Behavioral and Genetic Variability of Wild and Hatchery Juvenile Chinook Salmon in the Tuolumne River

Project Information

1. **Proposal Title:**

   Behavioral and Genetic Variability of Wild and Hatchery Juvenile Chinook Salmon in the Tuolumne River

2. **Proposal applicants:**

   A. Peter Klimley, H. T. Harvey & Associates, U.C. Davis
   Bernard May, U.C. Davis
   Thomas Quinn, University of Washington

3. **Corresponding Contact Person:**

   Peter Klimley
   H. T. Harvey & Associates
   3150 Almaden Expressway, Suite 145 San Jose, CA 95118
   408 448-9450 ext. 216
   pklimley@harveyecology.com

4. **Project Keywords:**

   Fish Genetics
   Fish mortality/fish predation
   Salmon/Steelhead Biology

5. **Type of project:**

   Research

6. **Does the project involve land acquisition, either in fee or through a conservation easement?**

   No

7. **Topic Area**:

   At-Risk Species Assessments

8. **Type of applicant:**

   Private for profit

9. **Location - GIS coordinates:**

Latitude: 37.231

Longitude: -121.00

Datum:

Describe project location using information such as water bodies, river miles, road intersections, landmarks, and size in acres.

The project site encompasses the lower Tuolumne River, from downstream of the La Grange dam to the Tuolunme's confluence with the San Joaquin River.

10. **Location - Ecozone:**

    13.2 Tuolumne River

11. **Location - County:**

    Stanislaus, Tuolumne

12. **Location - City:**

    Does your project fall within a city jurisdiction?

    No

13. **Location - Tribal Lands:**

    Does your project fall on or adjacent to tribal lands?

    No

14. **Location - Congressional District:**

    18, 19

15. **Location:**

    California State Senate District Number: 12

    California Assembly District Number: 25, 26

16. **How many years of funding are you requesting?**

    2

17. **Requested Funds:**
    a) Are your overhead rates different depending on whether funds are state or federal?

       No

       If no, list single overhead rate and total requested funds:

Single Overhead Rate: 10

Total Requested Funds: $655,603

b) Do you have cost share partners already identified?

No

c) Do you have potential cost share partners?

No

d) Are you specifically seeking non-federal cost share funds through this solicitation?

No

If the total non-federal cost share funds requested above does not match the total state funds requested in 17a, please explain the difference:

18. **Is this proposal for next-phase funding of an ongoing project funded by CALFED?**

No

Have you previously received funding from CALFED for other projects not listed above?

Yes

If yes, identify project number(s), title(s) and CALFED program.

P9940011	**San Joaquin River Basin Fall Run Chinook Genetic Base Line and Discrimination**	**ERP, CMARP - for Chinook, Salmon and Steelhead in the Central Valley Rivers**

19. **Is this proposal for next-phase funding of an ongoing project funded by CVPIA?**

No

Have you previously received funding from CVPIA for other projects not listed above?

No

20. **Is this proposal for next-phase funding of an ongoing project funded by an entity other than CALFED or CVPIA?**

No

Please list suggested reviewers for your proposal. (optional)

21. **Comments:**

Environmental Compliance Checklist

Behavioral and Genetic Variability of Wild and Hatchery Juvenile Chinook Salmon in the Tuolumne River

1. **CEQA or NEPA Compliance**
   a) Will this project require compliance with CEQA?

      Yes
   b) Will this project require compliance with NEPA?

      No
   c) If neither CEQA or NEPA compliance is required, please explain why compliance is not required for the actions in this proposal.

2. **If the project will require CEQA and/or NEPA compliance, identify the lead agency(ies).** *If not applicable, put "None".*

   CEQA Lead Agency: California Department of Fish & Game
   NEPA Lead Agency (or co-lead:) NMFS/USFWS, if NEPA compliance needed
   NEPA Co-Lead Agency (if applicable):

3. **Please check which type of CEQA/NEPA documentation is anticipated.**

   CEQA
   XCategorical Exemption
   -Negative Declaration or Mitigated Negative Declaration
   -EIR
   -none

   NEPA
   XCategorical Exclusion
   -Environmental Assessment/FONSI
   -EIS
   -none

   If you anticipate relying on either the Categorical Exemption or Categorical Exclusion for this project, please specifically identify the exemption and/or exclusion that you believe covers this project.

   A CEQA Categorical Exemption expected under CEQA Guidelines Article 19, Section 15306 and/or 15307 (California Code of Regulations, Title 14, Division 6, Chapter 3). If NEPA clearance is required for this research project due to use of Federal funding or other Federal involvement, then a Categorical Exclusion is anticipated under the guidelines of the appropriate lead agency.

4. **CEQA/NEPA Process**
   a) Is the CEQA/NEPA process complete?

      No

If the CEQA/NEPA process is not complete, please describe the dates for completing draft and/or final CEQA/NEPA documents.

The project team will work with CalFed staff to identify the appropriate lead agency, and is prepared to coordinate the preparation and submittal of all appropriate documentation within 1 month of notification of award of funding.

b) If the CEQA/NEPA document has been completed, please list document name(s):

5. **Environmental Permitting and Approvals** (*If a permit is not required, leave both Required? and Obtained? check boxes blank.*)

LOCAL PERMITS AND APPROVALS

Conditional use permit

Variance

Subdivision Map Act

Grading Permit

General Plan Amendment

Specific Plan Approval

Rezone

Williamson Act Contract Cancellation

Other

STATE PERMITS AND APPROVALS

Scientific Collecting Permit Required

CESA Compliance: 2081

CESA Compliance: NCCP

1601/03

CWA 401 certification

Coastal Development Permit

Reclamation Board Approval

Notification of DPC or BCDC

Other

FEDERAL PERMITS AND APPROVALS

ESA Compliance Section 7 Consultation

ESA Compliance Section 10 Permit

Rivers and Harbors Act

CWA 404

Other

PERMISSION TO ACCESS PROPERTY

Permission to access city, county or other local agency land. Agency Name: Turlock Irrigation District	Required
Permission to access state land. Agency Name:	
Permission to access federal land. Agency Name:	
Permission to access private land. Landowner Name:	

6. **Comments.**

Land Use Checklist

Behavioral and Genetic Variability of Wild and Hatchery Juvenile Chinook Salmon in the Tuolumne River

1. **Does the project involve land acquisition, either in fee or through a conservation easement?**

   No

2. **Will the applicant require access across public or private property that the applicant does not own to accomplish the activities in the proposal?**

   Yes

3. **Do the actions in the proposal involve physical changes in the land use?**

   No

   If you answered no to #3, explain what type of actions are involved in the proposal (i.e., research only, planning only).

   Proposed project will study juvenile chinook salmon and does not involve changes in land use.

4. **Comments.**

Conflict of Interest Checklist

Behavioral and Genetic Variability of Wild and Hatchery Juvenile Chinook Salmon in the Tuolumne River

Please list below the full names and organizations of all individuals in the following categories:

- Applicants listed in the proposal who wrote the proposal, will be performing the tasks listed in the proposal or who will benefit financially if the proposal is funded.
- Subcontractors listed in the proposal who will perform some tasks listed in the proposal and will benefit financially if the proposal is funded.
- Individuals not listed in the proposal who helped with proposal development, for example by reviewing drafts, or by providing critical suggestions or ideas contained within the proposal.

The information provided on this form will be used to select appropriate and unbiased reviewers for your proposal.

Applicant(s):

A. Peter Klimley, H. T. Harvey & Associates, U.C. Davis
Bernard May, U.C. Davis
Thomas Quinn, University of Washington

Subcontractor(s):

Are specific subcontractors identified in this proposal? Yes

If yes, please list the name(s) and organization(s):

Dr. Bernard P. May	U.C. Davis
Dr. Thomas P. Quinn	University of Washington

None	None
None	None
None	None
None	None

Helped with proposal development:

Are there persons who helped with proposal development?

Yes

If yes, please list the name(s) and organization(s):

Ronald Yoshiyama	**U.C. Davis**

Tim Ford	**Turlock Irrigation District**
Rhonda Reed, Tim Heyne, et.al.	**Tuolumne River Technical Advisory Committee, representing various organizations (Dept. of Fish & Game etc.)**
Thomas Quinn	**University of Washington**
Bernard May	**U.C. Davis**

Comments:

Members of the Tuolumne River Technical Advisory Committee reviewed this proposal and provided input during its preparation.

Budget Summary

Behavioral and Genetic Variability of Wild and Hatchery Juvenile Chinook Salmon in the Tuolumne River

Please provide a detailed budget for each year of requested funds, indicating on the form whether the indirect costs are based on the Federal overhead rate, State overhead rate, or are independent of fund source.

State Funds

Year 1												
Task No.	**Task Description**	**Direct Labor Hours**	**Salary** ***(per year)***	**Benefits** ***(per year)***	**Travel**	**Supplies & Expendables**	**Services or Consultants**	**Equipment**	**Other Direct Costs**	**Total Direct Costs**	**Indirect Costs**	**Total Cost**
1a	Radio Tagging and Tracking of Wild Juveniles via Electronic Monitoring Stations	1745	127000.00		5500.00	70963.00	9350.00	6991.00	1898.00	221702.0		221702.00
1b	Tagging and Electronic Tracking of Hatchery-raised Juveniles	240	17600.00			11968.00				29568.0		29568.00
2	Predation Analysis	220	17600.00							17600.0		17600.00
3	Genetic Analysis of Juveniles						75060.00			75060.0		75060.00
		2205	162200.00	0.00	5500.00	82931.00	84410.00	6991.00	1898.00	343930.00	0.00	343930.00

Year 2												
Task No.	**Task Description**	**Direct Labor Hours**	**Salary** ***(per year)***	**Benefits** ***(per year)***	**Travel**	**Supplies & Expendables**	**Services or Consultants**	**Equipment**	**Other Direct Costs**	**Total Direct Costs**	**Indirect Costs**	**Total Cost**
1a	Radio Tagging and Tracking of Wild Juveniles via Electronic Monitoring Stations	1745	127000.00		2860.00	49667.00	9350.00		569.00	189446.0		189446.00
1b	Tagging and Electronic Tracking of Hatchery-raised Juveniles	240	17600.00			11968.00				29568.0		29568.00
2	Predation Analysis	240	17600.00							17600.0		17600.00
3	Genetic Analysis of Juveniles						75060.00			75060.0		75060.00
		2225	162200.00	0.00	2860.00	61635.00	84410.00	0.00	569.00	311674.00	0.00	311674.00

Year 3												
Task No.	**Task Description**	**Direct Labor Hours**	**Salary *(per year)***	**Benefits *(per year)***	**Travel**	**Supplies & Expendables**	**Services or Consultants**	**Equipment**	**Other Direct Costs**	**Total Direct Costs**	**Indirect Costs**	**Total Cost**
		0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Grand Total=655604.00

Comments.

Budget Justification

Behavioral and Genetic Variability of Wild and Hatchery Juvenile Chinook Salmon in the Tuolumne River

Direct Labor Hours. Provide estimated hours proposed for each individual.

Lead Scientist (years 1 & 2) - 120 hours Lead Scientist (years 1 & 2) - 560 hours Project Management (years 1 & 2) - 60 hours Field Biologist (years 1 & 2) - 2240 hours Field Technician (years 1 & 2) - 320 hours Principal (years 1 & 2) - 50 hours Administrative Staff (years 1 & 2) - 80 hours Tech./Graphics Support (years 1 & 2) - 60 hours

Salary. Provide estimated rate of compensation proposed for each individual.

Lead Scientist - $100.00 Project Management - $100.00 Field Biologist - $65.00 Field Technician - $55.00 Principal - $150.00 Administrative Support - $60.00 Tech./Graphics Support - $75.00

Benefits. Provide the overall benefit rate applicable to each category of employee proposed in the project.

We will be using full burdened rates.

Travel. Provide purpose and estimate costs for all non-local travel.

Both years 1 & 2 respectively: On-site ATS consulting, 5d @$300/d RT Airfare, Minnesota-San Francisco @$600/trip Per diem, 5 d @ $100/d Tagging, per diem 20@ 120/d

Supplies & Expendables. Indicate separately the amounts proposed for office, laboratory, computing, and field supplies.

Year 1: Monitoring stations (rental), 16 @ 2 mos. @ $731/mo. (ATS, R2100 receiver, DCC, Yagi antenna) Deep-cycle batteries, 16 @ $100 ea Army Ammunition Boxes, 12 @ $100 ea Reference beacons for monitors, 16 @ $167 ea Radio beacons, 160 @ $136/ea. (ATS, implant transmitters for wild smolts) Radio beacons, 80 @ $136/ea. (ATS, implant transmitters for hatchery smolts) Temperature loggers, 16 @ $163/ea. (model Onset, tidbit) Portable tracking system, receiver @ $2,622, scanner @ $3,433; antenna @ $300 ea Year 2: Monitoring stations (rental), 16 @ 2 mos. @ $731/mo. (ATS, R2100 receiver, DCC, Yagi antenna) Radio beacons, 160 @ $136/ea. (ATS, implant transmitters for wild smolts)

Services or Consultants. Identify the specific tasks for which these services would be used. Estimate amount of time required and the hourly or daily rate.

T.P. Quinn (University of Washington)lead scientist will initially participate in tagging juvenile chinook salmon with radio beacons at two sites in the lower (sand-bedded) Tuolumne River and two sites in the upper (gravel-bedded) portion of the river below the La Grange Dam during Years 1 and 2. B.P. May, co-investigator and K.S. Williamson, graduate student, Molecular Biology, U.C. Davis. Will determine the degree of kinship between the salmon smolts through non-destructive tissue sampling and performing microsatellite-based tests of relatedness.

Equipment. Identify non-expendable personal property having a useful life of more than one (1) year and an acquisition cost of more than $5,000 per unit. If fabrication of equipment is proposed, list parts and materials required for each, and show costs separately from the other items.

Portable tracking System: Receiver @ $2,622.00 Scanner @ $3,433.00 Antenna @ $300.00 each

Project Management. Describe the specific costs associated with insuring accomplishment of a specific project, such as inspection of work in progress, validation of costs, report preparation, giving presentatons, reponse to project specific questions and necessary costs directly associated with specific project oversight.

Both years 1 & 2 respectively Cost is $3,000 (5h/wk X 6w) 30 hours @ $100 per hour for co-ordinating the project, preparing the reports and co-ordinating the workshops at such time presentations will be made.

Other Direct Costs. Provide any other direct costs not already covered.

Not applicable

Indirect Costs. Explain what is encompassed in the overhead rate (indirect costs). Overhead should include costs associated with general office requirements such as rent, phones, furniture, general office staff, etc., generally distributed by a predetermined percentage (or surcharge) of specific costs.

Not applicable

Executive Summary

Behavioral and Genetic Variability of Wild and Hatchery Juvenile Chinook Salmon in the Tuolumne River

This study will determine the genetic and behavioral variation within wild populations of juvenile chinook salmon (Oncorhynchus tshawytscha) within the Tuolumne River. Based on differences in the frequency and timing of spawning determined from carcass surveys (T. Heyne, pers. commun.), we will conduct genetic and behavioral studies of juvenile chinook at two sites in each of two reaches, one in the lower and one in the upper reaches of the Tuolumne River. Our primary tasks will be three-fold. Firstly, we will employ radio- tags and an array of sophisticated radio listening stations coupled with selected manual tracking to determine whether the timing of migration, rates of movement, and mortality of juveniles due to predation varies at two sites at each of two reaches in the river. Any differences in migration patterns will be related to physical properties of the aquatic environment (water temperature and current speed). Secondly, we will utilize molecular genetic techniques to determine whether the juveniles from these reaches are more related to each other than to individuals from the other reach. Thirdly, we will characterize the genetics and life history traits (migration, mortality, etc.) of hatchery-raised fish and compare them to the genetics and life history traits of naturally spawned fish within the tributary. We hope to provide information that management agencies can use to improve the success of juvenile chinook and determine the sources of mortality on juvenile salmon, genetic variation in migratory behavior, and potential differences between hatchery and wild fish. Our further objective is to help refine protocols for successfully studying salmon movement in tributary rivers. This research proposal is intended to deepen our understanding of the factors that affect success of juvenile salmonids through an integrated, multidisciplinary effort using a team of top researchers to study and identify correlations between genetics, behavior, and ecology of juvenile salmonids, as well as correlations to physical properties of the river and differences between channel reaches.

Proposal

H. T. Harvey & Associates, U.C. Davis

Behavioral and Genetic Variability of Wild and Hatchery Juvenile Chinook Salmon in the Tuolumne River

A. Peter Klimley, H. T. Harvey & Associates, U.C. Davis
Bernard May, U.C. Davis
Thomas Quinn, University of Washington

Behavioral and Genetic Variation in Juvenile Chinook Salmon in the Tuolumne River

Amount Requested: $655,603 (10% indirect costs of supplies and subcontracts) for 2 yrs.
Applicant:. A. Peter Klimley, Fisheries Ecologist, H.T. Harvey and Associates and Adjunct Associate Professor, Department of Wildlife, Fish, & Conservation Biology, U.C. Davis.
Tel. (408) 448-9450 ext. 216
Co-Investigators: B.P. May (U.C. Davis) and T.P. Quinn (University of Washington)

In Collaboration with (see Appendix I): 1) Turlock Irrigation District and 2) Tuolumne River Technical Advisory Committee (TRTAC). TRTAC is made up of the Turlock Irrigation District, Modesto Irrigation District, City & County of San Francisco, California Dept. of Fish & Game, and the U.S. Fish & Wildlife Service. TRTAC's collaborating stakeholder groups include the Tuolumne River Preservation Trust, Friends of the Tuolumne, California Sports Fishing Protection Alliance, Bay Area Water Users Association, East Stanislaus Resource Conservation District, National Marine Fishery Service, and local mining operators and landowners.

This study will determine the genetic and behavioral variation in wild populations of juvenile chinook salmon (*Oncorhynchus tshawytscha*) within the Tuolumne River. Based on differences in the frequency and timing of spawning determined from carcass surveys (T. Heyne, pers. commun.), we will conduct genetic and behavioral studies of juvenile chinook at two sites in each of two reaches, one in the lower and one in the upper reach of the Tuolumne River. Our primary tasks will be three-fold. Firstly, we will employ radio-tags and an array of sophisticated radio listening stations coupled with selected manual tracking to determine whether the timing of migration, rates of movement, and mortality of juveniles due to predation varies at two sites at each of two reaches in the river. Any differences in migration patterns will be related to physical properties of the aquatic environment (water temperature and current speed). Secondly, we will utilize molecular genetic techniques to determine whether the juveniles from these reaches are more related to each other than to individuals from the other reach. Thirdly, we will characterize the genetics and life history traits (migration, mortality, etc.) of hatchery-raised fish and compare them to the genetics and life history traits of naturally spawned fish within the tributary. We hope to provide information that management agencies can use to improve the success of juvenile chinook and determine the proportion of wild versus hatchery-raised fish in the Tuolumne and other tributaries of the Sacramento/San Joaquin Rivers.

B. PROJECT DESCRIPTION: PROJECT GOALS and SCOPE OF WORK

1. Problem

a. Location and Setting. The Tuolumne River is the largest tributary to the San Joaquin River, encompassing a drainage area of approximately 1,900 square miles (McBain & Trush 2000) [Fig. 1]. The river flows into the Central Valley and is a valuable source of water for agricultural and municipal supplies. The Don Pedro Reservoir provides irrigation water and hydropower for the cities of Turlock and Modesto. This river supports the largest naturally reproducing population of chinook salmon remaining in the San Joaquin Valley. The lower Tuolumne River below La Grange Dam is divided into two major zones based on its geomorphology (McBain & Trush 1998). The lower portion, a sand-bedded zone, extends upstream about 24 miles from the Tuolumne's confluence with the San Joaquin River. The upper portion, a gravel-bedded zone, extends upstream from approximately river mile 24 to 52. This research proposal will study juvenile chinook salmon in the Tuolumne River in both the

lower and upper and reaches, from the San Joaquin confluence to the upper spawning areas of the river that lie below the La Grange dam.

b. Introduction. The Tuolumne River supported large spring and fall migrations of chinook salmon during the first half of the 19th century (Yoshiyama *et al.*, 1998). Only the fall run is believed to remain, and it has fluctuated widely since 1971 when the Don Pedro Dam was completed, ranging from a high of 40,000 fish in 1985 to a low of approximately 100 fish during 1991-93 (McBain and Trush, 2000). However, in recent years the number of chinook salmon returning to the Tuolumne has increased. There were estimated to be 7,000 to 9,000 adults annually in 1997-99 and in fall 2000, as many as 18,000 chinook returned (T. Ford, Turlock Water District, pers. commun.). This is the largest naturally-reproducing population of chinook salmon remaining in the San Joaquin Valley. Although improving recently, the populations remain well below the U.S. Fish & Wildlife Service's target discussed below.

The Tuolumne River has been transformed by more than a century of intensive land and water resource development that altered the river's ecosystem. In 1995, a settlement agreement was issued as part of a licensing update for the new Don Pedro reservoir above the La Grange Dam. The Tuolumne River Technical Advisory Committee (TRTAC) was formed to administer restoration and management activities, and provides a forum for involvement by the many stakeholders (see list of participants above).

The river is now the subject of intensive restoration efforts. A primary focus of TRTAC's efforts is the recovery of chinook salmon populations. The settlement agreement requires a recovery strategy for chinook that emphasizes naturally occurring salmon populations and protects any remaining genetic distinction between populations of Tuolumne River salmon. The U.S. Fish and Wildlife Service's Anadromous Fish Recovery Program (AFRP) established an annual average production target of 38,000 fall-run chinook for the Tuolumne, and emphasizes natural salmon production. In 2000, TRTAC developed a *Habitat Restoration Plan for the Lower Tuolumne River* (McBain & Trush 2000), hereinafter "TRTAC Restoration Plan", which emphasizes recovery of chinook populations and incorporates the goals of both the settlement agreement and AFRP. It recognizes that success will depend on "a science-based understanding of the river and the biological communities within it."

The CALFED program contains a number of goals that directly relate to restoration and enhancement of chinook runs in the Tuolumne River (see section B of this proposal). The Tuolumne River is considered a "demonstration stream" for the CALFED Ecosystem Restoration Program (ERP) (CALFED 2001). CALFED has been a strong supporter of restoration planning and implementation on the Tuolumne, funding numerous projects prioritized by TRTAC's Restoration Plan and sponsored by its member agencies. Notable progress has been made in improving salmonid habitat and populations. However, increased understanding of factors affecting juvenile success and the role played by genetics will improve the results of future management and restoration efforts.

c. Statement of Problem. The Tuolumne River is the focus of major and important restoration efforts. Restoring a strong, natural chinook population is a goal of many agencies as well as CALFED. However, several important factors that affect this goal are not well understood. Additional information in the following areas would support current efforts to improve chinook populations:

(1) the role of genetic variability in the viability of chinook juveniles and in their emigration,
(2) factors affecting juvenile emigration and mortality,
(3) variability in behavior and migration success between hatchery and wild juveniles, and
(4) differences in juvenile migration and survival between upper and lower reaches.

With more detailed knowledge, restoration efforts and adaptive management activities can be tailored to be more effective, and the goal of chinook population recovery in the Tuolumne may be achieved more quickly and successfully.

d. Goals and Hypotheses. This study proposes to address the additional information needed that is noted immediately above. We will gather data and provide analyses in each of these areas to assist resource managers in their goal of supporting larger, healthier chinook populations in the Tuolumne River. Many of the study's findings will be applicable to other California watersheds as well, and will support salmonid restoration efforts elsewhere. We plan to investigate the relationships between juvenile behavior, genetics, and mortality and relate those to upper vs. lower reaches of the river, wild vs. hatchery fish, and migration movements. Our hypotheses include:

Factors Influencing Migration and Comparison of Upper and Lower River Reaches:

(1) Outmigration timing, rate of movement and survival of juveniles differ between the upper and lower reaches of the Tuolumne River, and between two study sites within each reach.

(2) Migrating juveniles do not move upstream in the San Joaquin River.

Mortality:

(3) High mortality occurs in degraded habitats characterized by slow-moving water such as former mine pits.

(4) A major cause of mortality in juveniles is predation by largemouth bass.

(5) High mortality of juveniles occurs in lower (sand-bedded) reaches of the river.

Genetics:

(6) Wild juveniles within each reach of the river are more genetically related than those from different reaches.

(7) Wild juveniles within a single study site are more genetically related to each other than to juveniles from any other site, even a site in the same reach.

(8) Wild juveniles in all parts of the river are more genetically diverse than hatchery juveniles.

(9) Timing and rate of outmigration are correlated to genetic relatedness.

Comparison of Wild and Hatchery Fish:

(10) Outmigration timing, rate of movement, and survival of juveniles differ between wild and hatchery-raised juveniles.

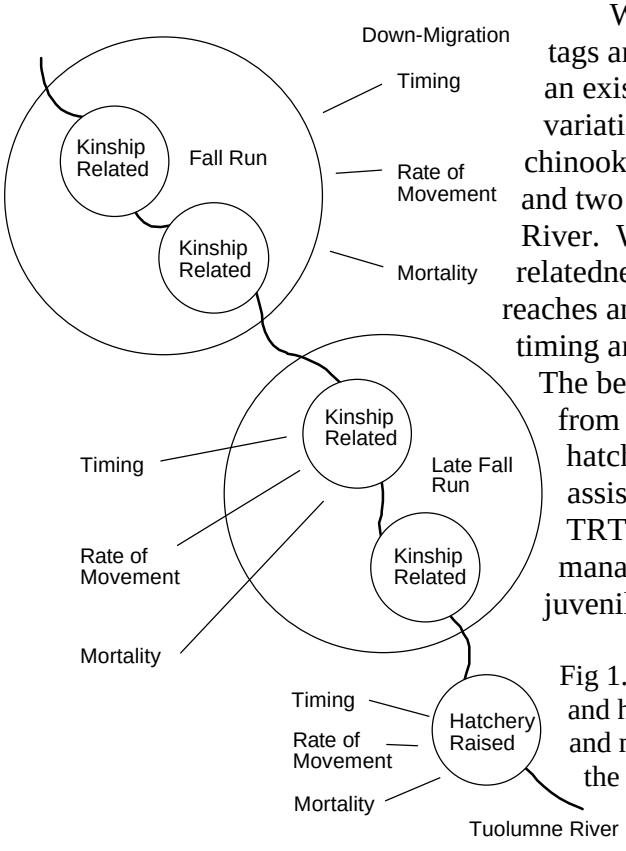
(11) Mortality of hatchery fish is greater than that of wild fish.

This study will investigate each of these hypotheses; related work that has been done by other researchers is discussed below. Our work will examine the genetic and behavioral variation within populations of juvenile chinook in the Tuolumne River. We will conduct genetic and behavioral studies of juvenile chinook at two sites in each of two reaches, one in the lower and one in the upper reach of the Tuolumne River. Our primary tasks will be three-fold. Firstly, we will employ radio tags and an array of sophisticated radio listening stations coupled with selected manual tracking to determine whether the timing of migration, rates of movement, and mortality of juveniles varies at the four sites in the river. Any differences in migration patterns will be related to physical properties of the aquatic environment (water temperature and current speed). Secondly, we will utilize molecular genetic techniques to determine whether the juveniles from within a site and within a reach are more related to each other than individuals from the other sites and the other reach. Thirdly, we will characterize the genetics, migratory behavior and, mortality of hatchery-raised fish and compare these to the genetics and behavior of

naturally-spawned fish within the tributary. We hope to provide information that management agencies can use to improve the success of juvenile chinook in the Tuolumne and other tributaries of the Sacramento/San Joaquin Rivers**.**

2. Justification.

California fishery biologists from governmental agencies, irrigation districts, and watershed advisory committees recently developed a plan for monitoring the response of chinook and steelhead populations to improvements to habitat in the Sacramento and San Joaquin rivers that are being made with funding from the CALFED Ecosystem Restoration Program. The two main objectives of the salmon monitoring program are to (1) increase the abundance of adults and juveniles within the river system and (2) monitor indicators of salmon health, habitat quality, and ecosystem processes. The knowledge gained will provide a basis for future adaptive management of the tributary. The document (CALFED, 2000) articulates various concerns and the need for scientific research to answer key questions. The document contains a number of hypotheses related to the distribution and movements of chinook salmon that will be addressed by this study. The Tuolumne River has been chosen as a site for our studies for three reasons. Firstly, the river supports a healthy population of fall-run chinook. Secondly, there is a very active program of restoration on the river. Thirdly, a research program is already in place on the river focusing on salmon biology.



We intend to use state-of-the-art electronic tags and monitoring stations in conjunction with an existing screw trap to describe the degree of variation in the timing of movement of juvenile chinook salmon from two sites in the lower portions and two sites in the upper portions of the Tuolumne River. We will compare the degree of genetic relatedness of individuals among and between reaches and relate this to differences in outmigration timing and rate of movement (see model, Fig. 1). The behavior and genetic diversity of wild fish from these reaches will be compared with that of hatchery-raised fish. Findings of this study will assist resource managers, involved agencies and TRTAC in tailoring restoration and adaptive management activities to improve success of juvenile chinook in the Tuolumne River.

Fig 1. *Conceptual model* of levels of genetic variation and how it might affect the timing, rate of movement, and mortality of juvenile chinook while migrating down the Tuolumne River. Genetically related juveniles may migrate at more similar times and rates, and may experience more similar mortality levels, than less related fish. Fish in the upper portion of the river may be more related and behave more similarly (as indicated by timing and rate of migration) than those in the lower portion of the river. Fish found within a specific study site may be even more highly related and migrate in a yet more similar manner. Hatchery-raised fish may have higher relatedness and more similar migration behavior than wild fish.

We will analyze the genetic diversity of 40 tagged wild juvenile chinook at each of two study sites in the upper portion of the Tuolumne River and at each of two study sites in the lower portion. We will also analyze the genetic diversity of 40 tagged hatchery fish released at a study site in the upper reach and of 40 released at a lower river study site. We hope to determine whether the timing and rate of outmigration differs among juveniles spawned in different reaches of the river, and if so whether it has a genetic basis. Microsatellites will be used to determine whether they are related by possessing the same father. A series of ten listening stations along the river will be used to detect the same individual repeatedly during outmigration. An extreme result would be that genetically related individuals from a single reach migrate down the river together in a group.

a. Outmigration Factors and Comparison of Upper and Lower River Reaches.
Hypotheses: 1) Outmigration timing, rate of movement and survival of juveniles differ between the upper and lower reaches of the Tuolumne and between study sites within each reach. 2) *Outmigration is correlated with magnitude of water flow in both the upper and lower reaches. 3) Migrating juveniles do not move upstream in the San Joaquin River.*

The California Department of Fish and Game (CDFG) is collecting information on the timing of outmigration and effects of various environmental factors. This assessment is based on the frequency of capture of juveniles and smolts and corresponding environmental measurements made at a pair of rotary screw traps installed six miles above the mouth of the Tuolumne River (Vasques and Kundargi, 2001) which are operated from January to June each year. Monitoring associated with the CALFED-funded restoration of Special Run Pools 9 and 10 in the upper portion of the river provides for annual spawning and seining surveys beginning in 2000.

The electronic marking program described below will use automated listening stations to individually detect tagged juveniles at ten sites as they swim up and down the Tuolumne River. This technique will provide complementary data to augment that collected from surveys and screw traps. Of 45 marked fish observed, 18 (40%) avoided being caught by the trap. The monitors we employ will provide more reliable and more comprehensive data to CDFG and other resource managers, due to a higher number of monitoring locations and the higher accuracy of electronic monitors in tracking individuals. The richer, more detailed data regarding the migration movements of juveniles yielded by this study will complement existing monitoring and will assist current management efforts.

New technologies often provide answers to questions that are unanswerable using existing methodologies. For example, the timing of the seaward migration of juvenile salmon has been inferred in the past from the numbers of individuals caught in separated pairs of traps, one upstream and another downstream. This method provided the classic description of the life history of the steelhead (*O. mykiss*) and coho salmon (*O. kisutch*) in Waddell Creek on the central coast of California (Shapovolov and Taft, 1954). Though this technique provides a wealth of data over time, it has a coarse spatial resolution limited to two geographic points separated by a long distance. A similar method using screw traps currently provides data on the Tuolumne.

Radio telemetry offers distinct advantages over trapping. Tag-detecting monitors can record the passage of tagged fish repeatedly and with less trauma because the fish is not captured and released during a census. Furthermore, automated monitors provide rates of passage on a finer spatial scale. Ten monitors will be deployed along the lower Tuolumne River, from the San Joaquin confluence to a location below the La Grange Dam. In addition, pairs of monitors will be placed on either side of two major sites where high mortality is believed to occur for more intensive analysis of predation, as described below in section A.2.

Finally, two more monitors will be deployed on the San Joaquin River, down which the young chinook swim on their route to the ocean. One monitor will be placed upstream and the other downstream of San Joaquin's confluence with the Tuolumne River. These two monitors will provide an estimate of the degree of upstream straying among juveniles. TRTAC participants have expressed concern that juveniles may be lured upstream by water management regimes in the San Joaquin that affect flows in the vicinity of the Tuolumne/San Joaquin confluence. Data we collect will help determine whether such upstream straying is occurring, and will provide an early indication of the magnitude of such straying if it occurs.

Radio telemetry is a proven technique, and has been used effectively on salmonids in both the Atlantic and Pacific oceans. The downstream migration of Atlantic salmon smolts (*Salmo salar* L.) has recently been studied using both radio (Bourgeoise and O'Connell, 1988; Jepsen *et al.*, 1998) and ultrasonic transmitters (Tytler *et al.*, 1978; LaCroix and McCurdy, 1996; Voegeli *et al.*, 1998). A high rate of mortality was observed in Atlantic salmon carrying radio beacons in their peritoneal cavities and external antennas as they passed through a reservoir during seaward migration (Jepsen *et al.*, 1998). During the 3-week period of the study, 90% of the tagged smolts died. The cause of death was predation by fish (56% were lost to pike) and birds (31%). Radio beacons have also been used to track downstream migration of juvenile chinook salmon in the Stanislaus River in California (Demko *et al.*, 1998). In the Stanislaus River study, 70% of the juvenile chinook salmon carrying stomach-implanted radio tags were lost through predation (Demko *et al.*, 1998). Radio and ultrasonic tracking has also been used on wild coho salmon (Moser et al. 1992).

A recent advance in this field is the use of electronic monitoring stations to detect fish carrying individually coded beacons as they pass within range of the monitors. Klimley *et al.* (1999) recently reviewed this technology, describing its operation and use to identify the movement patterns of hammerhead sharks (Klimley and Butler, 1988; Klimley *et al.*, 1988), yellowfin tuna (Klimley and Holloway, 1998), and white sharks (Klimley *et al.*, 2001a,b). Radio monitors have been used to detect the passage of upward migrating adult Atlantic salmon in the Sudalslågen River, Norway (Thorstad and Økland, 2000) and downward migrating smolts in the Stanislaus River, California (Demko *et al.*, 1998). A large array of monitors is currently detecting the passage of hatchery-raised and wild Atlantic salmon smolts on their outward migration through the Bay of Fundy (Lacroix and McCurdy, 1996; Voegeli *et al.*, 1998). Monitors, separated by equal distances (in river miles), can be deployed along an entire stream to detect the downstream and upstream movements of individual tagged salmonids, rate of movement, and areas of cessation of movement due to mortality. This approach, using equally spaced monitors, will be used in our study.

b. Agents of Juvenile Mortality. *Hypothesis: 1) Predation by introduced species such as largemouth, smallmouth and striped bass is a major cause of smolt mortality. 2) These predators inhabit degraded habitats such as former mine pits (CALFED, 2000). 3) High mortality of juveniles also occurs in lower reaches (sand-bedded portions) of the river.*

A 1987 smolt survival study conducted by CDFG estimated that 69% of 90,000 smolts released in the upper Tuolumne did not survive the 3-day outmigration to the San Joaquin River. Smolts with stomach-implanted radio-tags suffered high apparent mortality (80%) due to predation while passing through mine pits on the Stanislaus River (Cramer and Associates, 1998). Preliminary studies on the Mokelumne River indicated that predation by striped bass downstream of the Woodbridge Dam may be as high as 50% on migrating smolts (Boyd, 1994). It is important to know more precisely the rate of passage and mortality of salmon smolts before and after mine pits and other degraded sites, which may harbor high

abundances of predators. Upper reaches of the Tuolumne River contain mining sections that are believed to harbor abundant predators (McBain & Trush, 1999). However, lower sand-bedded sections of the river may also be the source of high juvenile mortality due to higher water temperatures in shallow sections and/or predation (McBain & Trush, 2000).

As part of the monitoring effort associated with the CALFED-funded restoration of Special Run Pools 9 and 10, bass abundance is being determined annually 1999-2002 through use of electrofishing and snorkel surveys. Smolt survival estimates are also being provided annually 2000-2002 through multiple mark recapture of smolts at the rotary screw trap. Our study will complement this work by providing detailed data about the survival of 200 individual smolts per year, information about areas of the river where mortality rates are high, and specific information regarding predator actions at two pool sites that will receive detailed study described below. With better information regarding magnitude and locations of juvenile mortality in the Tuolumne provided by this study, management strategies to improve the success of juvenile chinook can be refined.

c. Juvenile Success vs. Stream Flow. *Hypothesis. 1) Smolt survival within the tributaries is directly related to magnitude of stream flow (p. 16, CALFED, 2000).*

It is generally believed that high flows during outmigration promote smolt survival. Survival of San Joaquin hatchery-raised juvenile chinook salmon has been estimated by coded wire tag mark and recapture studies to be very low (0-30%) in the Delta during non-flood years, and there is concern that juvenile survival is also low in the tributaries. Survival of hatchery-reared smolts in the Stanislaus River was high (78%) when they were released with flows ranging from 804-1160 cf/min in April and low (28%) for smolts released when flows ranging from 604-808 cf/min. The importance of high spring flows in the success of smolt outmigration has been studied in the Tuolumne River and other Central Valley rivers (USFWS, 1992; USFWS 1987; CDFG 1998). CDFG and TRTAC continue to study the relationship between smolt survival and spring streamflow in the Tuolumne because of its importance. Early results indicate that juvenile and smolt survival are low when spring runoff is low, and that survival is poor in the mining reaches of the river (McBain & Trush, 2000). We need to continuously monitor the passage of individuals over time in varying flow rates to gain the most complete understanding of how water flow in the Tuolumne River influences smolt survival. This study will monitor movements and success of juveniles during migration over two separate migration seasons, and will relate findings to flow measurements. A deeper understanding of how flows affect chinook juveniles in tributaries during outmigration will allow more effective management of flow releases to support juveniles at this critical time in their life cycle.

d. Genetic Variation of Chinook Smolts. *Hypotheses. 1) Wild juveniles within each reach of the river are more closely related than those from different reaches. 2) Wild juveniles in upper reaches of the river are more related than those in the lower reach. 3) Wild juveniles in all parts of the river are more genetically diverse than hatchery juveniles. 4) Timing and rate of outmigration vary not only among reaches of the river, but also are correlated to genetic relatedness.*

Kinship analysis is a powerful tool for resolving population-level characteristics that ultimately impact the persistence as well as genetic variability of the population. For instance, evaluating the level of kinship among members of a population may indicate the relative incidence of different types of mating systems, variance in family size and reproductive success, homing behavior in adults, dispersal behavior in juveniles, and the heritability of behavioral or

phenotypic traits (Mousseau *et al.*, 1998). The degree of relatedness, full-sibling, half-sibling, or unrelated, among post-emergent juveniles of steelhead trout and chinook has been determined using microsatellite data, repeating base pair combinations (Bentzen *et al.,* 2001). Estimates of relatedness based on multilocus genotyping of microsatellites may be obtained through non-destructive sampling of captured fish. A greater than average relatedness was found in the upper reach of the Dungeness River, implying that adults returned to their "home" reach of the river.

A considerable number of microsatellite markers are currently available for the suggested analyses. Bentzen *et al.* (2001) mention that microsatellite loci that exhibit relatively high variability, specifically a high number of alleles/locus and high heterozygosity, are particularly well suited for kinship analysis. Recently, a suite of 12 microsatellite loci have been developed by Williamson *et al.* (2001, *in press*) that meet these criteria in fall-run chinook from the San Joaquin River basin. These microsatellite loci as well as other previously published genetic markers (Banks *et al.*, 1999, Nelson and Beacham, 1999) will be used for determining the multilocus genotypes of the fish in this study.

We will analyze the genetic diversity of 40 tagged wild juvenile chinook at each of two study sites in the upper portion of the Tuolumne River and at each of two study sites in the lower portion, for a total of 160 wild juveniles. We will also analyze the genetic diversity of 40 tagged hatchery fish released at a study site in the upper reach and of 40 released at a lower river study site, for a total of 80 hatchery juveniles. This work will be repeated during Year 2 of this study. We hope to determine whether the timing and rate of outmigration differs among juveniles spawned in different reaches of the river, and if so whether it has a genetic basis. Microsatellites will be used to determine whether they are related by possessing the same father. A series of ten listening stations along the river will be used to detect the same individual repeatedly during outmigration. An extreme result would be that genetically-related individuals from a single reach migrate down the river together in a group.

e. Behavior and Success of Hatchery-Raised vs. Wild Fish. *Hypotheses. 1) Mortality of wild juveniles is lower than hatchery-raised fish. 2) The outmigration timing and rate of movement differs between wild and hatchery-raised juveniles.*

Hatchery-raised chinook juveniles have been planted in the Tuolumne River in most years during late spring. These individuals were raised in a hatchery located on the Merced River. A proposal for the construction of a large hatchery on the Tuolumne has been advanced by the California Department of Fish and Game (CDFG) that could provide smolts to supplement the natural run, although state salmon hatchery operations throughout California are presently under review. The hatchery-raised juveniles, which migrate down the river out into the sea, may soon exceed the numbers of wild smolts. Hatchery fish can be produced in large numbers and released at chosen sites but they are produced from a restricted number of parents and consequently are less genetically diverse than wild individuals raised from parents throughout the river system. The rates of survival are believed to be lower in hatchery-raised fish than in wild individuals.

Hatchery fish are typically "reared in the open, over uniform concrete substrates; conditioned to minimal raceway flow regimes; provided no structure in which to seek refuge from water currents, predators, or dominant cohorts; held at high, stress-producing densities; surface fed; and conditioned to approach large, moving objects at the surface" (Maynard *et al.*, 1995). The survival of hatchery salmonids is often lower than wild fish (e.g., chinook salmon in the Columbia River system – Raymond 1988; Oregon coastal coho salmon – Nickelson et al. 1996), and often markedly so. For example, wild trout fingerlings have been recovered at rates 8.4 to 18.6 times greater than hatchery-raised fingerlings released in the same lake, suggesting

much lower mortality of the wild fingerlings (Green, 1952). The survival of naturally-spawned outmigrating coho salmon smolts was found to be three times greater that of hatchery-raised individuals (Salo and Bayliff, 1958). There are two likely major explanations for greater mortality in hatchery-raised than wild salmon juveniles:

(1) *Starvation*: Hatchery-raised fish are not accustomed to foraging for the diverse types of prey existing in the natural environment, and, consequently may be more likely to starve than wild individuals. In support of this conclusion, the contents within the stomachs of hatchery-raised trout were less than those of wild trout 28 days after release; the mean body mass of the former was less than that of the latter (Hochachka, 1961). Furthermore, the mean ratio of stomach content to body mass of wild chinook examined after release was three times that of hatchery-raised fish (Myers, 1980). We do not hypothesize that the fish actually die of starvation but rather that poor growth prolongs their period of vulnerability to gape-limited predators, inappropriate feeding behavior increases their vulnerabilty to predators (see below), and poor growth or condition inhibits completion of the complex suite of physiological processes associated with parr-smolt transformation and success in seawater.

(2) *Predation*: Empirical evidence exists that hatchery fish have increased risk-taking and lowered fright responses relative to wild fish (Flagg *et al.*, in press). Surface feeding at the hatchery is believed to condition the fish to approach the surface where they are more accessible to avian predators (Uchida *et al.*, 1989; Maynard *et al.*, 1995; Olla *et al.*, 1998). In addition, the coloration of hatchery-produced fish likely predisposes them to an increased risk of predation. The hatchery fish match the monochromatic gray of the concrete raceway instead of the mottled gray of the streambed (Donnelly and Whoriskey, 1991; Maynard *et al.*, 1996). Twelve to 30 percent of the juvenile chinook salmon released from a hatchery on the Klickitat River were consumed by predators along the 40-mile reach between the hatchery and the Columbia River (Ellis and Noble, 1960).

We intend to compare the timing of migration, rates of movement, and mortality due to predation of wild versus hatchery-raised chinook salmon. We hope to provide information, which agencies can use to determine optimal hatchery stocking strategies for the Tuolumne and other tributaries of the Sacramento/San Joaquin Rivers. In combination with other potential findings of this study, managers may be able to coordinate the timing and locations of hatchery releases with periods of expected optimal flows to minimize mortality of juveniles during emigration.

3. Approach

a. Research Plan. ***Task 1a****: Radio Tagging and Tracking of Wild Juveniles via Electronic Monitoring Stations* (A.P. Klimley, principal investigator, T.P. Quinn, co-investigator, and J.E. Richert, graduate student, Marine Ecology, UC Davis).

We will tag juvenile chinook salmon with radio beacons at two sites in the lower (sand-bedded) Tuolumne River and two sites in the upper (gravel-bedded) portion of the river below the La Grange Dam during Years 1 and 2 (Fig. 2). We will initially be assisted by Dr. T.P. Quinn, who has extensive experience tagging juvenile and adult salmon. Forty wild individuals will be tagged at each of two sites in the downstream reach and a forty at each of two sites in the upstream reach. Individuals will vary from 100-120 mm long. The tags on the juveniles will transmit 40 pulses/sec in a unique frequency and possess a longevity of 20 (rated) to 40 days (theoretical life). Tagging will be conducted during April and May, beginning just prior to the onset of migration. The wild fish will be captured by seine or fyke nets at the four sites. Variability in migratory behavior is anticipated within these zones. Carcass surveys have been

conducted by CDFG in four separate sections of the river (T. Heyne, pers. commun.). The number of carcasses observed in the upper two reaches greatly exceeds the number recorded in the lower reaches of the river. Adults also arrive at the upper reaches much earlier than at the lower reaches. The upper river apparently hosts a strong fall run of adult spawners, and the lower reaches may host a much smaller run of late-fall spawning. If so, there may be significant differences in behavior between juveniles that were spawned upstream and those that occur downstream.

A small incision will be made on the ventrum of each juvenile while anesthetized, the beacon (4 x 10 mm) inserted into the peritoneum, and the incision closed with either superglue or sutures (for technique, R. Bush, pers. commun.). Peritoneal implantation has less deleterious effects on long-term swimming performance than stomach implantation (Adams *et al.*, 1998), the technique that was used with smolts on the Stanislaus that exhibited a high mortality of 70% (Demko *et al.*, 1998). The beacons will have a small antenna that will trail behind the fish when swimming. We will conduct range tests to determine the minimum antenna length necessary for effective reception by the listening stations. Based upon the range test results, we will use the shortest feasible antenna length to minimize the effects of tagging on the juveniles.

The passage of fish down the river will be detected by electronic monitors deployed within the river. There will be ten automated monitoring stations, and they will be separated from each other by equal distance intervals (Fig. 1). We will use automated radio monitors obtained from Advanced Telemetry Systems, Inc (ATS). Each monitoring station will consist of an enclosure with an antenna (Yagi, 4-element), receiver (ATS, R4000), data logger (DCCII 5041), and power supply (12-V lead acid battery).

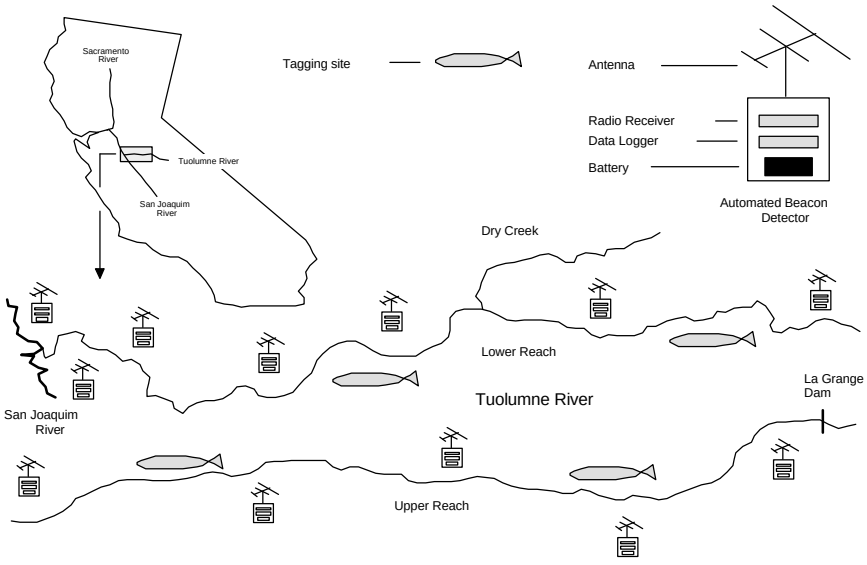


Fig 2. The sites at which juvenile wild and hatchery-reared salmon will tagged with radio beacons and their down-migration monitored with automated beacon detectors on the Tuolumne River.

We will interrogate the monitors every other day for their files of salmon passage. From the monitor records, we will be able to determine the: 1) timing of initial departure, 2) tenure between each pair of monitors, 3) rate of passage, 4) duration of outmigration, and 5) locations where mortality appears to be highest, potentially due to starvation or predation. We will record water temperature by an automated logger attached to a metallic bar driven into the bed of the river near each site. We will use reliable, low-cost data loggers (Onset, HOBO) that will continuously record hourly water temperatures. We will relate the temperature data that is collected to the abundance and passage of juvenile chinook. We will also secure flow data that is already being monitored along the river, and relate flow data to the abundance and passage of juvenile chinook as well.

Task 1b: *Tagging and Electronic Tracking of Hatchery-raised Juveniles* (A.P. Klimley, principal investigator and J.E. Richert, graduate student, Marine Ecology, U.C. Davis).

In addition to the tagging of wild fish, hatchery-raised fish will be obtained from the hatchery on the Merced River. Forty hatchery fish will be tagged and released at the upstream site where the wild individuals are released and 40 more at the downstream site, in both Year 1 and Year 2. A tissue sample (fin clip) will be taken from each individual for genetic analysis as described below. Individuals will vary from 100-120 mm long. The tags on the juveniles will transmit 40 pulses/sec in a unique frequency and possess a longevity of 20 (rated) to 40 days (theoretical life). Tagging will be conducted during the months of April and May and monitoring will be conducted as described above. We will compare the down-migration timing, rate of movement, and mortality of hatchery-raised juveniles to wild ones.

Task 2: *Predation Analysis* (A.P. Klimley, principal investigator and J.E. Richert, graduate student, Marine Ecology, U.C. Davis)

We will estimate the frequency with which juvenile chinook migrants are lost to predators. The tag-monitoring stations will be interrogated every other day. The records will indicate when each juvenile begins to move, whether up or down the river, and whether the outward movement halts between two listening stations. In the latter case, in areas where mortality is believed to occur, we will search intensively for the lost tag between the two stations using a hand-held antenna and receiver operated in an inflatable boat. Upon finding the pool in which the tag resides, we will lower a submersible antenna consisting of PVC tubing in the shape of an inverted "T". The signal from a co-axial cable enclosed within the cap of the "T" will be strongest when facing the transmitter. We will move in that direction until the signal becomes omni-directional and the subject with the transmitter is immediately below us. The subject may be a non-moving smolt, a smolt carcass, or a predator that has eaten the tagged smolt.

Ten monitors will be placed at equal spacing along the Tuolumne below the La Grange Dam. However, two particular localized sites will receive special study in Years 1 and 2 (spring 2002 and 2003) to better understand predation on juveniles. The site selection will be finalized in consultation with TRTAC and knowledgeable agency staff. One site could be Special Run Pool 10, where restoration is expected to begin in summer 2002 and be completed in summer 2003. Another site could be Special Run Pool 5, a 0.5-mile long remnant instream aggregate extraction area at river mile 33, or Special Run Pool 6, a similar 0.7-mile one at river mile 30 which could serve as a pre-restoration baseline. Alternatively, a site in the upstream Gravel Mining Reach could be selected to expand upon the monitoring and restoration work that is underway there. More detailed knowledge about predators at these or another selected location would complement the monitoring efforts already planned or in progress.

We will gain information about the predation in the following way. First, we will look at the strength and separation between targets on the fathometer display, which are indicative of species identity. For example, the readings from bass are strong due to the large size of the fish and are widely separated because of their solitary nature as adults. Second, we will search for the beacon by free diving (with mask and snorkel) carrying a receiver and antenna within a submersible housing. The signal from the tag will be strongest when the tag is directly in front, hidden in a salmon smolt or a predator that has eaten a tagged smolt. The housing (and antenna) will be rotated on a horizontal plane until the received signal is strongest. The diver can then look in that direction for the tagged juvenile or the predator, such as a large sunfish or a smallmouth or largemouth bass. We will also select a pool that could host a high concentration of predators, then tag ten largemouth bass in the pool with radio transmitters and use this technique to track them. We will monitor their movement and behavior as a baseline. These

actions will provide a set of criteria that can be used to assume that a smolt has been eaten by a bass.

Task 3*: Genetic Analysis of Juveniles* (B.P May, co-investigator and K.S. Williamson, graduate student, Molecular Biology, U.C. Davis).

We will determine the degree of kinship between the salmon smolts through non-destructive tissue sampling and performing microsatellite-based tests of relatedness. A tissue sample (fin clip) will be taken from each tagged individual for genetic analysis. The number of fish chosen is based on arriving at an adequate appraisal of the degree of relatedness within and between sampling sites. The study by Bentzen *et al.* (2001) was based on 147 individuals (7-12 juveniles/redd). Extraction of genomic DNA from tissue samples will be performed via a commercially available kit (QIAgen, DNAeasy). The amount of genomic DNA obtained from each sample will be quantified using a fluor-imager (Molecular Dynamics, 595) operated by fragment analysis software (Molecular Dynamics, Fragment NT). Polymerase Chain Reaction (PCR) amplification of the microsatellite loci to be genotyped will be performed using DNA primers labeled with one of three fluorophores (HEX, FAM, TET). We will record the PCR products (alleles) for each locus using an automated genotyper (MJ Research, BaseStation). This data acquisition platform has the capability of simultaneously resolving the genotypes of three separately labeled loci for 96 individuals in a single run. Automated scoring of genotypes will be performed with software (Cartographer). The genotype scoring algorithms used by Cartographer have already been defined for most of the microsatellite loci (Williamson *et al.*, 2001, in press) suggested (above) for the proposed analyses.

The degree of relatedness will be determined between the individuals within and between the two sites and the two reaches using three complementary approaches based on multilocus microsatellite genotypes. Individuals will be grouped according to their allele sharing coefficient (D_{PS}, Bowcock *et al.*, 1994) using UPGMA clustering (Blouin *et al.*,1996); reconstruction of parental genotypes based on the genotypes of full or half siblings (Banks *et al.*, 2000); and relatedness coefficients (r_{xy}) for different levels of kinship, to be calculated using the program Kinship 1.2 (Goodnight, 2000). An UPGMA tree based on allele-sharing coefficients would provide information about the likely family groupings within the Tuolumne River. This graphical method used in conjunction with the reconstruction of the parental genotypes would allow explicit tests of hypothesized patterns of mating that produced the various families sampled (Bentzen *et al.*, 2001). To test the hypothesis [H_{B1}] that the level of relatedness varies among river reaches for given levels of kinship, relatedness coefficients (r_{xy}) will be calculated for all pairs of individuals within each reach. Comparisons of the distributions of r_{xy} for full siblings, half siblings, and unrelated individuals (as determined from the mating reconstruction) will be made among different reaches. The degree of relatedness within a given reach will be correlated with the timing and rate of outmigration of juveniles in each reach. Spawning date is highly heritable in salmonids, including chinook salmon (Quinn et al., 2000) so it is likely that the early/upriver and late/downriver groups are genetically separate to some extent.

An intriguing outcome of study would be to demonstrate that salmon smolts migrate downstream together in kin-related schools. This hypothesis can be tested by tagging and tracking juveniles captured at the same time. Related individuals would be expected to pass through the detection range of a particular monitor at the same time if they were moving together in a school. Klimley and Holloway (1998) used this approach, tagging groups of yellowfin tuna and detecting them with monitors placed on fish-attracting buoys off Hawaii. The tunas returned together in the same school repeatedly over a period of nine months and arrived at the buoys with great temporal precision, often only minutes before or after they had arrived weeks before.

b. Hypothesis Testing. We will coordinate our studies closely with the CDFG biologists, who operate the rotary screw traps at Grayson Ranch, and with the Tuolumne River Technical Advisory Committee. Our automated monitors will provide a fine-grained spatial and temporal record of our individual juveniles, and will individually detect all juveniles bearing beacons. This technique provides more reliable and more comprehensive data than screw traps. Physical measurements of water flow at various points in the river will be obtained from records collected by the United States Geological Service and from temperature monitors we will install during the study. We will compare rates of juvenile passage to records of temperature and flow. Using these combined techniques, we will thus be able to evaluate the hypotheses noted in Section A.1.d. above.

c. Conclusions. We will combine modern techniques of radio tracking and molecular biology to traditional coded-wire tagging to detect variation in the migratory behavior of juveniles and its genetic basis. We will concentrate our work in the partially restored and well-studied Tuolumne River tributary of the Sacramento-San Joaquin River System. Our objective is to develop a series of protocols for successfully studying salmon movement in tributaries throughout California. We believe that this research proposal provides an integrated, multidisciplinary, coordinated effort to study and correlate genetics, behavior, and ecology of juvenile salmonids as well as physical properties of the river such as temperature, flow, and differences between channel reaches.

4. Feasibility

Dr. Peter Klimley, who will be leading the salmonid tracking effort, is an international authority on electronic tracking of marine species and has extensive experience in the development and use of multiple technologies. Dr. Thomas Quinn, who will collaborate on the salmonid tagging work, is a noted authority on salmonid biology, and he has wide experience in salmonid tagging and the comparative behavior of wild and hatchery-reared salmon. The radio telemetry that this study will employ is a proven technique, and has been used effectively on salmonids in both the Atlantic and Pacific oceans. The downstream migration of Atlantic salmon smolts (*Salmo salar* L.) has recently been studied using both radio (Bourgeoise and O'Connell, 1988; Jepsen *et al.*, 1998) and ultrasonic transmitters (Tytler *et al.*, 1978; LaCroix and McCurdy, 1996; Voegeli *et al.*, 1998). Radio beacons have also been used to track downstream migration of juvenile chinook salmon in the Stanislaus River in California (Demko *et al.*, 1998).

Dr. Bernard May is a recognized expert in application of molecular methods to critical genetics questions, and he will be leading this study's genetics component. Researchers have already successfully applied molecular methods to salmonids to provide insight into mating, homing, and timing of reproduction (Bentzen et al., 2001). A considerable number of markers are currently available for the suggested analyses. Bentzen *et al.* (2001) mention that microsatellite loci that exhibit relatively high variability, specifically a high number of alleles/locus and high heterozygosity, are particularly well suited for kinship analysis. Recently, microsatellite loci have been developed by Williamson *et al.* (2001, *in press*) that meet these criteria in fall-run chinook from the San Joaquin River basin. These loci as well as other previously published genetic markers (Banks *et al.*, 1999, Nelson and Beacham, 1999) will be used for determining the multilocus genotypes of the fish in this study.

5. Performance Measures

See Section 7.

6. Data Handling and Storage

a. Biotelemetry Laboratory. In November 2001, Dr. A.P. Klimley and his graduate students will move into a newly-built Biotelemetry Laboratory at H.T. Harvey & Associates' office in Davis, California. There will be four furnished offices for students and postdoctoral scholars. The students also possess desk space in the Department of Fish, Wildlife, and Conservation Biology at U.C. Davis, where Klimley is an Adjunct Associate Professor. The laboratory also contains a large workbench with machining equipment (lathe and mill) for building transmitter housings and electronic equipment (power supplies, oscilloscopes, signal generator, frequency counters, and solder stations) for assembling and repairing the electronic circuitry in transmitters.

The records from the tag-detecting automated monitors will be analyzed on PC and Macintosh-based workstations in the Biotelemetry Laboratory. The data will be processed initially using software custom-designed for the VR-02 monitors (Vemco, Ltd., Hallifax). Additional analysis will be carried out using either Excel macros or geographic information system (GIS) software such ARC INFO and Arc View. The processed data will be stored on floppy, hard drive, and compact optical disks. Klimley and his students have extensive experience describing the spatial distribution and movement of fishes on the basis of data collected by electronic listening stations. The results of these studies are contained in Klimley *et al.* (2001a,b), Klimley & Holloway (1999), Klimley *et al.* (1998), Klimley & Butler (1998), and Klimley *et al.* (1988).

b. Genomic Variation Laboratory. The Genomic Variation Laboratory, housed within the Department of Animal Science at U.C. Davis, is fully equipped to undertake molecular genetic-based analyses of population structure. The infrastructure is already in place that is required for the storage and processing of samples and the detection of molecular genetic markers in those samples for the delineation of population genetic structure. Ultra-cold REVCO freezers are available for the storage of genetic tissue samples (fin-clips) and genomic DNA isolated from those samples. Additionally, the lab is equipped with a chemical safety fume hood, and three high-speed centrifuges for processing the isolation of genomic DNA from fin-clips. Quantification of the amount of genomic DNA obtained from each sample will be performed using the Molecular Dynamics 595 Fluorimager and Fragment NT analysis software. The lab has eight 96-well MJ Research PT-100 thermocyclers for Polymerase Chain Reaction (PCR) amplification of targeted molecular markers. Polymerase Chain Reaction amplification of the microsatellite loci to be genotyped will be performed using DNA primers labeled with one of three fluorophores (HEX, FAM, TET) obtained from a commercial vendor (IDT, Inc.). Visualization of the amplified genetic markers will be carried out on the 96-lane, auto-loading, or the 48-lane, manual-loading MJ Research BaseStation Genotyper. This data acquisition platform has the capability of simultaneously resolving the genotypes of three separately labeled loci for 96, or 48 individuals, respectively, in a single run. Automated scoring of genotypes will be performed with the software package Cartographer. The genotype-scoring algorithms used by Cartographer are already defined for the microsatellite loci (Williamson *et al.*, 2001, *in press*) suggested for the proposed analyses.

Genetic analysis of groups of organisms generates a considerable amount of data that must be organized and stored in a manner that facilitates easy retrieval and analysis. GENETIX (Belkhir *et al.*, 1998) is a set of programs organized around a Microsoft Excel data sheet format. This software package has the flexibility to allow import and export of genotype data from and towards several other genetics packages. Consequently, it can be used as a convenient data entry system. GENETIX also computes several basic parameters of population genetics such as Nei's

D and H, Wright's F-statistics (the Weir-Cockerham's and Robertson-Hill's estimators), and linkage disequilibrium D according to Black & Krafsur.

7. Expected Products/Outcomes

Our hypotheses and potential findings are discussed above. We will submit the first-year and second-year results including data sets, findings and complete analyses to CALFED staff, with a copy to the Tuolumne River Technical Advisory Committee members and member agencies that are supporting this study. After submitting our final report to CALFED, we plan to present the results of our study at the meetings of the American Fisheries Society and American Society of Ichthyologists and Herpetologists. We also propose to publish the results of our studies in the journals such as the following: Transactions of the *American Fisheries Society, Copeia, Journal of Fish Biology*, *Journal of Heredity*.

8. Work Schedule

a. Project Start	1 February 2,002
b. Tagging of Juveniles, Yr. 1	1 April –31 May 2,002
c. Genetic Analyses	1 June 2,002 – 31 March 2,003
d. Tag Record Analyses	1 June 2,002 – 31 March 2,003
e. Final Report, Yr. 1	31 August 2,003
f. Tagging of Juveniles, Yr. 2	1 April – 31 May 2,003
g. Genetic Analyses	1 June 2,003– 31 December 2,003
h. Tag Record Analyses	1 June 2,003– 31 December 2,003
i. Publication Preparation	1 January 2,004 – 31 August 2,004
j. Final Report, Yr. 2	31 August 2,004

B. APPLICABILITY TO CALFED ERP and SCIENCE PROGRAM GOALS and IMPLEMENTATION PLAN and CVPIA PRIORITIES

ERP and Implementation Plan Goals: Several of the ERP priorities noted in the *ERP Draft Stage 1 Implementation Plan* (CALFED, 2001) will be addressed by this study.

(1) P. 71: "A variety of stressors have been identified in the San Joaquin [and its tributaries] that are detrimental to the survival of juvenile and adult fish. Efforts to improve our understanding of these stressors and actions to abate the problems are needed." This study will help identify where and how the primary losses of juveniles occur on the Tuolumne River and which portions provide relatively safe passage during the emigration season.

(2) P. 72: "Project should continue to identify Central Valley salmonid life history and habitat associations and requirements especially in relation to existing and restored habitats in all 3 San Joaquin River tributaries…" This study will show where juveniles reside during the emigration season; the study area encompasses both restored and non-restored sections of the Tuolumne River. The study will also provide much greater detail about emigration timing and rates of movement than is currently available.

(3) P. 138: "Assess the impact of hatchery practices on naturally spawning populations of chinook salmon and steelhead and operate hatcheries in a manner consistent with safe genetic practices that will maintain genetic integrity of all Central Valley salmonid populations." This study will analyze genetics of both hatchery and wild juvenile chinook salmon and will provide findings regarding genetic diversity of each. It will also

provide an early indication whether there are significant genetic differences between fish spawned in the upper vs. lower reaches, and whether substantial differences occur within reaches.

(4) P. 140: "Goal 1, At Risk Species, Objective 1: Achieve, first, recovery and then large self-sustaining populations of the following at-risk native species…: Central Valley winter-, spring-, and fall/late fall-run chinook salmon ESUs, …" and P. 23: "Conduct monitoring, assessment and research to improve the understanding of the ecological and physical processes affecting at-risk fishery resources…" This study will provide much richer data than is now available regarding juvenile chinook in the Tuolumne during migration and the factors that may correlate to their success, including water temperature, flow, timing and duration of outmigration, predation, and genetic diversity in wild vs. hatchery fish.

Science Program Goals: This study will support the Science Programs' goal to "build a body of knowledge that will continually improve the effectiveness of restoration actions." The proposed work is also consistent with the following Science Program goals, per pages 15-16 of the *ERP Draft Stage 1 Implementation Plan* (CALFED, 2001).

(1) At-risk species: "Improving the management of at-risk species is an important aspect of restoration. This requires knowledge of life history, environmental requirements and biology of at-risk species…"

(2) Integrated science in complicated field settings: "Integrated, interdisciplinary studies are the best was to advance process understanding and attack relevant restoration questions in a complicated field setting."

(3) Scientific basis for regulatory activities: "Managing water and protection of at-risk species uses science to establish regulations… Addressing the uncertainties in the science used for management is an important goal of the Science Program."

Our study is consistent with and will directly support the goals noted above. It will improve knowledge of the life history of juvenile salmonids, and provide deeper scientific understanding to incorporate into complex resource management decisions.

CVPIA Goals: Our study will address CVPIA priorities, including the Act's purpose to "… protect, restore and enhance fish, wildlife, and associated habitats in the Central Valley and Trinity River basins of California." Our study will support the overall goal of CVPIA's Anadromous Fish Restoration Program, which is to "develop…and implement a program which makes all reasonable efforts to ensure that….natural production of anadromous fish in Central Valley rivers and streams will be sustainable on a long term basis…"

Relationship to Other Ecosystem Restoration Projects:

This study will support and strengthen currently funded work that is deepening scientific knowledge of chinook salmon ecology within CALFED regions, as well as ERP projects that are underway to restore the Tuolumne River and improve its habitat values. Specifically, CALFED has recently funded ERP projects along the Tuolumne to design and restore Special Run Pool 9 (1997), Special Run Pool 10 (1999-2001), mining reach restoration work (1997-2001), and floodplain acquisitions (2000-01). This study will complement the restoration efforts by providing much more detailed information regarding the movements and success of wild and hatchery juvenile chinook as well as losses due to predators along the lower Tuolumne River, and will include a special focus on the mining reach areas that are the priority for current major restoration efforts.

This study will also build upon ERP-funded genetics research on Central Valley fall-run chinook salmon that is currently underway (CALFED project #P9940011). The work is being

led by Dr. B.P. May at U.C. Davis, as is the genetics component of the work proposed herein; the second year of this 3-year research effort was just completed. The research's goal is to develop a comprehensive genetic archive and describe the genetic variability of chinook salmon between and within tributaries in the San Joaquin River Basin, and to characterize and discriminate the genetic variation of fall-run chinook salmon in the tributaries of the San Joaquin River relative to those in watersheds of the Sacramento River basin. The first year objectives were to develop a suite of microsatellite markers for chinook salmon, evaluate their utility as molecular markers of genetic variation in fall-run chinook, and initiate microsatellite genotyping protocols. The second year effort resulted in the publication (Williamson, et al. 2001) of the development and characterization of 17 microsatellite loci, reducing the turnaround time required for the isolation of genomic DNA from chinook fin-clips obtained during yearly carcass surveys, and the development of microsatellite locus scoring algorithms for the genotyping analysis software. The upcoming third year objectives include determining if fall-run chinook from the San Joaquin River basin may be discriminated genetically from fish from the Sacramento River basin using microsatellite markers, determining if there is temporal variation of microsatellite allele frequencies within the San Joaquin system, and evaluating the genetic variation among certain hatcheries and natural spawning populations of fall-run fish within tributaries of the San Joaquin River system. The genetics aspect of the juvenile chinook study proposed herein will build upon these results.

C. QUALIFICATIONS

Summary information regarding the principal investigators' qualifications is provided below.

A. PETER KLIMLEY, Ph.D., Fisheries Ecologist, H.T. Harvey & Associates, Adjunct Associate Professor, Wildlife, Fish, & Conservation Biology, U.C. Davis, 2000 to present.
Selected Publications: 1) Klimley, A.P., B.J. Le Boeuf, K.M. Cantara, J.E. Richert, S.F. Davis, and S. Van Sommeran. 2000. Radio-acoustic positioning: a tool for studying site-specific behavior of the white shark and large marine vertebrates. *Marine Biology.* 138:429-446; 2) Klimley, A.P. and C. Holloway. 1999. Homing synchronicity and schooling fidelity by yellowfin tuna. *Mar. Biol.*, 133: 307-317; 3) Klimley, A.P., F. Voegeli, S.C. Beavers, and B.J. Le Boeuf. 1998. Automated listening stations for tagged marine fishes. *Mar. Tech. J.*, 32: 94-101; 4) 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; 5) 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.
BERNARD P. MAY, Ph.D., Adjunct Associate Professor, Animal Science Department, U.C. Davis, 1999 to present.
Selected Publications: 1) Williamson, K.S., J.F. Cordes, and B. May. 2,001. Characterization of microsatellite loci in Chinook salmon (*Oncorhynchus tshawytscha*) and cross-species amplification in other salmonids. Mol. Ecol. Notes, in press; 2) Jenneckens I., J.-N. Meyer, G. Hörstgen-Schwark, B. May, L. Debus, A. Ludwig. 2001. A fixed allele at microsatellite LS-39 exhibiting species-specificity for black caviar producer *Acipenser stellatus*. J. Appl. Icthyol., 17:39-42; 3) Pyatskowit, J., C.C. Krueger, H.L. Kincaid, and B. May. 2001. Inheritance of microsatellite loci in the polyploid derivative lake sturgeon (*Acipenser fulvescens*). *Genom*e, 44:185-191; 4) Tranah, G.J., J.J. Agresti, and B. May. 2000. New microsatellite loci for suckers (Catostomidae): primer homology in *Catostomus*, *Chasmistes*, and *Deltistes*. *Mol. Ecol. Notes*, 1:55-60; 5) McQuown, E.C., B.L. Sloss, R.J. Sheehan, J. Rodzen, G. Tranah, and B. May. 2000.

Microsatellite analysis of genetic variation in sturgeon: new primer sequences for *Scaphirynchus* and *Acipenser*. *Trans. Am. Fish. Soc.*, 129:1380-1388.

THOMAS P. QUINN, Ph.D., Professor, School of Aquatic and Fishery Sciences , University of Washington, 2000-present.

Selected Publications: 1) Rhodes, J.S. and T.P. Quinn. 1999. Comparative performance of genetically similar hatchery and naturally-reared juvenile coho salmon in streams. North American *J. Fisheries Managemt*., 19: 670-677; 2) Candy, J.R. and T.P. Quinn. 1999. Behavior of adult chinook salmon (*Oncorhynchus tshawytscha*) in British Columbia coastal waters determined from ultrasonic telemetry. *Can. J. Zool.*, 77: 1161-1169; 3) Rhodes, J.S. and T.P. Quinn. 1998. Factors affecting the outcome of territorial contests between hatchery and naturally reared coho salmon parr in the laboratory. J. Fish Biol., 53: 1220-1230; 4) McCormick, S.D., Hansen, L. P., Quinn, T. P., and Saunders, R. L. 1998. Movement, migration and smolting of Atlantic salmon. *Can. J. Fisheries Aquat. Sci. (Supplement 1),* 55: 77-92; 5) Quinn, T.P., S. Hodgson and C. Peven. 1997. Temperature, flow and the migration of adult sockeye salmon (*Oncorhynchus nerka*) in the Columbia River. *Can. J. Fish. Aquat. Sci.*, 54: 1349-1360.

D. COST

a. Budget: $655,603 (10% indirect costs of supplies and subcontracts) for 2 yrs (see attached Excel spreadsheets for Yr 1 and 2).

b. Budget Justification. Task 1a (A.P. Klimley, T.P. Quinn, & J.E. Richert): $411,147 for two years; lead scientist (120 hrs, project management, 40 h/7 wks, fieldwork), graduate student (20 h X 40 wk; 40 h X 8 wk), field technician (40 hrs X 7 wk), consultant (40 h X 1 wk), 160 radio beacons, listening station rental, temperature loggers, manual receiver purchase, travel, H.T. Harvey (HTH) overhead.

Task 1b (A.P. Klimley & J.E. Richert); $59,136 for two years; lead scientist (40 h X 2 wk), graduate student (40 h X 2 wk), field technician (40 h X 2 wk), 80 radio beacons, HTH overhead.

Task 2 (A.P. Klimley and J.E. Richert): $35,200 for 2 yrs; lead scientist (40 h X 2 wk) graduate student (40 h X 2 wk), field technician (40 hrs X 2 wk), HTH overhead.

Task 3 (B.P May and K.S. Williamson): $150,120 for 2 yrs; lead scientist (40 h X 12 wk), graduate student (20 h X 52 wks), sequencer rental, reagents, UCD overhead, HTH overhead.

E. LOCAL INVOLVEMENT

Prior to submitting this proposal, principal investigator Klimley collaborated with the Tuolumne River Technical Advisory Committee (TRTAC) members. TRTAC includes representatives from major involved state, federal and local agencies as well as stakeholder groups along the River. TRTAC therefore served as an excellent forum for soliciting broad-based input from local entities prior to proposal submission. Klimley described the proposed study in person to TRTAC in spring 2001 and incorporated the group's input into the study design. TRTAC was invited to review all drafts of the proposal and to collaborate actively in the study. TRTAC members support this study and believe the findings will help advance their goals (see letter from TRTAC indicating support for proposed studies, Appendix I). We performed additional active coordination during preparation of this proposal with staff of the Turlock Irrigation District and the Dept. of Fish & Game that are involved in the Tuolumne watershed. Both have indicated their support of this proposal.

F. COMPLIANCE WITH STANDARD TERMS AND CONDITIONS

We will comply with the standard State and Federal contract terms noted in the Proposal Solicitation Package documents.

G. LITERATURE CITED

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133: 307-317; Klimley, A.P., F. Voegeli, S.C. Beavers, and B.J. Le Boeuf. 1998. Automated listening stations for tagged marine fishes. *Mar. Technol.y J.*, 32: 94-101; 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. *Mar Ecol. Progr. Ser.*, 49:11-20; 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. *J.Fish Biol.*, 33:751-761.

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TUOLUMNE RIVER TECHNICAL ADVISORY COMMITTEE
DON PEDRO PROJECT - FERC LICENSE 2299

MODESTO IRRIGATION DISTRICT
TURLOCK IRRIGATION DISTRICT
CITY & COUNTY OF SAN FRANCISCO
CALIFORNIA DEPARTMENT OF FISH & GAME
U. S. FISH & WILDLIFE SERVICE

333 East Canal Drive
Turlock, CA 95381-0949
Phone: (209) 883-8275
Fax: (209) 656-2180
Email: tjford@tid.org

DRAFT

A. Peter Klimley, Ph.D.
Senior Ecologist: Fisheries Biology
H.T. Harvey & Associates
3150 Almaden Expressway, Suite 145
San Jose, CA 95118

October 4, 2001

Dear Dr. Klimley:

The Tuolumne River Technical Advisory Committee (TRTAC) supports your proposal to CALFED for a juvenile salmon study in the Tuolumne River. The TRTAC believes this investigation would fit well with the restoration actions consistent with the Tuolumne River Habitat Restoration Plan and will complement other monitoring evaluations in the Tuolumne River.

The TRTAC is a product of the 1995 Don Pedro Project FERC Settlement Agreement (FSA). The FSA is a document signed by 11 parties representing water agencies, fishery agencies, and environmental groups. The TRTAC has completed a Habitat Restoration Plan for the 52-mile reach of the Lower Tuolumne River from La Grange Dam to the San Joaquin River. The FSA, the habitat plan, and salmonid restoration plans developed by both the CDFG and US Fish and Wildlife Service, all recognize the importance of and the need for improvements from existing conditions.

Authorized by and signed on behalf of the TRTAC,

Tim Ford
Coordinator, TRTAC
Turlock and Modesto Irrigation Districts

Tim Heyne
California Department of Fish and Game

Patrick Koepele
Tuolumne River Preservation Trust

Gary Taylor
U. S. Fish and Wildlife Service

Nicole Sandkulla
Bay Area Water Users Association

Ron Yoshiyama
City and County of San Francisco

Dave Boucher
Friends of the Tuolumne

CC: TRTAC e-mail distribution