight of JSAT Tags

Fork Length (mm)	Mass (g)	% Body Mass (0.43 g tag)	% Body Mass (0.3 g tag)
60	1.8	23.9	16.7
65	2.2	19.6	13.6
70	2.9	14.8	10.3
75	3.4	12.7	8.8
80	4.4	9.8	6.8
85	5.1	8.4	5.9
90	6.0	7.2	5.0
95	7.1	6.1	4.2

Ultrasonic tags have been shown to affect juvenile fish survival and behavior of salmonids. This includes the VEMCO tags utilized on juvenile salmonids moving along the POST and Sacramento/San Joaquin arrays (Welch *et al.*, 2010, Ammann *et al.*, 2010) and the smaller JSATS tags used in the Columbia River. Typically the effect of a tag is assumed to be relative to the ratio of the tag weight to overall weight of the organism (tag burden). There is some variability in the accepted range of tag burden used in different studies (Winter, 1983, 1996 and 2000; Zale *et al.*, 2005; Adams *et al.*, 1998). Columbia Basin experts reviewed these studies and established a series of guidelines for their study protocols – recommending an intermediate tag ratio 5 to 6.5% (Peven *et al.*, 2005). However, coded ultrasonic beacons have been used with a tag burden averaging 9.3% (+/- 0.14%) with a range of 2.6% to 11.5% (Welch *et.al.*, 2008). NOAA Fisheries, Batelle Northwest, and the US Army Corps of Engineers are currently carrying out a study implanting coded beacons, and they have found average body burden of 3% by weight showed a significantly lower relative survival for study fish migrating from Lower Granite to McNary Dam on the Columbia, consistent with laboratory studies conducted at the same time (AFEP Research Review, December 2007). Additional studies on subyearling Chinook salmon indicate that burdens approaching 5% showed negative effects on the performance and behavior of the subyearling salmon after two weeks. These studies clearly demonstrate the potential for tag effects on study results. For this reason and to adjust study

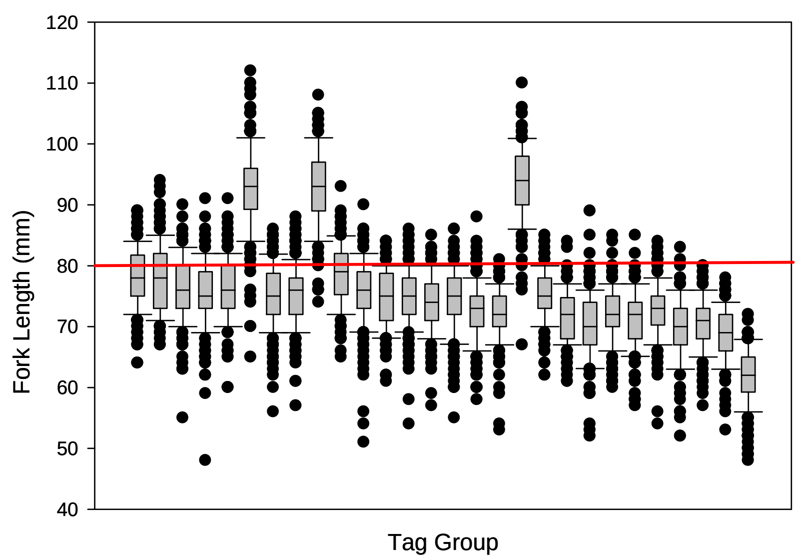


Fig. 5 Fork lengths of 28 samples of fall-run Chinook salmon smolts released from CNFH into Battle Creek. Shown are the 5th, 25th, median, 75th, and 95th percentiles. The red line indicated tentative tag size threshold with 0.3g JSAT L-AMT 1.1

results for tag-related impacts, we intend to conduct studies of the effect of JSATS implantation as performed in the past on the Vemco tags (Task 7).

The size distribution of fall-run Chinook released by the CNFH must be known in order to determine the feasibility of tagging 200 individuals of the population. Robert Null (U.S. Fish and Wildlife Service) and his colleagues measured the fork length and body mass for 28 subsamples of their most recent release of fall run Chinook salmon from the CNFH (Fig. 5). Indicated for each sample is the minimum, 5th percentile, 25th percentile, median, 75th percentile, 95th percentile, and maximum. Notice that the red line, indicating the acceptable length for tagging, passes near the 75th percentile, indicating ~25% of the fish in these samples could be tagged. Smolts of an appropriate size for tagging were present in 26 of the 28 samples of smolts released from Coleman.

Tag Implantation: We will tag individuals following the procedure of Moore *et al.* (1990) as modified by Lacroix et al. (2004). Fish will be anesthetized with Finquil (MS-222), weighed, measured, examined, photographed and then placed ventral side up in a groved foam pad. The transmitter will be inserted through an incision into the peritoneal cavity and then closed with two stitches of monofilament suture. Hatchery fish will be held for about 24 hours then released with the general production. Wild fish will be held until it is sufficiently dark. There will be a JSATS monitor in place at the release site, which will record when individuals leave the reach and begin their downstream migration.

Fall-run smolts are typically released by the CNFH in two large batches, one in early April and another in late April of each year. The survival of smolts differs greatly between these two releases each year (Robert Null, pers. comm.) This discrepancy is based on the difference in the rates of capture of outmigrating smolts with coded wire tags in trawls by the United States Fish and Wildlife Service in the mainstem of the river near Chipps Island. Furthermore, fewer adults return to the hatchery to spawn from one release versus the other release. There is considerable interest in finding out what factors contribute to the less or greater success of one release so that the hatchery might carry out future releases during benign environmental conditions promoting maximum outmigration success. Hence, our release strategy will be to tag and release with each larger (untagged) release group 150 hatchery-raised fall run smolts during early and 150 smolts during late April of each year. Separating the releases in time will allow for comparisons with varying environmental variables such as water temperature and flow rate.

Adult Chinook salmon returning to the CNFH were used to calculate indexes of survival for all production groups of fall Chinook salmon released in 2007 (Brood Year 2006). Survival indexes were calculated by dividing the number of fish returning to CNFH by the number of fish released for that tag group, and then multiplying the quotient by 100. Table 2 shows the index of survival for fall Chinook salmon production groups by release date. The survival index for the first release group of 2007 (0.054) was 7.7 times higher than the second release group (0.007). Cumulatively, the two fall Chinook salmon production releases in 2007 experienced the lowest survival index for recent years.

Table 2. Expanded numbers of Brood Year 2006 fall Chinook returning to CNFH from onsite-production releases that occurred on 4/12-13/2007 and 4/23-25/2007. Age 4 and 5 returns are not yet available.

			Number Returning to CNFH					
Brood Year	Release Date	Release Number	Age 2	Age 3	Age 4	Age 5	Total	Age 2&3 Survival Index
2006	4/12/2007	5,103,834	367	2,367	N/A	N/A	2,734	0.054
2006	4/23/2007	7,009,767	32	456	N/A	N/A	488	0.007

Task 4: Determining Reach-Specific Survival of Hatchery Spring-Run Chinook Salmon

Using the identical protocols described above for the fall run, we will tag and release 200 spring-run smolts raised by the Feather River Hatchery, 100 during early April and 100 during late April each year with two of the general releases of untagged fish from the hatchery (A Kastner, pers. comm.). Separating the releases in time will allow for comparisons with varying environmental variables such as water temperature and flow rate. Furthermore, this will provide information on a different run, with different temporal migration patterns and mortality estimates from the Feather River as opposed to the mainstem of the upper Sacramento River.

Task 5: Determining Reach-Specific Survival of wild Fall and Spring-Run Chinook Salmon

It is desirable to determine baseline rates of survival for wild fall- and spring- run as they may differ from hatchery fish, and come from different source points. Wild (i.e., naturally produced) fall- and spring-run smolts are captured each year by rotary screw traps in Mill and Deer Creeks (Fig. 4). We will tag 200 smolts with FL >80mm between October and May of each year. While there is some overlap in fall and spring run emigrate times, by using the date of capture and size in combination, it is possible to select representatives from both races. Fish >80 mm FL caught in the fall and winter are likely spring run, whereas those captured in April and May could be either fall or spring run. Small fin clips will be taken from all tagged fish for post-hoc analysis and genotyped to race at the NOAA Fisheries genetics laboratory in Santa Cruz. That lab has an on-going, large-scale program genotyping Chinook salmon samples from the ocean fishery for the Pacific Fisheries Management Council. Wild fish will be held until deemed fully recovered from tag implant and released at the place of capture after dark.

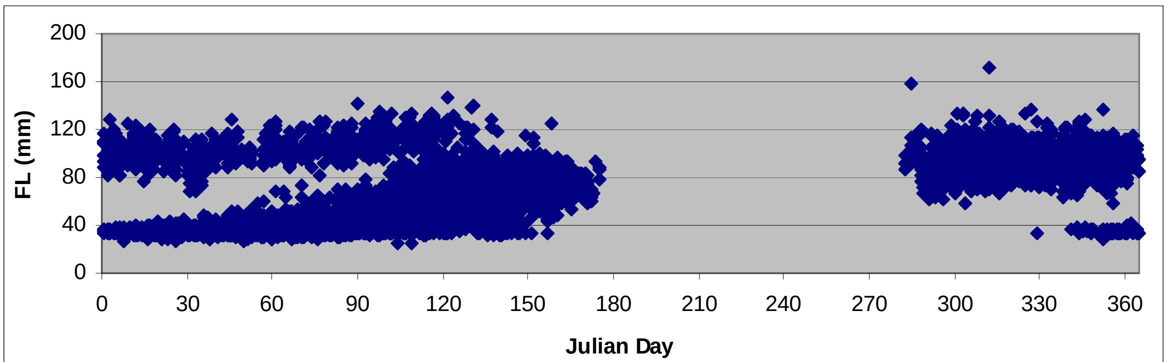


Fig 6. Size distribution of fall and spring run smolts captured in Mill Creek rotary screw traps 2000-2010

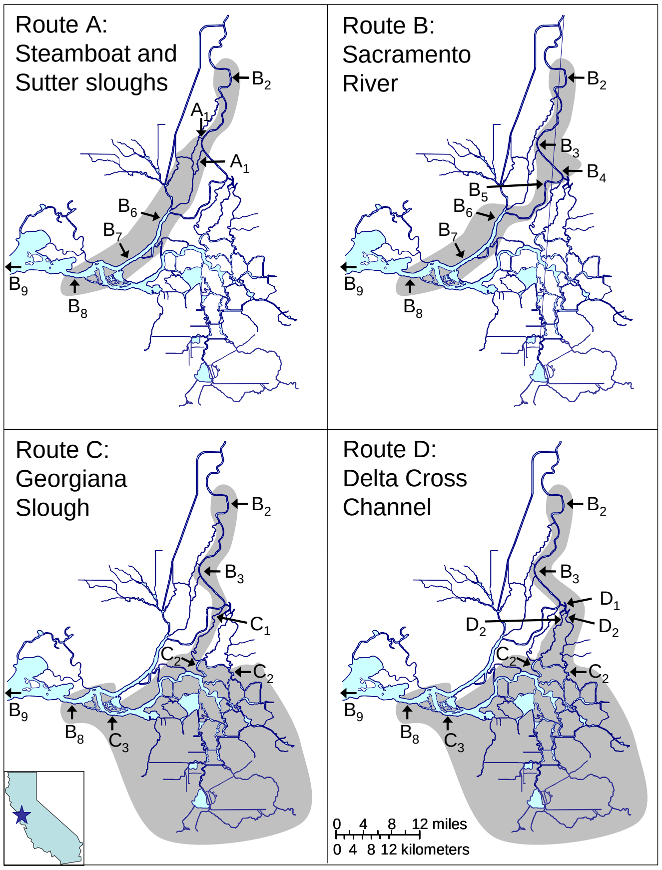


Fig. 7. Four migratory pathways taken by late-fall Chinook and steelhead smolts. We will determine the reach specific rates of survival for the four potential routes taken by fall and spring-run smolts, both when the Cross Delta channel is open and closed.

Task 6: Determining Delta-Specific Survival of HF and HS Chinook Salmon

We plan to conduct specific releases into the Sacramento River at the head of the Delta, replicating the protocols of Perry et al (2010). He described four pathways, through which late-fall and spring Chinook smolts passed through the Delta, and recorded reach-specific survival throughout each route (Fig. 7). Hatchery fall run and HS juveniles will be tagged and released at a site near Sacramento. Seventy five HF and 75 HS juveniles (Perry *et al.*, 2010 released 64-80/group) will be tagged and released before the Delta cross-channel gates are open; another 75 HF and 75 HS juveniles will be tagged and released after the Delta cross-channel gates are open during the normal downstream migration time window for each group.

Task 7: Data Management and Analysis

Data management- Project data will be held in a relational database hosted at the NMFS lab in Santa Cruz. Data will be provided to project collaborators via an ODBC connection that allows remote ODBC-compliant programs (e.g., Microsoft Access) to link to the live tables such that the programs always have access to the most recent data. The database will be modeled after the existing California Fish Tracking Consortium's database, modified as necessary to account for the differences in JSATS technology.

Analysis of Tracking Data. The basic data produced by our study are detections of tagged fish by acoustic monitors at various locations from the upper Sacramento River through the Delta to Chipps Island (river and delta exit). 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, particularly those characterizing natural water flow dynamics and water management manipulations by pumping and gate positions in the Delta.

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 pathway 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 increase survival. 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. Inter-annual 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. Gathering data in the river and the delta will allow the parsing of mortality between the two ecosystems, thus improving the knowledge of the relative contributions to factors in the two systems to juvenile salmon mortality, which will improve the ability to resolve impacts of water projects on the animals, and reduce the amount of hearsay.

Similar to our previous tagging efforts, there is a degree of uncertainty regarding tag retention rates and influence of tag on survival. Correction factors will be developed for these two issues through captive laboratory experiments with tagged fish. Specifically HF and HS run Chinook salmon ranging in size from ~75-120 mm will be brought to the NOAA SWFSC Laboratory in Santa Cruz. A series of experiments will be conducted on three groups of fish: 2 control groups (sham implant surgeries performed, and no surgeries) and a third group implanted with JSATS transmitter. Comparisons will be made for tag retention, growth, survival, and swimming performance.

IV. Feasibility

The JSATS technology has been successfully used to describe the outmigration behavior of smolts in the Columbia River. The present team of investigators has conducted very similar studies, but on larger smolts using VEMCO technology over the past five years, and are well trained to use the JSATS to monitor the reach specific movement and survival rates of smaller salmon smolts in the Sacramento River. One of us (Merz) is currently placing JSATS in smolts in the San Joaquin River. One of us (Klimley) was involved in the development of individually coded beacons and tag-detecting stations in the early 1980's and was the first to use it to describe the emigration and immigration of scalloped hammerhead sharks at a seamount in the Gulf of California. He brings to the project considerable technical expertise. Hayes and Lindley of

NMFS, Merz of Cramer Sciences, and Null of US F&W possess extensive expertise in conducting scientific studies on salmonids. This project is truly in the Delta Science Program's spirit of bringing scientists from academia, federal agencies, and private consultants together to conduct innovative and important, management-related research. The funding within this contract will be used to support the research goals of two academic institutions (UC Davis and UC Santa Cruz) and two federal agencies (NMFS and USFWS) and one private consulting firm (Cramer Fish Sciences).

V. Relevance to Delta Stewardship Council, Delta Science Program (DSP)

A. Relevance to this PSP

Stated under Topic 1, 'Native Fish Biology and Ecology", is that "one of the main goals of the DSP is to protect and recover, through ecosystem management and restoration, populations of native fishes that depend on the San Francisco Estuary. In spite of considerable scientific progress, many uncertainties remain about the basic life history, behavior, and population structure of these fishes, and about the present and future factors that affect their distribution and abundance. Focused and innovative basic science investigations are needed to address these uncertainties". Our study of the reach-specific survival of fall- and spring-run smolts is consistent with this goal, and utilization of innovative technologies to reach that goal. Under the Possible Questions to be addressed by this research, the first bulleted item is "How do native migratory fishes navigate through the San Francisco estuary. What factors affect their migratory behavior? What are the management implications?" Finally, we will be collecting information germane to the final two questions of interest: 1) "How do habitat attributes such as geometry, water flow, temperature, turbidity, contaminants, presence of predators, and food quantity and quality affect abundance and distribution of native fishes in the estuary?" and 2) How do connectivity between different habitat types and geographical extent and arrangement of habitats affect abundance and distribution of native fishes in the San Francisco Estuary". We are confident that information from the proposed study will lead to successful management and restoration strategies in the future. Rates of survival determined from our past three yearly releases of tagged late-fall and steelhead smolts into the Sacramento River are currently being used by the Pacific Fisheries Management Council quotas in deliberations on setting ocean harvest. This study will provide over time similar information for the most abundant run in the Sacramento River – the fall run.

B. Relevance to DSP Issues Outside this PSP

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, during water export operations, 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. Finally, 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 DSP 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 DSP. This research will provide information to fill knowledge gaps in life-cycle modeling and population biology for spring- and fall-run Chinook salmon. Current models do not have the fine spatial and temporal resolution data on migratory choices, rates, and survival to resolve local or regional factors influences. Migratory rates of both wild and hatchery spring and fall run smolts and pathway choices through the sloughs, delta, or in the Sacramento River will provide knowledge of the spatial-temporal environmental conditions encountered. Contrasts between races and origins of migratory choices and the resulting survival can be used to improve management of these economically and socially important resources with distinctly different life histories.

Environmental Influences on Key Species and Ecosystems. Our study will assess the influence of environmental factors, in particular water flow and water management operations, on survival and migratory patterns of salmonid smolts at within-year and among-year scales. Other variables that can be incorporated into the analyses of pathway choice and survival include water temperature, turbidity, riparian condition, and land use. Because the Delta Stewardship Council DSP 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 within-river 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. Currently, ESA-listed spring run migration influences Delta water export operations. Furthermore, the recent dramatic decline of the fall run, a significant factor in California's socio-economy, resulted in closure of the ocean fishery for 2008 and 2009. This decline has been ascribed by many to be due to Delta pumping activities. 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 wild and hatchery spring- and fall-run smolts enter the Clifton Court Forebay, approach the intakes of the state and federal pumping facilities, and become entrained and end up in the salvage facilities. Ultrasonic monitors at these locations will provide this information (see Fig. 6). Our proposed study will provide scientific data documenting the extent to which Delta water management operations affect both important Chinook salmon stocks in a comparative way to riverine influences. The experimental approach will quantify for the first time survival rates in defined reaches and specific locations along the migratory pathway. 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 smolt, such as striped bass, black bass, catfish, and pike minnows.

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 Battle Creek on the upper Sacramento River through the Delta to Chipps Island that can be used by other researchers to track other species of interest, such as delta smelt, juvenile sturgeon and striped bass. For example DWR will be releasing 50 striped bass, carrying individually coded beacons (V13, Vemco Ltd.), in the Upper and Middle Delta to describe their seasonal movements. It is anticipated that some of these fish will consume fall- or spring-run smolts during their downstream migration. We are interested in comparing the detection records of the paired monitors, the Vemco VR2W and Lotek JSATS, to see if the larger tag within the striped bass and smaller tag within the salmon smolt are detected at the same time – evidence of the former feeding upon the latter. This may be a future way of identifying predation as a source of mortality of outmigrating salmon smolts.

IV. Qualifications

Peter (Pete) Klimley (co-Principal Investigator), Adjunct Professor, Director, Biotelemetry Laboratory, University of California, Davis

Education: Scripps Institution of Oceanography (Ph.D.), Rosenstiel School of Marine and Atmospheric Science (M.Sci.), State University of New York @ Stony Brook (B.S.); Research Interests: marine and anadromous fisheries biology, ecology, and oceanography, biotelemetry: development of behavioral and environmental sensors, computer-decoded telemetry, automated data logging, archival tags: Related Papers: 1) Perry, P.W, P.L. Brandes, P. Sandstrom, A. Ammann, B.M. McFarlane, A.P. Klimley, and J.R. Skalski. 2009. Estimating migration and survival of juvenile Chinook salmon through the Sacramento–San Joaquin River Delta. *Journal of North American Fish Management*, 30: 142-156, 2) Heublein, J., J.T. Kelly, C.E. Crocker, A.P. Klimley and S. T Lindley. 2009. Migration of green sturgeon in Sacramento River. *Environmental Biology of Fishes*, 84:245–258, 3) Klimley, A.P., F. Voegeli, S.C. Beavers, and B.J. Le Boeuf. 1998. Automated listening stations for tagged marine fishes. *Marine Technology Journal*, 32: 94-101.

Sean A Hayes (co-Principal Investigator), Research Fisheries Biologist NOAA SWFSC, Assistant Adjunct Professor, University of California, Santa Cruz

Education: University of California, Santa Cruz (Ph.D.), Cornell University College of Ag and Life Science (B.S.); SUNY Cobleskill Fisheries and Wildlife (AAS). Research Interests: Salmonid freshwater growth, habitat use, migration behavior, mating system evolution, reproductive strategies and population structure; predator prey interactions between salmon, birds and pinnipeds; salmonid marine survival and ocean ecology. Related Papers: 1) Claiborne, A.M., Fisher, J.P., Hayes, S.A., and Emmett, R.L. *In rev*. Size at Release, Marine Survival, and Age of Maturity for Hatchery Spring Chinook Salmon 2002-2005. Trans. Am. Fish. Soc. 2) Hayes, S.A., Bond, M.H., Wells, B., Hanson, C.V., Jones, A.W. and MacFarlane, R.B. ***in press***. Using Archival Tags to infer habitat use of Central California Steelhead and Coho Salmon. *In* Advances in Fish Tagging and Marking Technology. AFS, Auckland, New Zealand. 3) Hayes, S.A., Bond, M.H., Hanson, C.V., Freund, E.V., Smith, J.J., Anderson, E.C., Ammann, A., and MacFarlane, R.B. 2008. Steelhead growth in a small central California watershed: upstream and estuarine rearing patterns. *Trans. Am. Fish. Soc.*, 137: 114-128,

Steven T. Lindley (Co-Investigator), Supervisory Research Ecologist, Fisheries Ecology Division, Southwest Fisheries Science Center, National Marine Fisheries Service.

Education: Duke University (Ph.D.); Research Interests: Landscape, ecosystem, and population ecology of aquatic organisms, statistical and numerical modeling, time series analysis, stable isotopes, telemetry, mark-recapture. Related papers: 1) Payne, J., K. Andrews, C. Chittenden, G.

Crossin, F. Goetz, S. Hinch, P. Levin, S. Lindley, M. Melnychuk, T. Nelson, E. Rechisky, and D. Welch. In press. Studying movements and survival of marine animals with large-scale acoustic arrays. In Life in the World's Oceans: Diversity, Distribution and Abundance, A. D. McIntyre, ed. Blackwell Publishing Ltd. (Oxford); 2) Lindley, S. T., C. B. Grimes, and 23 others. 2009. What caused the Sacramento River fall chinook salmon stock collapse? NOAA Tech Memo NMFS-SWFSC 447. 3) Mora, E. A., S. T. Lindley, D. L. Erickson and A. P. Klimley. 2009. Do impassable dams and flow regulation constrain the distribution of green sturgeon in the Sacramento River, California? *Journal of Applied Ichthyology*, 25: 39-47.

Joseph (Joe) Merz (co-Investigator), Research Associate, University of California Santa Cruz, Principal Restoration Ecologist, Cramer Fish Sciences
Education: University of California Davis (Ph.D.), California State University of California (M.Sci.), California Polytechnic State University San Luis Obispo (B.Sci.); Research Interests: Anadromous fisheries and riverine ecology, habitat restoration, biotelemetry: identification of migratory pathways and environmental cues, population modeling. Related Papers: 1) Beakes, M.P., W.H. Satterthwaite, E.M. Collins, D.R. Swank, J.E. Merz, R.G. Titus, S.M. Sogard, and M. Mangel In Press. Smolt transformation in two California steelhead populations: Effects of temporal variability in growth. *Transactions of the American Fisheries Society*. 2) Jeffres, C. A., J. E. Merz and J. J. Cech Jr. 2006. Movement of Sacramento sucker, *Catostomus occidentalis*, and hitch, *Lavinia exilicauda*, during a spring release of water from Camanche Dam in the Mokelumne River, California. *Environmental Biology of Fishes*, 75:365-373, 3) Merz, J.E. 2002. Seasonal feeding habits, growth and movement of steelhead trout in the lower Mokelumne River, California. *California Fish and Game*, 88: 95-111.

Arnold J Ammann (co- Investigator), Research Fisheries Biologist, NOAA SWFSC
Education: University of California Santa Cruz (M.Sci.), UC Santa Barbara (B.Sci.); Research Interests: Physiological ecology, movement and survival of salmon and steelhead; relationships between marine fish population dynamics and oceanography. Related Papers: 1) Ammann, A.J. 2004 SMURFs: standard monitoring units for the recruitment of temperate reef fishes. *Journal of Experimental Marine Biology and Ecology*, 299: 135-154. 2) Ammann, A.J. and Carr, M.H. 2000. Contrasting effects of La Nina and El Nino on recruitment of juvenile rockfish In: Ecosystem Observations for the Monterey Bay National Marine Sanctuary, pp.11-12.

Robert E. Null (co-Investigator), Supervisory Fish Biologist, Red Bluff Fish and Wildlife Office, U.S. Fish and Wildlife Service
Education: California State University, Chico (B.S.); Research Interests: Salmonid hatchery and wild fish interactions, freshwater growth, habitat use, migration behavior, reproductive strategies and population structure; predator. Related Papers: 1) U.S. Fish and Wildlife Service. 2010. Evaluation of the supplementation program at Livingston Stone National Fish Hatchery via the winter Chinook carcass survey. Red Bluff Fish and Wildlife Office. U.S. FWS Red Bluff, CA. 2) Null, R.E., K.S. Niemela , and S.F. Hamelberg, 2007. Post-spawn Migration of Steelhead Kelts in the Sacramento River Basin of California. American Fisheries Society Annual Meeting. 3.) Matala, A.P., W. Ardren, D. Hawkins, S.F. Hamelberg, R.E. Null., and K.S. Niemela. Relative reproductive success among Coleman National Fish Hatchery-origin and natural-origin components of the Battle Creek steelhead population. In Review.

Cyril J Michel (Co-Investigator), Graduate Student, UC Santa Cruz and NOAA SWFSC Education: University of California, Santa Cruz (B.Sci., M.Sci., *in progress*); Research Interests: Habitat use, migratory behavior, life-history strategies and predator-prey dynamics of fishes, fisheries conservation and management. Related presentations: 1) Michel, C.J., Ammann, A.J., Sandstrom, P.T., Chapman, E.D., Lindley, S.T., Klimley, A.P. and MacFarlane, R.B. 2009. "Movement and mortality patterns of Central Valley juvenile late-fall run Chinook salmon (*Oncorhynchus tshawytscha*) and the environmental factors that shape them", *94th Ecological Society of America Annual Meeting*, Albuquerque, NM. 2) Ammann, A.J., Michel, C.J., Sandstrom, P.T., Chapman, E.D., and Delaney, N. "Growth and swimming performance of Chinook salmon and steelhead yearlings implanted with acoustic transmitters", *1st Electronic Tagging Studies of Salmon Migration Conference*, Bodega Bay, CA. 3) Michel, C.J., Ammann, A.J., Sandstrom, P.T., Chapman, E.D., Lindley, S.T., Klimley, A.P. and MacFarlane, R.B. 2008. "A high-resolution account of the survival and movement rates of acoustically tagged juvenile Chinook salmon (*Oncorhynchus tshawytscha*) during the 2007 and 2008 season", *5th Biennial CALFED Science Conference,* Sacramento, CA.

VI. Literature Cited

Adams, N., D. Rondorf, S Evans, J. Kelly and R Perry 1998. Effects of surgically and gastrically implanted radio transmitters on swimming performance and predator avoidance of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) *Can. Jour. Fish. Aquat. Sci.*. 55: 781-787.

Adams, N., D. Rondorf, S. Evans, and J. Kelly. 1998. Effects of surgically and gastrically implanted radio transmitters on growth and feeding behavior of juvenile Chinook salmon. *Trans. Am. Fish. Soc.*, 127: 128-136.

Ammann, A.J, C. Michel, P. Sandstrom, E. Chapman, and N. Delaney. 2010. Growth and swimming performance of Chinook salmon and Steelhead yearlings implanted with acoustic transmitters. Abstract, Salmon Tracking Symposium Bodega Marine Laboratory.

Burnham, K.P. and D.R. Anderson. 1998. Model Selection and Inference: a Practical Information-Theoretic Approach*.* Springer-Verlag, New York.

Burnham, K.P., D.R. Anderson, G.C. White, C. Brownie, & K.H. Pollock. 1987. Design and analysis methods for fish survival experiments based on release-recapture. *American Fisheries Society Monograph 5*, Bethesda, MD.

Cormack, R.M. 1964. Estimates of survival from the sighting of marked animals. *Biometrika*, 51: 429-538.

Fisher, F.W. 1994. Past and Present Status of Central Valley Chinook Salmon. *Cons. Biol.,* 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.

Kjelson, M.A., P.F. Raquel & F.W. Fisher.1981.The Life-History of Fall Run Juvenile Chinook Salmon, *Oncorhynchus tshawytscha*, in the Sacramento San Joaquin Estuary of California. *Estuaries*, 4: 285-285.

Lacroix, G.L., D. Knox & P. McCurdy. 2004. Effects of implanted dummy acoustic transmitters on juvenile Atlantic salmon. *Trans. Am. Fish. Soc.*, 133: 211-220.

Lindley, S. T., E. Mora, R. S. Schick, P. B. Adams, J. J. Anderson, S. Greene, C. Hanson, B. P. May, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2007. Framework for assessing viability of Chinook salmon and steelhead in the Sacramento-San Joaquin basin. *San Francisco Estuary and Watershed Science*, 5(1), Article 4.

Lindley, S. T., C. B. Grimes, M. S. Mohr, W. Peterson, J. Stein, J. Anderson, D. Bottom, L. Botsford, C. Busack, T. Collier, J. Ferguson, A. Grover, D. Hankin, R. Kope, P. Lawson, A. Low, B. MacFarlane, K. Moore, M. Palmer-Zwahlen, F. Schwing, J. Smith, C. Tracy, R. Webb, B. Wells, and T. H. Williams. 2009. What caused the Sacramento River fall chinook salmon stock collapse? NOAA Tech Memo NMFS-SWFSC 447.

McMichael, G.A., M.B. Eppard, T.J. Carlson, J.A. Carter, B.D. Ebberts, R.S. Brown, M. Weiland, G.R. Ploskey, R.A. Harnish, and Z.D. Deng. 2010. The juvenile salmon acoustic telemetry system: a new tool. *Fisheries,* 35: 9-21.

Melnychuk, M.C., and Walters, C.J. 2010. Estimating detection probabilities of tagged fish migrating past fixed receiver stations using only local information. *Can. J. Fish. Aquat. Sci.,* 67: 641-658.

Michel, C., A. Ammann, S.T. Lindley, A.P. Klimely, R.B. MacFarlane 2010. Movement and Mortality Patterns of Central Valley Juvenile Late-fall Run Chinook Salmon (*Oncorhynchus tshawytscha*) and the Environmental factors that shape them. *1st Electronic Tagging Studies of Salmon Migration Conference*. Bodega Bay, May 20-21.

Moore, A., I. C. Russell, and E. C. E. Potter. 1990. The effects of intraperitoneally implanted dummy acoustic transmitters on the behavior and physiology of juvenile Atlantic salmon, *Salmo salar* L. *Jour. Fish Biol.*, 37: 713-721.

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.

Peake, S. 1998. Sodium bicarbonate and clove oil as potential anesthetics for nonsalmonid fishes. *North Am. Jour. Fish. Management.,* 18: 919-924.

Peake, S. and R. S. McKinley. 1997. Influence of transmitter attachment procedures on swimming performance of wild and hatchery-reared Atlantic salmon smolts. *Trans. Am. Fish. Soc.*, 126: 707-714.

Perry, P.W, P.L. Brandes, P. Sandstrom, A. Ammann, B.M. McFarlane, A.P. Klimley, and J.R. Skalski. 2009. Estimating migration and survival of juvenile Chinook salmon through the Sacramento–San Joaquin River Delta. *Jour North Am. Fish Management.*, 30: 142-156.

Peven, C., A. Giorgi, J Skalski, M. Langeslay, A. Grassell, S. Smith, T. Counihan, R. Perry and S. Bickford. 2005. Guidelines and recommended protocols for conducting, analyzing and reporting juvenile salmonid survival in the Columbia River Basin.

Proakis, J. G. 1995. Digital communications. McGraw-Hill, NewYork.

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.

Welch, D., E. Rechisky, M. Melnychuk, A. Porter, C. Walters, S. Clements, B Clemens, R. McKinley and C. Schreck. 2008, Survival of Migrating salmon smolts in large rivers with and without dams. *PLOS Biology*, 6: 2101-2108.

Winter, J.D. 1983. Underwater biotelemetry. Pages 371-395 *In* L.A. Nielsen and D.L. Johnson, eds. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Winter, J.D. 1996. Advances in underwater telemetry, pages 555-590 *In* B.R. Murphy and D.W. Willis, eds. Fisheries Techniques, 2nd Edition. American Fisheries Society, Bethesda, Maryland.

Winter, J.D. 2000. Designing telemetry studies and other technical and analytical considerations. Pp. 229-247 in J.H. Eiler, D.J. Alcorn, and M.R. Neuman (Eds.), Biotelemetry 15: Proceedings of the 15th International Symposium on Biotelemetry. International Society on Biotelemetry, Wageningen, The Netherlands.

Yoshiyama, R.M., Fisher, F.W., Moyle, P.B. 1998. Historical abundances and decline of Chinook Salmon in the Central Valley Region of California. *North Am. J. Fish. Management,* 18: 487-521.

Zale, A. and C. Brooke, 2005. Effects of surgically implanted transmitter weights on growth and swimming stamina of small adult west slope cutthroat trout. *Trans. Am. Fish. Soc.*, 134: 653-660.

STATE OF CALIFORNIA – CALIFORNIA NATURAL RESOURCES AGENCY ARNOLD SCHWARZENEGGER, Governor

DEPARTMENT OF WATER RESOURCES
DIVISION OF ENVIRONMENTAL SERVICES
3500 INDUSTRIAL BOULEVARD
WEST SACRAMENTO, CA 95691

June 28, 2010

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

Dear Delta Stewardship Council:

The California Department of Water Resources supports the proposal Survival and migratory patterns of Fall and Spring –Run Central Valley Juvenile Salmonids: number #0132.

Recent advances in acoustic telemetry technology have resulted in acoustic transmitters which are small enough to be implanted in previously untaggable critical life stages of the fall, winter and spring races of Chinook salmon (*Oncorhynchus tshawytscha*). The project will use this technology to tag and track the movements of hatchery-raised and wild fall and spring smolts released annually over a period of three years. This will enable us to evaluate the effect of natural and anthropogenic changes in flow and related water project operations on their survival and movement patterns within the Sacramento River and Delta. This study will provide resource managers in California with a more comprehensive understanding of the response of juvenile salmon outmigration under a wide variety of flow conditions and Delta water management practices.

Currently our Interagency Ecological Program provides some tracking of Salmonids, but not to the extent, nor in the size of fish targeted by this proposal, due to the lack of the miniaturized tags and the related array. Data from this project can be used to complete a detailed lifecycle model for Central Valley salmonids, which currently is deficient 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.

Thank you for considering this very important project. Please contact me with questions.

Sincerely,
Rich S Breuer

Richard S. Breuer
Chief, Environmental Water Quality and Estuarine Studies
(916) 376-9694

Joshua Israel, PhD
Applied Science Branch
US Bureau of Reclamation
2800 Cottage Way, MP-150
Sacramento CA 95825

Dear DSP Proposal Review Panel:

I am writing in support of the proposed project entitled "Survival and migratory patterns of juvenile spring and fall run Chinook salmon in Sacramento River and Delta" submitted to you by Dr. Pete Klimley and Dr. Sean Hayes. I reviewed the proposal over the past few days and believe it will provide additional information on life history patterns and demographics of spring and fall run Chinook in the Sacramento River. If selected, UC Davis and NOAA- Fisheries scientists will deploy new technology to track salmon along their migration routes in the Sacramento River and evaluate how these patterns are different between hatchery and natural-origin groups of fish. This study can provide critical information about the effect of hatcheries on the behavior and survival of juvenile fall and spring run Chinook salmon.

I am responsible for formulating and coordinating management studies involving salmonids and sturgeon at Reclamation facilities to assess their impact on fish habitat, migration, and population demographics. As a Fish Biologist, I participate in numerous fish and water operation management groups on behalf of Reclamation. In both of these cases, colleagues and I are often faced with making difficult decisions with high uncertainty. While basic information exists about spring and fall run salmon juvenile migration, we know little about the survival of these fish in the Sacramento River or Delta. The project proposed will develop new information about route selection of fall and spring run Chinook around the Delta Cross Channel, which may provide results that can be synthesized in salmon migration and survival models.

If funded, I hope the investigators will include biologists working for project operating agencies on its project team to develop and refine their study design and plan so that it can provide a maximum benefit to salmon and water operations.

Sincerely,

Josh Israel
Fish Biologist, Bureau of Reclamation

UNIVERSITY OF CALIFORNIA, DAVIS

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO • SAN FRANCISCO • SANTA BARBARA • SANTA CRUZ

DEPARTMENT OF WILDLIFE, FISH, AND CONSERVATION BIOLOGY
COLLEGE OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES
AGRICULTURAL EXPERIMENT STATION
COOPERATIVE EXTENSION
FAX: (530) 752-4154

ONE SHIELDS AVENUE
DAVIS, CALIFORNIA 95616-8751

30 June 2010

Delta Science Program
Delta Stewardship Council
650 Capitol Mall, Fifth Floor
Sacramento, CA 95814

Dear Delta Stewardship Council:

The following letter is to accompany a list of the scientific talks given at the recent symposium, entitled "Electronic tagging studies of salmon migration", held at the Bodega Marine Laboratory on 20-21 May 2010. This meeting was attended by scientists from academic institutions, state and federal agencies, and private companies. The results presented in talks at the meeting will be published in 2011 within a Special Issue of *Environmental Biology of Fishes*.

This meeting was organized by Phillip Sandstrom, a Graduate Student Researcher, and myself as a deliverable from the four year grant, entitled "Survival and migratory patterns of Central Valley juvenile salmonids, with myself and Bruce MacFarlane, the principle investigators of this CALFED-sponsored research program. We intend to hold a similar symposium with a broadened scope, entitled "Telemetric studies of fishes in the Sacramento/San Joaquin watershed", at the end of the proposed grant period. The results of these articles will also likely be published within a Special Issue of *Environmental Biology of Fishes*.

This letter is included with the proposal as a testament to the productive scientific output of the UC Davis, NMFS, U.S. Fish and Wildlife, and other investigators that collaborated in this CALFED-funded project.

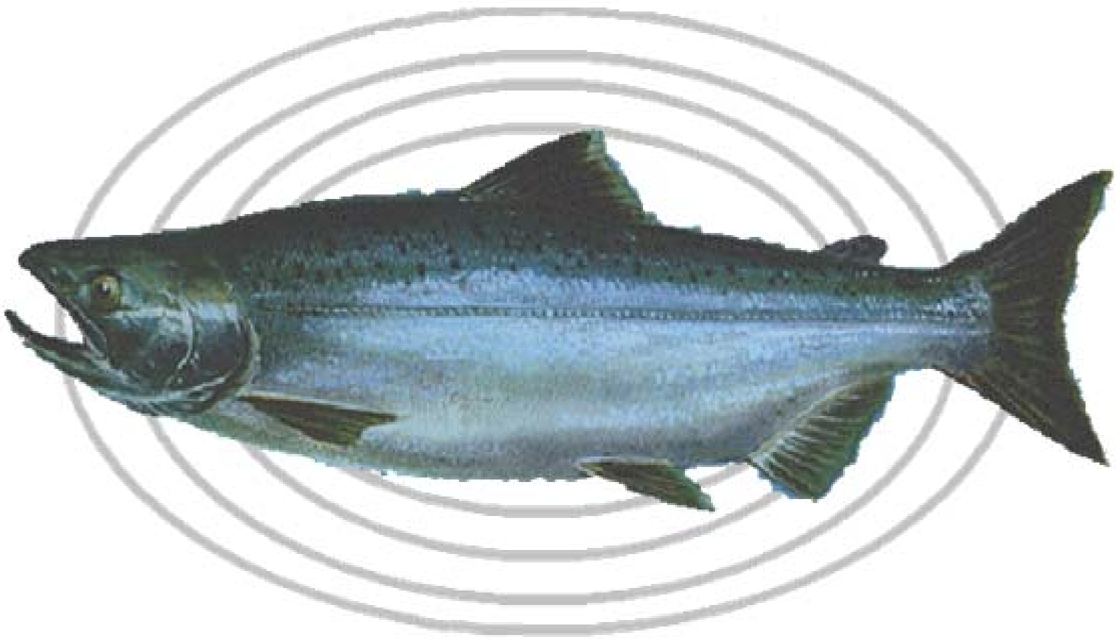
Cheers,

A. Peter Klimley

A. Peter Klimley, Ph.D.
Adjunct Professor
Director, Biotelemetry Laboratory

Symposium

Electronic Tagging Studies of Salmon Migration



Conference at

Bodega Marine Laboratory

Bodega Bay, California

20-21 May 2010

Acknowledgements

We would like to express our gratitude to the CALFED Science Program, now the Delta Science Program, for providing the funding that has made this conference possible. The following consulting firms, Cramer Fish Sciences, ECORP Consulting Inc., and ENVIRON INTERNATIONAL have made gracious donations to make possible our wine and beer mixer after the scientific sessions on Thursday.

Introduction

Tracking technology has held hostage our knowledge of the timing and extent of migration of salmonids. For example, the movements of salmonids were first determined by affixing plastic tags on the dorsum or dorsal fin with instructions to convey the date and location of capture to the releasers of the fish. These studies provided a start and end point to a fish's collective movement over a defined period, but were unable to provide information on the path taken by the fish between the two points. These "mark and recapture" studies almost invariably underestimated the extent of the movement of the fish. At least, a fish caught at the same locality of tagging might be assumed to be resident over the period between tagging and recapture, when it could have moved a considerable distance away before returning to that site. These studies, involving the marking of thousands of fish, were often conducted in conjunction with commercial fisheries, and the captured tagged fish were usually part of the annual harvest. Hence, the migration of the fish was interrupted at some point, with the loss of any information on the further movement of the individual. Furthermore, removal of the tagged individual from its environment precluded a single fish returning repeatedly to a single site, a behavioral phenomenon called "homing".

Recent advances in electronic tagging technology have expanded the horizon of our knowledge about salmon migration. Coded, ultrasonic beacons have been place within salmon smolts, and reach-specific rates of movement and survival are now being recorded by tag detecting monitors. The automated data loggers are placed along multiple reaches, each with different patterns of flow and river bed and bank geomorphologies at constant spatial intervals along the mainstreams of rivers, throughout the many interconnected waterways of deltas, and across sections of the bays. Archival tags, which determine the geographic coordinates of fish based on light measurement, have recently been miniaturized sufficiently to be placed on steelhead, an interoparous species that makes yearly migrations out of the watershed and into the ocean before returning to its spawning site on successive years. These tags, and their stored archives of positions, can be retrieved from a significant fraction of the migrating steelhead.

It is the purpose of this symposium to convince scientists worldwide of the value using these new tagging technologies to elucidate the migrations of salmonids. The results of many studies, although still in their infancy, are presented in this volume. These are just the first rewards for the technological effort. The symposium will begin with talks devoted to describing the technologies and their limitations. A second section of the symposium will be devoted to talks revealing what we have learned about the behavior and physiology of salmonids from these tagging studies. Thirdly, talks will be given on the mathematical analyses used to determine rates of survival and detection probability of detection arrays. A final section will be devoted to articles illustrating the extent of movement of salmonids both in the watershed and the open ocean. Recent advances in electronic tagging have considerably augmented the information available on salmonids. The talks given in this session will lead to manuscripts, which will be collected and published in a Special Issue of *Environmental Biology of Fishes*.

MAY 20, 2010

Tagging Technology: Limitations and Capabilities

Chair: Pete Klimley

9:00 **Welcome, Role of CALFED/Other agencies in collaborative telemetry studies**
Peter Klimley, BruceMacFarlane, Phil Sandstrom

9:20 **Ultrasonic and Radio Telemetry of Salmonids Past to Present: A Historical Review of Tagging Practices and Technologies**
Peter Klimley, University of California Davis (Davis, CA)

9:40 **Vemco Technologies**
Dale Webber, Amirix/Vemco (Hallifax, NS, Canada)

10:00 **Lessons Learned from the Columbia River Basin**
John Ferguson, National Marine Fisheries Service (Seattle, WA)

10:20 **BREAK**

10:40 Christa Woodley

11:00 **Mobile Receivers: Releasing the Mooring to See Where Fish Go**
Sean Hayes, National Marine Fisheries Service (Santa Cruz, CA)

11:20 **Benchmark and Field Tests of the Range of Automated Monitors for Three Sizes of Ultrasonic Transmitters**
Gabriel Singer, University of California Davis (Davis, CA)

11:40 **Monitor Detection Efficiency and Tidal Currents**
Arnold Ammann, National Marine Fisheries Service (Santa Cruz, CA)

12:00 **LUNCH**

Behavior and Physiology

Chair: Bruce MacFarlane

13:00 **Growth and Swimming Performance of Chinook Salmon and Steelhead Yearlings Implanted with Acoustic Transmitters**
Arnold Ammann, National Marine Fisheries Service (Santa Cruz, CA)

13:20 **Tag Size Effects on Fish While Migrating**
Michael Melnychuk, University of Washington (Seattle, WA)

13:40 **Differential Use of Repaired Banks and Naturalized Sites by Outmigrating Juvenile Hatchery Steelhead in the Sacramento River, California**
Peter Nelson, H.T. Harvey (Arcata, CA)

14:00 **Fine-scale Movement, Habitat Associations and Survival of Wild *Oncorhynchus mykiss* of the Mokelumne River, CA, from Acoustic Telemetry in Standardized Transects**
Walter Heady, University of California Santa Cruz (Santa Cruz, CA)

14:20 **Tracking Efficiency of Coded Acoustic Tags Based on Pulse Rate, Habitat Type and Flow Regimes in the Lower Yuba River**
Johnathan Nelson, California Department of Fish & Game (Rancho Cordova, CA)

14:40 **An Evaluation of Mobile Tracking Efficiency Using Coded Acoustic Tags in the Lower Yuba River**
Roger Bloom, California Department of Fish & Game (Rancho Cordova, CA)

15:00 **BREAK**

15:20 **The Hydrophone Data Repository an Online Tag Detection Sharing and Research Coordination solution**
Jennifer Scheurell, Sound Data Management (Seattle, WA)

15:40 **Post-spawn Migration of Steelhead Kelts in the Sacramento River Basin of California**
Robert Null, U.S. Fish & Wildlife Service (Red Bluff, CA)

16:00 **Using Radio Telemetry to Inform Rescue Strategies for Central Valley Spring-run Chinook Salmon**
Chris Mosser, University of California Davis (Davis, CA)

16:20 **Fish Passage Studies at the Suisun Marsh Salinity Control Gates in Montezuma Slough**
Robert Vincik, California Department of Fish & Game (Rancho Cordova, CA)

16:40 **Using the Eulerian Lagrangian Agent Method (ELAM) for Forecasting Fish Movement in Response to Levee Repair on the Sacramento River**
David Smith, U.S. Army Corps of Engineers (Vicksburg, MS)

17:00 **Fish Distribution and Entrainment Estimates from 3-D Particle Tracking with Vertical Migration Behavior**
Ed Gross, Bay Modeling (Oakland, CA)

MAY 21, 2010

Survival Estimates and Detection Probabilities

Chair: Cyril Michel

8:00 **Migration of Late-fall Chinook and Steelhead Smolts Relative to Dredge Removal and Disposal Sites in San Francisco Bay**
Alex Hearn, University of California Davis (Davis, CA)

8:20 **Using Acoustic Tags to Understand the Potential Impact of Exports on Survival through the Delta**
Patricia Brandes, U.S. Fish & Wildlife Service (Stockton, CA)

8:40 **Effects of Tides, River Flow, and Gate Operations on Entrainment of Juvenile Chinook Salmon into the Interior Sacramento-San Joaquin Delta**
Russell Perry, University of Washington (Seattle, WA)

9:00 **Movement and Mortality Patterns of Central Valley Juvenile Late-fall Run Chinook Salmon (*Oncorhynchus tshawytscha*) and the Environmental Factors that Shape Them**
Cyril Michel, National Marine Fisheries Service (Santa Cruz, CA)

9:20 **Survival of Juvenile, Late-fall Chinook Salmon Using Different Migration Routes to Negotiate the Sacramento-San Joaquin River Delta**
Russell Perry, University of Washington (Seattle, WA)

9:40 **Steelhead Pre-screen Loss in Clifton Court Forebay**
Kevin Clark, Department of Water Resources (Sacramento, CA)

10:00 **Sacramento River Steelhead (*O. mykiss*): Comparing Movement and Survival of Hatchery and Natural Smolts**
Philip Sandstrom, University of California Davis (Davis, CA)

10:20 **BREAK**

10:40 **Adjusting Survival Estimates to Account for Premature Tag Failure: Application to the VAMP 2008 Acoustic Telemetry Study**
Chris Holbrook, U.S. Geologic Survey (Cook, WA)

11:00 **Vernalis Adaptive Management Plan (VAMP) 2009 Tagging Study: Salmon vs. Predators**
Rebecca Buchanan, University of Washington (Seattle, WA)

11:20 **Testing of an Acoustic/Bubble/Strobe Light Barrier to Improve Escapement of Chinook Smolts in California's Sacramento-San Joaquin Delta**
Mark Bowen, U.S. Geological Survey (Denver, CO)

11:40 **2010 VAMP Study Plan and Related Challenges**
Patricia Brandes, U.S. Fish & Wildlife Service (Stockton, CA)

12:00 **Use of Telemetry to Evaluate Chinook Salmon Smolt Migration and Mortality in California's Sacramento – San Joaquin Delta**
Dave Vogel, Natural Resource Scientists, Inc. (Red Bluff, CA)

12:20 **LUNCH**

Movements and Migration

Chair: Phil Sandstrom

13:20 **Migration Timing, Rate, Pathways and Survival of Central Valley Steelhead through the Sacramento-San Joaquin Delta and Bays: A Case Study on the Mokelumne River**
Casey DelReal, East Bay Municipal Utilities District (Lodi, CA)

13:40 **A Fork in the Road: Using a VPS Array to Determine the Tracks of Salmon Smolts at the Junction between the Mainstem Sacramento River and the Delta Cross Channel**
Anna Stephenson, University of California Davis (Davis, CA)

14:00 **Movement Patterns of *O. mykiss* in the American River**
Erin Collins, California Department of Fish & Game (Sacramento, CA)

14:20 **Seasonal Movement Patterns of Feather River Natural and Hatchery Origin *O. mykiss***
Ryon Kurth, Department of Water Resources (Oroville, CA)

14:40 **BREAK**

15:00 **Acoustic Tracking of Wild Steelhead Smolts on the Alsea River, Oregon**
Camille Leblanc, Oregon State University (Corvallis, OR)

15:20 **Spatio-temporal Migration Patterns of Salmon Smolts Downstream and through the Strait of Georgia, B.C.**
Michael Melnychuk, University of Washington (Seattle, CA)

15:40 **Estuarine and Coastal Marine Behavior of Staging Adult Chinook Salmon Returning to the Klamath River Basin**
Josh Strange, University of Washington (Seattle, CA)

16:00 **Coho Salmon Residence Time and Habitat Use in Humboldt Bay, CA,: An Acoustic Telemetry Study**
Bill Pinnix, U. S. Fish & Wildlife Service (Arcata, CA)

16:20 **Klamath River Radio-Tagged Juvenile Coho and Their Response to Environmental Variables**
John Beeman, U. S. Geological Survey (Cook, WA)

16:40 **Movements and Behavior of Juvenile Coho Salmon on the Trinity River**
Robert Chase, Bureau of Reclamation (Red Bluff, CA)

17:00 **BREAKOUT SESSION:** New areas research: Questions in the Rivers and Tributaries, Estuaries, and off the Coast of California. Future potential of California Fish Tracking Consortium.

2010 PSP SIGNATURE PAGE

The applicant for this proposal must submit the signature form by printing it, having it signed, scanning the signed form, and uploading the scanned document by using the "upload" button on the signature page form on our website. If you do not have access to a scanner, you may submit your signed form via FAX to (916) 445 - 7311. Please send only one form per FAX transmission.

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

By signing below, I declare that:

- All representations in this proposal are truthful;
- I am authorized to submit the application on behalf of applicant (if applicant is an entity or organization);
- I have read and understand the conflict of interest section in the main body of the PSP and waive any and all rights to privacy and confidentiality of the proposal on behalf of the applicant, to the extent provided in this PSP, and
- I have read and understood all attachments of this PSP.

Proposal Title:	SURVIVAL AND MIGRATORY PATTERNS OF JUVENILE SPRING AND FALL RUN CHINOOK SALMON IN SACRAMENTO RIVER AND DELTA
Lead Investigator:	Abbott (Peter) Klimley
Organization:	University of California, Davis
Proposal #:	2010.01-0132
Signatory for the applicant organization:	**May Turner** **Contracts and Grants Analyst**

(Please print the name of the signatory)

May A. Turner
Signature

June 29, 2010
Date

(ABBOTT) PETER KLIMLEY

Professional Address	Residential Address
DIRECTOR BIOTELEMETRY LABORATORY 1334 ACADEMIC SURGE DEPARTMENT OF FISH, WILDLIFE, & CONSERVATION BIOLOGY UNIVERSITY OF CALIFORNIA DAVIS, CALIFORNIA 95616	2870 EASTMAN LN. PETALUMA, CA 94952 TEL: (707) 765-6516 (HOME) TEL: (707) 481-1447 (CEL)

TEL: (707) 752-5830 (OFFICE/LABORATORY)
752-4154 (FAX)

EDUCATION

1982 Doctor of Philosophy (Ph.D.), Marine Biology.
Scripps Institution of Oceanography, UC San Diego, California.
Dissertation: Social organization of schools of scalloped hammerhead sharks, *Sphyrna lewini* (Griffith and Smith), in the Gulf of California.
Committee: Bradbury, J., W. Evans, W. Heiligenburg, D. Nelson, and R. Rosenblatt (Chairman).

1976 Master of Science (M.Sc.), Biological Oceanography.
Rosenstiel School of Marine and Atmospheric Science, University of Miami, Coral Gables, Florida.
Thesis: Analysis of acoustic stimulus properties underlying withdrawal in adult lemon sharks, *Negaprion brevirostris* (Poey).
Chairman: Myrberg, Jr., A.

1970 Bachelor of Science (B.S.), Zoology.
State University of New York, Stony Brook, New York.

EMPLOYMENT

2008-Pres. Adjunct Professor, Department of Wildlife, Fish, & Conservation Biology, University of California, Davis.

2003-2008 Adjunct Associate Professor, Department of Wildlife, Fish, & Conservation Biology, University of California, Davis.

2001-2002. Senior Fisheries Ecologist, H.T. Harvey & Associates, San Jose.

1996-2002 Associate Research Behaviorist, Bodega Marine Laboratory, UC Davis.

1987-1995 Assistant Research Behaviorist, Bodega Marine Laboratory, UC Davis.

1984-1987 Assistant Research Scientist, Scripps Institution of Oceanography, UC San Diego.

1982-1984 Postgraduate Researcher, Scripps Institution of Oceanography, UC San Diego.

1977-1982 Graduate Research Assistant, Scripps Institution of Oceanography, UC San Diego, Office of Naval Research (ONR) Contract: Field behavior of sharks, Principal Investigator: Nelson, D.

1973-1976 Research Assistant, Graduate Department, Rosenstiel School of Atmospheric Science, University of Miami, ONR Contract: Acoustic behavior of sharks, Principal Investigator: Myrberg, Jr., A.

ADJUNCT FACULTY / RESEARCH ASSOCIATE

2007-Pres. Adjunct Associate Professor, Department of Biology, Clemson University, South Carolina.

2005-Pres. Research Associate, Watershed Center, John Muir Institute for the Environment, University of California, Davis.

1999-Pres. Adjunct Associate Professor, Department of Wildlife, Fish, & Conservation Biology, University of California, Davis.

1997-Pres. Research Associate, Institute of Marine Science, University of California, Santa Cruz.

1993-Pres. Adjunct Faculty Member, Centro de Investigaciones de Biologicas, La Paz, Mexico.

1991-Pres. Research Associate, Point Reyes Bird Observatory, Bolinas, California.

RESEARCH INTERESTS

Animal behavior and behavioral ecology of marine vertebrates

Conservation, research germane to marine protected areas

Marine and anadromous fisheries biology, ecology, and oceanography

Biotelemetry: development of behavioral and environmental sensors, computer-decoded telemetry, automated data logging, archival tags.

GRANTS/CONTRACTS (RECEIVED)

2010-2013 Studies of green sturgeon as conservation measures to offset operations of Red Bluff Diversion Dam, U.S. Bureau of Reclamation, 1,930,481.

2009-2010 Downloading tag-detecting monitors in Delta, U.S. Fish and Wildlife Service, $58,041.

2009-2010 LTMS fish tracking study. U.S. Army Corps of Engineers, San Francisco, $477,719.38.

2009-2011 Supplement: survival and migratory patterns of Central Valley juvenile salmonids, CALFED ERP Program, California, $ 218,016 (with B. MacFarlane).

2009-2013 Biological Studies of Green Sturgeon in Sacramento/San Joaquin Watershed, U.S. Army Corps of Engineers, Sacramento, $ 1,087,376.

2009-2010 Sacramento river green sturgeon migration and population assessment, United States Bureau of Reclamation, $154,910 (with B. May and J. Israel)

2009-2010 The Revillagigedo Archipelago as critical habitat for migratory sharks and the establishment of a chain of marine reserves in the eastern tropical Pacific, International Community Foundation, $40,000.

2008-2009 LTMS fish tracking study. U.S. Army Corps of Engineers, San Francisco, $480,536.76.

2008-2009 Studies of sevengill sharks in San Francisco Bay, Aquarium of the Bay, $64,508.

2008-2010 The effect of *Egeria* on largemouth bass: telemetric pilot study, Interagency Ecological Program, $201,585.

2008-2009 Research support, data analysis, and report preparation for LTMS salmonid tracking, US Army Corps, San Francisco, $54,523.

2008-2009 Supplement: survival and migratory patterns of Central Valley juvenile salmonids, CALFED ERP Program, California, $258,676 (with B. MacFarlane).

2007-2008 Tagging and tracking hammerhead sharks at the Galapagos Islands, Committee for Research and Exploration, National Geographic Society, $10,000.

2007-2008 Tagging and tracking hammerhead sharks at the Galapagos Islands, Expeditions Council, National Geographic Society, $10,000.

2007-2009 Sacramento river green sturgeon migration and population assessment, United States Bureau of Reclamation, $113,000 (with B. May and J. Israel).

2007-2009 Tagging scalloped hammerhead, Galapagos, and whale sharks relative to reserve creation in the Galapagos Islands, World Wildlife Fund, $50,000 (with A. Hearn).

2007-2009 Population biology, life history, distribution, and environmental optima of green sturgeon, Directed Action, California Fish & Game, $969,691 (with J. Cech, S. Doroshov, and B. May).

2007-2008 Movements of Greenland sharks near the seal colony at Sable Island, Canada (with J. Kelly and S. Compana), Committee of Research and Exploration, National Geographic Society, $30,000.

2005-2006 Biological Assessment of green sturgeon in the Sacramento-San Joaquin watershed, California Bay and Delta Authority, CALFED, California, Amendment, $273,050 (with J. Cech, S. Doroshov, B. May, and I. Werner).

2005-2008 Survival and migratory patterns of Central Valley salmonids. CALFED ERP Program, California, $1,499,859 (with B. MacFarlane).

2005-2008 Behavioral, physiological, and genetic studies of white sharks in the Gulf of the Farallones, Monterey Bay Aquarium, $500,000 (with B. Block and H. Dewar).

2005-2006 Telemetric and Isotopic Studies of the Feeding Ecology of White Sharks at Guadalupe Island, Pfleger Institute for Marine Studies, $35,000 (with F. Galvan-Magaña).

2004-2005 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, $41,105.

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, $385,530 (with J. Cech and L. Thompson).

2003-2006 Biological Assessment of green sturgeon in the Sacramento-San Joaquin watershed, California Bay and Delta Authority, CALFED, California, $1,266,893 (with J. Cech, S. Doroshov, B. May, and I. Werner).

2003-2004 Determination of population size and migratory corridor of hammerhead sharks and the conservation of the species in the Gulf of California, UC MEXUS, $24,100 (with F. Galvan-Magaña).

2001-2003 Tracking hammerhead sharks for creation of marine reserves, Committee for Research and Exploration, National Geographic Society (NGS), $38,788.

2001-2003 Biological Assessment of green sturgeon in the Sacramento-San Joaquin watershed, Anadromous Fish Research Program, CALFED, $641,362 (with J. Cech, S. Doroshov, and B. May).

2000-2001 Environmental contaminants in great white shark (*Carcharodon carcharias*) in California, Morris Animal Foundation, $6,446 (with K. Gilardi).

1999-2000 Predator-prey interactions in white sharks and elephant seals, Committee for Research and Exploration, National Geographic Society (NGS), $17,000.

1998-2000 Development and implementation of transponding system to track the annual migration of fishes, National Undersea Research Program (NURP), $83,741.

1997-1999 Automated monitoring of pelagic fish assemblage during El Niño/Southern Oscillation (ENSO), Biological Oceanography, NSF, $49,989.

1997-1998 Optimization of sensors and geopositioning algorithms for archival tags, NURP, $8,800.

1997-1998 Experimental study of geomagnetic topotaxis with elasmobranchs, Sensory Systems, NSF, $43,735.

1997-1998 Playback of ATOC-type signal to bony and cartilaginous fishes to evaluate phonotaxis, Department of Defense (DOD), $32,000.

1997-1999 Predator-prey interactions among white sharks and northern elephant seals, Animal Behavior and Multi-User Biological Equipment and Instrumentation, NSF, $115,631, Co-PI: B. Le Boeuf, UC Santa Cruz.

1995-1998 Tracking of juvenile white sharks, Sea World-San Diego, $119,958.

1995-1996 Publication of "Great White Sharks: The Biology of Carcharodon carcharias," Bodega Marine Laboratory, California Department of Boating and Waterways, David and Lucille Packard Foundation, Discovery Channel, Gulf of the Farallones National Marine Sanctuary, Monterey Bay National Marine Sanctuary, Natal Sharks Board, South Africa, National Audubon Society, PRBO International Biological Research, Primary Industries, Fisheries, South Australia, SARDI, Australia, Shark Research Institute, Princeton, $17,900.

1994-1996 Experimental studies of geomagnetic topotaxis on scalloped hammerhead sharks, Animal Behavior and Sensory Systems, NSF, $80,000.

1994-1996 Automated monitoring of yellowfin tuna at Hawaiian FADs and relationship to water mass dynamics, Pelagic Fisheries Research Program, University of Hawaii, National Marine Fisheries Service (NMFS), $202,000.

1993-1995 Development of sensors and algorithms for accurate position-determination by archival tag, Ocean Technology, NSF, $176,541.

1992-1993 Symposium, "Biology of the White Shark," Bodega Bay Sea Urchin Assoc., California Academy of Sciences, Cousteau Society, Gulf of the Farallones National Marine Sanctuary, Marine Mammal Commission, National Audubon Society, ONR, Sea World, San Diego, $15,300.

1990-1991 Long-term automated monitoring of pelagic fish assemblage at seamounts in the Gulf of California related to physical processes with satellite imagery, UC MEXUS, $5,291.

1987-1990 Orientation/navigation mechanisms of pelagic sharks, Animal Behavior and Biological Oceanography, NSF, $149,909.

1985-1986 Movement patterns and behavior of the white shark, Carcharodon carcharias, in the Point Reyes/Farallon National Marine Sanctuary, National Parks Service (NPS), $35,780.

1985-1986	Behavioral ecology of the white shark in the Point Reyes/Farallon Marine Sanctuary, NGS, $5,555.
1985-1987	Orientation/navigation mechanisms of pelagic sharks, Animal Behavior and Biological Oceanography, NSF, $159,994.
1984-1985	Movement patterns and behavior of the white shark, Carcharodon carcharias, in the Point Reyes/Farallon National Marine Sanctuary, NPS, $22,510.
1984-1985	Behavioral ecology of the white shark in the Point Reyes/Farallon Marine Sanctuary, NGS, $8,413.
1982-1983	Behavior of the white shark, Carcharodon carcharias, and scalloped hammerhead, Sphyrna lewini, ONR, $21,863.
1982-1983	Design and fabrication of microcomputer interface for decoding multisensor telemetry data and displaying it numerically and graphically in real time, Foundation for Ocean Research, $15,859.
1981-1982	Funds for vessel rental for telemetric study of movement patterns of the scalloped hammerhead shark, Sphyrna lewini, in the Gulf of California, Ship Funding Committee, Scripps Institution of Oceanography, $8,000.
1980-1981	Schooling and associated behaviors in the scalloped hammerhead, NGS, $8,000.

CONSULTING

2007-2008	Study plan for the LTMS green sturgeon research, United States Army Corps of Engineers, $15,711.
2006-2007	Connectivity of ocean migration between Galapagos, Mapelo, and Cocos Islands, Eastern Pacific Migratory Corridor Initiative, Conservation International, $8,000.
1998-1999	Environmental Impact Statement (EIS), Effect of Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) on marine mammals and fishes, Marine Acoustics Inc. (Subcontractor for Department of Defense), $15,000.

SOCIETIES

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

EDITOR

2010-Pres	*Plos One*, Editor
1997-Pres.	*Oecologia*, Off-board Editor.
2005-2006	*Environmental Biology of Fish*es, Associate Editor.
1995-2004.	*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 (England)
Journal of Fisheries Management (U.S.A.)
Marine Biology (Germany)
Marine Ecology Progress Series (U.S.A.)
Naturwissenschaften (Germany)
Northwestern Naturalist (U.S.A.)
Prentice Hall (U.S.A.)
Oecologia (U.S.A.)
Transactions of the American Fisheries Society (U.S.A.)
University of California, Press (U.S.A.)
University of Chicago, Press (U.S.A)

HONORS

2004 Who'sWho in America

2004 Writer's Guild

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.

1981 Scientific Achievement Award, Southern California Academy of Science.

LANGUAGES

German, Reading
Spanish, Fluent Reading and Speaking
Russian, Reading

INTERNET

2007-Pres. Central Valley Fish Tagging Consortium, Profile of APK (http://california fishtracking.ucdavis.edu/org_davis_peter.html)

2005-Pres. Tagging of Pacific Pelagics (TOPP), Profile of APK (http://www.toppcensus.org).

2004-Pres. Biotelemetry Laboratory, Biographies of APK and graduate students with project descriptions (http://wfcb.ucdavis.edu/www/faculty/Pete).

1997-Pres. Dr. Hammerhead, NOVA/PBS web page, research featured and questions about shark biology answered (www.pbs.org/wgbh/nova/sharks/masters/hammerhead.html).

FILMS

2009 Island of the White Shark, RTProductions (U.S.A.).

2009 Killer whale attack on white shark at Farallones, Special, National Geographic Channel (U.S.A.).

2009 But wait there's more, "Sharkstopper", Original Productions, Discovery Channel (U.S.A.).

2008 Hammerhead Highways, Geographic Explorer (U.S.A.), National Geographic Channel (U.S.A.).

2007 Perfect Predators, Tigress Productions (U.K.), Discovery Channel (U.S.A.).

2006 Requins Sous Haute Surveillance, Cinémarine (France), Channel Three, Thallasa (France).

2004 Sharks in America, British Broadcasting Corporation (U.K.), British Television (U.K.).

2003 White Shark Behavior, British Broadcasting Corporation (U.K.), Discovery Channel (U.S.A.)

2002 White Sharks of South Africa, Discovery Films (U.S.A.), Discovery Channel (U.S.A.)

2002 Megasharks, Australian Broadcasting, Australian Television (Australia).

2001 Sharks at the Farallones, KGO-TV News, American Broadcasting, San Francisco.

1999 Tracking White Sharks at Año Nuevo Island, National Geographic Films (U.S.A.), National Geographic Channel (U.S.A.).

1999 Sharks of Cocos Islands, Howard Hall Productions (U.S.A.), NOVA (U.S.A.).

1998 Megahai, Beyond Productions Limited (Australia), German Television (Germany).

1998 Hammerheads: Nomads of the Sea, Thomas Lucas Productions (U.S.A.), Discovery Channel (U.S.A.).

1996 The Science of Shark Attacks, Turner Broadcasting Network (U.S.A.).

1995 The Red Triangle, Tom Horton Films (U.S.A.), Discovery Channel (U.S.A).

1994 Sharks, Audubon Films (U.S.A)..

1993 The World of White Sharks, Osford Film Productions, Australia, Discovery Films.

1989 Hammerhead Science in Gulf of California, KTV, San Francisco (U.S.A.).

1988 World of Sharks, Public Broadcasting Service (U.S.A.), Turner Broadcasting Network (U.S.A.).

1983 Profiles of Ocean Pioneers, Public Broadcasting Service, U.S.A.

1982 Hammerheads of Sea of Cortez, Don Meir Productions (U.S.A.), Wild Kingdom (U.S.A.).

INTERVIEWS AND PUBLIC LECTURES

2003 The Secret Life of Sharks, interviewed by over 30 radio shows.

1999 Behavior and ecology of sharks, “Airtalk” with Larry Mantle, Public Radio, Los Angeles, California.

1999 White sharks preference for seals over humans, radio interview, “All Things Considered” with Linda Wertheimer, National Public Radio, Washington D.C.

1999 Tracking the white shark, television interview, John Fowler, Science Reporter, KTVU Oakland.

1998 Sharks: fact and fancy, radio interview, “These Days” with Dan Erwine, Public Radio, San Diego, California.

1998 Sharks: fact and fancy, public lecture, San Diego Natural History Museum, San Diego

1998 Tracking of white sharks at Año Nuevo Island, public lecture, Open House, Long Marine Laboratory, Santa Cruz.

1998 The behavior of sharks, radio interview, “Science for Schools,” Radio America, Washington D.C.

SYMPOSIUMS ORGANIZED (PENDING)

2011 Insights into Physiology, Behavior, and Ecology from Elasmobranch Tracking Studies, Meeting of the American Elasmobranch Society, Providence, 2 day symposium with 30 talks (with A. Hearn and J.T. Ketchum).

SYMPOSIUMS ORGANIZED

2010. Electronic Tagging Studies of Salmon Migration, Bodega Marine Laboratory, UC Davis (with P.T. Sandstrom and R.B. MacFarlane).

2005. The Green Sturgeon and Its Environment, 39th Annual Meeting, California-Nevada Chapter, American Fisheries Society, Holiday Inn Capital Plaza, Sacramento (with P.J. Allen, J.A. Israel, and J.T. Kelly).

2000. Revisiting the *Umwelt*: Environments of Animal Communication, University Club, UC Davis (with C.M. Greene, D.H. Owings, and L.A. Hart).

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

SCIENTIFIC TALKS AND POSTERS (ABSTRACTS PUBLISHED)

95. Singer, G., A. Ammann, P.T. Sandstrom, C. Michel., E.D. Chapman, R.B. MacFarlane, and A.P. Klimley. 2010. Benchmark and field tests of the range of automated monitors for three sizes of ultrasonic transmitters. Talk, Conference on Electronic Tagging and Studies of Salmon Migration. Bodega Marine Laboratory, Bodega Bay.

94. Sandstrom, P.T., G. Singer, A.J. Ammann, C.J. Michel, S. Lindley, R.B. MacFarlane, and A.P. Klimley. 2010 Sacramento steelhead trout: comparing wild and hatchery smolts. Talk, Conference on Electronic Tagging and Studies of Salmon Migration. Bodega Marine Laboratory, Bodega Bay.

93. Michel, C.J., A.J. Ammann, P.T. Sandstrom, E.D. Chapman, S.T. Lindley, A.P. Klimley, and R.B. MacFarlane. 2010. Movement and mortality patterns of Central Valley juvenile late-fall run Chinook salmon (*Oncorhynchus tshawytscha*) and the environmental factors that shape them. Talk, Conference on Electronic Tagging and Studies of Salmon Migration. Bodega Marine Laboratory, Bodega Bay.

92. Klimley, A.P. 2010. Ultrasonic and radio telemetry of slamonids past to present: a historical review of tagging practices and technologies. Talk, Conference on Electronic Tagging and Studies of Salmon Migration. Bodega Marine Laboratory, Bodega Bay.

91. Klimley, A.P., R.B. MacFarlane, and P.T. Sandstrom. 2010. Welcome, role of CALFED/other agencies in collaborative telemetry studies. Talk, Conference on Electronic Tagging and Studies of Salmon Migration. Bodega Marine Laboratory, Bodega Bay.

90. Chapman, E.D., A.R. Hearn, A.P. Klimley, P.E. LaCivita, W.N. Brostoff, and A.M Bremner. 2010. Migration of late-fall Chinook and steelhead smolts relative to dredge removal and disposal sites in San Francisco Bay. Talk, Conference on Electronic Tagging and Studies of Salmon Migration. Bodega Marine Laboratory, Bodega Bay.

89. Flagg, M., M. Crenshaw, J. Roberts, J. Harkness, T. Gray, A.P. Kimley. 2010. SeaTag: The development of a naew family of 'revolutionary' wildlife tags and environmental micro-observation stations. Poster, 44rd Annual Conference, California-Nevada Chapter, American Fisheries Society.

88. Klimley, A.P., M.J. Thomas, & M.G. Nafus, A.R. Hearn. 2009. Past and future studies of green sturgeon movements in the San Francisco estuary germane to dredge removal and disposal. Symposium , Green sturgeon, longfin smelt, and dredging operations in the San Francisco Estuary, San Francisco Estuary Institute, Oakland.

87. Klimley, A.P. 2009. Shark Control in Tuna Nets: Sonic Attraction or Withdrawal? Talk, Workshop on mitigating bycatches in tuna purse-seine fisheries on fish aggregating devices (FADs), International Seafood Sustainability Foundation, Sucrietta, Spain.

86. Buckhorn M. and P. Klimley. 2009. Movements of Sevengill Sharks in San Francisco Bay. Poster, Joint Meeting of the Ichthyologists and Herpetologists, 22-27 July 2009, Portland, Oregon.

85 Ketchum, J., G. Shillinger, A. Hearn, E. Espinoza, P. Klimley. 2009. Movements and Migratory Patterns of Sharks in the Galapagos Marine Reserve and Eastern Tropical Pacific. Poster, Joint Meeting of the Ichthyologists and Herpetologists, 22-27 July 2009, Portland, Oregon.

84. Chapple, T., S. Jorgensen, S. Anderson, A. P. Klimley, L. Botsford, B. Block. 2009. A Mark-Recapture Population Estimate of Great White Sharks, *Carcharodon carcharias*, off California. Talk, Joint Meeting of the Ichthyologists and Herpetologists, 22-27 July 2009, Portland, Oregon.

83. Hearn, A., J. Ketchum, S. Bessudo, R.Arauz, G. Soler, E. Espinoza, C. Penaherrera, P. Klimley. 2009. Site Fidelity and Inter-island Movement of Scalloped Hammerhead Sharks, *Sphyrna lewini*, in the Galapagos Marine Reserve and Eastern Tropical Pacific. Talk, Joint Meeting of the Ichthyologists and Herpetologists, 22-27 July 2009, Portland, Oregon.

82. Hearn, A., J. Ketchum, P. Klimley, and E. Espinoza. 2009. Hotspots Within hotspots? Aggregations of Pelagic Fishes at Southeastern Corner of Wolf Island, Galapagos. Talk, Joint Meeting of the Ichthyologists and Herpetologists, 22-27 July 2009, Portland, Oregon.

81. Stephenson, A., P.T. Sandstrom, A.P. Klimley. 2009. High resolution tracking of salmon smolts at the Delta Cross Channel. Poster, 43rd Annual Conference, California-Nevada Chapter, American Fisheries Society.

80. Sandstrom, P.T. and A.P. Klimley. 2009. Acoustic tag retention of steelhead trout (*Onchorhynchus mykiss*). Poster, 43rd Annual Conference, California-Nevada Chapter, American Fisheries Society.

79. Hearn, A., J.T. Ketchum, A.P. Klimley. 2009. Hotspots within hotspots? Hammerhead shark movements around Wolf Island, Galapagos. Poster, 43rd Annual Conference, California-Nevada Chapter, American Fisheries Society.

78. Buckhorn, M., A.P. Klimley, M. McGill, C. Slager. 2009. Movements of sevengill sharks within San Francisco Bay. Poster, 43rd Annual Conference, California-Nevada Chapter, American Fisheries Society.

77. Chapman, E.D., P.T. Sandstrom, A.J. Ammann, C. Michel, A.P. Klimley, R.B. MacFarlane, and S.L. Lindley. 2009. Diel migrations of salmon smolts in the Sacramento River, Delta, and San Francisco Bay estuary. Poster, 43rd Annual Conference, California-Nevada Chapter, American Fisheries Society.

76. Thomas, M.J., E. Chapman, J.A. Israel, and A.P. Klimley. 2008. Telemetric studies of adult green sturgeon in the Sacramento River. Poster, 5th Biennial CALFED Science Conference, Sacramento.

75. Teo, S.L., P.T. Sandstrom, E.D. Chapman, R. Null, K. Brown, A.P. Klimley, B. Block. 2008. There and back again: tracking the migration of Sacramento River steelhead kelts to the Pacific Ocean and back again. Poster, 5th Biennial CALFED Science Conference, Sacramento.

74. Sandstrom, P.T., A.P. Klimley, R.B. MacFarlane, S.L. Lindley, A.J. Ammann, E.D. Chapman, and C. Michel. 2008. Survival and migratory patterns of Central Valley juvenile salmonids. Poster, 5th Biennial CALFED Science Conference, Sacramento.

73. Sandstrom, P.T., A.J. Ammann, E.D. Chapman, A.P. Klimley, R.B. MacFarlane, S.L. Lindley, and C. Michel. 2008. Fine-scale movement and depth distribution of juvenile steelhead trout in the Sacramento River and San Francisco Bay estuary. Poster, 5th Biennial CALFED Science Conference, Sacramento.

72. Israel, J.A. and A.P. Klimley. 2008. Population biology, life history, distribution, and environmental optima of green sturgeon, *Acipenser medirostris*. Poster, 5th Biennial CALFED Science Conference, Sacramento.

71. Cocherell, D.E., A.P. Klimley, J.J. Cech, Jr. 2008. Temperature preference studies of juvenile green sturgeon *Acispenser medirostris*, using a large annular laboratory apparatus. Poster, 5th Biennial CALFED Science Conference, Sacramento.

70. Chapman, E.D., P.T. Sandstrom, A.J. Ammann, C. Michel, A.P. Klimley, R.B. MacFarlane, and S.L. Lindley. 2008. Diel migrations of salmon smolts in the Sacramento River, Delta, and San Francisco Bay estuary. Poster, 5th Biennial CALFED Science Conference, Sacramento.

69. Ammann, A.J., P.T. Sandstrom, E.D. Chapman, C. Michel, A.P. Klimley, S.L. Lindley, and R.B. MacFarlane. 2008. The range of detection of coded ultrasonic beacons by automated monitors in varying aquatic environments. Talk, 5th Biennial CALFED Science Conference, Sacramento. Poster, 5th Biennial CALFED Science Conference, Sacramento.

68. Sandstrom, P.T., A.J. Ammann, E.D. Chapman, A.P. Klimley, R.B. MacFarlane, S.L. Lindley, and C. Michel. 2008. Fine-scale movement and depth distribution of juvenile steelhead trout in the Sacramento River and San Francisco Bay estuary. Talk, 5th Biennial CALFED Science Conference, Sacramento.

67. Michel, C.J. A. Ammann, P. Sandstrom, E. Chapman, S. Lindley, A.P. Klimley, and R. MacFarlane. 2008. A high-resolution account of the survival and movement rates of acoustically tagged juvenile chinook salmon (*Onchorhynchus tshawytscha*) during the 2007 and 2008 season. Talk, 5th Biennial CALFED Science Conference, Sacramento.

66. Chapman, E.D., P.T. Sandstrom, A.J. Ammann, C. Michel, A.P. Klimley, R.B. MacFarlane, S.L. Lindley. 2008. Diel migrations of salmon smolts in the Sacraemnto River, Delta, and San Francisco Bay estuary. Talk, 5th Biennial CALFED Science Conference, Sacramento.

65. MacFarlane, B.R., A.P. Klimley, S.L. Lindley, A.J. Ammann, P.T. Sandstrom. 2008. Survival and migratory patterns of Central Valley juvenile salmonids: progress report. Talk, 5th Biennial CALFED Science Conference, Sacramento.

64. Chapple, T.K., S. Anderson, S.J. Anderson, A.P. Klimley, B.A. Block. 2008. A validation for the use of fin photographs for individual identification and a comparison of two analysis frameworks for the great white shark, Carcharodon Carcharias. Poster, American Society of the Ichthyologists and Herpetologists, Montreal.

63. Klimley, P., R. Arauz, S. Bessudo, A.Hearn, H. Guzman, S. Henderson, J. Ketchum, G. Shillinger, and G. Soler. 2008. Movements of sharks at seamounts and island, biotic "hot spots", relative to marine protected areas in the eastern Pacific Ocean Corridor. Talk, American Association for Advancement of Science, Boston.

62. Ketchum, J.T., A. Hearn, and A.P. Klimley. 2008. Shark movements and biological hotspots: implications for managing marine resources at the Galapagos Islands. Talk, Conservation Society, San Francisco Chapter, Oakland.

61. MacFarlane, R.B., A.P. Klimley, A.J. Ammann, P.T. Sandstrom, S. Lindley, and E.D.Chapman. 2008. Survival and migratory patterns of Central Valley juvenile salmonids: overview. Advances in Fish Tagging and Marking Technology Symposium, Aukland, New Zealand.

60. Sandstrom, P.T., A.J. Ammann, A.P. Klimley, B.R. MacFarlane, S.L. Lindley, E.D. Chapman, and C. Michel. 2008. Fine-scale movement and depth distribution of steelhead in the Sacramento River and San Francisco Bay. Advances in Fish Tagging and Marking Technology Symposium, Aukland, New Zealand.

59. Klimley, A.P., Hamilton, S.A., Cech, J.J., Jones, G.J, Miranda, J.B., Cocherell, D.E., Chun, S., and L.C. Thompson. 2007. Responses of fish to pulsed-flow releases in the South Fork

American River watershed. Talk, American River Water Conference, Sacramento State University, Sacramento.

58. Ammann, A.J., P. Sandstrom, E. Chapman, C. Michel, P. Klimley, R. MacFarlane, and S. Lindley. 2007. The performance of Vemco V7, V9, and V16 transmitters and receivers under varying conditions. Poster, 8th Biennial State of the Estuary Conference, Oakland.

57. Chapman, E.D., P.T. Sandstrom, A.J. Arnold, C. Michel, A.P. Klimley, B.R. MacFarlane, S.L. Lindley. 2007. Diel migrations of salmon smolts in the Sacramento River, Delta, and San Francisco Bay Estuary. Poster, 8th Biennial State of the Estuary Conference, Oakland.

56. MacFarlane, R.B., A.P. Klimley, A.J. Ammann, P.T. Sandstrom, S. Lindley, and E.D.Chapman. 2007. Survival and migratory patterns of Central Valley juvenile salmonids: overview. Poster, 8th Biennial State of the Estuary Conference, Oakland.

55. Michel, C.J., A.J. Ammann, S.T. Lindley, P.T. Sandstrom, E.D. Chapman, A.P. Klimley, and R.B. MacFarlane. 2007. Acoustically monitored movement patterns of juvenile Chinook salmon (*Onchorhynchus tschawytscha*) from the Sacramento River Watershed during a low flow year. Poster, 8th Biennial State of the Estuary Conference, Oakland.

54. Sandstrom, P.T., A.J. Ammann, A.P. Klimley, B.R. MacFarlane, S.L. Lindley, E.D. Chapman, and C. Michel. 2007. Fine-scale movement and depth distribution of steelhead in the Sacramento River and San Francisco Bay. Poster, 8th Biennial State of the Estuary Conference, Oakland.

53. Klimley, A.P. 2006. Acoustic arrays on seamounts and islands. Talk, Advanced Sampling Technology Workshop, Acoustic Tagging and Integrated Ocean Observing Systems, National Marine Fisheries Service, Santa Cruz.

52. Sandstrom, P.T., A.J. Ammann, L.L. Schlipp, R.B. MacFarlane, and A.P. Klimley. 2006. The range of detection of coded ultrasonic tags by automated monitors in the Sacramento-San Joaquin watershed. Poster, 4th Biennial CALFED Science Conference, Sacramento.

51. Klimley, A.P. and R.B. MacFarlane. 2006. Survival and migratory patterns of Central Valley juvenile salmonids. Poster, 4th Biennial CALFED Science Conference, Sacramento.

50. Hamilton, S.A., D.E. Cocherell, J.B. Miranda, G.J. Jones, J.J. Cech, P.S. Young, D.E. Conklin, J. O'Hagan, and A.P. Klimley. 2006. Trout behavior and responses to pulsed flows: investigations utilizing electgromyogram telemetry. Poster, 4th Biennial CALFED Science Conference, Sacramento.

49. Heublein, J.C., J.T. Kelly, and A.P. Klimley. 2006. Spawning migration and habitat of green sturgeon, Acipenser medirostris, in the Sacramento River. Talk, 4th Biennial CALFED Science Conference, Sacramento.

48. Cocherell, D.E., S.A. Hamilton, and A.P. Klimley. 2006. Adult hardhead minnow and rainbow trout temperature preference in a large, annular apparatus. Talk, 4th Biennial CALFED Science Conference, Sacramento.

47. Richert, J.E., R. Cervantes-Duarte, R. Gonzalez-Armas, F. Galvan-Magaña. 2006. Spatio-temporal variability in the trophic ecology of large pelagic fishes of the southern Gulf of California, Talk, 55th Annual Tuna Conference, Lake Arrowhead.

46. Richert, J.E., R. Cervantes-Duarte, R. Gonzalez-Armas, F. Galvan-Magaña. 2006. Spatio-temporal variability in the trophic ecology of large pelagic fishes of the southern Gulf of California, Talk, American Society of Limnologists and Oceanographers, Halifax, Canada.

45. Jorgensen, S., S. Anderson, S. Van Sommeran, C. Fitz-Cope, B. Block, and P. Klimley. 2006. Ecological, physiological, and genetic studies of white sharks in the Gulf of the Farallones, Talk, Meeting of the American Society of Ichthyologists and Herpetologists, New Orleans.

44. Hoyos, M., C. Ribot, P. Blanco, P. Klimley, and M. Domeier. 2006. Preliminary studies of the genetics, isotope ratios, movements and behavior of white sharks at Guadalupe Island, Mexico. Talk, Meeting of the American Society of Ichthyologists, New Orleans, Louisiana.

43. Hamilton, S., S. Chun, J. Miranda, G. Jones, D. Cocherell, L.C. Thompson, A.P. Klimley. 2006. Trout behavioral response to pulsed flows: investigations utilizing radio and electromyogram telemetry, Talk, VII International Congress of the Biology of Fish, St. John's, Newfoundland, Canada.

42. Thompson, L.C., S. Hamilton, G. Jones , J. Miranda, A.P. Klimley, and B. Hodge. 2006. Fish response to a one-way whitewater kayaking flow pulse release in Silver Creek, a tributary of the South Fork, American River. Talk, 40th Annual Meeting, California-Nevada Chapter, American Fisheries Society, San Luis Obispo, California.

41. Hamilton, S., S. Chun, J. Miranda, G. Jones, D. Cocherell, L.C. Thompson, and A.P. Klimley. 2006. Radio and electromyogram telemetry examining movement patterns, swimming speed and oxygen consumption of trout in response to pulsed flows in the American River. Talk, 40th Annual Meeting, California-Nevada Chapter, American Fisheries Society, San Luis Obispo, California.

40. Hamilton, S., S. Chun, J. Miranda, D. Cocherell, G. Jones, J. Graham, L.C. Thompson, and A.P. Klimley. 2005. Radio-telemetry studies assessing pulsed flow impacts on the behavior and distribution of fishes in the American River. Talk, First Pulsed Flow Program Workshop, Davis, California.

39. Hamilton, S. Chun, J. Miranda, D. Cocherell, G. Jones, J. Graham, L.C. Thompson, and A.P. Klimley 2005. Radio-telemetry studies assessing pulsed flow impacts on the behavior and distribution of fishes in the American River. Talk, 39th Annual Meeting, California-Nevada Chapter, American Fisheries Society, Sacramento, California.

38. Klimley, A.P., P.J. Allen, J.A. Israel, and J.T. Kelly. 2005. So where do we go from here? Scientific and management implications for conserving green sturgeon. Talk, 39th Annual Meeting, California-Nevada Chapter, American Fisheries Society, Sacramento, California.

37. Kelly, J.T. and C.E. Crocker. 2005. Movements of adult and sub-adult green sturgeon (*Acipenser medirostris*) in the San Francisco Bay Estuary, Talk, 39th Annual Meeting, California-Nevada Chapter, American Fisheries Society, Sacramento, California.

36. Jorgensen, S.J., M.R. O'Farrell, A.P. Klimley, S.G. Morgan, and L.W. Botsford. 2004. Site fidelity in a semi-pelagic rockfish (*Sebastes mystinus*): spillover or stay at home?, Talk, 85th Meeting, Western Society of Naturalists, Rohnert Park, California.

35. Richert, J.E., S.J. Jorgensen, A.P. Klimley, and A. Muhlia-Melo. 2004. Seamounts as hot spots of pelagic fish diversity in the Eastern Pacific Ocean, Poster, North Pacific Marine Science Organization, Honolulu.

34. Richert, J.E., S.J. Jorgensen, A.P. Klimley, and A. Muhlia-Melo. 2004. Investigating pelagic fish communities at seamounts in the southern Gulf of California: an integrative approach, Poster, Gulf of California Conference, Tucson.

33. Richert, J.E., S.J. Jorgensen, A.P. Klimley, and A. Muhlia-Melo. 2004. Ultrasonic tagging of pelagic fishes at seamounts in the Southern Gulf of California: an integrated approach, Poster, 55th Annual Tuna Conference, Lake Arrowhead.

32. Jeffres, C.A., A.P. Klimley, J.E. Merz, and J.J. Cech, Jr. 2004. Movement of Sacramento sucker (*Catostomus occidentalis*) and hitch (*Lavinia exilicauda*) during a spring, pulse flow below Camanche Dam in the Mokelumne River, California, Talk, Annual Meeting, California-Nevada and Humboldt Chapters, American Fisheries Society.

31. Kelly, J.T., A.P. Klimley, and C.E. Crocker. 2003. Movements of adult and sub-adult green sturgeon (*Acipenser medirostris*) in the San Francisco Estuary, Poster, 6th Biennial State of the Estuary Conference.

30. Richert, J., A. Muhlia-Melo, and A.P. Klimley. 2003. Examen del nicho ecológico de las comunidades de peces pelágicos asociados a montañas submarinas del Golfo de California, IX Congreso Asociación de Investigadores del Mar de Cortés.

29. Kelly, J.T and A.P. Klimley. 2002. Occurrence of white sharks at Point Reyes, Fifth Biennial Symposium of the Gulf of the Farallones.

28. Curtis, T.H., J.T. Kelly, K.L. Menard, R.K. Laroche, R.E. Jones, and A.P. Klimley. 2001. Scavenging of white sharks on humpback whale at Point Reyes, Fifth Biennial Symposium of the Gulf of the Farallones.

27. Klimley, A.P. and B.J. LeBoeuf. 2000. Tracking of white sharks at Año Nuevo Island, Biennial Workshop of the Gulf of the Farallones National Marine Sanctuary, San Francisco (invited speaker).

26. Klimley, A.P. 1999. The behavior and ecology of the white shark, *Carcharodon carcharias*, Congresso, Societa Italiana di Biologia Marina, Vibo Valentia, Italy (invited speaker).

25. Klimley, A.P. and C. Holloway. 1999. School fidelity and homing synchronicity of yellowfin tuna, *Thunnus albacares*, XXX Congresso, Societa Italiana di Biologia Marina, Vibo Valentia, Italy (invited speaker).

24. Klimley, A.P. and C. Holloway. 1998. Simultaneous tracking of five white sharks at Año Nuevo Island, Symposium in honor of Donald Nelson, American Society of Ichthyologists and Herpetologists (ASIH), University of Guelph, Canada (invited speaker).

23. Klimley, A.P. and C. Holloway. 1996. Benchmark tests of accuracy of two archival tags, workshop on Salmonid Biology, Ecology, and Oceanography, Seattle (invited speaker).

22. Klimley, A.P. and C. Holloway. 1996. Automated monitoring of yellowfin tunas at Hawaiian FADs, 47th Annual Tuna Conference, Lake Arrowhead, California.

21. Klimley, A.P. and C. Holloway 1995. Automated monitoring of yellowfin tuna at Hawaiian FADs, Workshop, Pelagic Fisheries Research Program, University of Hawaii, Hawaii.

20. Klimley, A.P. 1995. Approaches to improve geolocations from archival tags, Planning Workshop for Atlantic Bluefin Tuna Tagging Studies, Southeast Fisheries Center, Miami, Florida (invited speaker).

19. Klimley, A.P. 1994. Do white sharks (*Carcharodon carcharias*) select prey based upon high fat content?, American Society of Ichthyologists and Herpetologists (ASIH), University of Southern California, Los Angeles, California.

18. Klimley, A.P. and W. Mangan. 1994. Optimizing positional accuracy of archival tags with irradiance and magnetic sensors, 45th Annual Tuna Conference, Lake Arrowhead, California (invited speaker).

17. Klimley, A.P. and W. Mangan. 1994. "Listening" stations for retrieval of data from archival tags, 45th Annual Tuna Conference, Lake Arrowhead, California (invited speaker).

16. Klimley, A.P. 1993. Behavioral studies of white sharks and prey at the South Farallon Islands, Second Biennial Workshop on Research within the Gulf of the Farallones, San Francisco, California (invited speaker).

15. Klimley, A.P., S.D. Anderson, and P. Pyle 1993. Displays and intraspecific competition among white sharks, *Carcharodon carcharias*, during predatory attacks on pinnipeds, Symposium on the Biology of the White Shark, Bodega Marine Laboratory, UC Davis, Bodega Bay, California.

14. Klimley, A.P., S.D. Anderson, and P. Pyle. 1993. Behavior of white sharks and pinnipeds during predatory attacks: exsanguination versus bite and spit hypothesis, Symposium, on the Biology of the White Shark, Bodega Marine Laboratory, UC Davis, Bodega Bay, California.

13. Klimley, A.P., S.D. Anderson, P. Pyle, and R.P. Henderson. 1992. Spatio-temporal patterns of white shark (*Carcharodon carcharias*) predation at the South Farallon Islands, California, ASIH, University of Illinois, Urbana-Champaign, Illinois.

12. Klimley, A.P., I. Cabrera-Mancilla, and J.L. Castillo-Geniz. 1992. Descripcion de los movimientos horizontales y verticales del tiburon martillo (*Sphyrna lewini*) del sur del Golfo de California, Mexico, IX Simposium Internacional de Biologia Marina, La Paz, Mexico.

11. Klimley, A.P., S.D. Anderson, P. Pyle, and R.P. Henderson. 1989. A description of predatory attacks by white sharks on pinnipeds, ASIH, California State University, San Francisco, California.

10. Klimley, A.P. 1988. Homing of a shark to a seamount and relationship to local geomagnetic features, Animal Behavior Society (ABS), University of Montana, Missoula and ASIH, University of Michigan,Ann Arbor, Michigan.

9. Klimley, A.P. and D.R. Nelson. 1983. Functional analysis of schooling in the scalloped hammerhead, *Sphyrna lewini*, Conference on Ethology and Behavioral Ecology of Fishes, University of Illinois, Normal, llinois.

8. Klimley, A.P. 1983. Areal distribution of the white shark, *Carcharodon carcharias*, along the California coast, Southern California Academy of Science, California State University, Fullerton, California.

7. Klimley, A.P. and D.R. Nelson. 1982. Mass schooling of scalloped hammerhead sharks, *Sphyrna lewini*, in the Gulf of California, ABS, Colorado State University, Fort Collins, Colorado.

6. Klimley, A.P. 1980. Cardumenes de la cornuda, *Sphyrna lewini*, al Golfo de California, CIBCASIO, La Paz, Mexico.

5. Klimley, A.P. and S.T. Brown. 1982. Stereophotographic technique to determine individual size, spatial relationships, and size segregation within schools of the scalloped hammerhead, *Sphyrna lewini*, Southern California Academy of Science, California State University, Dominguez Hills, California.

4. Klimley, A.P. and S.T. Brown. 1982. Determinacion por medio de technicas estereofotagrafias del tamaño individual, relaciones especiales, y posible segragacion entre tamanos dentro de los cardumenes del tiburon cornuda, *Sphyrna lewini*, CIBCASIO, Ensenada, Mexico.

3. Klimley, A.P. 1982. Mass schooling of scalloped hammerhead sharks, *Sphyrna lewini*, in the Gulf of California, ABS, Colorado State University, Fort Collins, Colorado.

2. Klimley, A.P. 1980. Cardumenes de la cornuda, *Sphyrna lewini*, al Golfo de California, CIBCASIO, La Paz, Mexico.

1. Klimley, A.P. and A.A. Myrberg. 1977. Stimulus properties underlying withdrawal response in the lemon shark, *Negaprion brevirostris,* ASIH, University of Florida, Tallahassee, Florida.

SEMINARS

2003 The behavior of the white shark, Paul Szabo Memorial Lecture, Hackley Preparatory School, Tarrytown, New York.

2003 Hunting strategy of white sharks at seal colony, Marine Biology Division, Scripps Institution of Oceanography, San Diego, California.

2002 Predatory strategy of white sharks at a seal colony, John P. McGrath Seminar Series, Southampton College, New York.

2002 Behavior and ecology of the white shark, Tiburon Marine Center, San Francisco State University, California.

2001 Biophysics of hammerhead navigation, University of San Francisco, California.

2001 Dispelling the myths of sharks, Natural History Series, Mystic Aquarium, Connecticut.

2001 La importancia de conservacion de peces en Golfo de California, SEMERNAP, Marine Reserve Headquarters, Loreto, Mexico.

2000 Who is afraid of the white shark?, Behnke Memorial Lecture, Pacific Chapter, Undersea & Hyperbaric Medical Society, San Francisco, California.

2000 Hunting strategy of white sharks at seal colony, Boston University Marine Program (BUMP)/Woods Hole Oceanographic Institution (WHOI), Woods Hole, Massachusetts.

1999 Simultaneous tracking of white sharks at Año Nuevo Island, Long Marine Laboratory, UC Santa Cruz and UC Davis, California.

1998 School fidelity, homing synchronicity, and route traveling by pelagic fishes, Scripps Institution of Oceanography, University of California, San Diego.

1997 Homing synchronicity and school fidelity of yellowfin tunas, Southwest Fisheries Center, Tiburon, California.

1996 Electromagnetic landscape detection by scalloped hammerhead sharks, Center for Animal Behavior, UC Davis.

1996 Registro de presencia de atun aleta amarilla en los dispositivos de agregacion en Hawaii, utilizando sistemas de registro automatico continuo, Centro de Investigaciones Biologicas de Baja Noroeste (CIBNOR), La Paz, Mexico.

1995 The predatory behavior of the white shark, University of South Florida, University of Washington, Seattle, Washington, and UC Davis, California.

1994 The predatory behavior of the white shark, Washington State University, Pullman, Oregon.

1994 Development of sensors and algorithms for accurate position-determination by archival tag, Southwest Fisheries Center, Tiburon, California.

1993 The ecological determinants of movement patterns in the scalloped hammerhead shark, Southwest Fisheries Center, Hawaii.

1993 The predatory behavior of the white shark. Southwest Fisheries Center, Hawaii

1992 Autecology of the white shark along the western coast of North America, Oregon State University, Southwest Fisheries Center, Tiburon, California.

1991 Ecological determinants of movements and geomagnetic map-sense in the scalloped hammerhead shark, Scripps Institution of Oceanography, University of California, San Diego. California.

1990 The ecological determinants of movement patterns in the scalloped hammerhead shark, University of California, Santa Cruz, California.

1989 The ecological determinants of movement patterns in the scalloped hammerhead shark, University of California, Berkeley, California.

1988 Los determinantes ambientales por los movimientos de un tiburon pelagico, Departamiento de la Pesca, Direccion de la Oceanografia, and Universidad Autonoma, D.F. Mexico.

1988 Autecology of the white shark along the western coast of North America, Oregon State University, Corvallis, Oregon.

1988 The ecological determinants of movement patterns in a pelagic shark, Sphyrna lewini, Oregon State University, Corvallis, Oregon.

1987 Sharks and divers, Naval Diving and Salvage Training Center, Panama City, Florida.

1987 Autecology of the white shark in California, California State University, Long Beach, California.

1987 Field studies of the white shark, Carchardon carcharias, in the Gulf of Farallones National Marine Sanctuary, Point Reyes National Seashore Center, Point Reyes, California.

1986 The distribution and autecology of the white shark, *Carcharodon carcharias*, along the western coast of North America with particular reference to the Point Reyes-Farallon National Marine Sanctuary, Western Regional Headquarters, Point Reyes, California.

1986 The ecological determinants of movement patterns in the scalloped hammerhead shark, *Sphyrna lewini*, Bodega Marine Laboratory, Bodega Bay, California.

1985 The distribution and autecology of the white shark, Carcharodon carcharias, along the western coast of North America, Bodega Marine Laboratory, Bodega Bay, and Scripps Institution of Oceanography, La Jolla, California.

1985 A functional analysis of schooling in the scalloped hammerhead shark, *Sphyrna lewini*, Bodega Marine Laboratory, Bodega Bay, California.

BOOKS/SPECIAL ISSUES (PENDING)

1. Klimley, A.P. In press. The Biology of the Sharks, Rays, and Chimaeras. University of Chicago Press.

BOOKS/SPECIAL ISSUES (PUBLISHED)

4. Klimley, A.P., P. Allen, J. Israel, and J. Kelly (Eds). 2006. The green sturgeon, *Acipenser medirostris*, and Its Environment. Special Issue, *Environmental Biology of Fishes*, 79.

3. Klimley, A.P. 2003. The Secret Life of Sharks: A Leading Biologist Reveals the Mysteries of Shark Behavior. Simon and Schuster, New York, 292 pp.

2. Greene, C.M., D.H. Owings, L.A. Hart, and A.P. Klimley (Eds). 2002. Revisiting the *Umwelt*: Environments of Animal Communication. Special Issue, *Journal of Comparative Psychology*.

1. Klimley, A.P. and D.G. Ainley (Eds). 1996. Great White Sharks: The Biology of *Carcharodon carcharias*. Academic Press, San Diego, 528 pp.

ARTICLES (MANUSCRIPTS COMPLETED)

96. Richert, J.E., F. Galvan, A.P. Klimley. In prep. Trophic ecology of three pelagic fishes in the southern Gulf of California: implications for fishery management. *Fisheries Ecology and Management.*

95. Richert, J.E., F. Galvan, A.P. Klimley. In prep. The use of nitrogen stable isotopes in the study of migratory fishes and pelagic marine ecosystems in the Eastern Tropical Pacific Ocean. *Marine Biology*.

94. Cocherell, D.E., J.J. Cech, Jr., and A.P. Klimley. In prep. Temperature preferences of the hardhead minnow, *Mylopharodon conocephalus*, and rainbow trout, *Oncorhnchus mykiss*. *Environmental Biology of Fishes**.

93. Kelly, J.T., S.E. Lankford, J.J. Cech Jr. & A. P.Klimley. In prep. The energetic costs of swimming using flow-vector kinesis in green sturgeon (*Acipenser medirostris*). *Journal of Canadian Fisheries Research*.

92. Mazur, R.A. and A.P. Klimley. In prep. Telemetric study of variation in black bear home ranges in relation to preferred foods in Sequoia National Park, California. *Midlands Naturalist.*

91. Richert, J.E., F. Galvan-Magaña, and A.P. Klimley. In prep. Feeding habits and trophic interactions among large pelagic fishes in the southern Gulf of California. *Journal of Applied Ichthyology*.

SCIENTIFIC ARTICLES (SUBMITTED)

90. Ketchum, J.T., F. Galván-Magaña, and A.P. Klimley. In prep. Distribution, segregation, environmental preferences, and habitat use of whale sharks (*Rhincodon typus*) in the southwestern Gulf of California. *Ciencias Marinas*.

89. Jorgensen, S.J., J.E. Richert., and A.P. Klimley. Submitted. Seasonal assemblages of fishes at seamount in the Gulf of California. *Ecology*.

88. Lindley, S.T., D.L. Erickson, M.L. Moser, G. Williams. O.P. Langness, M. Belchik, D. Vogel,G. Stutzer, J.T. Kelley, J.C. Heublein, and A.P. Klimley. Submitted. Electronic tagging of green sturgeon reveals population structure and movement among estuaries. *Fisheries Bulletin*.

87. Nance, H.A., A.P. Klimley, F. Galván-Magaña, Jimmy Martínez-Ortíz, and P.B. Submitted. Decline and Divergence: Evolutionary Processes Causing Population Structure in the Scalloped Hammerhead Shark, *Sphyrna lewini*. *Molecular Evolution*.

86. Anderson, S.A., T.K. Chapple, S.J Jorgensen, A.P. Klimley and B.A Block. Submitted. Validation of long-term individual identification and site fidelity of great white sharks, *Carcharodon carcharias*, off California using dorsal fins. *PLOS One*.

85. Chapple, T.K., S. Jorgensen, S. Anderson, B. Block, and A.P. Klimley. Submitted. Population estimate of the great white shark in the Gulf of the Farallones. *Nature*.

84. Chun, S., S.A. Hamilton, D.E. Cocherell, J.J. Cech, Jr., and A.P. Klimley. Submitted. Experiments on the lateral displacement of rainbow trout *Oncorhnchus mykiss* and hardhead minnow *Mylopharodon conocephalus*. *Transactions Environmental Biology of Fishes* *.

SCIENTIFIC ARTICLES (IN PRESS)

83. Bessudo S., G. Soler, A. P. Klimley, J. T. Ketchum, R. Arauz, and A. Hearn. Major revisions. Vertical and horizontal movements of hammerhead sharks (*Sphyrna lewini*) at Malpelo Island in the Eastern Tropical Pacific. *Environmental Biology of Fishes*.

82. Kelly, J.T. and A.P. Klimley. Major revisions. Using vector analysis to relate the swimming movements of fish to the movement of water currents. *Environmental Biology of Fishes*.

81. Chun, S., S.A. Hamilton, D.E. Cocherell, J.J. Cech, Jr., and A.P. Klimley. In press. Experiments on the longitudinal displacement of rainbow trout, *Oncorhnchus mykiss*, and hardhead minnow, *Mylopharodon conocephalus*. *Environmental Biology of Fishes* *.

80. Thompson, L.C., S. A. Hamilton, S. Chun, A.P. Klimley, and J.J. Cech. In Press. Longitudinal movement of fish in response to a single-day flow pulse. *Environmental Biology of Fishes* *.

79. Hamilton, S.A., S. Chun, G. Jones, J. Miranda, and L. Thompson. In press. Activity of brown trout monitored using electromygram- detecting transmitters during pulsed flows in South Fork of American River. *Environmental Biology of Fishes* *.

78. Hamilton, S.A., G.J. Jones, J.B. Miranda, D.E. Cocherell, J.J. Cech, L.C. Thompson, and A.P. Klimley. In press. Distribution of juvenile and adult rainbow trout, *Oncorhynchus mykiss*, during pulsed flows in the South Fork American River, California. *Environmental Biology of Fishes* *

SCIENTIFIC ARTICLES (PUBLISHED)

77. Hearn, A., J. Ketchum, and A.P. Klimley. 2010. Hotspots within hotspots? Hammerhead shark movements at Wolf Island in Galapagos Marine Reserve. *Marine Biology*, Available on line.

76. Perry, P.W, P.L. Brandes, P. Sandstrom, A. Ammann, B.M. McFarlane, A.P. Klimley, and J.R. Skalski. 2009. Estimating migration and survival of juvenile Chinook salmon through the Sacramento–San Joaquin River Delta. *Journal of North American Fish Management*, 30: 142-156.

75. Jorgensen, S.J., C.A. Reeb, T. K. Chapple, S. Anderson, C. Perle, S.R. Van Sommeran, C. Fritz-Cope, A.C. Brown, A.P. Klimley, B.A. Block. 2009. Fidelity, homing and population structure revealed using electronic and genetic tag in white sharks of the Eastern Pacific. Proceeding of the Royal Society B., 1155: 1-11.

74. Mora, E.A., S.T. Lindley, D.L. Erickson, A.P. Klimley. 2009. Do impassable dams and flow regulation constrain the distribution of green sturgeon in the Sacramento River, California? *Journal of Applied Ichthyology*, 25 (Suppl. 2): 39–47.

73. Hearn, A., A.P. Klimley, and J. Ketchum. 2009. Vulnerability of top predators to climate change and adaptation options for their coastal and pelagic ecosystems: sharks case study. Pp. 42-44 *in* Hoffman, J., A. Fonseca, and C. Drews (Eds.), Cetaceans & Other Marine Biodiversity of the Eastern Tropical Pacific: Options for Adapting to Climate Change. Proceedings of Conference Adaptación Cambio Climàtico, San Jose Costa Rica.

72. Grigg, E.K., A.P. Klimley. S.G. Allen. D.E. Green, D.L Elliott-Fisk, and H. Markowitz. 2009. Identifying spatial and seasonal relationships between Pacific harbor seals, *Phoca vitulina richardii*, and their prey, at multiple scales. *Fisheries Bulletin*, 107:359–372.

71. Jorgensen, S.J., A.P. Klimley, and A. Muhlia-Melo. 2009. Diving of scalloped in anoxic zone in Gulf of California. *Journal of Fish Biology*, 74:1682–1687

70. Campos, B., M. Fish, G. Jones, R. Rily, A.J. Allen, A.P. Klimley, and J.J. Cech. 2009. Movement of brown smoothhound sharks in Tomales Bay, California: effects diel and tidal cycles. *Environmental Biology of Fishes.* 85: 3-13

69. Heublein, J., J.T. Kelly, C.E. Crocker, and A.P. Klimley. 2009. Migration of green sturgeon in Sacramento River. *Environmental Biology of Fishes*, 84:245–258.

68. Klimley, A.P. 2008. Electric field production and detection in animals. *The Encyclopedia of Applied Animal Behaviour and Welfare*, University of Lincoln, Riseholme Park, United Kingdom.

67. Lindley, S.T., M.L. Moser, D.F. Erickson, M. Belchik, D.W. Welch, E. Rechiski, J. Heublein, J.T. Kelly, and A.P. Klimley. 2008. Marine migration of North American green sturgeon. *Transactions of the American Society of Fisheries*, 137:182-194.

66. Klimley, P. 2007. Colourplate section. *Environmental Biology of Fishes*, 79: 423-425.

65. Klimley, A.P., P. J. Allen, J. A. Israel and J.T. Kelly. 2007. Green Sturgeon and its Environment: Past, Present, and Future. *Environmental Biology of Fishes*, 79: 415-421.

64. Kelly, J.T., A.P. Klimley, and C.E. Crocker. 2007. Movements of green sturgeon, *Acipenser mediostris*, in the San Francisco Estuary, California. *Environmental Biology of Fishes*, 29: 281-195.

63. Klimley, A.P., P. J. Allen, J. A. Israel and J.T. Kelly. 2007. Green Sturgeon and its Environment: Introduction. *Environmental Biology of Fishes*, 79: 187-190.

62. Qayum, H.A., A.P. Klimley, J.E. Richert, and R. Newton. 2006. Broad-band versus narrow-band irradiance for estimating latitude by archival tags. *Marine Biology*, 151: 467-481.

61. Klimley, A.P. and T.C. Curtis. 2006. Attack versus ecotourism: negative and positive interactions. Pp. 33-44 *in* Timm, R.M. and J.M. O'Brien (Eds.), Proceedings, Twenty-Second Vertebrate Pest Conference. University of California, Davis.

60. Jorgensen, S.J., D.M. Kaplan, A.P. Klimley, S. G. Morgan, M.R Ferrell, and L.W. Botsford. 2006. Limited movement of blue rockfish (*Sebastes mystinus*): internal structure of the home range. *Marine Biology Progress Series*, 327: 157-170.

59. Jeffres, C.A., A.P. Klimley, J.E. Merz, and J.J. Cech, Jr. 2006. Movement of Sacramento sucker (*Catostomus occidentalis*) and hitch (*Lavinia exilicauda*) during a spring release of water from Camanche Dam in the Mokelume River, California. *Environmental Biology of Fishes*, 75: 365-373.

58. Curtis, T.H., J.T. Kelly, K.L. Menard, R.K. Laroche, R.E. Jones, and A.P. Klimley. 2006. Observations of the behavior white sharks scavenging at a whale carcass at Point Reyes, California. *Bulletin, California Fish and Game*, 92:113-124.

57. Klimley, A.P., J.T. Kelly, and R.L. Kihslinger. 2005. Directional and non-directional movements of bat rays, *Myliobatis californica*, in Tomales Bay, California. *Environmental Biology of Fishes,* 74:79-88.

56. Klimley, A.P., J.E. Richert, and S.J. Jorgensen. 2005. The home of blue water fish. *American Scientist*, 93:42-49.

55. Kelly, J.T and A.P. Klimley. 2003. The occurrence of the white shark, *Carcharodon carcharias*, at Point Reyes Headlands, California. *Bulletin of California Fish and Game*, 89: 187-196.

54. Muhlia-Melo, A., P. Klimley, R. González-Armas, S. Jorgensen, A. Trasviña-Castro, J. Rodriguez-Romero, and A. Amador-Buenrostro. 2003. Study of the pelagic assemblages of the Espiritu Santo seamount during El Niño 97-98 conditions. *Geophysica Internacional*, 42: 473-481.

53. Klimley, A.P., S.J. Jorgensen, A. Muhlia-Melo, and S.C. Beavers. 2003. Movements of yellowfin tuna (*Thunnus albacares*) to and from Espiritu Santo Seamount in Gulf of California. *Fisheries Bulletin*, 101: 684-692.

52. Greene, C.M., D.H. Owings, L.A. Hart, A.P. Klimley. 2002. Revisiting the *umwelt*: environments of animal communication. *Journal of Comparative Psychology*, 116: 115.

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.

50. Klimley, A.P., S. C. Beavers, T.H. Curtis, and S.J. Jorgensen. 2002. Movements and swimming behavior of three species of sharks in La Jolla Canyon, California. *Environmental Biology of Fishes*, 63: 117-135.

49. Klimley, A.P., B.J. Le Boeuf, K.M. Cantara, J.E. Richert, S.F. Davis, S. Van Sommeran, and J.T. Kelly. 2001. The hunting strategy of white sharks at a pinniped colony. *Marine Biology*. 13: 617-636.

48. Klimley, A.P., B.J. Le Boeuf, K.M. Cantara, J.E. Richert, S.F. Davis, and S. Van Sommeran. 2001. Radio-acoustic positioning: a tool for studying site-specific behavior of the white shark and large marine vertebrates. *Marine Biology*. 138:429-446.

47. Klimley, A.P. 1999. Sharks beware. *American Scientist*, 87: 488-491.

46. Klimley, A.P. and C. Holloway. 1999. Homing synchronicity and schooling fidelity by yellowfin tuna. *Marine Biology*, 133: 307-317.

45. Klimley, A.P. and S.C. Beavers. 1998. Playback of ATOC-type signal to bony fishes to evaluate phonotaxis. *Journal of Acoustic Society of America*, 104:2506-2510.

44. Klimley, A.P., F. Voegeli, S.C. Beavers, and B.J. Le Boeuf. 1998. Automated listening stations for tagged marine fishes. *Marine Technology Journal*, 32: 94-101.

43. Klimley, A.P. and C. Holloway. 1997. Benchmark tests of accuracy of two archival tags. P. 34 *in* Boehlert, G.W. (Ed.), Application of Acoustic and Archival Tags to Assess Estuarine, Nearshore, and Offshore Habitat Utilization and Movement by Salmonids. NOAA Technical Memorandum NMFS, NOAA-TM-NMFS-SWFSC-236, 62 pp.

42. Klimley, A.P. 1996. Dancing with sharks. *Natural History Magazine*, 105:54-55.

41. Sillman, A.J., G.A. Letsinger, S. Patel, E.R. Loew, and A.P. Klimley. 1996. Visual pigments and photoreceptors in two species of shark, *Triakis semifasciata* and *Mustelus henlei*. *Journal of Experimental Zoology*, 276:1-10.

40. Klimley, A.P. and D.G. Ainley. 1996. White shark research in the past: a perspective. Pp. 3-4 *in* Klimley, A.P. & D.G. Ainley (Eds.), IBID.

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.

38. Klimley, A.P., P. Pyle, and S.D. Anderson. 1996. The behavior of white shark and prey during predatory attacks. Pp. 175-191 *in* Klimley, A.P. and D.G. Ainley (Eds.), IBID.

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. Pp. 91-108 *in* 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.

31. Klimley, A.P., E.D. Prince, R.W. Brill, and K. Holland. 1994. Archival tags 1994: present and future. *NOAA Technical Memorandum*, NMFS-SEFSC-357, 30 pp.

30. Klimley, A.P. 1994. The predatory behavior of the white shark. *American Scientist*, 82:122-133 (won Silver Excel Award for best feature article of year).

29. Klimley, A.P. 1993. Highly directional swimming by scalloped hammerhead sharks, *Sphyrna lewini*, and subsurface irradiance, temperature, bathymetry, and geomagnetic field. *Marine Biology*, 117:1-22.

28. Klimley, A.P., I. Cabrera-Mancilla, and J.L. Castillo-Geniz. 1993. Descripcion de los movimientos horizontales y verticales del tiburon martillo *Sphyrna lewini*, del sur de Golf de California, Mexico. *Ciencias Marinas*, 19:95-115.

27. Klimley, A.P., S.D. Anderson, P. Pyle, and R.P. Henderson. 1992. Spatio-temporal patterns of white shark (*Carcharodon carcharias*) predation at the South Farallon Islands, California. Copeia, 1992:680-690.

26. Galvan-Magaña F., H. Nienhuis, and A.P. Klimley. 1989. Seasonal abundance and feeding habits of sharks of the Lower Gulf of California. *California Fish and Game*, 75:74-84.

25. Klimley, A.P. and S.B. Butler. 1988. Immigration and emigration of a pelagic fish assemblage to seamounts in the Gulf of California related to water mass movements using satellite imagery. *Marine Ecology Progress Series*, 49:11-20.

24. Klimley, A.P., S.B. Butler, D.R. Nelson, and A.T. Stull, 1988. Diel movements of scalloped hammerhead sharks (*Sphyrna lewini* Griffith and Smith) to and from a seamount in the Gulf of California. *Journal of Fish Biology*, 33:751-761.

23. Klimley, A.P. 1987. Field studies of the white shark, *Carcharodon carcharias*, in the Gulf of Farallones National Marine Sanctuary. Pp. 33-36 *in* Croom, M.M. (Ed.), Current Research Topics in the Marine Environment. Gulf of the Farallones National Marine Sanctuary, San Francisco.

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.

20. Klimley, A.P. 1985. Schooling in the large predator, *Sphyrna lewini*, a species with low risk of predation: a non-egalitarian state. *Zeitschrift für Tierpsychologie* (=*Ethology*), 70:297-319.

19. Klimley, A.P. and D.R. Nelson. 1985. Functional analysis of schooling in the scalloped hammerhead shark (*Sphyrna lewini*). *Research Reports*, National Geographic Society, 21:227-229.

18 Klimley, A.P. 1985. The areal distribution and autoecology of the white shark, *Carcharodon carcharias*, off the west coast of North America. *Southern California Academy of Sciences*, Memoirs, 9:15-40.

17. Klimley, A.P. and D.R. Nelson. 1984. Diel movement patterns of the scalloped hammerhead shark (*Sphyrna lewini*) in relation to El Bajo Espiritu Santo: a refuging central-position social system. *Behavioral Ecology and Sociobiology*, 15:45-54.

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 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.

REPORTS

3. Klimley, A.P., J.J. Cech, Jr., S.I. Doroshov, B.P. May, and I. Werner. 2006. Biological assessment of green sturgeon in the Sacramento/San Joaquin watershed, Phase 5. CALFED Ecosystem Restoration Progra, Contract ERP-02D-P57,

2*. Klimley, A.P., L.C. Thompson, and J.J. Cech, Jr. 2006. Experimental and field studies to assess pulsed water flow impacts on the behavior and distribution of fishes in the South Fork of the American River. Public Interest Energy Research Program, California Energy Commission.

1. Klimley, A.P. 2005. Life history model for the green sturgeon, *Acipenser medirostris*. Delta Regional Ecosystem Restoration Implementation Plan, California Bay-Delta Authority.

CRUISES (CHIEF SCIENTIST)

2000 Automated monitoring of white sharks and seals, 24 days, Central California, R/V Robert Gordon Sproul, Scripps Institution of Oceanography, University of California, San Diego.

1999 Studies of pelagic fish assemblage at seamounts and islands, 16 days, Gulf of California, Mexico, R/V Robert Gordon Sproul, Scripps Institution of Oceanography, University of California, San Diego.

1999 Studies of pelagic fish assemblage at seamounts and islands, 10 days, Gulf of California, Mexico, R/V BIP, Centro de Investigaciones Biologicas de Baja California del Norte (CIBNOR).

1989 Telemetry tracking of sharks, 28 days, Gulf of California, Mexico, scientific party of 10 United States and 8 Mexican scientists, R/V Robert Gordon Sproul, Scripps Institution of Oceanography, University of California, San Diego.

1988 Geomagnetic, bathymetric surveys, and tracking of sharks, 33 days, Gulf of California, Mexico, 11 United States and 10 Mexican scientists, R/V Robert Gordon Sproul, Scripps Institution of Oceanography, University of California, San Diego.

1986 Record attendance of sharks at seamount with coded tags and moored automated data loggers, 34 day, 10 United States and 9 Mexican scientists, R/V Robert Gordon Sproul, Scripps Institution of Oceanography, University of California, San Diego.

1985 Detect visitation of sharks to seamount with individually coded tags and moored automated data loggers, 20 days, Gulf of California, Mexico, 4 United States and 3 Mexican scientists, Private charter, La Paz.

1983 Telemetry tracking of white sharks, 4 X 4-day cruises, Gulf of the Farallones, 6 scientist per cruise, R/V Susan K, Bodega Marine Laboratory, UC Davis.

1982 Studies of social organization of sharks, 3 X 10-day cruises, 4 United States and 6 Mexican scientists per cruise, R/V Don Juan Batiz, Centro de Ciencias Interdisciplinarios de Ciencias Marinas, La Paz.

1981 Telemetry tracking of sharks, 10 days, 10 United States and 10 Mexican scientists, Don Jose Abaroa, Private charter, La Paz.

1980 Studies of social organization of sharks, 3 X 10-day cruises, 4 United States and 6 Mexican scientists per cruise, R/V Don Juan Batiz, Centro de Ciencias Interdisciplinarios de Ciencias Marinas, La Paz.

TEACHING (UNDERGRADUATE)

COURSES

Annually Guest lecturer, “Techniques for Marine Vertebrates”, Field Methods in Ecology (WFC 100), Wildlife, Fish, and Conservation Biology (WFCB), Instructors, D. Anderson, D. Kelt, and D. Van Vuren.

Annually. Guest lecturer, “Electroreception in Fishes”, Physiology of Fishes (WFC 121), WFCB, UC Davis, Instructor, J. Cech.

Annually Guest lecturer, “Conservation of Sharks,” Wildlife Ecology and Conservation (WFC 10), Instructors, D. Kelt and P. Moyle.

Annually. Guest lecturer, “Physiological Telemetry”, Physiological Ecology (ECL 203), Physiology Graduate Group, UC Davis, Instructors, J. Cech. and S. Doroshov,.

Spring 2000[1] Instructor, Methods in Marine Vertebrate Biology (WFC 195) Wildlife, Fish, and Conservation Biology.

Spring 2000[1] Instructor, Methods in Marine Vertebrate Biology/Advanced Laboratory Topics (WFC198), Wildlife, Fish, and Conservation Biology.

Fall 1999 Instructor, Marine Conservation Biology (WFC 190), WFCB, UC Davis.

Spring 1999 Guest lecturer, “Ecology of Sharks”, Population Biology and Ecology (BIS 122), Bodega Marine Laboratory, UC Davis, Instructor: Strong.

Fall 1998 Guest lecturer, “Sharks of California”, Marine Biology Quarter (MBQ), UC Los Angeles (at Bodega Marine Laboratory), Instructor, Buth.

Spring 1998. Guest lecturer, “Animal Migration and Navigation”, Introduction to Animal Behavior (NPB 102), Department of Neurobiology, Physiology, and Behavior, UC Davis, Instructors: Clayton and Nevitt.

Winter 1985. Guest lecturer, “Social Organization of Animal Societies”, Animal Behavior (BIO 351), Department of Biology, California State University, Long Beach, Instructor, Nelson.

[1] Student evaluations submitted for course.

ADVISING

RESEARCH FELLOWS (REU, NSF)

Summer 1998 Kelly Cantara, Southampton University, New York.

Summer 1998 Salvador Jorgensen, State University of California, Sonoma, California.

Summer 1998 David Melrose, State University of California, Sonoma, California.

RESEARCH INTERNS

Spring 2005 Terry Fei Fan Ng, Special Study for Advanced Undergraduates (WFC 199), University of California, Davis.

Spring 2005 Emily Berryhill, Special Study for Advanced Undergraduates (WFC 199), University of California, Davis.

Spring 2004 Atsumi Ngui, Special Study for Advanced Undergraduates (WFC 199), University of California, Davis.

Spring 2003 Emily Dickson, Special Study for Advanced Undergraduates (WFC 199), University of California, Davis.

Summer 1999 Tobey Curtis, Undergraduate Research Thesis, Southampton University, New York.

Spring 1999 John Richert, Undergraduate Research Thesis, Southampton University, New York.

Spring 1998 Kelly Cantara, Undergraduate Research Thesis, Southampton University, New York.

Spring 1996 Nathan Kochly, Senior Research Thesis, UC Santa Cruz, California.

Summer 1995 George Letsinger, Special Study for Advanced Undergraduates (NPB 199), UC Davis, Co-supervisor, Sillman.

Summer 1995 Sean Patel, Special Study for Advanced Undergraduates (NPB 199), UC Davis, Co-supervisor, Sillman,.

Spring 1995 Elizabeth Anthony, Senior Research Thesis, UC Santa Cruz, California.

TEACHING (GRADUATE)

GROUP MEMBERSHIPS

2007-Pres. Membership, Graduate Group in Geography, UC. Davis

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

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

COURSES

Winter 2003 Instructor, Biotelemetry in Ecology (EEG 290), Ecology Graduate Group, UC Davis.

Winter 2000 Instructor, Communication: The Animal in the Context of the Environment (ANB 230), Animal Behavior Graduate Group, UC Davis, Co-instructors, Hart, Marler, and Owings.

Fall 1999 Instructor, Management and Fisheries Ecology (ECL 290), Co-instructor, Dewees.

Winter 1998. Instructor, "Behavioral and Sensory Adaptations to the Marine Environment", Seminar on Animal Behavior (ANB 290), Animal Behavior Graduate Group, UC Davis.

Fall 1998. Guest lecturer, "Ethological Analysis", Methods and Grant Writing (ANB 201), Department of Neurobiology, Physiology, and Behavior, UC Davis, Instructor: Nevitt.

Spring 1983 Guest lecturer, "Elasmobranchs", Ichthyology (S 294A), Scripps Institution of Oceanography, UC San Diego, Instructor, Rosenblatt.

Winter 1983 Instructor, Quantitative Methods of Ethological Analysis (S 296), Scripps Institution of Oceanography, UC San Diego, Co-instructor, Heiligenberg.

STUDENTS (MAJOR PROFESSOR)

2009-Pres. Ethan Mora, M. Sci., Ecology Graduate Group, UC Davis.

2009-Pres. Melia Nafus, Ph.D., Ecology Graduate Group, UC Davis.

2009-Pres. Jamilynn Poletto, Ph.D., Animal Behavior Graduate Group, UC Davis.

2008-Pres. Anna Stephensen, M. Sci., Ecology Graduate Group, UC Davis.

2007-Pres. Phillip Sandstrom, Ph.D., Ecology Graduate Group, UC Davis. SEA GRANT Predoctoral Fellow.

2005-Pres. James Ketchum, Ph.D., Ecology Graduate Group, UC Davis, CONACYT Predoctoral Fellow.

2003-2007 Emma Grigg, Ph.D., Ecology Graduate Group, UC Davis.

2001-2007. John Richert, Ph.D., Ecology Graduate Group, UC Davis, NSF Predoctoral Fellow.

2001-2007. John Kelly, Ph.D., Animal Behavior Graduate Group, UC Davis.

STUDENTS (COMMITTEE MEMBER)

2007-Pres. Kim Sora, Ph.D., Department of Geology, UC Santa Cruz.

2006-Pres. Danielle Brown, Ph.D., Animal Behavior Graduate Group, UC Davis.

2007-Pres. Taylor Chapple, Ph.D., Marine Ecology, Ecology Graduate Group, UC Davis.

2006-Pres. Holly Nance, Ph.D., Department of Biology, Clemson University.

2005-Pres Sean Hanser, Marine Ecology, Ecology Graduate Group

2005-2007. Rachel Mazur, Ph.D., Conservation Ecology, Ecology Graduate Group, UC Davis, United States Forestry Service.

2005-Pres. Katherine McHugh, Animal Behavior Graduate Group, UC Davis, NSF Predoctoral Fellow, Committee Member.

2003-Pres. Mauricio Hoyos-Padilla, Ph.D., Centro de Investigaciones Interdisciplinarios de Ciencias Marinas, CICIMAR, Co-supervisor with F. Galvan-Magaña

2001-2006 Salvador Jorgensen, Ph.D., Marine Ecology, Ecology Graduate Group, UC Davis, Postdoctoral Fellow, Hopkins Marine Laboratory, Stanford University.

1996-2001. Jesus Rodriguez-Romero, Ph.D., Departamiento de Ciencias Marinas, Centro de Investigaciones Biologicas, Norte de California (CIBNOR), Mexico, Co-supervisor with A. Muhlia-Melo.

1995-2000 Rogelio Gonzales-Armas, Ph.D., Departamiento de Ciencias Marinas, CIBNOR, Mexico, Co-supervisor with A. Muhlia-Melo.

1995-2000 Agustin Hernandez-Herrera, Ph.D., Departamiento de Ciencias Marinas, CIBNOR, Mexico , Co-supervisor with Muhlia-Melo.

1996-1998 Joseph Reid, M.Sci., Ecology Graduate Group, UC Davis, Co-supervisor with J. Cech.

1995-1997 Larry Bucholz, M.Sc., Electrical Engineering Graduate Group, UC Davis, Co-supervisor with R. Spencer.

1985-1988 Steven Butler, M.Sci., Scripps Institution of Oceanography, UC San Diego, Co-supervisor with R. Rosenblatt.

STUDENTS (QUALIFYING EXAM MEMBER)

2010 Julia Coates, Ph.D., Ecology Graduate Group, UC Davis, Subject: General Ecology, Chair of Committee.

2009 Mark Elbroch, Ph.D., Ecology Graduate Group, UC Davis, Subject: Quantitative Methods.

2009 Greta Weigert, Ph.D., Ecology Graduate Group, UC Davis, Subject: Quantitative Methods.

2008 Dovi Kacev, Ph.D., Ecology Graduate Group, UC Davis, Subject: General Ecology, Chair of Committee

2006 Tim Mussen, Ph.D., Ecology Graduate Group, UC Davis, Subject: Behavioral Ecology.

2005 Rachel Mazur, Ph.D., Ecology Graduate Group, UC Davis, Subject: Quantitative Methods.

Sean A Hayes
NOAA Fisheries
110 Shaffer Road
Santa Cruz, CA 95060
Day: 831-420-3937
sean.hayes@noaa.gov

Highest Grade: ZP-03-03, 10/2005-present

WORK EXPERIENCE

NOAA Southwest Fisheries Science Center/ University of California Santa Cruz
10/2005 - Present

Santa Cruz, CA US Grade Level: 03/03
Hours per week: 40
Research Fisheries Biologist ZP 03/ Assistant Adjunct Professor

The Scott Creek Program: I developed and oversee a research program in a small California watershed dedicated to understanding ecological challenges of endangered steelhead and coho salmon.

Specific project objectives include

1. Study migration timing, physiology, abundance, survivorship, growth, age, habitat use and movements of juvenile and adult salmonids in freshwater and marine environments.
2. Use Archival tag and PIT tag telemetry to study fish movements and habitat use.
3. Study associated diet and nutrient flow.
4. Measure genetic effective population size and reproductive success
5. Monitor differences between hatchery-produced and wild fish for the above objectives
6. Conduct broodstock collection for local hatchery and NOAA Fisheries captive coho broodstock program.
7. Study sources of mortality for juvenile salmon and conduct predator/prey studies.
8. Perform regular public outreach and provide scientific advice to federal and state agencies on status and ecological requirements of protected salmonids
9. Develop new research tools to enhance salmon survey techniques

California Current Salmon Ocean Survey- working with Bruce MacFarlane, Brian Wells, and Jeff Harding along with members of NWFSC FED to reestablish a coastal salmon survey. This will be a 14 day cruise from Newport OR to San Francisco CA in June-July 2010 (immediately following a 9-day NWFSC cruise from La Push WA to Newport OR with identical protocol), followed annually by two regular 15 day cruises in July and October beginning 2011. Specific objectives:

1. Conducts surface trawls for juvenile salmonids and associated fishes
2. Collect associated oceanographic data- CTD, Secchi, Nutrients and Chorophyll
3. Plankton sampling
4. Hydroacoustic sampling
5. IGF blood sampling for fish growth

Open ocean elephant seal acoustic array. This is a pilot study with Dan Costa's lab and the TOPP program at UCSC. We are attaching prototype acoustic receivers capable of detecting acoustically tagged organisms in the North Pacific that seals may encounter during their migrations along the California Current, through the Gulf of Alaska, along the Aleutians and eastern half of the central North Pacific above the 40 degree line. Tag detections will be associated with seal's satellite tracked position and oceanographic data of the water column collected by additional on-board instrumentation

I supervise all personnel and acquire most project funding from outside grants, including salary for 3 technicians/graduate students, undergraduates and field/laboratory supplies ~200k/year. During this project I have or currently am mentoring 5 graduate students (4 as committee members- Danielle Frechette, Ann-Marie Osterback, Kristine Atkinson, Joelle Casagrande), and 12 undergraduate interns. I have an Assistant Adjunct Professor appointment with University of California Santa Cruz Dept. of Ocean Sciences. (Supervisor: R. Bruce MacFarlane- 831 420 3939)

I also perform regular guest lectures for UCSC, Cal State's Moss Landing Marine Labs, SUNY Cobleskill, and California Polytechnic Institute.

NOAA Northwest Fisheries Science Center 6/2009-9/2009 NOAA Rotational Assignment Program

Served a temporary appointment with the NWFSC Fish Ecology group under Bob Emmett in Newport Oregon. Specific objectives were to

1. Study the research programs of Emmett, Beckman, Brodeur, Peterson, Weitkamp and Zamon for the purposes of developing inter-center collaborations and bringing institutional knowledge to the SWFSC's salmon estuarine and ocean ecology program
2. Conduct size biased juvenile to adult marine survival analysis of Chinook salmon populations returning to the Columbia River through scale analysis.

NOAA SWFSC 1/2002 - 9/2005

Santa Cruz, CA US
Hours per week: 40
Post Doctoral Researcher

Refer to above position above for job details, which is a continuation of postdoc.

NOAA Southwest Fisheries Science Center 4/2001 - 12/2001

Honolulu, Hawaii US Grade Level: 11/01
Hours per week: 40-60
Ecologist , GS

Protected species investigation- Field assessment of endangered Hawaiian Monk Seal populations. Fieldwork conducted at French Frigate Shoals, Northwest Hawaiian Islands. Field duties: 3 month trips for assessing seal populations, tagging (flipper and PIT), studying shark predation effect on population, and deployment of 'crittercam' (video cameras attached to seals) for foraging ecology studies, small boat handling around submerged reefs and surf. Analysis of field data from VHF telemetry study to assess survivorship/movements of monk seal pups and observation data to assess level of shark predation on monk seal pups and the effect of shark culling/harassment on shark predation (Supervisor's Name: Jason Baker, Supervisor's Phone: 808 983 5711- Jason.baker@noaa.gov)

University of California 9/1994 - 3/2000
Santa Cruz, CA US
Hours per week: 50
Graduate Student Researcher

PhD Thesis research focused on mating strategies and reproductive success of male harbor seals in central CA. Studied animal movements through VHF telemetry and acoustic tracking of vocalizing males. Studied reproductive success by capture and DNA sampling 400 seals, followed by microsatellite DNA paternity analysis. Extensive experience with animal instrumentation, tagging, small boats handling, DNA analysis and acoustic analysis.

Additional research: acoustic tracking methods and function of vocalization behavior in blue whales and fin whales in the Sea of Cortez, Mexico, Monterey Bay, and the Channel Islands, CA. Developed a free floating GPS based acoustic system for recording and tracking marine mammals in a pelagic environment. Collected behavioral and acoustic data from foraging blue and fin whales. Extensive boat handling experience. Participated in Acoustic Thermometry of Ocean Climate (ATOC) Experiment, Marine Mammal Research Program

Research Assistant for fieldwork conducted at Amsterdam Island, Indian Ocean. Flight energetics and foraging ecology of yellow-nosed albatross using doubly labeled H_2O measurements, satellite telemetry and altimeters. Duties included capture and handling of albatross for sampling and instrumentation. Blood volume measurements and flipper morphometrics of Sub-Antarctic fur seals. Duties involved capture/restraint of fur seals for blood sampling, body morphometric measurements.
(Daniel P. Costa, Supervisor's Phone: 831 459 2691, costa@biology.ucsc.edu)

Teaching Assistant for 6 courses: Ecology, Behavioral Ecology, Comparative Physiology, Intro. to Cell & Molec. Bio., Field methods in Animal Behavior, Biology of Marine Mammals.

Undergraduate Research Experience:
1993- summer-fall NSF-REU intern with Mark Bain USFWS Cornell co-op
1992- summer- Shakleton Pt. Field station Oneida Lake intern with John Forney
1991- summer-fall USFWS intern Yellow N.P.
1989,1990 summer- SUNY Oneonta Bio Field Sta. Otsego Lake with Prof John Foster of SUNY Cobleskill.

EDUCATION
University of California
Santa Cruz, CA US
PhD - 12/2002
371 Quarter Hours
Major: Ecology and Evolutionary Biology
Advisors: Daniel P. Costa, Burney J. LeBoeuf.

Cornell College of Ag and Life Science
Ithaca, NY US
Bachelor's Degree - 1/1994
60 Semester Hours
Major: Biology
GPA: 3.4 out of 4.0

State University of NY
Cobleskill, NY US
Associate Degree - 5/1991
75 Semester Hours
Fisheries and Wildlife Technology
GPA: 3.87 out of 4

REVIEWER Experience
Journals: Aquatic Biology, Evolution, Canadian Journal of Zoology, Canadian Journal of Fisheries and Aquatic Sciences, Conservation Genetics, Ecology, Journal of Fish Biology, Marine Mammal Science, Molecular Ecology, North American Journal of Fisheries Management, Proceedings of the Royal Society-B, Transactions of the American Fisheries Society
Grant reviewer for National Oceanographic Partnership Program (NOPP) 2007

AFFILIATIONS (past and present)
American Fisheries Society member
Monterey Bay Salmon and Trout Project NOAA liaison board member
Marine Mammal Society member

SELECTED PRESENTATIONS (reverse chronological)

Hayes, S.A., Teutschel, N.M., Michel, C., Champagne, C., Frechette, D., Costa, D.P., Mellinger, D., Yack, T., and MacFarlane, R.B. 2010. Mobile Receivers: Releasing the mooring to see where fish go. Electronic Tagging Studies of Salmonid Migration, Bodega Bay Marine Lab May 20-21st.

Frechette, D., Osterback, A.-M.K., Hayes, S.A., Bond, M.H., Moore, J.W., Shaffer, S.A., and Harvey, J.T. 2010. Where does marine survival begin? Tracking sources of smolt mortality between the smolt trap and the sea. *In* 12th Annual Salmon Ocean ecology meeting. *Edited by* R.B. MacFarlane, Santa Cruz CA.

Hayes, S.A., Bond, M.H., Charrier, G., Frechette, D.M., Garza, J.C., Gilbert-Horvath, E., MacFarlane, R.B., Moore, J.W., Moss, C., Osterback, A.-M.K., Pearse, D.E., Shaffer, S.A., Streig, D., and Sturm, E. 2010. Exploring the impacts of and ways to improve salmon hatcheries as a recovery tool in small coastal watersheds. *In* 44th Annual meeting of American Fisheries Societey Cal-Neva chapter, Redding CA.

Hayes, S.A., Hanson, C.V., Bond, M.H., Pearse, D.E., Jones, A., Garza, J.C., and MacFarlane, R.B. 2010. Emigration behavior of resident and anadromous juvenile *Oncorhynchus mykiss*: exploring the interaction among genetics, physiology and habitat. *In* Pacific Coast Steelhead Management Meeting, Redmond, OR.

Hayes, S.A., Ammann, A.J., Bond, M.H., et al. 2009. From Ridge Tops to Wave Tops, exploring the life history of Central California Steelhead in stream, estuarine and ocean habitats. *Invited* *speaker:* Oregon State University Hatfield Marine Science Center, July 9 2009, Moss Landing Marine Labs November 12, 2009, San Jose State University February 10, 2010

Hayes, S.A., Ammann, A.J., Bond, M.H., et al. 2009. Using electronic tags to study central California steelhead and coho salmon. 11th Annual Salmon Ocean ecology meeting, Juneau Alaska.

Hayes, S. A., M. H. Bond, and R. B. MacFarlane. 2008. Using Archival Tags to Study Central California Steelhead and Coho Salmon. Advances in Fish Tagging and Marking Technology, American Fisheries Society, Auckland, New Zealand 24-28 February.

Hayes, S.A. 2007. Exploring the evolution of aquatic mating systems in pinnipeds. *In* 17th Biennial Conference on the Biology of Marine Mammals. Capetown South Africa.

Bond, M.H., Hanson, C.V., Hayes, S.A., et al. 2007. Does loss of the estuary = loss of anadromy in southern steelhead? *In* AFS 137th Annual Meeting. San Francisco, California Sept 2-6th.

Bond, M.H., Hayes, S.A., Sturm, E., et al. 2007. Coho Salmon on the edge, challenges faced at the southern end of their range. *In* AFS 137th Annual Meeting. San Francisco, California Sept 2-6th.

Bond, M.H., Hayes, S.A., Hanson, C.V., et al. 2007. The influence of estuarine habitat on coastal California steelhead ocean survival. *In* California Estuarine Research Society. Bodega Bay Marine Lab, March 18-20th.

Hayes, S.A., Ammann, A.J., Bond, M.H., et al. 2007. Bar-built estuaries and salmonids on the central coast: A case study of Scott Creek. *In* California Estuarine Research Society. Bodega Bay Marine Lab, March 18-20th.

Bond, M.H., Hayes, S.A., Freund, E.V., et al. 2007. Central California Salmonids: Estuaries, Hatcheries and Predators. *In* Monterey Bay Marine Sanctuary Currents Symposium. CSUMB, March.

Hayes, S.A., Bond, M.H., Freund, E.V., et al. 2007. Using archival tags to monitor freshwater and marine habitat use and predation of central California steelhead and coho salmon. *In* American Fisheries Society 137th Annual Meeting. San Francisco, California Sept 2-6th.

Hayes, S.A., Bond, M.H., Harding, J., et al. 2007. From barriers to beaches, monitoring central California coho and steelhead in Scott Creek. *In* AFS 137th Annual Meeting. San Francisco, California Sept 2-6th.

Bond, M.H., Hayes, S.A., Hanson, C.V., et al. 2006. Movement patterns of steelhead in a central California stream: using passive integrated transponders to monitor fish behavior. *In* AFS 136th Annual Meeting, Lake Placid, NY, Sept. 10-14.

Hayes, S.A., Hanson, C.V., Bond, M.H., et al. 2006. 50 years since Shapovalov and Taft: Steelhead on the central California coast today. *In* AFS 136th Annual Meeting, Lake Placid, NY, Sept. 10-14.

Bond, M.H., Hayes, S.A., Hanson, C.V., et al. 2005. Size-Dependent Mortality of Coastal California Steelhead and the Estuarine Life History. In American Fisheries Society 135th Annual Meeting. Anchorage, AK.

Pearse, D.E., Hayes, S.A., and Garza, J.C. 2005. Over the falls? Genetic interactions between anadromous steelhead and resident rainbow trout in a small coastal California stream. In Society for the Study of Evolution. Fairbanks, AK.

Hayes, S.A., Bond, M.H., Hanson, C.V., et al. 2005. Reversed growing seasons for coastal salmonids living at their southern extreme: Growth patterns of a steelhead living in a Mediterranean climate. In AFS 135th Annual Meeting. Anchorage, AK.

Hayes, S.A., Bond, M.H., Hanson, C.V., et al. 2004. Interactions between endangered wild and hatchery salmonids; can the pitfalls of artificial propagation be avoided in small coastal streams? *In* Fisheries Society of the British Isles Nature and Culture: Comparative Biology and Interactions of Wild and Farmed Fish. Imperial College, London.

Hayes, S.A., Hanson, C.V., Bond, M.H., et al. 2003. Seasonal Fluctuations of Na+, K+ -ATPase in Central California Salmonids prior to Ocean Entry. In West. Div. of AFS. San Diego, CA.

PROFESSIONAL PUBLICATIONS

Hayes, S.A., Teutschel, N.M., Michel, C., Champagne, C., Frechette, D., Costa, D.P., Mellinger, D., Yack, T., and MacFarlane, R.B. *in Prep*. Mobile Receivers: Releasing the mooring to see where fish go. Planned submission to special edition of Environmental Biology of Fishes: Electronic Tagging Studies of Salmonid Migration.

Moore, J.W., Carlson, S.M., Twardochleb, L., Hwan, J.L., Fox, J.M., and Hayes, S.A. *In SWFSC internal review*. Trophic tangles through time: opposing direct and indirect effects of an invasive omnivore. for submission to PNAS.

Claiborne, A.M., Fisher, J.P., Hayes, S.A., and Emmett, R.L. *In review*. Size at Release, Marine Survival, and Age of Maturity for Hatchery Spring Chinook Salmon 2002-2005. Trans. Am. Fish. Soc.

Hayes, S.A., Hanson, C.V., Bond, M.H., Pearse, D., Garza, J.C., and MacFarlane, R.B. In *SWFSC internal review*. Should I stay or should I go? The influence of genetic origin on emigration behavior and physiology by resident and anadromous juvenile *Oncorhynchus mykiss*. *For submission to* Trans. Am. Fish. Soc.

Hayes, S.A., Bond, M.H., Wells, B., Hanson, C.V., Jones, A.W. and MacFarlane, R.B. ***Accepted-in press***. Using Archival Tags to infer habitat use of Central California Steelhead and Coho Salmon. *In* Advances in Fish Tagging and Marking Technology. American Fisheries Society, Auckland, New Zealand.

Costa, D.P., Tremblay, Y. & Hayes, S.A. **2009.** Research on Higher Trophic Levels Ed: D Glickson; Oceanography in 2025: A Workshop; National Research Council pp 124-129.

Pearse, D.E., Hayes, S.A., Bond, M.H., Hanson, C.V., Anderson, E.C., MacFarlane, R.B., and Garza, J.C. **2009**. Over the falls? Reproductive isolation and ecotype evolution in resident trout and anadromous steelhead. Journal of Heredity. doi:10.1093/jhered/esp040

Renfree, J. S., Hayes, S. A., and Demer, D. A. 2009. Sound-scattering spectra of steelhead (*Oncorhynchus mykiss*), coho (*O. kisutch*), and Chinook (*O. tshawytscha*) salmonids. ICES Journal of Marine Science, 66: 000–000.

Bond, M. H., S. A. Hayes, C. V. Hanson, and R. B. MacFarlane. **2008**. Marine survival of steelhead (*Oncorhynchus mykiss*) enhanced by a seasonally closed estuary. Can. J. Fish. Aquat. Sci **65:**2242–2252.

Hayes, S.A., Bond, M.H., Hanson, C.V., Freund, E.V., Smith, J.J., Anderson, E.C., Ammann, A., and MacFarlane, R.B. **2008**. Steelhead growth in a small central California watershed: upstream and estuarine rearing patterns. Trans. Am. Fish. Soc. **137**: 114-128, DOI: 110.1577/T1507-1043.1571.

Bond M.H., Hanson C.V., Baertsch R., Hayes S.A., MacFarlane R.B., **2007**. A new low cost in-stream antenna system for tracking passive integrated transponder (PIT) tagged fish in small streams. Trans. Am. Fish. Soc. **136:**562-566.

Hayes, S. A., E. V. Freund, C. V. Hanson, M. H. Bond, and R. B. MacFarlane. **2007** Archival tagging of salmonids on the Central California coast. Editors: Sheridan, P., J. W. Ferguson,

S. L. Downing. 2007. Report of the National Marine Fisheries Service Workshop on Advancing Electronic Tag Technology and Their Use in Stock Assessments. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFSF-F/SPO-82, 82 p.

Hayes S.A., Pearse D.E., Costa D.P., Harvey J.T., Le Boeuf B.J., Garza J.C., **2006**. Mating system and reproductive success in eastern Pacific Harbour seals. Molecular Ecology **15**:3023-3034.

Hayes, S. A., Bond, M. H., Hanson, C. V. & MacFarlane, R. B. **2004.** Interactions between endangered wild and hatchery salmonids; can the pitfalls of artificial propagation be avoided in small coastal streams? J. Fish Biol. **65**(Supplement A): 101-121.

Hayes, S. A., Kumar, A., Costa, D. P., Mellinger, D. K., Harvey, J. T., Southall, B. L. & Boeuf, B. J. L. **2004** Evaluating the function of male vocalizations in the harbor seal (*Phoca vitulina*) through playback experiments. Animal Behaviour **67**: 1133-1139.

Hayes, S. A., Costa, D. P., Harvey, J. T. & Le Boeuf, B. J. **2004** Aquatic mating strategies of the male Pacific harbor seal (Phoca vitulina richardsi); are males defending the hotspot? Marine Mammal Science **20**: 639-656.

Costa, D. P., Crocker, D. E., Gedamke, J., Webb, P. M., Houser, D., Blackwell, S., Waples, D., Hayes, S. A. & Le Bouef, B. J. **2003**. The effect of a low-frequency sound source (acoustic thermometry of the ocean climate) on the diving behavior of juvenile northern elephant seals, *Mirounga angustirostrus*. J. Acoust. Soc. Am., **113:** 1155-1165.

Van Parijs, S. M., Corkeron, P. J., Harvey, J. T., Hayes, S. A., Mellinger, D. K., Rouget, P. A., Thompson, P. M., Wahlberg, M. & Kovacs, K. M. **2003**. Patterns in the vocalizations of male harbor seals. *J. Acoust. Soc. Am.*, 113, 3403-3410.

Costa, D. P. & Hayes, S. A. **2000**. Underwater acoustic pollution. In: McGraw-Hill Yearbook of Science and Technology, pp. 405-407. New York: McGraw-Hill.

Hayes, S. A., Mellinger, D. K., Costa, D. P., Croll, D. A. & Borsani, J. F. **2000**. An inexpensive passive acoustic system for recording and localizing wild animal sounds. J. Acoust. Soc. Am., 107, 3552-3555.

REFERENCES

Morgan Bond
University of Washington
School of Aquatic and Fishery Sciences
Box 355020
Seattle, WA 98195
mobond@u.washington.edu

Daniel P. Costa
University of California, Santa Cruz
Long Marine Lab
100 Shaffer Road
Santa Cruz CA 95060
831 459 2786
costa@biology.ucsc.edu

David Demer
NOAA Southwest Fisheries Science Center

8604 La Jolla Shores Drive
La Jolla, CA 92037-1508
858 546 5603
david.demer@noaa.gov

James T. Harvey
Moss Landing Marine Laboratories
8272 Moss Landing Rd
Moss Landing, CA 95039
831-632-4434
harvey@mlml.calstate.edu

Bruce MacFarlane
NOAA Southwest Fisheries Science Center
110 Shaffer Road
Santa Cruz, CA 95060
831 420 3939
bruce.macfarlane@noaa.gov

Devon Pearse
NOAA Southwest Fisheries Science Center
110 Shaffer Road
Santa Cruz, CA 95060
831 420 3906
devon.pearse@noaa.gov

GRANTS

California Fisheries Restoration Grant Program 2010: **Monitoring the life cycle of coho salmon and steelhead trout in Scott Creek** $612,069

West Coast & Polar Regions Undersea Research Center (NURP) 2009: **A low cost roving oceanographic acoustic array for the Northeast Pacific- expanding the role of the elephant seal as an oceanographic sampler** $168,141

California Fisheries Restoration Grant Program 2008: **Monitoring salmonids in Coastal Santa Cruz and San Mateo Counties** $198,299

NOAA Advance Sampling and Technology Working Group 2008**: Multi-scattering detection, enumeration, and identification of anadromous species during migrations in streams and rivers-** $76,000 collaboration with Dave Demer

California Sea Grant Program 2007: **Exploring the impact of avian predators on central California salmonids** $255,000, collaboration with Scott Shaffer and Jonathan Moore

NOAA Advance Sampling and Technology Working Group 2007: **Acoustic identification and enumeration of epipelagic fish and jellyfish** $90,500 collaboration with Dave Demer

California Fisheries Restoration Grant Program 2006: **Coho salmon and steelhead population dynamics on the central California coast: full life cycle monitoring, redd surveys, and coho recolonization** $299,066

California Fisheries Restoration Grant Program 2004: **Monitoring life history traits of ESA-listed salmonids on the central California coast** $192,000

ADDITIONAL INFORMATION
NOAA Bronze Medal Award for Hurricane Katrina Recovery Effort

CURRICULUM VITAE

NAME:	STEVEN T. LINDLEY
ORGANIZATION:	National Oceanic & Atmospheric Administration National Marine Fisheries Service Southwest Fisheries Science Center Fisheries Ecology Division 110 Shaffer Road Santa Cruz, California 95060 (831) 420-3921
PRESENT POSITION:	Supervisory Research Ecologist (Landscape Ecology team leader)
APPOINTMENTS:	Research Associate Institute of Marine Science University of California, Santa Cruz

EDUCATION:

Ph.D., Biological Oceanography, Duke University, 1994.

B.A. (with Honors and Distinction in the Major), Aquatic Biology, University of California at Santa Barbara, 1989.

TITLE OF PH.D. DISSERTATION:

Regulation of the maximum quantum yield of phytoplankton photosynthesis by iron, nitrogen and light in the eastern equatorial Pacific.

EXPERIENCE:

2005-present	Supervisory Research Ecologist (team leader) Landscape Ecology Team Fisheries Ecology Division Southwest Fisheries Science Center, NMFS Santa Cruz, California
1996–2005	Ecologist Southwest Fisheries Science Center, NMFS Santa Cruz / Tiburon, California
1995–1996	Research Associate Duke University Marine Laboratory Beaufort, North Carolina

1994–1995 Postdoctoral Fellow
Stanford University and Carnegie Institution of Washington
Stanford, California

RESEARCH INTERESTS:

Landscape, ecosystem, and population ecology of aquatic organisms, statistical and numerical modeling, time series analysis, stable isotopes, telemetry, mark-recapture.

SELECTED SERVICE:

NMFS Science Center Point of Contact, National Academy of Science review of water operations in California's Central Valley, 2009-present.
Biology Team, Klamath Dams Removal Secretarial Decision, 2009-present.
Pacific Ocean Shelf Tracking Project Science Management Committee, 2009-present.
Central Valley Project Improvement Act Fish Program Independent Panel, 2008.
NMFS Technical Recovery Team (Chair), Central Valley salmonids, 2003–2007.
Wild Salmon Center expert review, Pacific Salmon Conservation Assessment, 2006.
USGS Independent Review Panel, Humpback Chub Population Estimation, 2003.
NMFS Species of Concern Budget Review Panel, 2002–present.
NMFS Biological Review Team, Green Sturgeon, 2002–present.
NMFS Biological Review Team, Steelhead, 2003–present.
NMFS Biological Review Team, Chinook Salmon, 1998–present.

Reviewer for *Conservation Biology, Canadian Journal of Fisheries and Aquatic Sciences, Deep Sea Research, Environmental Biology of Fishes, Ecology, Environmental and Ecological Statistics, Estuaries, Estuaries and Coasts, Evolutionary Applications, Fishery Bulletin (US), Landscape Ecology, North American Journal of Fisheries Management, Northwestern Naturalist, Oikos, San Francisco Estuary and Watershed Science, Transactions of the American Fisheries Society, Theoretical Population Biology*, USGS Western Fisheries Research Center, NOAA Undersea Research Program (NURP) and Saltonstall-Kennedy Program, NASA SIMBIOS, NMFS Species of Concern Program, Pacific Ocean Shelf Tracking Project.

PROFESSIONAL AFFILIATIONS:

Ecological Society of America

HONORS AND AWARDS:

NOAA Office of the General Council Team Award, 2010, "*For outstanding service and cooperation across line offices, under extraordinarily tight time pressure, to support measures to benefit distressed Chinook salmon and theatened steelhead populations in the lower Tuolumne River.*"

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

Dissertations Initiative for the Advancement of Limnology and Oceanography (DIALOG) I. Selected Symposium Participant, 1994, American Society of Limnology and Oceanography.

GRANTS:

The future of the California Chinook salmon fishery: roles of climate variation, habitat restoration, hatchery practices, and biocomplexity. 2010-12. California Ocean Protection Council and NOAA Sea Grant. $510K. (Co-PI).

Utilizing ecosystem information to improve the decision support system for central California salmon. NASA Applied Sciences Program. $900K. 2009-11. (Co-I).

Improving stream temperature predictions for river water decision support systems. NASA Applied Sciences Program. 2008-10. $900K. (Co-PI).

Developing Statistically Robust IPCC Climate Model Products for Estuarine-dependent and Anadromous Fish Stock Assessments. 2008-09. NOAA Fisheries and the Environment. $47K. (Co-PI).

Characterization of habitat preferences of green sturgeon in the coastal ocean. 2008. NMFS Species of Concern Program. $33K. (PI).

Feeding and habitat use of green sturgeon (*Acipenser medirostris*) in Washington estuaries. 2008. NMFS Species of Concern Program. $35K. (co-PI).

Impact of freshwater and terrestrial ecosystem conditions on estuarine-dependent and anadromous fish. 2007. NOAA Fisheries and the Environment. $47K. (PI).

Estimating the abundance of Rogue River green sturgeon. 2007. NOAA Species of Concern program. $35K. (PI).

Survival and migratory patterns of Central Valley juvenile salmonids. 2006-09. CALFED Science Program. $1.5M. (Co-PI).

Scoping workshop for incorporating acoustic tagging and coast-wide acoustic receiver arrays into U.S. ocean observing systems: scientific and institutional opportunities and challenges. 2006. NOAA Stock Assessment Improvement Program. $27K. (PI).

Marine migration and estuary use of green sturgeon. 2004-06. NOAA Candidate Species Program. $112K. (PI).

PUBLICATIONS:

Payne, J., K. Andrews, C. Chittenden, G. Crossin, F. Goetz, S. Hinch, P. Levin, S. Lindley, M. Melnychuk, T. Nelson, E. Rechisky, and D. Welch. In press. Studying movements and survival of marine animals with large-scale acoustic arrays. *In* Life in the World's Oceans: Diversity, Distribution and Abundance, A. D. McIntyre, ed. Blackwell Publishing Ltd. (Oxford)

Lindley, S. T., C. B. Grimes, M. S. Mohr, W. Peterson, J. Stein, J. Anderson, D. Bottom, L. Botsford, C. Busack, T. Collier, J. Ferguson, A. Grover, D. Hankin, R. Kope, P. Lawson, A. Low, B. MacFarlane, K. Moore, M. Palmer-Zwahlen, F. Schwing, J. Smith, C. Tracy, R. Webb, B. Wells, and T. H. Williams. 2009. What caused the Sacramento River fall chinook salmon stock collapse? NOAA Tech Memo NMFS-SWFSC 447.

Mora, E. A., S. T. Lindley, D. L. Erickson and A. P. Klimley. 2009. Do impassable dams and flow regulation constrain the distribution of green sturgeon in the Sacramento River, California? Journal of Applied Ichthyology 25(S2): 39-47.

Heublein, J. C., J. T. Kelly, C. E. Crocker, A. P. Klimley, and S. T. Lindley. 2009. Migration of green sturgeon, *Acipenser medirostris*, in the Sacramento River. Environmental Biology of Fishes 84(3): 245-258.

Rundio, D.E. and S. T. Lindley. 2008. Seasonal patterns of terrestrial and aquatic prey abundance and their use by *Oncorhynchus mykiss* in a coastal basin with a Mediterranean climate. Transactions of the American Fisheries Society 137: 467-480.

Lindley, S. T., M. L. Moser, D. F. Erickson, M. Belchik, D. Welch, E. Rechiski, J.T. Kelly, J. Heublein and A. P. Klimley. 2008. Marine migration of North American green sturgeon. Transactions of the American Fisheries Society 137: 182-194.

Schick, R. S., and S. T. Lindley. 2007. Directed connectivity among fish populations in a riverine network. Journal of Applied Ecology 44: 1116-1126.

Adams, P. B., C. Grimes, J. E. Hightower, S. T. Lindley, M. L. Moser and M. J. Parsley. 2007. Population status of North American green sturgeon *Acipenser medirostris*. Environmental Biology of Fishes 79: 339-356.

Moser, M. L. and S. T. Lindley. 2007. Use of Washington estuaries by subadult and adult green sturgeon. Environmental Biology of Fishes 79: 243-253.

Lindley, S. T., E. Mora, R. S. Schick, P. B. Adams, J. J. Anderson, S. Greene, C. Hanson, B. P. May, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2007. Framework for assessing viability of Chinook salmon and steelhead in the Sacramento-San Joaquin basin. San Francisco Estuary and Watershed Science 5(1), Article 4.

Williams, J. G., J. J. Anderson, S. Greene, C. Hanson, S. T. Lindley, A. Low, B. May, D. McEwan, M. S. Mohr, R. B. MacFarlane, and C. Swanson. 2007. Monitoring and research needed to manage the recovery of threatened and endangered Chinook and steelhead in the Sacramento-San Joaquin basin. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-SWFSC-399.

Newman, K. B. and S. T. Lindley. 2006. Accounting for demographic and environmental stochasticity, observation error and parameter uncertainty in fish population dynamics models. North American Journal of Fisheries Management 26: 685-701.

Newman, K. B., S. T. Buckland, S. T. Lindley, L. Thomas, and C. Fernandez. 2006. Hidden process models for animal population dynamics. Ecological Applications 16: 74-86.

Lindley, S. T., R. S. Schick, A. Agrawal, M. Goslin, T. Pearson, E. Mora, J. J. Anderson, B. May, S. Greene, C. Hanson, A. Low, D. McEwan, R. B. MacFarlane, C. Swanson, and J. G. Williams. 2006. Historical population structure of Central Valley steelhead and its alteration by dams. San Francisco Estuary and Watershed Science. Volume 4, Issue 1, Article 3. http://repositories.cdlib.org/jmie/sfews/vol4/iss1/art3.

Schick, R. S., A. L. Edsall and S. T. Lindley. 2005. Historical and current distribution of Pacific salmonids in the Central Valley, CA. U. S. Dept. Commer., NOAA Tech. Memo. NMFS-SWFSC-369.

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 (U.S.) 101: 321–331.

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 (U.S.) 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 I 46: 637–654.

Lindley, S. T., and R. T. Barber. 1998. Phytoplankton response to natural and experimental iron addition. Deep-Sea Research II 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 0˚, 140˚W. Deep-Sea Research II 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.

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 II 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 Niño. Deep-Sea Research II 43: 933 –969.

Lindley, S. T., R. R. Bidigare, and R. T. Barber. 1995. Phytoplankton photosynthesis parameters along 140˚W in the equatorial Pacific. Deep-Sea Research II 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.

In review:

Lindley, S. T., D. L. Erickson, M. L. Moser, G. Williams, O. P. Langness, B. W. McCovey, Jr., M. Belchik, D. Vogel, W. Pinnix, J. T. Kelly, J. C. Heublein, and A. P. Klimley. Electronic tagging of green sturgeon reveals population structure and movement among estuaries. Trans Am Fish Soc.

Busch, D. S., P. McElhany, M. H. Ruckelshaus, D. A. Boughton, T. Cooney, P. W. Lawson, S. Lindley, M. M. McClure, N. J. Sands, B. C. Spence, T. C. Wainwright, T. H. Williams Comparison of methods used to assess extinction risk of ESA-listed anadromous Pacific salmonids.

Israel, J. A., N. M. Neuman, M. L. Moser, S. T. Lindley, B. W. McCovey, D. Erickson, and A. P. Klimley. Recent advances in understanding the life history of green sturgeon (*Acipenser medirostris*) and potential anthropogenic threats to this imperiled fish. Journal of Applied Ichthyology.

SELECTED AGENCY REPORTS:

Lindley, S. T., C. B. Grimes, M. S. Mohr, W. Peterson, J. Stein, J. Anderson, C. Busack, L. Botsford, T. Collier, D. Bottom, A. Grover, D. Hankin, R. Kope, P. Lawson, A. Low, J. Ferguson, B. MacFarlane, M. Palmer-Zwahlen, F. Schwing, J. Smith, C. Tracy, R. Webb, B. Wells, and T. H. Williams. 2009. What caused the Sacramento River fall chinook salmon stock collapse? Report to the Pacific Fishery Management Council.

Cummins, K., C. Furey, A. Giorgi, S. Lindley, J. Nestler, and J. Shurts. 2008. Listen to the river: an independent review of the CVPIA fisheries program. Prepared under contract with Circlepoint for the U.S. Bureau of Reclamation and the U.S. Fish and Wildlife Service. 90 p.

Deas, M., P. Goodwin, S. Lindley, C. Woodley and T. Williams. 2008. Temperature Management and Modeling Workshop in support of an Operations Criteria and Plan Biological Assessment and Biological Opinion. Report to the CALFED Science Program.

Lindley, S. T., L. Wooninck, and C. B. Grimes (eds.). 2007. Acoustic tagging and the Integrated Ocean Observing System: report from the workshop held 14-15 November 2006 in Santa Cruz, CA. NMFS SWFSC Administrative Report 2007-01.

Lindley, S., C. Legault, P. Mundy, J. Murphy and R. Waples. 2006. NMFS Science Center Evaluation of the Peer Reviews of the Long-Term Central Valley Project and State Water Project Operations Section 7 Consultation. 16 p. http://swr.nmfs.noaa.gov/pdf/ScienceCenterReportOnOCAPBiOpReviews.25May06.final.pdf.

Kitchell, J.F., C.Grimes, S.T. Lindley, D.Otis and C. Schwarz. 2003. Report to the Adaptive Management Work Group, Glen Canyon Dam Adaptive Management Program: an independent review of ongoing and proposed scientific methods to assess the status and trends of the Grand Canyon population of the humpback chub (*Gila cypha*).

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. 1997. Estimating escapement of the Sacramento River winter-run chinook: a review of methods. NMFS SWFSC Administrative Report T-97-02. 19 p.

Curriculum Vitae

Arnold J. Ammann

NOAA National Marine Fisheries Service
Southwest Fisheries Science Center
110 Shaffer Road
Santa Cruz, California 95060

Phone: (831) 420-3968
Fax: (831) 420-3980
Email: arnold.ammann@noaa.gov

EDUCATION:

2001	Master of Arts Biology	University of California Santa Cruz
1994	Batchelor of Arts Aquatic Biology	University of California Santa Barbara
1991	Associate of Arts degree	Fresno City College, CA

EXPERIENCE:

2002-present *Research Fishery Biologist,* NOAA-NMFS Santa Cruz CA, Salmon Ecology Team

2002 (Sept) *Field Biologist,* NOAA-NMFS Santa Cruz CA, Salmon Ecology Team

2002 (July-Nov) *Post-graduate researcher*, UCSC Santa Cruz CA, Marine ecology research – PISCO

2002 (May-June) *Research Technician,* NOAA-NMFS Santa Cruz CA, Juvenile rockfish survey

2002 (Jan-April) *Research Technician*, Moss Landing Marine Laboratories, Harbor seal predation study

2001 (June-Sept) *Research Biologist,* NOAA-NMFS Santa Cruz CA, Habitat Ecology Team

1998 to 2001 *Graduate student researcher, Master's program,* UCSC – Biology Dept.
Advisor: Dr. Mark H. Carr

TITLE OF MASTER'S THESIS:

Evaluation of Standard Monitoring Units for the Recruitment of Fishes

RESEARCH INTERESTS:

Physiological ecology of salmon and steelhead. Movement and survival of juvenile chinook salmon and steelhead trout. Relationships between marine fish population dynamics and oceanography.

GRANTS AND AWARDS:

Survival and migratory patterns of Central Valley juvenile salmonids. 2006-09.
CALFED Science Program. $1.5M. (Co-PI).

Friends of the Long Marine Laboratory Award 2000 and 2001

Myers Oceanography and Marine Biology Trust Award 1999

SELECTED PUBLICATIONS:

Perry, R. W., Skalski, J. R., Brandes, P. L., Sandstrom, P. T., Klimley, A. P., Ammann, A., & MacFarlane, B. 2010 Estimating Survival and Migration Route Probabilities of Juvenile Chinook Salmon in the Sacramento-San Joaquin River Delta. North American Journal of Fisheries Management 30, 142-156.

Fisher, J., M. Trudel, A. Ammann, J. A. Orsi, J. Piccolo, C. Bucher, E. Casillas, J. A. Harding, B. MacFarlane, R. Brodeur, J.F.T. Morris, and D. W. Welch. "Comparisons of the coastal distributions and abundances of juvenile Pacific salmon from central California to the northern Gulf of Alaska," American Fisheries Society Symposium, v.57, 2007, p. 31.

Hayes, S.A., Bond, M.H., Hanson, C.V., Freund, E.V., Smith, J.J., Anderson, E.C., Ammann A.J., & MacFarlane R.B. 2008. Steelhead growth in a small central California watershed: Upstream and estuarine rearing patterns. Transactions of the American Fisheries Society 137(1):114-128.

Ammann, A.J. 2004 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. 1999. In: *Ecological role of natural reefs and oil and gas 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

Joseph Merz, Ph.D.,
Principal Scientist/Restoration Ecologist – Cramer Fish Sciences

Introduction

During his career, Dr. Joseph Merz has worked for city, university, and state entities in California as a fisheries biologist consistently involved with studies to monitor fish populations and enhance their habitat. He has also worked as an environmental studies lecturer for California State University (Sacramento), where he has helped students obtain over $200,000 in project funds, and as a natural resources lecturer at the University of California (Davis Extension). Joe teaches professional courses in salmonid ecology, habitat restoration and fish passage.

Dr. Merz has coauthored a variety of peer-reviewed publications, focusing on river rehabilitation, fish movement, invasive species, woody debris/redd associations, and evaluation of spawning habitat enhancement. Personally, he has been honored with multiple awards and scholarships for his performance, and has initiated numerous interagency and multidisciplinary research and restoration grants totaling over US $5 million for California restoration projects. He is noted for presentations on human and habitat interactions to professional and lay organizations. He is a member of American Fisheries Society and the Southwestern Association of Naturalists.

General Qualifications

Joe has monitored benthic macroinvertebrate and fish communities throughout California and the West Coast. Joe has extensive experience with terrestrial monitoring including mammalian, ornithological, herpetological and botanical surveys. Joe has performed numerous assessments of habitat manipulation on aquatic resources. These include habitat enhancement, flow manipulation, invasive species, and regulation implementation. He has used a variety of monitoring equipment in the assessment of fisheries resources over the past 19 years including, back-pack and boat electrofishing, seining, trawling, hook and line, aerial photogrammetry, and video monitoring. He has extensive experience with gastric levage and fish diet analysis. Joe has installed monitoring stations for PIT tag arrays, video fish surveillance, and rotary screw trapping; used salmonid embryo survival assessment equipment; and established habitat quality monitoring sites to measure hyporheic water quality, and remote water quality monitoring stations to measure temperature, dissolved oxygen, and turbidity. He has also installed other fish traps, including incline planes, fykes, adult weirs, and minnow traps. He has designed and implemented fish trapping projects, video monitoring equipment, and passive monitoring stations, and has experience with video, motion sensor, and sonar technologies, in addition to acoustic and radio telemetry methodologies. Joe has extensive experience with habitat typing and delineation with the use of GIS and aerial maps. One of Joe's unique strengths is his public outreach skills and ability to collaborate with a variety of constituents. For example, he taught at university and public education levels, worked with federal and state representatives, and partnered with local entities (i.e., outreach groups, planners, volunteer organizations, etc.). Joe has prepared NEPA, EIR, EIS, CEQA, and ESA assessments, reports, and documents. In addition, Joe has designed a web page for a utility district fisheries and wildlife office and built his own university web page. He also has primary Visual Basic 6 skills with Access code writing. Joe designed the gravel enhancement and fish community database for a major California utility district, and has significant experience analyzing data including fish community surveys, benthic macroinvertebrate data, fish diet analysis, habitat monitoring, and fish migration monitoring.

Education and Training

Ph.D. Conservation Ecology. University of California, Davis. 2004.
M.S. Biological Conservation. California State University Sacramento. 1994.
Cal Poly San Luis Obispo, CA. B.S. Environmental and Systematic Biology. 1991.

Certification

USFWS - Principles & Techniques of Electrofishing
California Department of Transportation – Commercial Drivers License
California Boating and Waterways Boater Safety Training
Emergency Medical Technician Certification

Employment History

Principal Scientist, Cramer Fish Sciences. 2007–present.
Research Associate, UC Santa Cruz, Institute of Marine Sciences. 2008–present.
Fisheries Biologist II, East Bay Municipal Utility District. 1996–2007.
Lecturer, Environmental Studies, California State University, Sacramento. 2001–2007.
Lecturer, Natural Resources, University of California, Davis Extension. 2000–present.
Lecturer, Northwest Environmental Training Center, Seattle, Washington, 2008–present
Aquatic Ecologist, ENTRIX INC. 1993–1996.
Contract Biologist, California Department of Fish and Game. 1991–1994.
Firefighter/Engineer California Department of Forestry and Fire Protection. 1989–1991.

HONORS AND AWARDS

Editor's Choice- *Science* Magazine
Theodore Roosevelt Environmental Excellence Award – Team member
Environmental Excellence, East Bay Municipal Utility District
Outstanding Performer, East Bay Municipal Utility District
State Merit Award, California Department of Forestry and Fire Protection
Sacramento Safari Club Scholarship in Biology
Stockton Sportmen's Club Annual Scholarship Award

Selected Peer-Reviewed Publications

Elkins, E.M., G.B. Pasternack, and J.E. Merz. 2007. Use of slope creation for rehabilitating incised, regulated, gravel bed rivers. Water Resources Research.

Jeffres, C. A., A. P. Klimley, J. E. Merz and J. J. Cech Jr. 2006. Movement of Sacramento sucker, *Catostomus occidentalis*, and hitch, *Lavinia exilicauda*, during a spring release of water from Camanche Dam in the Mokelumne River, California. Environmental Biology of Fishes 75:365-373.

Merz, J.E., and P. B. Moyle. 2006. Salmon, wildlife, and wine: Marine-derived nutrients in human dominated ecosystems of Central California. Ecological Applications 16(3):999-1009.

Merz, J.E., J.R. Smith, M.L. Workman, J.D. Setka, and B. Mulchaey. 2008. Invasive aquatic macrophyte assessment within a salmon spawning reach of a regulated California stream. North American Journal of Fisheries Management.

Merz, J.E. 2001. Association of fall-run Chinook salmon redds and woody debris in the lower Mokelumne River, California. California Fish and Game 87(2):51-60.
Merz, J.E., and L.K. Chan. 2005. Effects of gravel augmentation on macroinvertebrate assemblages in a regulated California river. River Research and Applications 21:61-74.
Merz, J.E., and W.R. Merz. 2004. Morphological features used to identify Chinook salmon sex during fish passage. Southwestern Naturalist 49(2): 1-12.
Merz, J.E., G.B. Pasternack and J.M. Wheaton. 2006. Sediment budget for salmonid spawning habitat rehabilitation in a regulated river. Geomorphology 76:207-228.
Merz, J.E., and J. D. Setka. 2004. Evaluation of a spawning habitat enhancement site for Chinook salmon in a regulated California river. North American Journal of Fisheries Management 24:397-407.
Merz, J.E., J. D. Setka, G.B. Pasternack and J.M. Wheaton. 2004. Predicting benefits of spawning habitat rehabilitation to salmonid (*Oncorhynchus spp*.) fry production in a regulated California river. Canadian Journal of Fisheries and Aquatic Sciences. 24:397–407.
Merz, J.E. 2002. Seasonal feeding habits of steelhead trout in the lower Mokelumne River, California. California Fish and Game 88(3) 95-111.
Merz, J.E. 2002. Comparison of prickly sculpin and juvenile fall-run Chinook salmon diets in the lower Mokelumne River, California. Southwestern Naturalist 47(2):195-204.
Merz, J.E. 2001. Association of fall-run chinook salmon redds and woody debris in the lower Mokelumne River, California. California Fish and Game 87(2):1-15.
Merz, J.E. 2001. Diet of juvenile fall-run Chinook salmon in the lower Mokelumne River, California. California Fish and Game 87(3):11-26.
Merz, J.E., and C. D. Vanicek. 1996. Comparative feeding habits of juvenile Chinook salmon, steelhead, and Sacramento squawfish in the lower American River, California. California Fish and Game 82(4):149-159.Wheaton, J.M., G. B. Pasternack and J. E. Merz. 2004. Spawning habitat rehabilitation – I. Conceptual approach and methods. International Journal of River Basin Management 2(1):3–20.
Merz, J.E., J.R. Smith, M.L. Workman, J.D. Setka, and B. Mulchaey. 2008. Aquatic Macrophyte Encroachment in Chinook Salmon Spawning Beds: Lessons Learned from Gravel Enhancement Monitoring in the Lower Mokelumne River, California. North American Journal of Fisheries Management 28:In Press.
Satterthwaite, W. H., Beakes, M.P., Collins, E., Swank, D.R., Merz, J.E., Titus, R.G., Sogard, S.M., Mangel, M. 2009. Steelhead life history on California's central coast: insights from a state dependent model. Transactions of the American Fisheries Society, in press.
Sawyer, A. M., Pasternack, G. B., Merz, J. E., Escobar, M., Senter, A. E. 2008. Construction constraints on geomorphic-unit rehabilitation on regulated gravel-bed rivers. River Research and Applications. DOI: 10.1002/rra.1173.
Wheaton, J.M., G. B. Pasternack and J. E. Merz. 2004. Spawning habitat rehabilitation – II. Using hypothesis development and testing in design, Mokelumne River, California, U.S.A. International Journal of River Basin Management 2(1):21-37.
Wheaton, J.M., G. B. Pasternack, and J. E. Merz. 2004. Including Habitat Heterogeneity In Salmonid Spawning Habitat Rehabilitation Design. In: Fifth International Symposium on Ecohydraulics in Madrid, September 12-17, 2004.
Workman, M.L. and J.E. Merz. Introduced Yellowfin Goby, *Acanthogobius flavimanus*: Diet and Habitat Use in the Lower Mokelumne River, California. San Francisco Estuary and Watershed Science. Vol. 5, Issue 1 February 2007. Article 1.

Distributed Reports (Partial List)

Heady, W., and J.E. Merz. 2007. Lower Mokelumne River salmonid rearing habitat restoration project – Summary Report. Prepared for: CVPIA Anadromous Fish Restoration Program, Lodi, California.

Merz, J.E. 2001. Draft biological assessment of Murphy Creek aquatic resources – Dam removal assessment. Prepared for: CVPIA Anadromous Fish Restoration Program, Stockton, California.

Merz, J.E. and M.S. Saldate. 2005. Lower Mokelumne River Fish Community Survey. 1 January 1997 Through 30 June 2004. Mimeo Report. East Bay Municipal Utility District, 1 Winemasters Way Suite K2, Lodi, CA 95240

Merz, J.E., and J.D. Setka. 2004. Riverine habitat characterization of the lower Mokelumne River, California. Mimeo Report to the Federal Energy Regulatory Commission . East Bay Municipal Utility District, 1 Winemasters Way Suite K2, Lodi, CA 95240

Invited Seminars, Panels and Presentations (Partial List)

California Ocean Protection Council, Half Moon Bay, California 2008
Panel Discussion: Closure of the California Salmon Fishery

Ecology and Evolutionary Biology Seminar, University of California, Santa Cruz 2007
A Non-Conventional Valuation of a Keystone Species

Biology Seminar Series, California State University, Sacramento 2006
Salmon, Wildlife and Wine: Role and Management of Salmon in Human Dominated Ecosystems of California

California Urban Water Association 2005
Removal of a Water Impoundment on Murphy Creek, California

Salmonid Restoration Federation 2004
Effects of a Controlled Flood Release on Rooted Aquatic Vegetation

Robert Edmund Null

15590 Jellys Ferry Road, Red Bluff, California 96080 ▫ Cell (530) 526-3508 ▫ Work (530) 527-3043

EDUCATION

B.S., 1996 California State University, Chico, California
Major: Biological Sciences

WORK HISTORY

2001 – Present	**Supervisory Fish Biologist** U.S. Fish and Wildlife Service Red Bluff Fish and Wildlife Office Red Bluff, California
2000 - 2001	**Biologist (Marine/Fisheries)** California Department of Fish and Game Trinity River Restoration Project Weaverville, California.
1998 - 2000	**Fishery Biologist** U.S. Fish and Wildlife Service Red Bluff Fish and Wildlife Office Red Bluff, California
1997 - 1998	**Biological Science Technician,** Glenn-Colusa Irrigation District Hamilton City, California.
1995 - 1998	**Scientific Aide** California Department of Fish and Game Hamilton City, California.

Cyril Joseph Michel

cyriljmichel@gmail.com

D.O.B: December 6th, 1984
Nationality: American

Current address:
121 James St
Santa Cruz, CA 95062

Permanent address:
821 Chemin des Brusquets
Vallauris, France 06220

Phone: (831) 419-1061

Education:
-B.S. Marine Biology, GPA: 3.42 (August 2006). University of California-Santa Cruz.
-M.A. Ecology and Evolutionary Biology (*in progress, expected graduation September 2010*). University of California-Santa Cruz.

Research Interests:
Ichthyology, predator-prey dynamics in rivers, fisheries ecology, conservation and management. Particular interest in anadromous species such as salmonids or striped bass.

Honors/Awards:
-Named to the Dean's List at UC Santa Cruz, Fall 2003
-Friends of the Long Marine Laboratory Award in 2008
-Dr Earl H. Myers and Ethel M. Myers Oceanographic and Marine
-Biology Trust in 2008
-VEMCO VR100 student award

Research/Field Experience:
Fall 2006 to present: Experience acoustically tagging and tracking juvenile Chinook salmon and steelhead as part of a CALFED funded Sacramento River salmonid movement and mortality study. I have worked on this project as a research assistant initially, and now as a graduate student researcher. Different skills that I have acquired throught this project included, but are not limited to: surgical tagging of fish, acoustic monitor deployment, boat operating, data quality control, database management, telemetry data analysis and use of Program MARK and ArcGIS.

Spring 2006: Field experience for a 3 month long independent research project in which the spatial distribution of signal crawfish (*Pacifastacus lenuisculus*) in different flow rates was studied in the Scott Creek watershed. This was done by using a mark-and-recapture method and crawfish traps.

Winter 2005 to Fall 2006: Experience and backround knowledge on all of the following Salmonid research methods: adult fish weirs, salmonid anethesizing, salmonid PIT tagging and FLOY tagging, PIT tag reader technology, DNA and scale sampling, scale mounting, otolith sampling, smolt trapping (including purse seins, fyke nets and inclined plane traps), species and gender identification (as well as spawning stage), electro-fishing, temp logger/acoustic tag surgical implantations/fish suturing, and Palm pilot data entry. I am also experienced with methods for testing water characteristics such as salinity, turbidity and flow rate. Work done for Sean Hayes up until September, then for Arnold Ammann and the Salmon Ecology Team (NOAA's NMFS).

Employment:
March 2006-September 2006: Field and Lab Assistant for NOAA-NMFS for the Scott Creek salmon ecology team under the supervision of Sean Hayes.

September 2006-August 2007: Research Assistant for NOAA-NMFS for the CALFED project monitoring juvenile migration of steelhead and late-fall run Chinook salmon through the Sacramento River and through the bay using acoustic tag technology.

September 2007-present: Graduate Student Researcher at University of California – Santa Cruz, working in conjunction with NOAA-NMFS's CALFED project, monitoring juvenile migration of steelhead and late-fall run Chinook salmon through the Sacramento River and through the bay using acoustic tag technology.

Teaching Experience:
Teaching Assitant for Biol 107: Ecology, an upper division undergraduate course at University of California-Santa Cruz. Spring 2009.

First-Author Poster Presentations:
Michel, C.J., Ammann, A.J., Sandstrom, P.T., Chapman, E.D., Lindley, S.T., Klimley, A.P. and MacFarlane, R.B. 2007. "Acoustically monitored movement patterns of juvenile Chinook salmon (*Oncorhynchus tschawytscha*) from the Sacramento river watershed during a low flow year" *8th Biennial State of the Estuary Conference*, Oakland, CA.

First-Author Oral Presentations:

Michel, C.J., Ammann, A.J., Sandstrom, P.T., Chapman, E.D., Lindley, S.T., Klimley, A.P. and MacFarlane, R.B. 2010. "Movement and mortality patterns of Central Valley juvenile late-fall run Chinook salmon (*Oncorhynchus tshawytscha*) and the environmental factors that shape them", *1st Electronic Tagging Studies of Salmon Migration Conference,* Bodega Bay, CA.

Michel, C.J., Ammann, A.J., Sandstrom, P.T., Chapman, E.D., Lindley, S.T., Klimley, A.P. and MacFarlane, R.B. 2009. "Movement and mortality patterns of Central Valley juvenile late-fall run Chinook salmon (*Oncorhynchus tshawytscha*) and the environmental factors that shape them", *94th Ecological Society of America Annual Meeting*, Albuquerque, NM.

Michel, C.J., Ammann, A.J., Sandstrom, P.T., Chapman, E.D., Lindley, S.T., Klimley, A.P. and MacFarlane, R.B. 2009. "Movement and mortality patterns of Central Valley juvenile late-fall run Chinook salmon (*Oncorhynchus tshawytscha*) and the environmental factors that shape them", *7th Annual Fisheries and Marine Ecosystems Meeting*, Surrey, BC, Canada.

Michel, C.J., Ammann, A.J., Sandstrom, P.T., Chapman, E.D., Lindley, S.T., Klimley, A.P. and MacFarlane, R.B. 2008. "A high-resolution account of the survival and movement rates of acoustically tagged juvenile Chinook salmon (*Oncorhynchus tshawytscha*) during the 2007 and 2008 season", *5th Biennial CALFED Science Conference*, Sacramento, CA.

Unpublished Manuscripts

Michel, C.J., Ammann, A.J., Sandstrom, P.T., Chapman, E.D., Lindley, S.T., Klimley, A.P. and MacFarlane, R.B. *In prep.* The environmental factors that influence mortality of Sacramento River yearling Chinook salmon (*Oncorhynchus tshawytscha*).

Michel, C.J., Ammann, A.J., Sandstrom, P.T., Chapman, E.D., Lindley, S.T., Klimley, A.P. and MacFarlane, R.B. *In prep.* Migration through a changing landscape: Sacramento River yearling Chinook salmon movement (*Oncorhynchus tshawytscha*) and the environment.

Michel, C.J and Singer, G.S. 2006. Distribution of signal crawfish (*Pacifastacus lenuisculus*) according to water flow rate in a small coastal stream. *unpublished manuscript*.

Certifications:
California Department of Boating safety course (01/31/06)
NOAA Small Boats Operator training (in process)
American Red Cross First Aid
American Safety and Health Institute Adult CPR
<u>SCUBA:</u>
NAUI Basic open water certified (12/3/04)
NAUI Advanced open water certified (3/05)
NAUI Rescue Diver certified (5/05)
NAUI Oxygen Administrater certified (5/05)
NAUI Training Assistant certified (5/05)

Languages:
English: fluent
French: fluent (mother-tongue)
Spanish: beginner

Computer Experience:
ESRI ArcGIS 9, Program MARK, Microsoft SQL server 2005, Microsoft Office (including Excel, Access, Word, Powerpoint), Macromedia Dreamweaver 2004, Cranes Systat, R, and USACE's HEC-RAS.

Delta Science Program
2010 Proposal Solicitation Package
Review Compilation

Proposal # 132

Survival and Migratory Patterns of Juvenile Spring and Fall Run Chinook Salmon in Sacramento River and Delta

Delta Science Program
2010 PSP Final Review Panel Meeting
January 19-20, 2011

2010 Final Review Panel – Summary of Review

Proposal # 132

Proposal Title: Survival and Migratory Patterns of Juvenile Spring and Fall Run Chinook Salmon in Sacramento River and Delta

Lead Primary Investigator: Abbott (Peter) Klimley

Applicant Organization: University of California, Davis

Amount Requested: $1,746,955

Panel Findings:

Relevance to Topic Areas: The proposed research is highly relevant to the PSP and to the ongoing issues about Chinook salmon outmigration. The proposal relates directly to Topic 1: Native Fish Biology and Ecology.

Quality of the Proposed Research: The proposed research has the ingredients for generating very useful information on reach-specific survival of juvenile salmon, and detailed information on their passage through the key Delta region. The quality and usefulness of the data from the project depends on many, high-risk steps going perfectly, and thus something or several things will likely not go as planned. Tags may have larger effects on small fish than expected, environmental conditions may not create sufficient contrast for inference of effects, and receivers can malfunction or have low detection rates. Yet, this type of reach-specific survival rates are critical information for better understanding the population dynamics of Chinook.

Main Summary Comments of Reviewers: There are many issues with the proposal, but these can be addressed with additional information and revised sampling methods. These issues should be addressed before the project proceeds. These issues relate primarily to the approach and the specification of methods to be used. The Panel identified the following major issues: 1) confirm the actual availability of tags and receivers to be purchased, 2) examine the optimal number of receivers and their placement, 3) examine the data quality and costs tradeoffs between the number of tags and the number of receivers, 4) examine the tagging and release design to ensure convincing results are obtained, and 4) detail plans for assessing tag effects on fish of the small size, as this is at the limit before tagging effects become too important. The investigators should also explain in more detail how environmental variables will be incorporated into the analysis of reach-specific survival.

This is a large, complex and expensive proposal that can generate potentially critical information. Therefore, to ensure the project's deliverables can withstand critical review, a revised proposal should: 1) include provisions for setting up a scientific advisory panel, 2) include a section that discusses lessons learned from the prior telemetry study, 3) discuss foreseeable constraints and identify potential pitfalls and contingency plans in case the research does not progress as planned, and 4) plan to mesh this study with Hilborn's study (Proposal 066) should both proposals be funded.

Funding Category: Above Average/Sufficient

External Technical Reviews

Proposal 0132: Review 1

Proposal Title: SURVIVAL AND MIGRATORY PATTERNS OF JUVENILE SPRING AND FALL RUN CHINOOK SALMON IN SACRAMENTO RIVER AND DELTA

Proposal Number: 0132

Proposal Applicant: University of California, Davis

Project

comments	The proposal does a fair job of explaining the context of the problem and how the proposed project may help address the problem. However, detail is lacking and generalizations are made that hurt the overall quality of the proposal and make it difficult to assess whether it will be able to address the hypotheses. The project appears to be well set-up to achieve the stated objectives, but these are not research objectives, they are merely methods objectives. Section I.B. should present the research objectives. The proposal instead lists methods as objectives (e.g., establish a net work of receivers or tag four groups...). These are not research objectives. Section I.C. lists hypotheses to be tested but these are vague. For example, the first hypothesis states that tagged fish experience significant mortality but the measure of significance is not given here or in the approach for this task. The second hypothesis states that mortality rates will vary. Is this really a worthwhile and testable hypothesis? The final hypothesis states that mortality rates and variability in movement 'patterns' (which is really a second hypothesis and not well-defined) will be higher when gates are open (it should add 'than when DCC gates are closed' for clarity). Again, the level of the difference (significance level) should be included here or at least in the detailed approach.
rating	Sufficient

Background

comments	The background section is fairly well-developed and presented. However, there are problems with the discussion of tag burden and tagging effects. The proposal seems to select a tag burden of 8% as acceptable for the work proposed. This value is then later called into question when the proposal discusses work that has been conducted in the Columbia River basin (on page 11 of the proposal). The proposal cites a paper by Ammann et al. as in prep - so it is not available for review. This reference should be eliminated until that work is available. Further, the proposal states that one of the study team (Merz) has implanted JSATS tags into 85 mm smolts, as apparent justification that this has no detrimental effects on the tagged fish (page 6). Just because a tag can be 'successfully' placed inside a fish, does not mean there will be no tagging effect on that fish. Later in the proposal, it states that correction factors will be developed based on tagging effects measured in laboratory experiments (page

	15). This is problematic as lab studies may provide insight into relative degrees and types of tagging-related effects, but the results will likely not be directly transferable to field data. Therefore, the basis for the 8% body burden used throughout the proposal is called into question. The proposal also mentions that Lotek will have a 0.30 g tag available prior to the initiation of this study, however the proposal is not clear on whether this smaller tag would be used for some or all of the tasks. If the smaller tag is used and it follows the specifications listed on page 6 of the proposal (0.30 g, 150 dB, and 15 s pulse rate), then the performance of the tag will be much reduced over the JSATS tag that has been used in recent Columbia River studies (0.43 g, 156 dB, 3 to 5 s pulse rate). The source level (dB) and pulse rate relate directly to effective range, with the 156 dB signal having about double the range of the 150 dB signal. If the proposed project uses the 150 dB/15 s PRI tag, the receivers will need to be placed closer together and in areas of slower water than has typically been the case in Columbia River studies mentioned in this proposal. The example of pulse rates and detection distances at the end of the first full paragraph at the top of page 7 should be recalculated based on more realistic ranges with the smaller tag and with the PRI that is proposed for use in this study (15 s...?). The proposal does not explain the receiver spacing or expected range. Further, the availability of the small tags and the Lotek receivers is stated as 'available in early fall of 2010'. This should be confirmed prior to funding, as it is typical for many telemetry vendors to promise a product of certain specifications by a certain date or at a certain price (e.g., 2000 to 2500/receiver) and then not deliver on time or at the same price. This could have major implications for the project schedule and budget, as well as the size of fish which might be able to be tagged. The conceptual model of the study is good, but no basis is given for the sample sizes selected (apart from saying that Perry released about the same number for one small task (DCC on vs DCC off). A power analysis with expected detection probabilities, a range of sample sizes and expected precision levels should be presented to show what the expected error will be for the various tasks.
rating	Sufficient

Approach

comments	It is difficult to tell exactly what will be done to address each specific task. The maps in Figure 4 are not legible. It is unclear why funding was requested for only 22 receivers, when 28 are needed. Does this 28 include any spares in the event receivers are lost or damaged? Will pre-, in-, and post-season testing be performed on each receiver to document effectiveness? There is no real mention of any QA/QC approaches throughout the proposal (for equipment or data processing/analyses). There is no mention of any tag life tests to provide a data set for tag-life

	corrections. Table 1 on page 11 is a very good table. However, as stated earlier, the proposal selects a tag burden in the 8% range and justifies that, in part, on the statement that Brown et al. (cited as in press - but it has now been published) found a threshold of significant tagging effects over 7.6%, when in fact that threshold in the published paper is somewhere below 6.7% (see Brown et al. 2010, NAJFM 30:499-505). In that study, the survival and growth of juvenile fall Chinook salmon was significantly lower over the 30 d study period for fish in the 80-89 mm size range. Based on this, it is unlikely that there would be no tagging effects on the size of fish the proposal promises to tag (e.g., page 10; 'maybe even 75 mm....'). Further, the proposal cites work by Welch et al. (2008), stating that they tagged fish with an average burden of 9.3%. Just because others have done it - does not justify doing it. The proposal goes on to recap some of the findings from the Columbia Basin tagging effects research (bottom of page 11) - which showed that tag burdens as low as 5% may have detrimental effects on post-release performance. The proposal then states that it will conduct studies of the effect of JSATS implantation. As stated earlier in this review, the proposal is not clear on exactly what these studies will entail, or how they will apply a 'correction factor' to the field data. At the top of page 12, the proposal discusses that the work would only be able to tag the largest 25% of the fall-run juveniles (and this is using the poorly justified 8% burden level). This would clearly not be representative of that population, thus any results from those groups of fish would be of questionable value in terms of absolute indicators of performance. This may however provide some insight into how the largest of these fish may perform. In Task 7, the proposal is overly simplistic in its approach to the management application of the study results (e.g., page 15, 'can be subsequently afforded protection to increase survival'). In general, the proposal leaves the reader with the feeling that it will demonstrate cause and effect relationships, when in reality it is more likely that it will simply demonstrate relationships (even though it is possible they would be spurious). Finally, as previously stated, the description of the lab studies and how results from these may be applied to the field data is very weak.
rating	Inadequate

Feasibility

comments	Apart from the problems listed above, the approach appears feasible in terms of the experience and qualifications of the study team. One cause for concern is the reliance on equipment that is not yet available (the Lotek equipment listed on page 6). If Lotek is unable to deliver on these promises prior to the start of the research, suitable replacements would have to found. This may have budget and schedule implications as well, as currently available receivers are substantially more expensive

	than those proposed for procurement under this proposal.
rating	Sufficient

Relevance To The Delta Science Program

comments	The work proposed, if the study design deficiencies are addressed and the frame of inference is suitable (e.g., to the largest 25% of the fall run), then this work would appear to address priority research needs in the DSP quite well.
rating	Above Average

Qualifications

comments	The track record of the study team appears to qualify them well to succeed in the proposed project if the study design and approach problems are adequately addressed.
rating	Above Average

Overall Evaluation Summary Rating

comments	If the proposed study is modified to address the concerns, primarily around the availability of the equipment specified, the size of the fish to be tagged, the sample sizes, and the frame of inference, then this would appear to be a worthwhile study.
rating	Sufficient

Proposal 0132: Review 2

Proposal Title: SURVIVAL AND MIGRATORY PATTERNS OF JUVENILE SPRING AND FALL RUN CHINOOK SALMON IN SACRAMENTO RIVER AND DELTA

Proposal Number: 0132

Proposal Applicant: University of California, Davis

Project

comments	Goals, objectives, and hypotheses are clearly stated, and this idea is timely and important. The Juvenile Acoustic Telemetry System (JSATS) is the best choice of equipment for conducting a survival study on small juvenile salmonids because of miniaturization of tags and phase-shift key encoding which will reduce data-processing costs and increase detectability. The scope of proposed receiver deployment is justified and necessary to obtain the survival information desired. There is a possibility that the number of receivers requested may not be sufficient to populate survival detection arrays to adequate densities, but information on receive spacing within arrays is not sufficient for me to tell. Also, the authors need to be certain that the number of tagged fish will deliver the precision in survival estimates that they may require. Receiver spacing and sample size requirements are discussed in more detail below. Results should add substantially to the knowledge base because smaller tags can be successfully implanted in a greater proportion of each population without introducing tag effects that could bias behavior, travel time, and survival estimates.
rating	Superior

Background

comments	The conceptual model is clearly stated and sufficient to understand the proposed research. The authors added considerable detail describing the JSATS relative to other acoustic telemetry systems.
rating	Above Average

Approach

comments	The proposed team of scientists appears to be well qualified to conduct the research, and the team draws on multidisciplinary talents from many institutions. Most of the described infrastructure appears to be sufficient to accomplish the proposed research. Management, administration, and resources are clearly defined. The research will deliver valuable products, particularly if the issues raised below are considered and addressed. The plan for dissemination of results seems to be well thought out, and data produced by this effort will lay the

	groundwork for building larger more comprehensive databases in the future.
rating	Above Average

Feasibility

comments	The approach is fully documented and technically feasible. Studies like this have been conducted on the Columbia River for several years now. I am slightly concerned that proposed sample sizes of tagged fish and the number of requested JSATS receivers may not be sufficient to provide enough precision for reach survival estimates, but I would need more information to be certain. The number of fish tagged and released and detection probabilities for each reach will affect the precision of survival estimates and also the power of statistical tests to detect differences in survival among river reaches. This is a good proposal, and I recommend funding it after careful consideration of the density of receiver deployments at each cross section, and after setting those receiver densities high enough to maximize tag detection probabilities. The authors also might want to consider whether more tags might be needed to obtain desired precision in survival estimates after receiver densities are increased to provide >95% detection probabilities at each array. The reason for this is that you have to add a lot of tags to increase survival precision if array detection probabilities are not high. I recommend that the authors download a sample size program and manual from http://www.cbr.washington.edu/paramest/samplesize/ to help them address these considerations. Conducting study on two groups of fish instead of four would allow the researchers to double sample sizes without increasing the proposed budget. Receiver numbers, spacing, and allocation among arrays: The proposal mentions a decode range of 300 m, but this may be overly optimistic especially in noisy areas with high flow, and I could not find a description of receiver spacing at each sampled cross section. In dam-passage survival studies on the lower Columbia River from 2006 through 2009, JSATS receivers were deployed •152 m apart and •76 m from shore at each cross section. With this receiver spacing, tag detection probabilities for arrays covering deep cross sections upstream of Bonneville Dam usually were >95%, but for shallower cross sections downstream of Bonneville Dam, detection probabilities were between 60% and 80%. Flows through these cross sections ranged from 1 to 2 m / s and the pulse repetition rate of tags was 3 pings per second. Reducing the distance between adjacent receivers in two arrays downstream of Bonneville Dam in 2010 from •152 m to about 100 m increased tag detection probabilities to 95%. Spacing acoustic receivers 200-300 m apart likely will yield poor tag

detectability. Given the relative cost of tags and receivers and how many additional tags have to be added to increase precision, it makes sense to deploy enough receivers at each cross section to maximize detectability before adding tags. I think that populating each array adequately should be the first consideration. Next, the researchers can determine the number of arrays that can be deployed given the number of available receivers and then either propose to add more receivers or to reduce the number of receiver arrays (and river reaches studied) accordingly.

After receiver densities are adequate, consider sample sizes of tagged fish:

I ran two scenarios through the sample size program described above. In the first run, I assumed that the number of released tags ranged from about 150 to 300 (i.e., from the minimum number proposed to double that number). In addition, I assumed that the detection probability at the first array was 0.6, which may be optimistic for JSATS nodes spaced 300 m apart or 150 m from shore. An output figure, which cannot be pasted here, showed the ½ 95% confidence interval (CI) curves as a function of sample size. The ½ 95% CIs on survival estimates would be about 7.37% if samples size was 150 fish and 5.83% if samples size was 300 fish. In short, survival estimates would have to differ by at least 14.7% to detect significant differences between survival rates in two river reaches at n=150 and by about 11.7% if sample sizes were doubled (n=300).

The situation improves considerably if the detection probability of the primary array were increased to 0.95 by deploying receivers at distances of about 100 m from each other and 50 m from shore, especially for areas where the channel is shallow and has extensive sand bars that absorb sound transmissions from tags. Results of sample size modeling show that the ½ 95% CI would be about 5.1 when n=150 and 3.6, when n=300. Under these conditions, researchers will have a better chance of detecting survival differences >10.2% when n=150 or >7.2% when n=300.

Other considerations:

It may be in the best interest of the researchers to conduct a tag life study to ensure that the tags last as long as specified or assumed. Early failure of the tags can negatively bias the results of a survival study. This portion of the study could possibly be leveraged off of the tag retention, growth, survival, and swimming performance portion of the study, if active tags are implanted in the fish and monitored throughout the life of the tag. You need to know how long each tag keeps transmitting at the expect rate (e.g. 60.12 days), and it would be good to have at least 50 tags in the study.

	On p. 20-21, it is stated that "A post-processing program has been developed to eliminate false detections from these files. This consists of filtering criteria where detections must match a the list of tags released, the detection date and the release date, requires a minimum of four detections over an interval of 60 seconds, and match the time spacing between the intervals to the known tag pulse rate." With a 15 second ping rate interval, it is not wise to filter assuming that every ping would be detected. In noisy and high flow environments detection of all pings is not very likely. The choice of ping rate is a balance between detectability at survival-detection arrays and tag life. On the lower Columbia River, tag life settings started out at 10 pings / second, but ended up at 3 pings / second to improve detectability for estimating route-specific survival at dams. Experience will provide insight for identifying the optimum pulse repetition interval for the Sacramento River and Delta, but detectability will be important to precision in this study. The tight receiver spacing described above for the Columbia River that provided 95% detection probabilities also was for tags pinging once every 3 seconds. In the proposal, the authors appropriately expressed concern about detection ranges and the ability to detect slow pinging tags.
rating	Above Average

Relevance To The Delta Science Program

comments	The proposal does clearly and directly address priority research Topic 1. I cannot imagine protecting and recovering native fishes without high quality reach survival and travel time information that has inference for the smaller fish in those populations. Small acoustic tags like those proposed are absolutely critical to provide the proper inference for populations dominated by small individuals. This proposal gives a lot of attention to integration, collaboration and multiple disciplines. The information that can be provided by this proposal, even with possible precision deficiencies in survival estimates, is far better than Delta resource managers have had to work with so far. This proposal will allow tagging of runs of salmon that could not previously be tagged because of body burden considerations. I am certain that any information on survival and travel times for these runs will be welcome.
rating	Superior

Qualifications

comments	The project team is made up of highly experienced individuals that have demonstrated ability to implement a research study of this scope and technical complexity. Proposed infrastructure and

	support seems to be adequate. Again, I would like to see the authors revisit issues of acoustic receiver allocation and sample sizes relative to the precision of survival estimates, but these adjustments can be made without jeopardizing the project.
rating	Superior

Overall Evaluation Summary Rating

comments	To summarize, I believe that this proposal is superior and worthy of funding, but the authors should provide more detail describing the acoustic receiver locations, numbers, and densities. The researchers also should carefully consider whether expected precision will allow them to accomplish proposed objectives. Other concerns about filtering data, pulse repetition rates, and tag life (as mentioned earlier) should be addressed.
rating	Superior

Final Review Panel

Assigned Panelists Reviews

Proposal Number:	0132
Proposal Title:	SURVIVAL AND MIGRATORY PATTERNS OF JUVENILE SPRING AND FALL RUN CHINOOK SALMON IN SACRAMENTO RIVER AND DELTA
Proposal Applicant:	University of California, Davis
Amount Requested:	$1,746,955
Primary Investigator:	Abbott (Peter) P.. Klimley

FRP primary Reviewer's Evaluation Summary and Rating

Provide a brief explanation of your summary and rating.

Comments:

Purpose	Tag and track juvenile fall and spring run Chinook, both hatchery and wild, from their source points and compute reach-specific survival rates. In addition, tag and track fall and spring hatchery fish at the entrance to the Delta and compute survival rates with the DCC open and closed.
Background/Conceptual Models	The background is well described. Fall run Chinook drive the fishery; winter run are endangered; spring run are threatened. The decline in Fall run caused closure of the ocean fishery in 2008 and 2009. New technology allows for tagging (individually-coded ultrasonic tags) of smaller fish then in the past and the availability of low cost monitors. What was missing or not highlighted was the previous work on this topic. There was much debate over earlier tagging studies of salmon through the Delta, related to the VAMP. How this proposed study would address the issues with the earlier studies was not described.
Approach	Task 1 is management. Task 2 is to add 28 monitors to the existing array of about 300. Locations will include tributaries (Feather River below hatchery, mouths of Deer and Mill Creeks), and mainstem from Battle Creek to the head of the Delta. The authors do not present evidence that they have considered the trade-off between number of receivers and number of tagged fish. Task 3 is the actual tagging and releasing. The authors use earlier work to justify that these new tags will not affect such small fish. They are certainly at the lower limit of the size of fish that can be tagged. Some laboratory work tailored to this situation to determine any tag effects and assess tag performance is warranted. If people think the tag has effects, then

the rest of the entire study loses important credibility. The authors already are using hatchery fish for a significant portion of the releases. It is a little confusing to determine how many fish will be tagged by the authors and when they will be released. At one point, the authors examine the size distribution of released fish and say 200 tags, but then later say, for Fall run, they will tag 150 in an early April release and 150 in a late April release, as part of usual (CNFH) hatchery releases. A table showing the details of the fish tagging for each of the three years would clarify this. Task 4 is about the hatchery Spring run fish, and the authors will tag 200 with an early April release and 200 with a late April release (related to the Feather River Hatchery). Task 5 is the tag and release of the wild fall and spring run fish. They will tag 200 smolts caught at the Mill and Deer Creeks rotary screw traps between Oct and May, and use size and timing to assign them to a run. Fin clips will be taken but it was not clear if the genetic analysis was going to be done or might be done. Task 6 is the Delta study. Hatchery fall (75) and hatchery spring (75) will be released near Sacramento before the DCC closes and the same number just after the DCC closes, and followed within the Delta. Task 6 seemed to be a one-time release, which may not be very informative. Task 7 is the analysis. Mark-recapture modeling applied to the trajectories of individuals with explanatory variables (flow, temperature, turbidity, channel form, riparian cover, and timing of hatchery releases). They will also compute movement rates between monitors. Then Task 7 gets vague. The authors add "analysis of data in relation to site of water projects, diversions, by-passes." Yet, the relationship between survival and movement routes relative to water removals is of major management importance.

Feasibility

The project is doable, although before 1.7 million dollars is invested, the authors need to examine the trade-offs on costs and data quality between more receivers versus more tags. Also, some lab studies should be done to clearly show these tags can be used on small fish. Also, the analysis of the data needs to be better described, especially as it relate to testing of the hypotheses and determining the correlates to the difference in survival rates. The authors cite previous work on tagging but never directly address how their study will not have the same problems as earlier studies. If the study goes perfectly, the results have great potential for being extremely useful. In this type of study, many things can go wrong and even small problems can result in data that is not very useful.

Relevance

	The proposed study is highly relevant, but also has a high probability of something going wrong.
Qualifications	The authors are qualified to do the proposed work.
Summary Comments	The study is very much needed and the authors have presented a good approach. Given the high cost of the study and the likelihood that something will go wrong, perhaps a smaller version (one-year, two releases with Fall run hatchery fish) would be a more prudent approach. Also, before investing in monitors versus tags, the trade-offs should be examined to optimize the system for the long-term. Above average (higher if the authors show the monitor versus tag trade-offs, and do a scaled down version).

Please identify your overall ranking for this proposal:

- Superior
X Above Average
- Sufficient
- Inadequate

Proposal Number:	0132
Proposal Title:	SURVIVAL AND MIGRATORY PATTERNS OF JUVENILE SPRING AND FALL RUN CHINOOK SALMON IN SACRAMENTO RIVER AND DELTA
Proposal Applicant:	University of California, Davis
Amount Requested:	$1,746,955
Primary Investigator:	Abbott (Peter) P.. Klimley

FRP secondary Reviewer's Evaluation Summary and Rating

Provide a brief explanation of your summary and rating.

Comments:

Purpose	The purpose of this proposal is to augment knowledge of the migratory patterns and success of smaller CVC smolt by the use of minute transmitters. The goal is clearly stated and timely for this full-scale project; however, objectives and hypotheses need clarification. Objectives should focus of needed results: Establish a network of receivers capable of detecting movements of juvenile fishes through the system with high reliability; Tag sufficient numbers of juveniles to generate convincing estimates of reach-specific survival rates; and Conduct experiments to evaluate the efficacy of the DCC to enhance out-migration of juveniles. Hypotheses should also be recast in a testable form to reflect the objectives.
Background/Conceptual Models	The background information is generally adequate, but information on tag burden and effects, correction factors, laboratory experiments, and the field performance evaluations of the actual tag designs and receivers to be used is lacking or contradictory.
Approach	The approach is highly feasible and should accomplish the aims of the proposed study; however, the approach description is inadequate. Many faults were identified by both reviewers under their headings of Approach/Feasibility and should be addressed before funding. Most deal with the lack of details, contradictory or vague information, or no justification of receiver placement, tags settings and detection trade-offs, sample sizes, or statistical power.
Feasibility	The project is feasible if the new high tech JSTATS tools can be obtained in a timely manner and at the cost anticipated in the budget. This issue should be

	resolved before funding to ensure that the schedule can be met with the budget as allocated. The team clearly has the talent and the experience to pull the study off.
Relevance	The proposal is highly relevant to PSP topics related to Native Fish Biology and Ecology and the migration of fishes thru the SF estuary. It is also relevant to other DSP issues including Life Cycle Models and Population Biology of Key Species, Environmental Influences on Key Species, and Assessment and Monitoring. The proposal makes a strong case for relevance.
Qualifications	The team is highly qualified and experienced with telemetry and salmonids in the study area. Several members of the team are currently participating in a similar study on larger smolt in the system.
Summary Comments	There are many problems with the proposal that can be addressed and should be before funding is promised. These problems relate primarily to the approach and the specification of methods to be used. Two excellent reviews address the main points that should be dealt with in revising the proposal. These are at a minimum: 1) the actual availability of tags and receivers to be purchased, 2) the number of receivers and their placement, 3) the number of tags and the number of runs they will be used on to achieve convincing results, 4) details of plans to assess tag effects on fish size and other QA/QC questions.

Please identify your overall ranking for this proposal:

- \- Superior
- X Above Average
- \- Sufficient
- \- Inadequate

Proposal Number:	0132
Proposal Title:	SURVIVAL AND MIGRATORY PATTERNS OF JUVENILE SPRING AND FALL RUN CHINOOK SALMON IN SACRAMENTO RIVER AND DELTA
Proposal Applicant:	University of California, Davis
Amount Requested:	$1,746,955
Primary Investigator:	Abbott (Peter) P.. Klimley

FRP secondary Reviewer's Evaluation Summary and Rating

Provide a brief explanation of your summary and rating.

Comments:

Purpose	Identification of the problem, questions, critical unknowns - The problem is clearly identified. Chinook salmon runs are severely depleted and major knowledge gaps impede recovery efforts. Project goals and objectives - The goals and objectives are clearly identified. However, the objectives are more along the lines of research tasks than actual scientific objectives. Clearly stated hypothesis - The proposal clearly states three hypotheses. However, like the objectives, these don't really appear to be scientifically driven but more general hypotheses for a conceptual understanding of the salmon populations. Description of relevant studies - The authors included a short but dense description of relevant studies in the Bay-Delta and other systems.
Background/Conceptual Models	Conceptual model - A conceptual model of the influence of management on salmon populations and the study design are presented both in figures and in the narrative. The authors also provide a description of the decline of the salmon runs and the implications. The figures however are difficult to read. Physical setting - The specifics of the physical environment where the study will be conducted are not described in this section, nor is a map included.
Approach	Methods and techniques - In general, the proposed tasks are appropriate for meeting the project objectives. The authors go into great detail describing tagging procedures. The specific methods used in this study are outside of my technical expertise. However, one of the technical reviewers had serious misgivings about several of the technical aspects of the proposed work and he/she gave the approach a ranking of

	"insufficient". The second technical reviewer seemed to have more confidence in the approach but still raised concerns about spacing of receivers and required sample sizes to support statistical tests. Equipment and facilities - The authors clearly describe the equipment to be used in the proposed study along with the related studies that they are involved in. Data collection - Data collection and storage are clearly described. Statistical analysis and quality control - The authors provide details for how the data will be processed and how population data/survival will be investigated. However, it is not clear how or if the collected data will be used to test the research hypotheses. Scheduling - Scheduling is only included in the Task and Budget Summary. Deliverables - The deliverables are clearly described. Reasonableness of timeline - A timeline is not provided.
Feasibility	Foreseeable constraints - Constraints are not identified. Contingencies or requirements - Contingencies are not described. Project management coordination - Project management is not clearly outlined. Other comments - The feasibility of this project is argued through the experience and diversity of the research team. Although it is true that the research team has an impressive track record conducting similar studies, foreseeable constraints and contingencies should have been identified. For example, what happens if the smaller tags don't meet performance standards? Permitting also should have been discussed in the proposal.
Relevance	Relevance to this PSP - As correctly identified in the proposal, the proposed work directly addresses the needs state in the PSP, particularly priority topic #1. Relevance to the Delta Science Program - The authors also draw clear connections to how the proposed research addresses the broader needs of the Delta Science Program.
Qualifications	Experience and expertise of participants - The proposal team has extensive experience related to the proposed research and represents a diverse range of fields and institutions. The proposal text could have provided more insights into the experience of the team and their roles. Rather, the reader must dig through the extended attachments to find the relevant information. Further, the resumes were inconsistent and should have been abridged to highlight experience relative to this proposal. Individual roles and responsibilities - The individual roles and responsibilities for each of the project participants should have been made clearer in the body of the proposal. Tasks are associated with

various participants in the Task and Budget Summary form. Organizational structure - This also should have been clarified.

Summary Comments

This is a very interesting proposal which very clearly addresses the priorities raised in the PSP along with those of the Delta Science Program overall. The proposal is very well written and easy to follow. The authors make a compelling argument as to why the study is needed and the benefits that will arise from its results. The proposal team has the experience, skills, and diversity to suggest that they will be able to successfully complete the proposed work. The proposal had a few general shortcomings including: 1. One of the technical reviewers had serious concerns regarding the technical approach and the other technical reviewer mentioned several valid questions. 2. The objectives are really tasks and the hypotheses don't appear to be testable. Statistical methods for testing the hypotheses are not provided. 3. This is a very large project requesting substantial financial resources. However, the authors do not discuss foreseeable constraints or contingency plans if the study does not unfold as proposed. Although the researchers probably have the experience and wherewithal to overcome typical research setbacks, they should have included some discussion of potential pitfalls and contingency plans.

Please identify your overall ranking for this proposal:

- \- Superior
- X Above Average
- \- Sufficient
- \- Inadequate

UNIVERSITY OF CALIFORNIA, DAVIS

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO • SAN FRANCISCO SANTA BARBARA • SANTA CRUZ

DEPARTMENT OF WILDLIFE, FISH, AND CONSERVATION BIOLOGY
COLLEGE OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES
AGRICULTURAL EXPERIMENT STATION
COOPERATIVE EXTENSION
FAX: (530) 752-4154

ONE SHIELDS AVENUE
DAVIS, CALIFORNIA 95616-8751

28 February 2011

David S. Zezulak, Ph.D.
EPM I - Water Branch
Ecosystem Restoration Program
Department of Fish and Game
830 S Street
Sacramento, California 95811-7023

Dear Dr. Zezulak:

This is an addendum containing our responses to comments made about our proposal, entitled "Survival and migratory patterns of juvenile spring and fall run Chinook salmon in Sacramento River and Delta." This should help you evaluate our proposal without having an additional round of peer review. We appreciate your willingness to let us do this rather than modifying the format and content of the proposal.

The panel acknowledged that "The proposed research has the ingredients for generating very useful information on reach-specific survival of juvenile salmon, and detailed information on their passage through the key Delta region". However, the panel was concerned that the success of the project is contingent upon several conditions being met and additional details provided. These are identified as items 1-7 here and addressed in numbered sections below:

1) *Verify that the Lotek JSAT tags and receivers are ready for productions and available for purchase, and details on tag life and tag-life studies.*
2) *Examine the tagging and release design to ensure convincing results are obtained, and detail plans for assessing tag effects on fish of the small size, as this is at the limit before tagging effects become too important.*
3) *Ensure that the Lotek monitors detect smolts with a high probability as they pass through reaches separated by paired monitors or arrays of them.*
4) *Examine the optimal number of receivers and their placement and determine the data quality and costs tradeoffs between the number of tags and the number of receivers (power analysis).*
5) *Explain in more detail how environmental variables will be incorporated into the analysis of reach-specific survival.*
6) *Identify lessons learned from the prior telemetry study and discuss foreseeable constraints and potential pitfalls, with contingency plans in case the research does not progress as planned.*
7) *Include provisions for setting up a scientific advisory panel and plan to mesh this study with Hilborn’s study (Proposal 066) should both proposals be funded.*

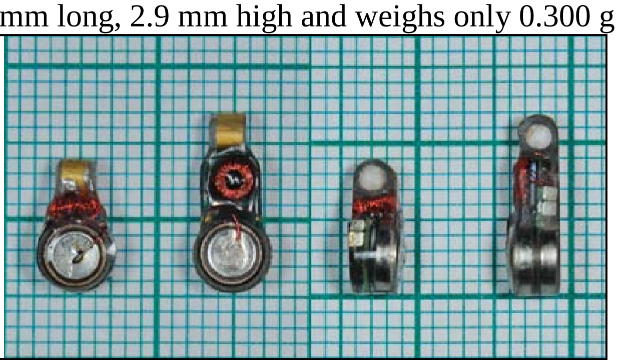
1) Verify that Lotek JSAT tags and receivers ready for productions and available for purchase, and details on tag life and tag-life studies.

At this point the JSAT transmitter tag L-AMT 1.1 (0.3g, 154dB) is currently commercially available from Lotek Wireless[1]. We have received several for conducting range tests in the field (details below) and they appear to function quite well. In addition, one of the co-PI's, Bob Null, USFWS Coleman National Fish Hatchery, has purchased and received six of the Lotek JSAT receivers and we are using these in the preliminary range testing experiments. Specific details on the tag life and size are provided below and at: http://www.lotek.com/juvenile-salmon-acoustic-telemetry-system.htm. From our past work, we have found typical downstream migration times for yearling late-fall Chinook from the upper release sites on the Sacramento river to the Golden Gate is approximately 25.6 ± 9.9 (st dev) days. When using the JSAT L-AMT 1.1, the best configuration for this to optimize tag life is the 10 sec pulse rate, with the 154 dB re: 1 µPa @ 1 m, lasting an estimated 42 days. The reviewers had expressed concerns about detectability based on previous studies on the Columbia and the specifications in our original proposal for tags at 150 dB and 15 sec pulse rate. These tags will be 4 dB louder, and with a pulse interval that is 5 seconds shorter. Results from range tests experiments conducted on Feb 24, 2011 are addressed in section 3 below. The reviewers expressed concern about conducting our own tag life study. This was part of the original proposal, but was not clarified under Task 7. However, the proposed budget did include for 50 extra tags per year for a tag life study under Task 7.

2) Examine the tagging and release design to ensure convincing results are obtained, and detail plans for assessing tag effects on fish of the small size, as this is at the limit before tagging effects become too important. In other words, is Lotek's JSAT beacon is so large that it would likely diminish the swimming performance of the smaller fall and spring smolts and artificially reduce our survival estimates?)

Lotek JSAT and Smolt Swimming Performance. In 2001, the Portland District of the U.S. Army Corps of Engineers (USACE) initiated development of the Juvenile Salmon Acoustic Telemetry System (JSATS) [McMichael *et al.*, 2010]. The objective for the development of this system was to provide an active transmitter small enough for implantation in the majority of the size distribution of juvenile Chinook salmon emigrating seaward through the Columbia River hydropower network. The JSATS used in the Columbia River weigh 0.433 g in air. They were 5.21 mm wide, 12.00 mm long, and 3.77 mm high (thick). Each tag transmitted a unique code at a frequency of 416.7 kHz and a mean source level of 155.6 dB (relative to 1 µPascal at 1 m). Using this system, they were able to implant JSATS within fish with minimum sizes ranging from 93-113 mm FL (McMichael *et al.*, 2010), individuals considerably smaller than the late-fall run smolts tagged in the Sacramento River (Michel *et al.*, 2010). However, we will be using an even smaller version of the JSATS transmitter, the L-AMT 1.1 (Fig. 1). This coded ultrasonic transmitter is 5.1 mm wide, 11.2 mm long, 2.9 mm high and weighs only 0.300 g in air.

Fig. 1. Front (left) and side (right) views of the ultra-miniature L-AMT 1.1 and the L-AMT 2.1 coded transmitters soon to be available from Lotek Wireless. The latter is comparable in size to the beacons used in the Columbia River studies; the former is considerably smaller than the Columbia River beacon. Square = 1 mm.



Reviewer #1 was specifically concerned about the tag burden of our tag being so high that it would adversely affect the swimming performance of even the larger fall run smolts. Tag burden (i.e., the mass of the transmitter relative to the mass of the fish) can indeed influence the behavior and survival of implanted salmon smolts. Many researchers have demonstrated the crucial importance of tag burden in biotelemetry studies (Peak *et al.*, 1997; Adams *et al.*, 1998a, 1998b; Lacroix et al., 2004; Zale *et al.*, 2005; Welch *et al.*, 2007). The lower the tag burden, the less the adverse effect on a fish with respect to its normal migratory behavior. If the tag-burden is too great, it may cause a reduction in swimming ability, predator avoidance, growth, tag retention, and survival during migration (Peake *et al.*, 1997; Anglea *et al.*, 2004: Lacroix *et al.*, 2004; Brown *et al.*, 2006; Welch *et al.*, 2007; Chittenden *et al.*, 2009; and Hall *et al.*, 2009). The prior mentioned studies focus on the larger smolt size classes. Only recently has the maximum tag-burden tolerated by smaller salmon juveniles have been determined for smolts varying in fork length from 80 to 109 mm such as fall and spring-run smolts (Brown *et al.*, 2010). This was done by implanting within these smolts a JSAT with a mass in air of 0.64 g together with a passive integrated transponder (PIT) with a mass in air of 0.10 g -- resulting in a collective mass of 0.74 g in electronics implanted within the peritoneum of the smolt. The purpose of pairing the JSATs with PITs was to determine survival over an extended reach of the river once they passed bypass facilities and fish ladders at hydroelectric dams along the Snake and Columbia Rivers

The probability of mortality and growth were determined by Brown *et al.* (2010) for both implanted smolts and non-implanted smolts in three size classes, 80-89 mm, 90-99 mm, and 100-109 mm FL (Fig. 2). The probability of mortality and growth of the treatment fish never exceeded the values for the controls at the minimum tag-burden of 9.9% for the 0.74 collective mass of the JSAT and PIT. However, the error bars of both the control and treatment for growth did overlap at a 9.9% burden and the two curves of probability converged at that same tag-burden percentage. Our tag with a mass in air of 0.30 is less than half the weight of the tag used in this study. The JSAT would have a burden of 4.6% for the mean body mass of the smolts tested, and a burden of 3.6% for the smallest smolts with a body mass of 8.4 g and a burden of 6.4% for the smallest smolts with a body mass of 4.7 g (below the threshold of 6.7% suggested by Reviewer # 1 and Brown et al. (2010)). It is very likely that the treatment curves for the probability of mortality and growth would converge at these smaller tag-burden values. Hence, we are confident that we can tag fish of the 80-90mm size class with minimal impact on their behavior and physiology. Note that a significant percentage of both the fall and spring run Chinook smolts have FLs in the former size class as apparent from fig 3.

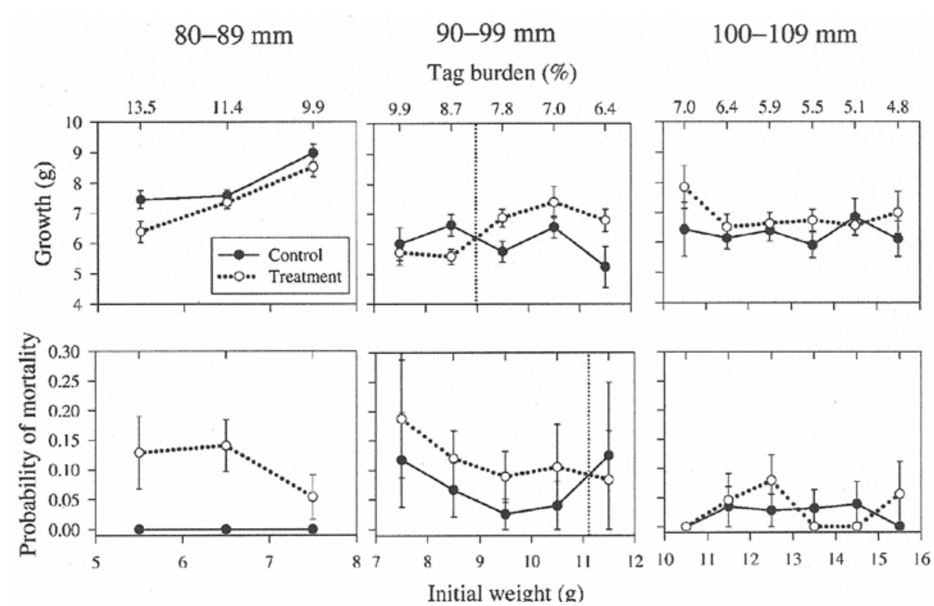


Fig. 2. The growth and probability of mortality for juvenile Chinook smolts of varying lengths that were implanted with a larger JSAT (0.64 g) and a PIT (0.10 g) [treatment] and not implanted with a tag as a function of their weight. The perpendicular dotted lines indicate when the former performed better than the latter smolts.

However, at the same time we believe it imperative that experiments be conducted to assess the effects of the tags on smaller smolts. Evaluation of tag effects and tag life will be done each year of the study. The first year will consist of a laboratory tank trial at Coleman National Fish Hatchery (CNFH), Anderson CA, comparing growth and survival between tagged fish and controls, and documenting tag retention and healing in transmitter implanted fish. First year methods are described below. The second year will involve an identical study but using fish transported and maintained at Sacramento CA to resemble experiences of fish released at that location. The third year will be a repeat at either location if conditions warrant, or the addition of swimming performance trials.

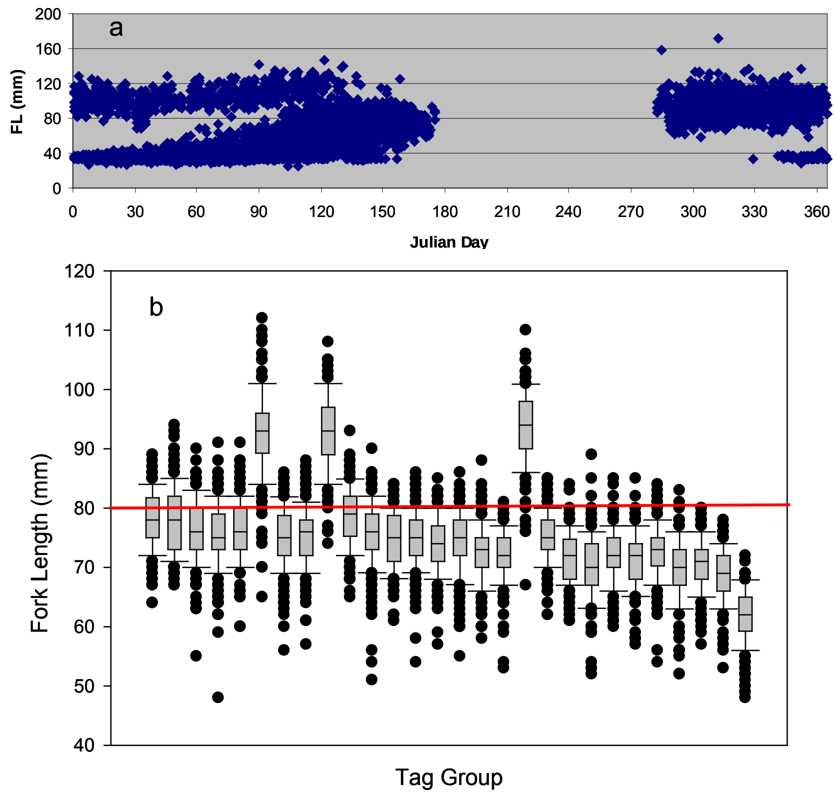


Fig. 3 a) Size distribution of fall and spring run smolts captured in Mill Creek rotary screw traps 2000-2010 and b) Fork lengths of 28 samples of fall-run Chinook salmon smolts released from CNFH into Battle Creek. Shown are the 5th, 25th, median, 75th, and 95th percentiles. The red line indicated tentative tag size threshold with 0.3g JSAT L-AMT 1.1

Surgeries will be performed at CNFH. We will use fall run subyearling Chinook salmon of 80-100mm FL. Tag implantation of the first release group will include 150 fish for river release (RR) and 50 fish for a combined tag life and tag effects study (tag effects with acoustic tag; henceforth TE-AT). In addition, another 100 fish will be used as controls for the tag effects study, of which 50 will receive Passive Integrated Transponders (TE-PIT) tags and 50 un-tagged controls (TE-CT). The TE-PIT treatment will be a pseudo-control, with a 0.1g tag, that will allow individual identification for tracking individual growth rates. The TE-CT group will be an untagged control, but will provide only a group mean growth rate. Allocation of tag effects fish will occur sequentially with implantation surgeries for the 150 fish release group as follows: RR, TE-AT, RR, TE-PIT, RR, TE-CT, and repeating. These treatments will be divided between two surgeons and all treatments allocated in one day.

Fish will not be fed 48 hours prior to surgery and 24 after surgery. Fish are placed in an anesthetic bath of 90mg l^{-1} tricaine methanesulfonate (MS-222) buffered with 350mg l^{-1} sodium bicarbonate. Fish are weighed (g), measured (FL in mm), scored for condition of fins, scales, and eyes, photographed and placed ventral side up on a padded V-shaped surgery cradle. During surgeries the fish's gills are irrigated with a continuous flow of water containing 30mg l^{-1} MS-222 buffered with 60mg l^{-1} sodium bicarbonate. Anesthetic baths, measuring boards and surgery padding are treated with Stress Coat (Aquarium Pharmaceuticals Inc. Chalfont, Pennsylvania). For RR and TE-AT treatments a 6mm incision is made anterior of the pelvic girdle and 3mm to the side of the linea alba using a Sharpoint® microsurgical knife (15° straight stab 3mm blade). Tags are inserted through the incision into the body cavity. The incision is closed with two simple interrupted sutures of absorbable monofilament MonoSwift® 5/0 with FS-2 needles (CP Medical, USA). TE-PIT treatment fish were implanted with a PIT tag by pushing the tag into the body cavity through a 3mm incision. TE-CT treatment will only be weighed, measured, scored for condition of fins, scales, and eyes, and photographed. We expect the duration of the workup and surgical procedure; from leaving the drug bath to entering the recovery bucket, to take about 3min. (range 2-4 min.). Fish are then placed into a recovery bucket and monitored until regaining equilibrium and swimming normally, probably about 5min. Temperature and dissolved oxygen of anesthesia baths will be monitored and baths replaced when needed or after every 15-20 fish. Prior to implantation tags are soaked for 5 minutes in a disinfectant solution of 0.1% chlorohexidine deacetate (Nolvosan®) and then double rinsed in sterilized distilled water.

All tag effects fish will be maintained CNFH in an outdoor circular tank 2m (d) x 1.5m (h) supplied with ozone treated freshwater and fed commercial trout pellets twice daily at a ration of 2% tank biomass per day. A Lotek WHS 4000 JSATS receiver will be kept in the tank, and downloaded every week, in order to confirm operation of the transmitters. The tank will be monitored daily for mortalities or shed tags. At 14, 28 and 42 days (expected life of transmitters) postsurgery, all fish will be weighed (g), measured (FL in mm), scored for condition of fins, scales, eyes, and photographed. The TE-AT treatment will also be scored for incision healing, number of sutures present, and suture inflammation. On day 42 all treatments will be euthanized in a lethal dose of MS-222 and autopsied to determine internal health, and if tagged, determine tag retention and if tags are encapsulated.

Patterns in individual growth rate will be compared for the TE-AT and TE-PIT treatments. Treatment group growth rates will be compared for TE-AT, TE-PIT, and TE-CT (as fish in CT treatment cannot be individually identified). Some effect is always likely, and in this case we would specify the magnitude of the effect and incorporate it into any analysis of survival and rates of migration. Similar experiments were conducted by biologists of the National Marine Fisheries Service to ascertain the minimum size prior to tagging late-fall Chinook and steelhead smolts (Ammann *et al.*, in prep.).

3) Ensure that Lotek monitors detect smolts with a high probability as they pass through reaches separated by paired monitors or arrays of them?

Both reviewers seemed well versed in Columbia River studies and expressed concern about monitor detection ranges and efficiencies. At this point we would like to clarify the scale difference between the two rivers, with the Sacramento literally being an order of magnitude smaller in both watershed area and flow (Fig. 4), and the majority of our river cross-sections will be less than 100m wide (Table 1), considerably narrower than the Columbia River, hence the underlying reason for so few monitors being requested. That stated, we acquired monitors and tags from Lotek and conducted our own range testing experiments to determine detection probabilities. These results were then incorporated into a power analysis, using the program suggested by reviewer # 2.

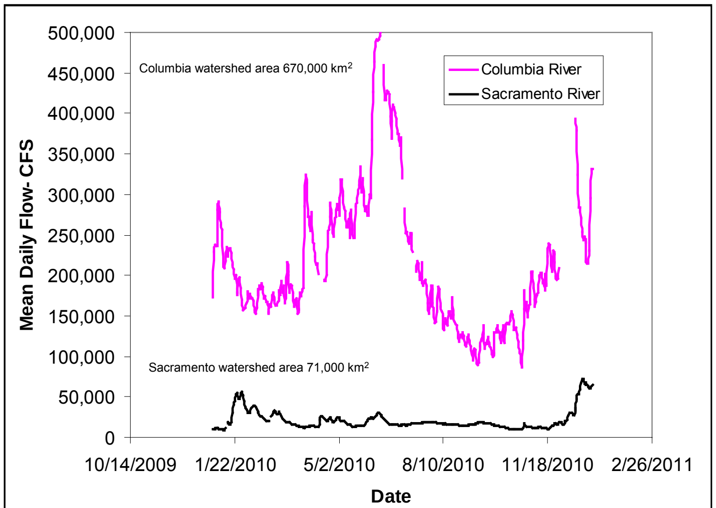


Fig 4. Comparison of flow rates between the Columbia and Sacramento Rivers

Monitor and Tag Range Tests: On Feb 24, 2011, we conducted range tests under fairly poor conditions (i.e. noisy- high flow, rain, wind, boat traffic etc) at Knights Landing on the Sacramento River. One of our investigators (R. Null) had already acquired several of the Lotek WHS 4000 low-cost automated receivers (~$2000 ea) and 4 of the JSAT L-AMT 1.1 transmitters (154 dB, 0.3 g size). This reach of the river, 75 m across, was chosen due to its channelized nature, with steep banks on either side and a depth of < 6 m, because it is highly representative of reaches of the river, through which the smolts will be monitored with our array, extending from mid way up the Sacramento River at Colusa to the base of San Francisco Bay.

Three of the L-AMT 1.1 JSATS, which characteristically propagate their signals with least attenuation in the direction away from the battery, were suspended in mid water in the center of the channel on a jig from a stationary boat paired with a reference beacon, which propagates its signal omni-directionally without regard to its orientation relative to that of the receiver. A tag-detecting monitor was then suspended at the same location and then moved away in 25 m increments, out to 150m. The bulk of the transmitter codes were recorded along with that of the beacon out to a distance of 125 m. From this we observed 95% of all tag transmissions detected at 75 m, dropping to 26% of transmissions detected at 100m. From this, we determined the probability of **two or more pings** being detected while traveling through a detection field radius of 75 and 100m respectively using a binomial model with p=0.95 (for 75m) and p = 0.26 for 100. We assumed a fish swim/river flow speed of 2m/s and calculated the number of pings (n) likely to occur when a fish traveled through the field ¾ of the way off-center (roughly 5 and 7 pings respectively). These were conservative measures, using the detection probability at the outer edge, not compensating for increasing detection probability as fish moved closer to the receiver while passing through the field. Probabilities of detection on these hypothetical paths were 0.999 (for 75m) and 0.55 (for 100m).

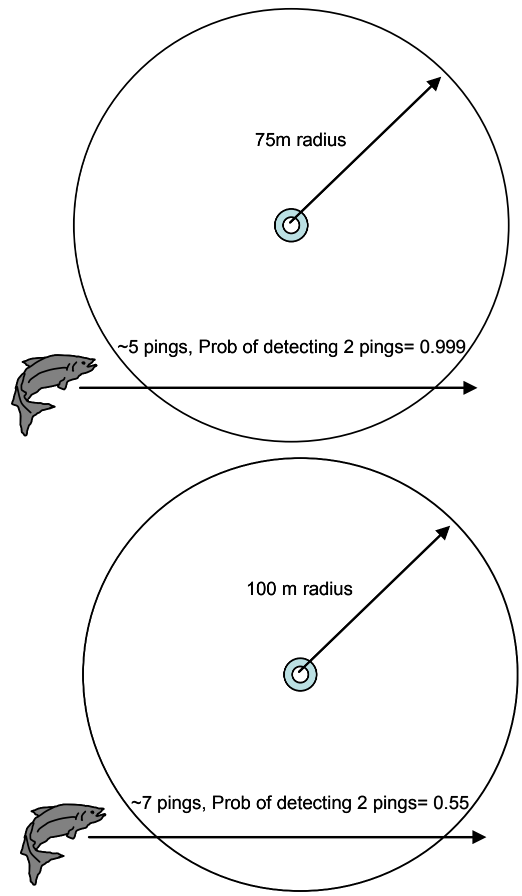


Fig 5. Conservative probability of detecting JSAT tagged fish passing through a receiver detection field of 75 and 100m, ¾ distance off center.

Using these results we re-evaluated our monitor placement plan for the proposed study reaches. River width between riparian corridor edges was measured using Google Earth for each location, and then the optimal number of monitors for each location was determined to maintain distances between monitors and shore of less than 100m. Due to the critical nature that receivers function continuously at each point, and to compensate for monitor loss or failure, a minimum of two monitors will placed at each location, even when river widths are narrow enough to ensure high detection rates with a single monitor. This plan is laid out in Table 1, where a total of 78 monitors would be ideal for the first year of study, providing a mean spacing between monitors and shore of only 45m.

Table 1. Planned monitor placement, river width and inter-monitor/shore spacing

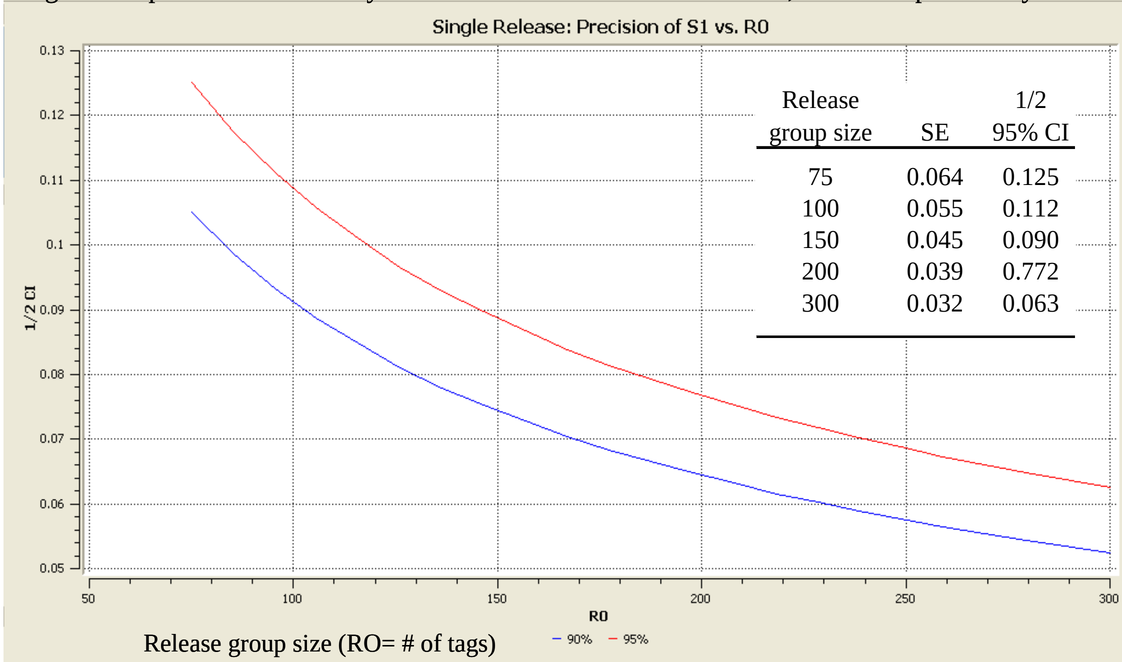
Location Name	Lat	Long	River Width	# of monitors	Mean distance between monitors and/or shore (m)
Sacramento Mainstem					
Battle Creek- release site	40.3916	-122.1842	40	2	13
Battle Creek confluence	40.2137	-122.1690	45	2	15
SR_JellysFerry	40.3174	-122.1899	112	2	37
SR_ButteCityBr	39.4570	-121.9951	148	2	49
Below FR confluence	38.7830	-121.6165	150	2	50
			subtotal	**10**	
Feather River					
Feather River HWY 70 Bridge	39.5118	-121.5723	110	2	37
Feather River @ SR conf	38.7933	-121.6290	170	2	57
			subtotal	**4**	
Delta- points used by Russ					
SR_Freeport	38.4556	-121.5022	173	2	58
SR_SutterSteam	38.2463	-121.6026	130	2	43
SR_Steamboat	38.2850	-121.5868	66	2	22
SR_DCCNorth	38.2571	-121.5170	113	2	38
SR_DCC	38.2449	-121.5050	98	2	33
Georg_SloughN	38.2359	-121.5178	52	2	17
SR_Ryde	38.2378	-121.5573	107	2	36
Mok_NorthFork	38.2232	-121.5073	67	2	22
Mok_SouthFork	38.2255	-121.4914	77	2	26
Mok_GeorgianaS	38.1267	-121.5778	173	2	58
Mok_PotatoS	38.1170	-121.4989	170	2	57
SR_BlwSutter	38.3107	-121.5762	145	2	48
SR_RioVista	38.1567	-121.6796	716	8	80
Decker_IsS	38.0831	-121.7595	950	10	86
SJ_Antioch	38.0243	-121.8173	510	6	73
Chipps Island	38.0483	-121.9311	992	11	83
			subtotal	**59**	Mean spacing = 45m
Tag test monitors				**2**	
Year 1 replacement monitors				**3**	
		Total Monitors Required		**78**	
Budgeted for:	46	have:	12	need:	20

4) Examine the optimal number of receivers and their placement and determine the data quality and costs tradeoffs between the number of tags and the number of receivers (power analysis)

As per the reviewer's advice, power analyses were conducted using the recommended software 'SampleSize' available from the Columbia Basin Research Program at the University of Washington (http://www.cbr.washington.edu/paramest/samplesize). We parameterized the model to determine the 95% confidence interval (CI) around the survival estimate for release groups ranging in size from 75 to 300 fish, assuming a detection efficiency of 90%, and a probability of survival of 50%. Reviewer 2, recommended parameterizing the model with 95% detection efficiency, and we observed 99.9% for detections within 75m. However, as some of our monitors are likely to be space 80-85m, apart, we used a more conservative 90% detection efficiency. Also, to be conservative, the largest confidence intervals were observed around 50% survival rates, and CI's improved when survival was greater or less than 50%.

In addition this overlapped with the results of Perry et al. (2010) who observed a roughly 35-54% survival for fish released into the Delta. Figure 6 is provided to demonstrate the relative power and confidence across the range of potential release groups sizes.

Fig. 6 Sample Size Power analysis Model Parameters: Survival = 0.5, Detection probability = 0.90



Our original proposal budgeted for 300 tags/year for the Delta releases with 4 release groups- 75 fish each, for paired gate open/close for spring and fall run hatchery Chinook. Perry et al.'s (2010) release groups sizes for late fall run Chinook were 64 and 80, a subset of which traveled through the Delta with a roughly 43% difference in Delta survival between the two releases. Given the power analysis above, release group sizes of 75 are expected to have roughly a ±12.5% CI. While it seems sufficient power exists, we would propose a change from the original proposal, which would be to cancel the objectives of Task 5- tagging of wild spring and fall run fish, and follow a recommendation of Reviewer # 2 to redistribute the 200 tags proposed for that task into Tasks 4 (Feather River Hatchery spring run Chinook tagging) and Task 6 (Delta specific survival of HF and HS run Chinook) at least for year one of the study. This would serve several purposes. First, would be to increase the release group sizes in Tasks 4 and 6, and the associated statistical confidence. Secondly, it would reduce the research impact on wild fish in this system, until the effects of JSAT tagging on their survival can be better understood. Thirdly, it would allow for the redistribution of monitors and associated resources (genetic analysis and travel) from Task 5, to cover the purchase of an additional 20 monitors, to meet the ideal number and spacing described in Table 1, which is 78 monitors for year 1. Our original proposal only requested funding for 46 monitors, and the co-PI's currently possess an additional 12 monitors, about 20 monitors short of ideal. This change in tasking and redistribution of resources would just cover this shortfall.

Due to these proposed changes, it seems appropriate to present a summary of our new experimental design and tagging efforts as recommended by the reviewers (Table 2). In addition, the experimental reaches are have also been defined as well.

For Task 3- Coleman National Fish Hatchery Fall run

Reach 1- Release site to Battle Creek confluence with Sacramento River
Reach 2- Jelly's ferry to Butte City (this = "upper river" in Michel 2010)

Reach 3- Butte City to Freeport (this = 'lower river' in Michel 2010)
Reach 4- Freeport to Chipps Island (this = delta coverage in Perry et al 2010, and Michel 2010)

For Task 4- Feather River Hatchery Spring Run

Reach 1- HWY 70 bridge to Feather River confluence
Reach 2- Sacramento River main-stem just below Feather River confluence to Freeport (for comparative survival of Feather River Spring Run and Sacramento River Fall Run Chinook through this section)
Reach 3- Freeport to Chipps Island as above

For Task 6- Delta Survival of Hatchery Fall- and Spring-Run

Reach 3- Freeport to Chipps Island as above

Table 2- annual schedule	Lead Investigator	Release Site	Total # of tags	Release groups sizes (N)	95% CI	Chinook Run
Task 1: Project Management & Dissemination of Results	Klimley					
Task 2: Expanding & Maintaining Array	Klimley					
Task 3: Survival of Hatchery Fall-Run Chinook	Merz & Null	Battle Creek	300	150 (early April) 150 (late April)	± 11.2%	Hatchery fall
Task 4: Survival of Hatchery Spring-Run Chinook	Klimley & Merz	Feather River	300	150 (early April) 150 (late April)	± 11.2%	Hatchery spring
Task 5: Survival of Wild Fall- and Spring-Run	Cancelled	Mill and Deer Creek				
Task 6: Delta Survival of Hatchery Fall- and Spring-Run	Hayes & Michel	Sacramento River @ confluence w Delta	400	100 open- HF 100 closed- HF 100 open- HS 100 closed HS	± 9%	Hatchery fall & spring
Task 7: Tag life/effects, Data management and Analysis	Lindley and Ammann	Laboratory	50			Hatchery fall yr 1

5) The investigators should also explain in more detail how environmental variables will be incorporated into the analysis of reach-specific survival.

A necessary step in understanding the survival and movement dynamics of out-migrating salmon smolts involves relating these to environmental variables. Determining what environmental factors seem to be driving patterns in survival and movement is essential because it not only provides insight into why exactly these patterns exist, but also provides us with predictive power towards understanding changes in these patterns given changes in conditions alone (an especially important asset as we enter an era of climatic incertitude).

The Sacramento River watershed, Sacramento-San Joaquin Delta, and San Francisco Bay estuary are highly studied systems, and therefore many spatial-temporal environmental variables are readily available. Of these variables, many have been known to influence survival and movement patterns in salmonids in other systems, but also specifically in this system. The variables of interest that are available are as follows, followed by their sources in parentheses:

(1) water flow recorded at 15 different gauges (United States Geological Survey (USGS), California Department of Water Resources (DWR),
(2) water temperature recorded at 120 gauges (temperature loggers attached to the existing acoustic monitor array run by the California Fish Tracking Consortium and from DWR and USGS), and
(3) water turbidity recorded at 15 different gauges (USGS, DWR).

The high resolution data provided by acoustic tagging studies of this nature allow us to relate small scale movement and survival information with equally small scale environmental data (many of the spatial-temporal variables listed above are measured at 15 minute intervals). Additionally, ESRI ArcGIS software will allow us to relate the spatial fluctuations in survival and movement to high resolution spatial information. These spatial variables of interest that are available are as follows, followed by their sources in parentheses:

(1) riprap presence, to be summarized as % of riprapped shoreline out of total shoreline for a given region (DWR, United States Army Corps of Engineers, Unites States Fish and Wildlife Service Sacramento River Bank Survey),
(2) levee presence, to be summarized as % of leveed shoreline out of total shoreline for a given region (DWR),
(3) water diversions, to be summarized as diversions per km for a given region or average cubic meters of water diverted per km for a given region (CalFish Passage Assessment Database),
(4) riparian habitat type, categorized and summarized as percent of riparian zone that is either designated as agricultural, urban, natural, or livestock in a given region (DWR land use survey),
(5) channel depth, or average cross sectional depth for a given region (DWR, NOAA),
(6) average channel width for a given region (satellite imagery), and
(7) wetlands and off-channel rearing habitat, to be summarized as average area of accessible wetlands per km for a given region (TBD, potentially from satellite imagery).

Finally, many environmental variables are too difficult to be measured at a temporal resolution that is biologically meaningful, but can be modeled. Some river examples of additional variables of interest can be modeled using the source mentioned in parentheses:

(1) water velocity, to be summarized as average channel velocity for a given region (HEC-RAS simulations at many different river discharge levels using DWR bathymetric models) and
(2) river cross-sectional area, to be summarized as average cross-sectional area for a given region (HEC-RAS simulations at many different river discharge levels using DWR bathymetric models).

The difficulty in understanding the influence of environmental variables on movement and survival rests in finding a way to best relate the environmental data to the acoustic tag data. For movement data, which will be summarized as a movement rate per individual fish between each acoustic monitor station in this study, the spatial variables can be directly associated to the movement rate for the same regions. Spatial-temporal variables can be averaged for the period of time an individual smolt travelled through a region, and can therefore also be related directly to individual smolt movement rates. The influence of these variables can then be assessed by using structural equation modeling, specifically path analysis. This will not only allow us to understand the strength and direction of relationships between environmental variables, but also understand how they collectively influence movement rates, and which variables are the most important players. Additionally, this analysis will allow us to test and ultimately improve the accuracy of our conceptual models.

Assessing the influence of environmental variables on survival is inherently more difficult than with movement, but possible. To calculate survival rates, a spatial adaptation of the Cormack-Jolly-Seber (CJS) model for live recaptures is used. The survival rates provided using this method are a reflection of how the model is built, and how one's data suggest survival and detection probabilities vary through space. It would therefore be statistically incorrect to simply calculate survival rates using the best fit model, extract them, and assess the influence of the environment on them outside the context of the CJS model. Michel (2010) provides a novel method for constructing different survival models that attempt to use a linear environmental predictor when estimating survival rates. Each environmental variable will therefore have its own associated survival model, and using standard model selection techniques (using akaike's information criterion), one can parse out the best fit models, in other words, the models of the most influential environmental variables.

Finally, once the above-mentioned techniques have been applied to distinguish what environmental variables may be influencing small scale fluctuations in survival and movement rates, this information can be used in determining if these same environmental variables may be the cause for large-scale changes in movement or survival rates (e.g. interannual fluctuations). For example, Michel (2010) determined that water velocity had one of the strongest relationships with movement rates on a reach-specific scale. However, there were also significant yearly differences in movement rates, and these could have been due to the statistically significant yearly differences in water velocities.

6) Identify lessons learned from the prior telemetry study and discuss foreseeable constraints and potential pitfalls, with contingency plans in case the research does not progress as planned.

Much knowledge has been gained from the telemetry work conducted up through the present. Many studies were presented at the Bodega Bay Telemetry conference in May of 2010, and will be described in detail in the associated publication of a special volume for the Environmental Biology of Fishes. The big picture conclusions were published by Perry et al (2010), which described survival rates of only 35-54% for late-fall Chinook passing through the Delta, and the Master's thesis by Michel (2010), showing cumulative downstream survival of only 7% from upper river release sites to the Golden Gate Bridge (Fig 7).

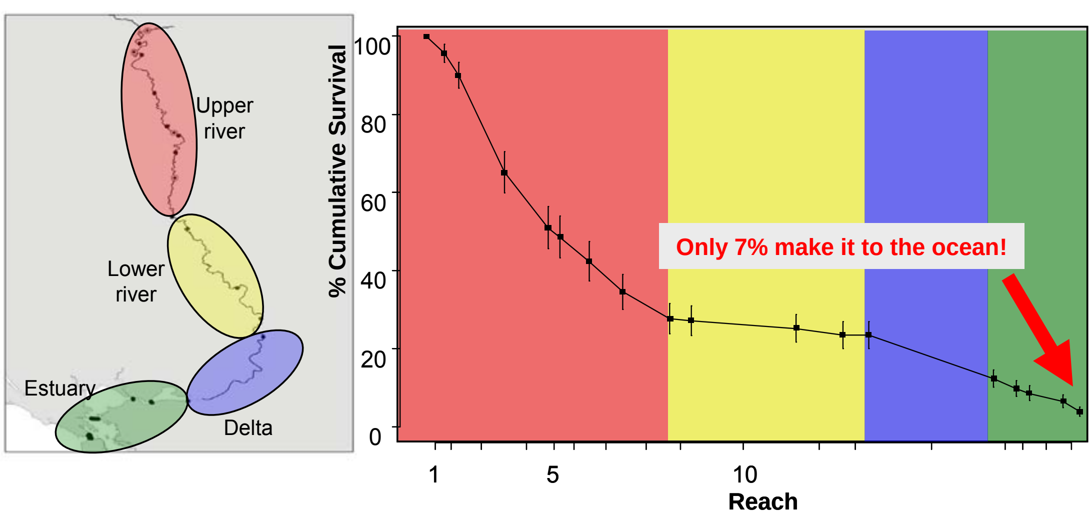


Fig 7. Late Fall Chinook Cumulative Downstream migration and survival 2007-2009

Within this work were dozen's of lesson's learned. These included discovering the high mortality associated with releasing experimentally tagged fish in small groups in areas where much larger batch releases of hatchery fish were occurring, likely due to large number of predator present. The solutions were to either release experimental fish with the large hatchery releases (as proposed here), or to find slightly different release sites where predators are not aggregated in anticipation. The team also learned a great deal about the logistics of monitor placement, recovery, loss-rates and methods to prevent loss. Associated with this were the challenges placed upon statistical models when data/monitors were lost, and the statistical solutions necessary to account for these losses. Additional lessons were learned about species specific tag effects between Chinook and steelhead, with steelhead being more likely to reject tags without dying. Statistical methods were developed by the team to identify 'false positives detections' by monitors in the data, and the potential for the transfer of tags from the subject fish to a predator through consumption. Many of these lessons were learned the first year, which required adaptations to the study design in subsequent years. While this limited the value of the first year's data, the majority of these lessons have been learned, and can be avoided with the implementation of this new project, which is conceptually quite similar to the initial efforts, merely using new technology. That said, there will be unforeseen challenges with this new project, but this team has demonstrated a creative and resilient track record of adapting to and overcoming those problems as they present themselves.

Finally one of the critical and positive lessons learned was the concept of 'if you build it, they will come'. The joint UC Davis-NMFS team, which are the PI's of this proposal, was the team which established the original network of Vemco monitors in the Sacramento basin for the tracking of late-fall Chinook and steelhead, with less than 100 monitors. This provided a synergy by which many other groups were able to rapidly capitalize on the presence of the founding array to leverage funding for additional projects, expanding it to over 300 monitors, with dozens of projects, multiple species and thousands of tagged fish being tracked, and the evolution of the large collaborative California Fish Tracking Consortium. The same potential exists for this project. A collaborative postdoctoral position has already been applied for through the OPC program to expand this project to include the tagging of winter-run Chinook salmon, pending the funding of this project. It is also likely the resources to achieve the original goals of task 5- tagging of wild spring and fall run Chinook will also be found. In addition the JSAT technology will enable the tagging of many other species and life stages (potentially even Delta Smelt), which is otherwise not currently possible.

7) Include provisions for setting up a scientific advisory panel and plan to mesh this study with Hilborn's study (Proposal 066) should both proposals be funded.

As per recommendations in the Summary Review, the PI's are happy to receive input from a Scientific Advisory Panel (SAP). It was not clear, what format and timeline the DSP preferred for that. However the PI's are currently undertaking other projects funded by the Bureau of Reclamation and similar criteria were established for those projects. Specifically it was proposed for the purposes of coordination with state and federal agencies (and to receive feedback) updated presentations will be made at six month intervals- both at the annual BDCP Science Review, and at a proposed annual BDCP Multiple Stressors Workshop, scheduled to provide mid-year follow-ups between the Science Review meetings. This would be an ideal mechanism by which to provide bi-annual progress reports and updates, since many members of a proposed SAP would be present at these meetings.

Finally, with one of the primary goals of this and our other projects is to provide input for Dr. Lindley's Shiraz life cycle model. Dr. Lindley also serves as co-PI on the modeling effort proposed by Ray Hilborn (Proposal 066). As a collaborator on both this and Dr. Hilborn's proposals, Dr. Lindley will be receiving these results in near 'real-time' and they will be integrated into both projects.

We hope you find this response to the constructive comments of the reviewers sufficient, and, if not, we are certainly willing to provide more information to you on specific issues.

Cordially yours,

A. Peter Klimley, Ph.D.
Adjunct Professor, UC Davis
Director, Biotelemetry Laboratory

Sean A. Hayes, PhD
Adjunct Associate Professor, UC Santa Cruz
Salmon Ocean Ecology Team Leader
NOAA Fisheries, Santa Cruz

Literature Cited

Adams, N., D. Rondorf, S Evans, J. Kelly and R Perry 1998a. Effects of surgically and gastrically implanted radio transmitters on swimming performance and predator avoidance of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) *Can. Jour. Fish. Aquat. Sci.*. 55: 781-787.

Adams, N., D. Rondorf, S. Evans, and J. Kelly. 1998b. Effects of surgically and gastrically implanted radio transmitters on growth and feeding behavior of juvenile Chinook salmon. *Trans. Am. Fish. Soc.*, 127: 128-136.

Ammann, A.J, C. Michel, P. Sandstrom, E. Chapman, and N. Delaney. 2010. Growth and swimming performance of Chinook salmon and Steelhead yearlings implanted with acoustic transmitters. Abstract, Salmon Tracking Symposium Bodega Marine Laboratory.

Anglea, S.M., D.R. Geist, R.S. Brown, K.A. Deters, and R.D. McDonald. 2004. Effects of surgically and gastrically implanted radio transmitters on swimming performance and predator avoidance of juvenile Chinook salmon (*Oncorhynchus tshawytscha*). *Can. J. Fish. Aquat. Sci.*, 55: 162-170.

Brown, R.S., R.A. Harnish, K.M. Carter, J.W. Boyd, and M.B. Deters. 2010. An evaluation of the maximum tag burden for implantation of acoustic transmitters in juvenile Chinook salmon. *North Am. J. Fish. Management*, 30: 499-505.

Brown, R.S., D.R. Geist, K.A. Deters, and A. Grassell. 2006. Effects of surgically implanted acoustic transmitters >2% of body mass on the swimming performance, survival, and growth of juvenile sockeye and Chinook salmon. *J. Fish Biol.*, 69: 1626-1638.

Chittenden, C.M., K.G. Butterworth, K.F. Cubitt, M.C. Jacobs, A. Ladouceur, D.W. Welch, and R.S. McKinley. 2009. Maximum tag-to-body-size ratios for an endangered coho salmon (O. kisutch) stock based on physiology and performance. *Env. Biol. Fishes*, 84: 129-140.

Hall, J.E., J. Chamberlin, A.N. Kagley, C. Greene, and K.L. Fresh. 2009. Effects of gastric and surgical insertions of dummy ultrasonic transmitters on juvenile Chinook salmon in seawater. *Trans. Am Fish. Soc.*, 138: 52-57.

Lacroix, G.L., D. Knox & P. McCurdy. 2004. Effects of implanted dummy acoustic transmitters on juvenile Atlantic salmon. *Trans. Am. Fish. Soc.*, 133: 211-220.

Lindley, S, P. Klimley, B. MacFarlane, & A. Ammann. 2005. Estimating survival and migration rates with ultrasonic tagging. Limited circulation, available from authors.

McMichael, G.A., M.B. Eppard, T.J. Carlson, J.A. Carter, B.D. Ebberts, R.S. Brown, M. Weiland, G.R. Ploskey, R.A. Harnish, and Z.D. Deng. 2010. The juvenile salmon acoustic telemetry system: a new tool. *Fisheries*, 35: 9-21.

Michel, C. 2010. River and estuarine survival and migration of yearling Sacramento River Chinook Salmon (*Oncorhynchus Tshawytscha*) smolts and the influence of environment. Master of Arts, Ecology and Evolutionary Biology, University of California, Santa Cruz.

Peake, S. and R. S. McKinley. 1997. Influence of transmitter attachment procedures on swimming performance of wild and hatchery-reared Atlantic salmon smolts. *Trans. Am. Fish. Soc.*, 126: 707-714.

Perry, R.W., Skalski, J.R., Brandes, P.L., Sanstrom, P.T., Klimley, A.P., Ammann, A., and MacFarlane, B. 2010. Estimating Survival and Migration Route Probabilities of Juvenile Chinook Salmon in the Sacramento–San Joaquin River Delta. North American Journal of Fisheries Management 30:142-156: 142-156.

Welch, D.W., S.D. Batten, and B.R. Ward. 2007. Growth, survival, and tag retention of steelhead trout (*O. mykis*) surgically implanted with dummy acoustic tags. *Hydrobiologica*, 582: 289-299.

Zale, A. and C. Brooke, 2005. Effects of surgically implanted transmitter weights on growth and swimming stamina of small adult west slope cutthroat trout. *Trans. Am. Fish. Soc.*, 134: 653-660.