Distribution and demographic status of steelhead trout (O. mykiss) in tributaries of waterways of the Central Valley

Project Information

1. **Proposal Title:**

   Distribution and demographic status of steelhead trout (O. mykiss) in tributaries of waterways of the Central Valley

2. **Proposal applicants:**

   Michael Johnson, University of California, Davis
   Donald Huggins, University of California, Davis

3. **Corresponding Contact Person:**

   Ahmad Hakim-Elahi
   The Regents of the University of California
   Sponsored Programs 118 Everson Hall One Shields Avenue
   530 752-2075
   vcresearch@ucdavis.edu

4. **Project Keywords:**

   Anadromous salmonids
   Aquatic Ecology
   At-risk species, fish

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:**

   University

9. **Location - GIS coordinates:**

Latitude:	39 14’ 25
Longitude:	121 16’ 09 W
Datum:	NAD27 CONUS

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

Research will be conducted in both tributaries of the Sacramento and San Joaquin Rivers located in the Central Valley.

10. **Location - Ecozone:**

    4.4 Battle Creek, 5.1 Upper Cottonwood Creek, 5.2 Lower Cottonwood Creek, 7.4 Deer Creek, 7.5 Big Chico Creek, 7.6 Butte Creek, 8.1 Feather River, 8.2 Yuba River, 8.3 Bear River and Honcut Creek, 9.1 American Basin, 9.2 Lower American River, 13.1 Stanislaus River, 13.2 Tuolumne River, 13.3 Merced River, 11.2 Mokelumne River, 11.3 Calaveras River, Code 15: Landscape

11. **Location - County:**

    Butte, Calaveras, Colusa, Fresno, Merced, Sacramento, San Joaquin, Shasta, Stanislaus, Sutter, Tuolumne, Yolo, Yuba

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:**

    02,03,05,11,18,20

15. **Location:**

    California State Senate District Number: 12,14,1,4

    California Assembly District Number: 2,3,4,5,8,9,10,17,26,29

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

    3

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

       Yes

       If yes, list the different overhead rates and total requested funds:

State Overhead Rate: 10%

Total State Funds: $4,905,289.00

Federal Overhead Rate: 26%

Total Federal Funds: $5,586,043.00

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?

No

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

Distribution and demographic status of steelhead trout (O. mykiss) in tributaries of waterways of the Central Valley

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

      No
   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.

      Research not needing compliance

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

   CEQA Lead Agency:
   NEPA Lead Agency (or co-lead:)
   NEPA Co-Lead Agency (if applicable):

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

   CEQA
   -Categorical Exemption
   -Negative Declaration or Mitigated Negative Declaration
   -EIR
   Xnone

   NEPA
   -Categorical Exclusion
   -Environmental Assessment/FONSI
   -EIS
   Xnone

   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.

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

      Not Applicable

   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	Required
Rivers and Harbors Act	
CWA 404	
Other	

PERMISSION TO ACCESS PROPERTY

Permission to access city, county or other local agency land. Agency Name: State Agency	Required
Permission to access state land. Agency Name: State Parks	Required
Permission to access federal land. Agency Name: USFS	Required
Permission to access private land. Landowner Name:	Required

6. **Comments.**

Land Use Checklist

Distribution and demographic status of steelhead trout (O. mykiss) in tributaries of waterways of the Central Valley

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).

   Research only.

4. **Comments.**

Conflict of Interest Checklist

Distribution and demographic status of steelhead trout (O. mykiss) in tributaries of waterways of the Central Valley

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):

Michael Johnson, University of California, Davis
Donald Huggins, University of California, Davis

Subcontractor(s):

Are specific subcontractors identified in this proposal? No

Helped with proposal development:

Are there persons who helped with proposal development?

No

Comments:

Budget Summary

Distribution and demographic status of steelhead trout (O. mykiss) in tributaries of waterways of the Central Valley

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**
1	Postgraduate Researcher II	2000	32052	7400	17500	60000		43000		159952.0	15870	175822.00
2	Postgraduate Researcher II	2000	32052	7400	10500	156000		385000		590952.0	19737	610689.00
3	All personnel and expenses are included under task 2									0.0		0.00
4	No activity in year 1									0.0		0.00
5	Postgraduate Researcher II	2000	32052	7400	4000	20568				64020.0	6277	70297.00
6	Postgraduate Researcher II	2000	32052	7400						39452.0	3820	43272.00
7	No activities in year 1									0.0		0.00
8	Michael Johnson (UCD)	600	78000	5400		12000			25000	120400.0	4015.	124415.00
		8600	206208.00	35000.00	32000.00	248568.00	0.00	428000.00	25000.00	974776.00	49719.00	1024495.00

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**
1	Postgraduate Researcher II	2000	32052	7400	17500	66000				122952.0	12170	135122.00
2	Postgraduate Researcher II	2000	32052	7400	10500	144000				193952.0	19270	213222.00
3	All personnel and expenses are included under task 2									0.0		0.00
4	Postgraduate Researcher V	1500	36552	6300						42852.0	3270	46122.00
5	Postgraduate Researcher II	2000	32052	7400	4000	20500		8000		71952.0	7070	79022.00
6	Postgraduate Researcher II	1500	32052	5550						37602.0	2865	40467.00
7	Postgraduate Researcher IV	2000	34944	8000						42944.0	4160	47104.00
8	Michael Johnson (UCD)	300	78000	2700					25750	106450.0	1395	107845.00
		11300	277704.00	44750.00	32000.00	230500.00	0.00	8000.00	25750.00	618704.00	50200.00	668904.00

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**
1	Postgraduate Researcher II	2000	32052	7400	17500	66000				122952.0	12170	135122.00
2	Postgraduate Researcher II	2000	32052	7400	10500	144000				193952.0	18537	212489.00
3	All personnel and expenses are included under task 2									0.0		0.00
4	Michael Johnson (UCD)	300	78000	2700						80700.0	1395	82095.00
5	Postgraduate Researcher II	2000	32052	7400	4000	20500		8000		71952.0	7070	79022.00
6	Postgraduate Researcher V	320	36552	1344	10500					48396.0	1748	50144.00
7	Michael Johnson (UCD)	300	78000	2700						80700.0	1395	82095.00
8	Michael Johnson (UCD)	300	78000	2700					26525	107225.0	4048	111273.00
		7220	366708.00	31644.00	42500.00	230500.00	0.00	8000.00	26525.00	705877.00	46363.00	752240.00

Grand Total=2445639.00

Comments.

Budget Justification

Distribution and demographic status of steelhead trout (O. mykiss) in tributaries of waterways of the Central Valley

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

Michael Johnson proposed hours x 3yr = 5,900. Don Huggins proposed hours x 3yr = 5,500. Jennifer Nickells proposed hours x 3yr = 1,420. Postgraduate Researcher II(4)proposed hours x 3yr = 26,100. Postgraduate Researcher IV (1) proposed hours x 3yr = 2,000. Postgraduate Researcher V (2)proposed hours x 3yr = 11,920. Programmer Anlalyst III proposed hours x 3yr = 3,000. Undergraduate Assistant(s) proposed hours x 3yr = 15,000.

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

Michael L. Johnson is an Associate Research Ecologist IV with an annual salary of $78,000. Dr. Don Huggins is a Visiting Research Ecologist I with an annual salary of $78,100. Jennifer Nickell is an Administrative Assistant, with an annual salary of $36,096.00 will work a small percentage on the project. A Postgraduate Researcher II (PGR II) has an annual salary of $32,052. A Postgraduate Researcher IV (PGR IV) has an annual salary of $34,944. A Postgraduate Researcher V (PGR V) has an annual salary of $36,552. A Programmer Analyst III with an annual salary of $51,688.

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

Associate Research Ecologist benefit rate is 24%. Visiting Research Ecologist benefit rate is 24%. Administrative Assistant benefit rate is 24%. All PGR(s) benefit rate is 24%. Undergraduate Assistant(s) benefits rate is 3%.

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

Travel is calculated on the assumption that personnel will be in the field for 250 days per year (fish team) or 150 days per year (any other field personnel). Additional time in the field for the fish team is to conduct spawning surveys during the spawning season. Although the University of California currently allows per diem of $46, per diem allowed for this project will be $30/day/person and lodging at $40/day/person. Total cost per person for the field season is ($30 x 250) + ($40 x 250) = $17,500 for the fish teams or ($30 x 150) + ($40 x 150) = $10,500. Travel to and from the field will require four heavy-duty vans, each at $785/mo x 12 months = $9420 + the cost of gasoline. Gasoline per vehicle is based on the assumption of either 36 weeks in the field (fish teams) or 30 weeks per year (other field personnel), 250 miles per week with a mileage estimate of 10 miles per gallon and a cost of $2.50 per gallon = $1875 per vehicle field season (30 weeks) or $2250 per vehicle per season (36 weeks). Availability of vans is questionable if vehicles are rented for only a portion of the year. Renting the vans for the entire year guarantees that they can be used when needed at any point in time during the year. Also, we anticipate occasional trips to the field throughout the year to conduct flow measurements, and collect water samples for analysis. Total travel cost is $9420 + $1875 = $11,295 x 2 = $22,590 + ($9420 + $2250) x 2 = $23,340 = $49,930.

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

Task 1. Supplies include wet suits, waders, neoprene booties, dip nets, aerators, net pens, measuring boards, Garman GPSMAP 175 GPS unit, Ohaus Navigator Electronic Balance, rechargeable batteries and recharging units, TX 1400BE implantable glass tags (5000 count) ($19,500), MK6/100 Implanters, N100 replacement needles, IR5600 BPA power supply, 30m nylon bag seines, 30m nylon block seines, Keson 100m measuring tape, and miscellaneous sampling gear such as envelopes for scale storage, vials, ethanol, slides, forceps, totes, buckets, film, tools. Chemical disposal costs are included in this category. Task 2. Field supplies include waders, neoprene booties, and miscellaneous sampling gear such as envelopes for scale storage, vials, ethanol, slides, forceps, totes, buckets, film, and tools. Chemical disposal costs are included in this category. Stable isotope analysis costs $5 per sample for both carbon and nitrogen isotopes and requires weighing tins and sample vials. We anticipate that each year we will analyze 4000 samples ($20,000) requiring 4000 5 x 8mm tins and vials ($3,500). Macroinvertebrate sample processing and identification requires sample vials, formalin, alcohol, slides, mounting medium, and maintenance service on the microscopes ($20,000). Additional supplies and expenses include periphyton samplers (40 @ $722 per 10), GC columns, chemical reagents, and maintenance on the GC for PUFA analysis ($10,000). Temperature loggers include 100 StowAway Tidbit submersible temperature loggers (each @ $100), 50 Optical StowAway temperature loggers (each @ $185), and 8 Optical shuttle data transporters (each @ $189). Task 5. Supplies include software and software licenses, maintenance contracts on computers, and DOQQs for GIS analysis (approximately $1000 per watershed). Task 8. Administrative supplies are necessary to conduct the project including paper, telephone, fax, and general office supplies for three locations (campus office, lab, off-campus offices), and cleaning service fees (off-campus office). All field supplies are required for sampling fish. No PIT tagging is anticipated for the first year of the project, but the supplies will be purchased during the first year so that year two activities are not delayed. Although steelhead will not be collected until an assessment of the populations are completed, samples of macroinvertebrates, periphyton, detritus, and other species of fish (non-salmonids) will be collected for stable isotope and PUFA (polyunsaturated fatty acid) analyses. These analyses are used to understand the general trophic structure and the quality of the food in the system. Temperature loggers are used to understand the water temperatures in detail for several reaches in the streams. DOQQs are required to develop the potential stream shading models for the different watersheds that are selected for intensive study. Administrative costs for the project are primarily to support general office activities and rent space off-campus. As a result of the difficulties in obtaining space on campus, we rent approximately 2200 sq ft of general office and lab space off-campus. This space is used as office space for all of the postgraduate researchers associated with the project, and also serves as the laboratory space for the identification of periphyton and macroinvertebrates. The cost of renting this space is requested for all three years of the project as it is anticipated that this project will be the only project supported by this space.

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.

None.

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.

Task 1. $3000 is requested for a single computer to be used in the analyses of all project data. Other equipment requested include three each of a Smith Root LR-24 backpack electrofisher and batteries ($5,248), Gateway Solo 3450 notebook computer for data logging ($2,199), Hydrolab Quanta multi-parameter water quality instrument ($3,995), BioDevices Aqua 2002 dissolved Oxygen data logger ($2,500), and a Marsh-McBirney Flo-Mate model 2000-21 flow meter and top setting metric wading rod ($4,185), and FS2001-FT PiTAG reader ($2,395). Task 2. Equipment requested includes Agilent 6980 GC with injector and autosampler tray, Agilent Headspace Sampler ($42,000 for both), Shimadzu TOC 5000A total organic carbon analyzer, Shimadzu ASI 5000A autosampler and TOC link software ($65,0000 for all three), Lachat 8000 FIA+ QuikChem Automated Ion Analyzer and a Lachat BD-46 block digestor ($72,000 for both), an Isotemp 223F laboratory freezer (-20oC) ($4,000) and a Revco Ultralow freezer (-80oC) ($8539), an Olympus phase contrast microscope with video ($20,000), Hydrolab Quanta multi-parameter water quality instrument (4 each @ $3,995), and a BioDevices Aqua 2002 dissolved oxygen data logger (20 each @ $2,500). Several items of equipment for the field and laboratory are requested during the first year. These will be used throughout the course of the project. Currently, we perform these analyses using equipment from other laboratories on campus. However, the yearly cost of rental is much higher than simply purchasing the item. For example, we have an arrangement for our Navarro project to use a GC for PUFA and energetics analyses, and the cost we are charged to use the equipment in the other lab is $48,000 per year. We can purchase our own GC and headspace sampler, and purchase the supplies necessary to run the analyses for $42,000 in the first year. We have similar arrangements for the nutrient (Lachat) and carbon (TOC analyzer) analyses. Nutrient and carbon analyses are required to determine the limits of productivity in the system and the amount of carbon input to the system at different times during the year. One of the major hypotheses currently being proposed is that salmonid carcasses provide nutrients to the system that are required for survival of larval fish and fry. Other hypotheses propose that carcasses also serve as a source of carbon. Through a combination of TOC and stable isotope analyses, we can determine the relative contribution of carbon derived from salmon carcasses and from other sources. However, the requested analytical equipment is required. Periphyton community analysis requires the use of a phase contrast microscope that is not readily available from UCD Microscope Services. Microscope Services may be able to rent us the scope, but only if it is not required by courses and it may be recalled at any time depending on demand in the classroom. Because we anticipate a large number of samples of various sorts, we will need a 80oC freezer to maintain the tissue. For example, proteases begin to degrade heat shock proteins almost immediately even if stored at 20oC and therefore we require a 80oC freezer. The Hydrolab water quality instrument will be used for standard water quality analyses such as pH and conductivity. The DO loggers will be used to measure primary productivity and DO in pools instrumented for temperature analysis.

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.

Project management will be the responsibility of Dr. Michael Johnson. He will be responsible for maintaining the schedule of sampling, analysis and report preparation, giving presentations, and responding to project specific questions. Dr. Donald Huggins and Ms Jennifer Nickell will assist Dr. Johnson. Dr. Huggins has over 30 years experience as an aquatic ecologist and will assist with the management of the project in the field and will also be available for presentations and response to questions. Ms Nickell will be responsible for tracking all expenses and purchasing. The staff of the John Muir Institute of the Environment will provide additional administrative support in terms of general accounting and personnel. Completion of subtasks for each year will be documented in quarterly reports to Calfed.

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

$77,275.00.

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.

State Indirect Cost rate is 10% which includes rent, phones, furniture, general office supplies, general staff,etc. Federal Indirect Cost rate is 26%, (most of the work preformed will be off-campus,which includes rent, phones, furniture, general office supplies, general staff,etc.

Executive Summary

Distribution and demographic status of steelhead trout (O. mykiss) in tributaries of waterways of the Central Valley

Executive Summary We propose an intensive investigation to determine the distribution, abundance, genetic structure, and demographic status of steelhead trout (Oncorhynchus mykiss) in the tributaries of the Sacramento and San Joaquin Rivers. The project will be performed in two phases that are divided up into seven tasks. Phase I will be performed during the first year of the project and involves as complete an assessment of the current distribution and abundance of steelhead as is possible. Once this assessment is completed, Phase II will focus intensive research on a few watersheds where we will perform a complete evaluation of the aquatic system including other species of fish, macroinvertebrates, primary producers, nutrient dynamics, carbon sources, assessment of hydrologic regimes, and complete habitat analyses (land uses in the watershed, riparian, and instream habitats). We will determine how individual fish physiological and biochemical performance impacts the ability of the individual to survive from the egg stage to out-migration, and if the current habitat and flow regimes can support the maintenance of the populations when individual fish performance is considered. In addition, we will determine the efficacy of current habitat improvement projects with respect to increasing the reproductive output and survival of steelhead trout specifically. We will then evaluate streams in which steelhead are absent to determine if conditions are suitable to support steelhead populations, and if not, what steps would have to be taken to support steelhead. Finally, we will determine through the use of indicator metrics, if habitat improvement projects are successful in achieving their desired goal. The proposed project will cooperate fully with projects already in place in many of the tributaries in the Central Valley. Because steelhead remain for two years in the headwaters of the tributaries, the current project will concentrate on the tributaries.

Proposal

University of California, Davis

Distribution and demographic status of steelhead trout (O. mykiss) in tributaries of waterways of the Central Valley

Michael Johnson, University of California, Davis
Donald Huggins, University of California, Davis

A. Project Description: Project Goals and Scope of Work

1. Problem

With increasing anthropogenic influences in the Central Valley and the Sierra Nevada, the population of steelhead trout (*O. mykiss*) is declining rapidly. Recent estimates place the population of adults in the entire state at around 250,000 adults, most of which are found in the Klamath-Trinity system. An estimate for the size of the entire Sacramento River run in 1991-92 was less than 10,000 adults (McEwan and Jackson 1996). Major factors identified as responsible for the decline are habitat loss and degradation of spawning and rearing habitat (IEP 1998, McEwan and Jackson 1996). Despite these estimates, there is no current understanding of the status of steelhead in the tributaries that flow into the Central Valley and it is assumed that the population is still quite low. Wild stocks are primarily confined to the upper Sacramento River Tributaries including Deer, Mill, and Antelope Creeks and the Yuba River. It is possible that populations exist in other tributaries but insufficient sampling has been conducted to make a determination.

The November 1998 IEP steelhead monitoring, assessment, and research document (IEP 1998) identified 40 salmonid projects ongoing at that time, and only 8 were focused on steelhead specifically. As a result, there is the increasing realization that there exists “a paucity of baseline information and significant knowledge gaps regarding Central Valley steelhead” (IEP 1998). Consequently, there was a call at the October 2000 Calfed Bay-Delta Program Science Conference for focused research on steelhead in the Central Valley (Calfed 2000).

The research outlined in this proposal seeks to fill these knowledge gaps by conducting a general assessment of tributaries of the Central Valley for the presence of steelhead. Additionally, we will perform focused research into steelhead ecology and physiological performance, and develop metrics to allow an evaluation of the status of steelhead populations in the tributaries of the Sacramento and San Joaquin Rivers. This project will not duplicate any of the work currently underway or recently completed (e.g., the temperature tolerance work of C. Myrick). In fact, it is generally known that steelhead are in decline throughout the region as a result of habitat loss, altered stream flows, and other stressors such as agricultural chemicals (e.g., IEP Steelhead Program Project Work Team 1998, Calfed 2000, see also the our conceptual model). What is not clear are the finer-scale mechanisms behind the decline. For example, Calfed’s Comprehensive Monitoring, Assessment, and Research Program for Chinook Salmon and Steelhead in the Central Valley Rivers (Calfed 2000) lists 21 individual hypotheses concerning juvenile rearing. Hypothesis D-1 proposes that juveniles do not select (rearing) habitat primarily on the basis of water depth and mean column velocity, features modeled by PHABSIM, but instead select habitat primarily based on streambed complexity. This hypothesis underscores a lack of understanding about the limiting factors in juvenile rearing success. The proposed research will provide the basic information necessary to evaluate a large number of these hypotheses. Additionally, we will provide an assessment of the relative role of these stressors in each watershed in which steelhead are present. This information is critical if restoration efforts are to be successful across the entire Central Valley because it is not known if stressor mitigation for chinook salmon will be successful in restoring steelhead.

Specifically, the proposed research will address the following hypotheses as outlined in the Calfed's Comprehensive Monitoring, Assessment, and Research Program (CMARP) document, and the research needs outlined in the IEP Steelhead Project Work Team's Monitoring, Assessment, and Research on Central Valley Steelhead (IEP 1998) documents (CMARP hypotheses are listed as a letter-number combination, IEP research needs are listed as a number-letter combination, a full discussion of these hypotheses and needs can be found in the original documents):

- Distribution, Abundance, and Status – 1a (distribution), 1b (run size), 1c (origin), 1d (life stage), 2b (use of intermittent streams), 3a (maturation status), 3b (genetic structure)
- Upstream Migration – A-11, A-12, A-13
- Spawning – B-7, 2a and B-8a (habitat/temperature), B-9, B10, B-11, B-12, B-13, B-14, B-18, B-19
- Incubation and Emergence – C-1 (sediment)
- Juvenile Rearing – D-1 (flow/habitat), D-7 (growth and lipid stores), D-9 (riparian function), D-13 through D-19 (diet), D-20 (disease)

Due to page limitations for this proposal, it is not possible to explicitly discuss the methodology by which each of these hypotheses will be tested. However, none of the tasks we propose require the development of new methodologies. Instead, we will use established techniques and those currently used by CDFG to maintain consistency in the data. Because we expect to find steelhead in several different watersheds, we will focus our research on upstream migration, spawning, incubation and emergence, and juvenile rearing in specific watersheds. We will select at least four watersheds distributed across the northern and central Sacramento River Valley, and the central and southern San Joaquin Valley. These watersheds will be selected after initial assessments of status and discussions with Calfed and CDFG.

We are currently finishing a 4-year study of steelhead in the Navarro River watershed along the North Coast of California. The Navarro River project addresses many of the same questions and hypotheses posed above and below with the obvious exception of the site specificity of many of the hypotheses. We bring a wealth of experience with steelhead to the proposed research. With only a few exceptions (e.g., PHABSIM modeling), we have already performed the field and laboratory studies outlined below.

2. Justification

The core of the conceptual model for this project is simply the steelhead life cycle with associated stressors that can impact each stage (Figures 1a-d). This has been our conceptual core for the Navarro River steelhead project and is essentially the same conceptual model (absent the detailed stressor identification) presented in Calfed's CMARP for Chinook Salmon and Steelhead in Central Valley Rivers (Calfed 2000). The proposed project is divided into two phases; assessment of the distribution and status of steelhead (year 1), and understanding the impacts of watershed-specific stressors and habitat improvement measures implemented to overcome those stressors, on steelhead (years 2 and 3). Note that over the next several years, we plan to study steelhead across the entirety of the Valley-Bay/Delta system, but the current state of knowledge about steelhead is such that the first three years must be spent investigating basic steelhead biology in the Sierra tributaries to the Sacramento and San Joaquin Rivers.

The key to evaluating the conceptual models is to obtain measurements for the various components of the models. Consequently, each of the tasks has as its objective to obtain a set of measurements that can be used estimate the relevant rates and effects within the models. For example, the left side of Figures 1b-d is the steelhead life cycle with the stages connected by the action that links adjacent stages. Eggs must hatch before the alevin stage can be reached, alevins must survive to reach the fry stage and so on. Our goal is to estimate the number of eggs produced, measure the hatching (emergence) success to obtain an estimate of the number of alevins, measure their survival to obtain an estimate of the number of fry. Within each of the boxes on the right sides of Figures 1b-d, are concepts that represent system components (e.g., macroinvertebrates), stressors (e.g., sediment), interventions (e.g., buffer zone), and processes (e.g., decomposition). Each of the tasks (except the administrative task) has as its goal to provide measures of each of the boxes, and relate the boxes to each other. The arrows that link the boxes on the right side of each figure to the steelhead life cycle are the mechanisms by which those stessors/components impact the steelhead life cycle. For example, the temperature tolerances of steelhead are well known, but the physiological and biochemical mechanisms that set those tolerances are not as well known. Therefore, the tasks we outline below are aimed at elucidating the mechanism by which the stressor impacts steelhead. In the process of conducting all seven tasks, we will perform a cumulative effects assessment of the stressors on steelhead populations (see description of Task 6).

Each of the concepts in the models can be measured in various ways, and these measures are indicators of the concepts. For example, the concept "macroinvertebrates" can be measured in several ways; biomass, species richness, species diversity, EPT score, or a benthic macroinvertebrate index of biotic integrity. We will identify several indicators of each of these concepts, which will then be tested for use as performance metrics using ROC curve analysis (see below). Initially, we will attempt to develop performance metrics of both steelhead population status and stressor impacts as these two aspects of the conceptual model reflect the current condition of the population and the potential change in that condition over time. Objective 1 is designed to obtain the necessary information on the left side of Figures 1b-d, objectives 2 and 3 are designed to obtain the necessary information on the right side of Figures 1b-d, objectives 4 and 5 are designed to integrate the results of objectives 1, 2 and 3, and objectives 6 and 7 are designed to use the information gained from objectives 1-5 to synthesize the performance metrics and evaluation procedures of management activities.

The project is targeted research and folds into the Calfed Adaptive Management Process (Calfed Restoration Program, Draft Stage 1 Implementation Program, Figure 1) in that it will provide essential information that will assist with the assessment, evaluation and adaptation of restoration actions. In addition, a direct objective of this research is to provide performance metrics that can be used directly in the adaptive management process.

The research project is structured by seven objectives and their associated hypotheses. Each of these hypotheses is used to group the tasks and relate the objectives to the conceptual model.

This project is designed to address the following objectives:

1) Provide basic life history information on steelhead stocks in the Sacramento River system and the San Joaquin river system to fill in gaps in the current understanding of steelhead life histories including current distribution, spawning surveys/redd counts, emergence, survival, and physiological and biochemical performance under temperature stress
2) Evaluate the condition of the entire biotic community including non-salmonid fish species (native and exotic), periphyton and primary productivity, and benthic macroinvertebrates, and relate that condition to the reproduction and survival of steelhead.
3) Evaluate in-channel habitat and water quality conditions and relate these conditions to the reproduction and survival of steelhead.
4) Develop appropriate population models for the stocks in the various tributaries (using the information obtained in life history studies and in-channel habitat evaluation) that can be used to project potential population sizes and evaluate the potential effectiveness of restoration and habitat improvement projects,
5) Perform watershed cumulative effects assessments (including upslope evaluations of potential sediment delivery, riparian shading, and biotic interactions such as predation) for each watershed in which steelhead are present, concentrating on identifying watershed-specific stressors and evaluating their effect(s) on the population in that watershed,
6) Evaluate the effectiveness for steelhead specifically, of habitat improvement (HI) projects that have been placed into streams for salmonids and identify locations and potential restoration/habitat improvement measures that could improve the reproduction and/or survival of steelhead populations,
7) Develop performance metrics to monitor the status of steelhead populations and allow the adaptive management process to operate to its fullest capability.

Hypothesis: The demographic status of steelhead populations is similar across tributary watersheds in the Sacramento River (Objective 1).

Task 1. Assess the distribution and demographic status of steelhead throughout the Central Valley tributaries.

Subtasks – All years

- Conduct redd counts in key spawning areas in each watershed.
- Monitor emergence success of eggs deposited in spawning areas – count 0+ age class as soon as possible after emergence to minimize reduction in population size due to early mortality.
- Determine the population density of 0+, 1+, and 2+ age classes measured in mid-summer and again in late summer.
- Snorkel counts of steelhead at established sites in specific habitat types.
- Determine the overwintering densities of juvenile fish

Figure 1a.

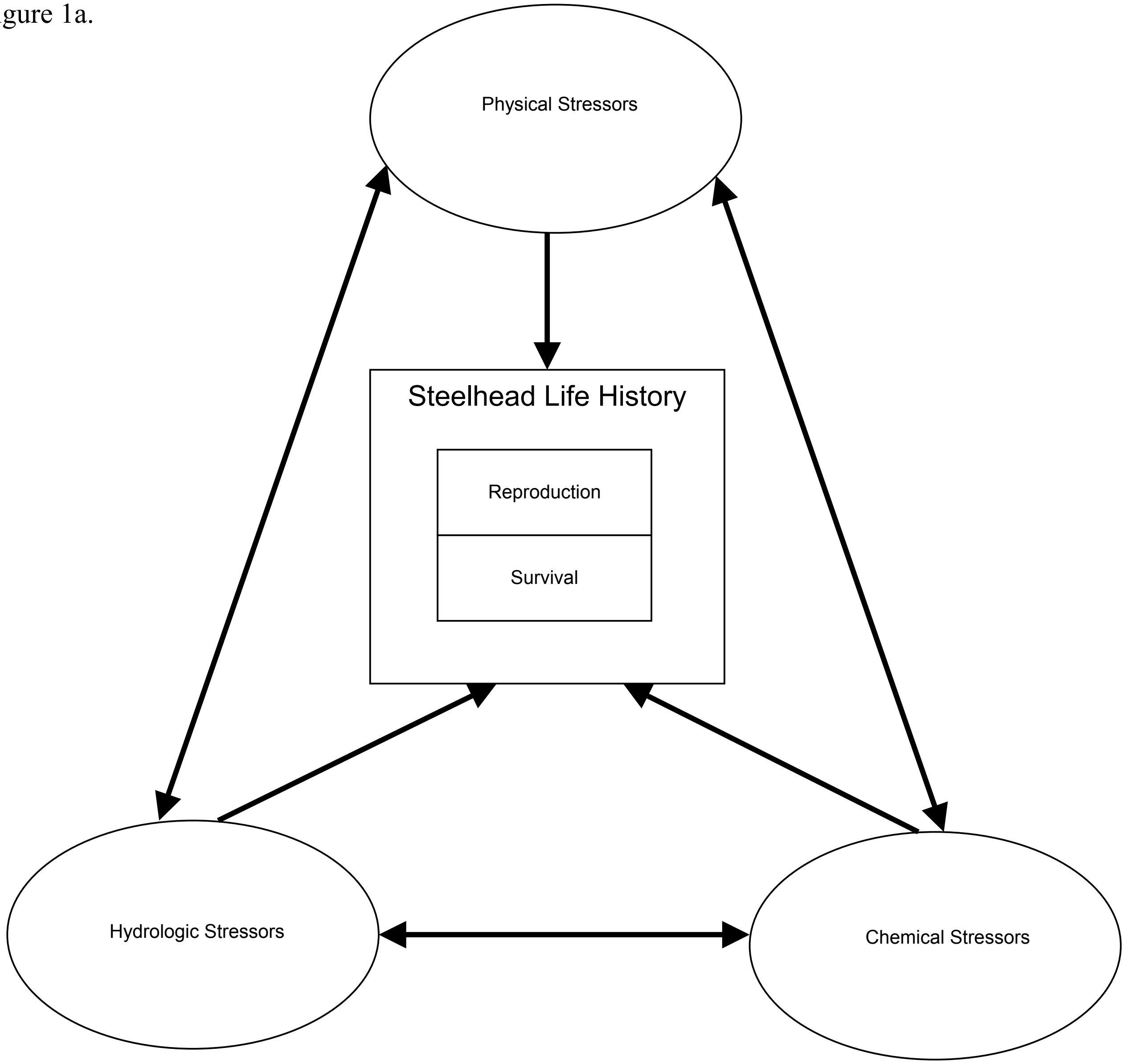
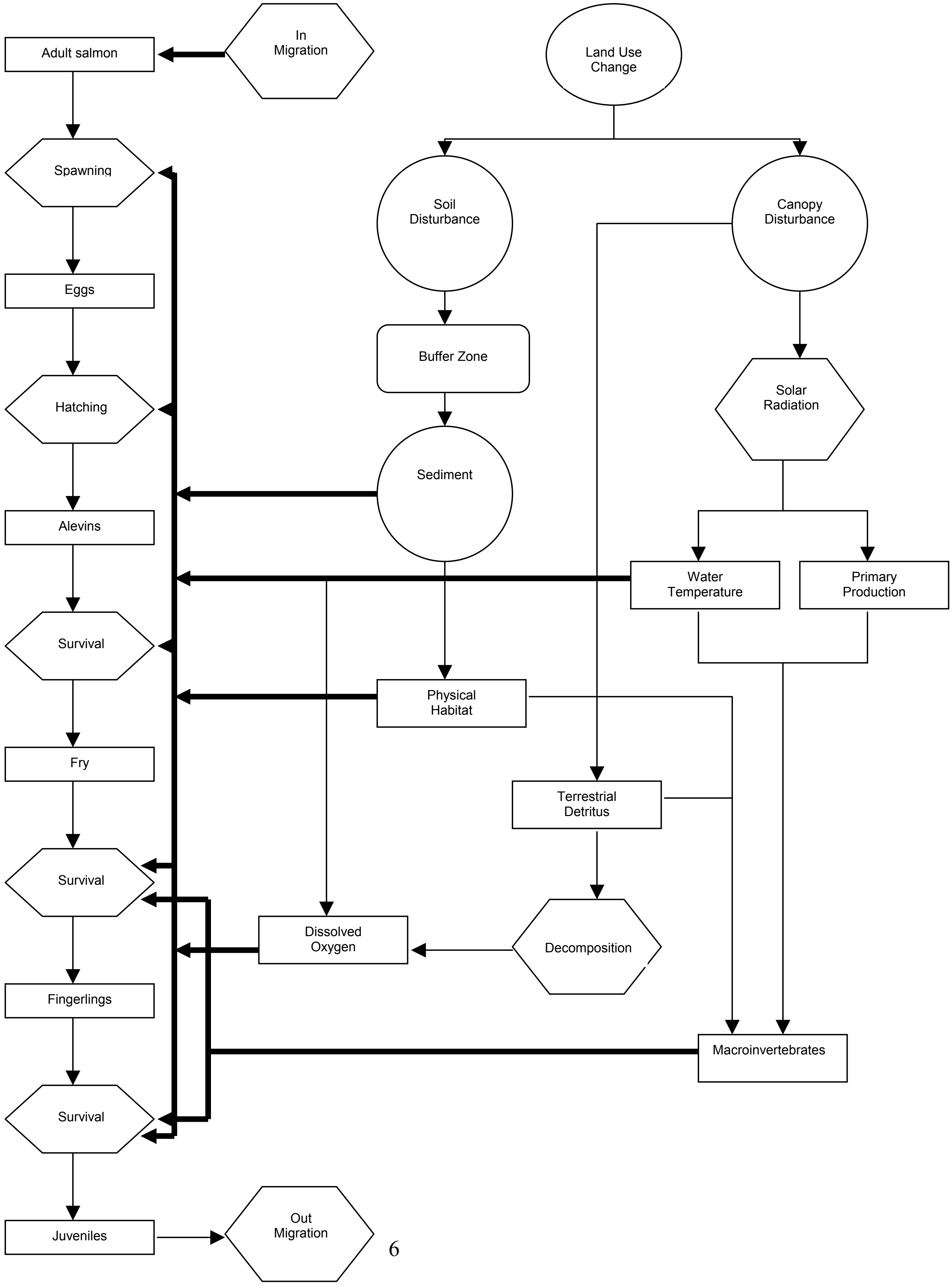
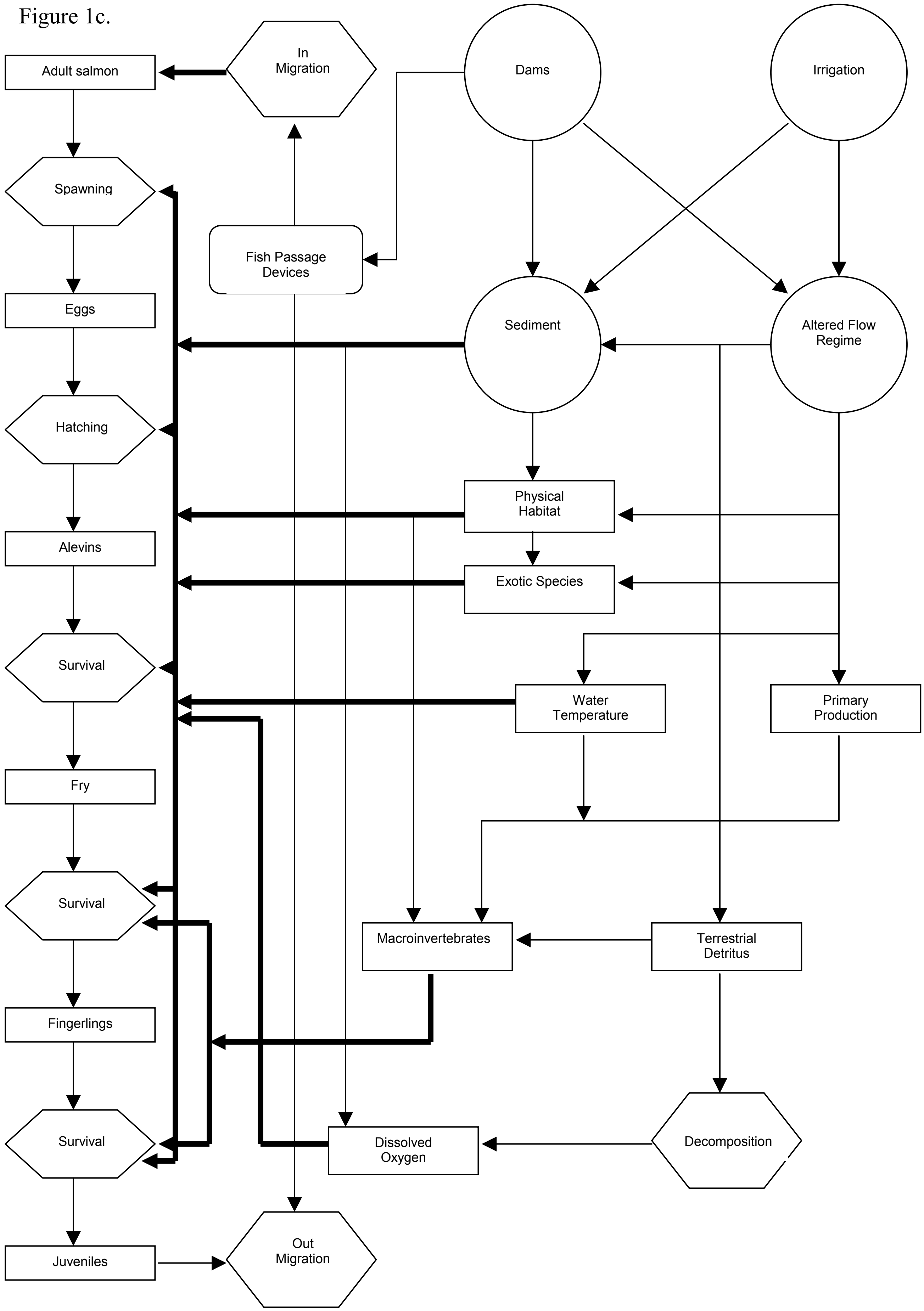

Physical Stressors
Steelhead Life History
Reproduction
Survival
Hydrologic Stressors
Chemical Stressors

Figure 1b.



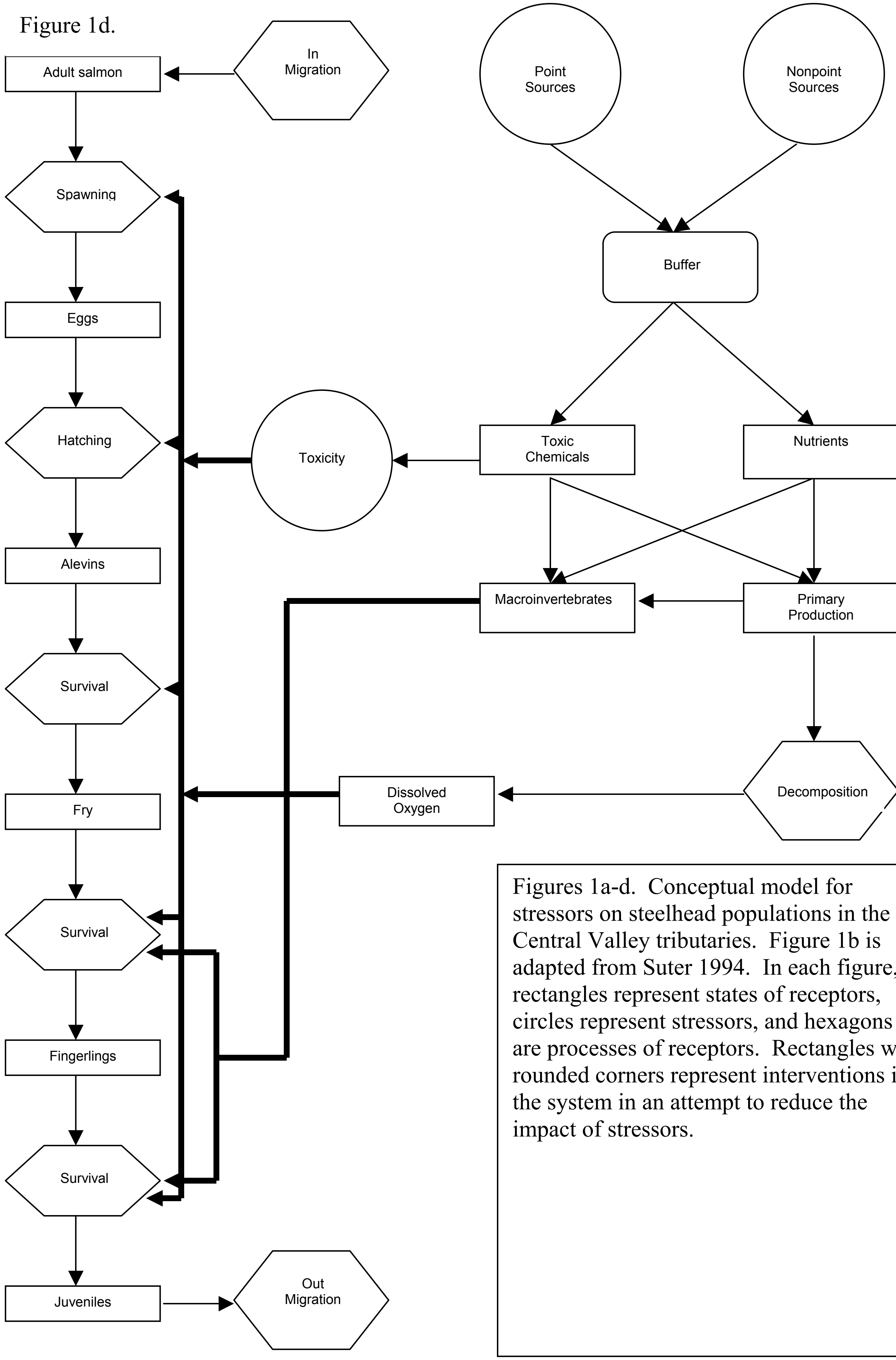
Adult salmon
In Migration
Land Use Change
Spawning
Soil Disturbance
Canopy Disturbance
Eggs
Buffer Zone
Solar Radiation
Hatching
Sediment
Alevins
Water Temperature
Primary Production
Survival
Physical Habitat
Fry
Terrestrial Detritus
Survival
Dissolved Oxygen
Decomposition
Fingerlings
Macroinvertebrates
Survival
Juveniles
Out Migration

Figure 1c.



Adult salmon
In Migration
Dams
Irrigation
Spawning
Fish Passage Devices
Eggs
Sediment
Altered Flow Regime
Hatching
Physical Habitat
Alevins
Exotic Species
Survival
Water Temperature
Primary Production
Fry
Survival
Macroinvertebrates
Terrestrial Detritus
Fingerlings
Survival
Dissolved Oxygen
Decomposition
Juveniles
Out Migration

Figure 1d.



Figures 1a-d. Conceptual model for stressors on steelhead populations in the Central Valley tributaries. Figure 1b is adapted from Suter 1994. In each figure, rectangles represent states of receptors, circles represent stressors, and hexagons are processes of receptors. Rectangles with rounded corners represent interventions in the system in an attempt to reduce the impact of stressors.

Subtasks – Year 2 and Year 3

- Electroshock and PIT tagging of fish to monitor survival
- Establish the ability of steelhead stocks to produce heat shock proteins and withstand temperature stress, and relate that ability to survival during the late summer period
- Compare results among watersheds to establish distribution and relative condition.

Hypothesis: The condition of the biotic community is directly related to the survival and reproduction of steelhead (Objective 2).

Task 2. Measure the condition of the biotic community including non-salmonid fish species (native and exotic), periphyton and primary productivity, and benthic macroinvertebrates, and relate that condition to the reproduction and survival of steelhead.

Subtasks – All years

- Measure primary productivity and secondary productivity and relate to steelhead survival and reproduction.
- Evaluate food quantity, quality and general trophic structure
- Measure terrestrial invertebrate input to the system and relate to steelhead reproduction and survival.
- What are the trends in abundance and composition of resident fish community?

Hypothesis: Instream habitat is sufficient to support current and future steelhead populations (Objective 3).

Task 3. Evaluate water quality, instream and riparian habitat in streams with and without steelhead.

Subtasks

- What is the condition of the riparian community, including the relative abundance of native and exotic vegetation, along the stream corridor and how do these relate to habitat used for spawning and rearing of steelhead.
- Measure the instream habitat condition in spawning and rearing reaches including:
    - Cobble embededness
    - Bank stability
    - Water temperature, turbitidy, and suspended sediment
    - Large woody debris
    - Pool frequency and volume
    - Flow and discharge
    - Sediment storage
    - V*
    - Stream gradient
    - Bed load
    - Fine sediment deposition rate
- Evaluate nutrient conditions in watersheds to determine the role of nutrients in limiting steelhead populations (too little or too much)

- Compare the averages and range of variation in these measures from reaches with high reproductive success or survival relative to reaches with low reproductive success or survival, and to conditions in reaches with no steelhead
- Evaluate the results of PHABSIM modeling to determine if the results are consistent with choices of steelhead trout

Hypothesis: Populations of steelhead are sustainable based on current demographic performance (Objective 4).

Task 4. Develop appropriate population models for the stocks in the various tributaries (using the information obtained in life history studies and in-channel habitat evaluation) that can be used to project potential population sizes and evaluate the effectiveness of restoration and habitat improvement projects.

Subtasks

- Using demographic information obtained during the course of the study, develop estimates of the parameters (with appropriate estimates of variances) necessary for parameterization of an age projection matrix population model
- Assess the potential for density dependence in survival based on the amount of available habitat
- Determine the sensitivity of population growth rate to changes in specific matrix elements
- Relate specific restoration/habitat improvement measures to specific matrix elements to gain an understanding of how specific projects might generally effect the population growth rate of steelhead

Hypothesis: Watershed land management practices impact steelhead populations (Objective 5).

Task 5. Develop stressor profiles watershed-specific stressors (e.g., sediment delivery, riparian shading, exotic species, mining waste) for each watershed in which steelhead are present, and develop a cumulative effects assessment.

Subtasks

- Identify and map all potential sediment delivery sites in the watersheds
- Estimate the rate of sediment delivery and LWD delivery to, storage in, and transfer from lower order channels to higher order channels
- Use the potential shading map and the actual shading map to establish the temperature load to the aquatic system
- Evaluate instream flows
- Identify additional stressors in each watershed
- Perform a cumulative effects assessment

Hypothesis: Habitat improvement (HI) projects for salmonids are effective in increasing the survival and reproduction of steelhead (Objective 6).

Task 6. Evaluate HI projects to determine their effectiveness in increasing survival and reproductive success of steelhead.

Subtasks

- Inventory and categorize (spawning, rearing, etc) HI projects in steelhead streams

- Measure improvement in stream habitat (e.g., pool volume, reduction in embeddedness, water temperature) and flow conditions resulting from HI project
- Document use of HI sites by steelhead relative to the rest of the stream including density of fish, survival, spawning success, and emergence success
- Identify additional locations where successful HI projects could be implemented to improve the demographic performance of steelhead

Hypothesis: Performance metrics exist to readily evaluate the status and trends of populations of steelhead (Objective 7).

Task 7. Develop performance metrics that provide information to managers in a time and cost-efficient manner as to whether the implementation of habitat improvement projects (Calfed and other programs) is successful.

Task 8. Project Administration

Subtasks (all years)

- Project administration
- Scientific Advisory Committee meetings
- Quarterly and annual reports

Uncertainties

(There are numerous views and categorizations of uncertainty, but generally the types of uncertainty tend to agree with the following discussion.) Statisticians usually view uncertainty as being composed of three categories: structural, parameter, and stochastic. Structural uncertainty refers to lack of knowledge about the correct model. Parameter uncertainty occurs when values of model parameters are not known, and stochastic uncertainty occurs because parameters tend not to be fixed but vary over time and space (Smith and Ye 1998). In the case of our conceptual models, these uncertainties are manifested in the way in which stressors are tied to each life stage. Our method of dealing with structural uncertainty is to treat the conceptual model as a hypothesis of system structure and function (e.g., Johnson et al. 1991, 1993, Huggins et al. 1993).

The critical aspect of conceptual model testing and revision when dealing with stressor identification and causal associations is understanding when one is dealing with observational data and when one is dealing with experimental data. Classical statistics is designed for analyzing data from experiments where replication and random assignment to treatments is possible. Unfortunately, watersheds across various spatial scales are not independent units and therefore, field data from watersheds do not follow a classical experimental design structure leading to the potential for pseudoreplication (Hurlbert 1984). Consequently, our analyses will not follow a classical statistical design (e.g., ANOVA) and instead will focus on the overall goodness-of-fit of the models to data. We will use a Linear Structural Equation (LSE) technique that we have used successfully in the past to estimate both the overall model structure and the direct and indirect effects of the model components on each other.

Parameter uncertainty is typically discussed as a problem of statistical inference and is classically handled by increasing the replication of the parameters of interest (Smith and

Ye 1998). Coupled with this is the stochastic uncertainty that is a result of the natural variation that is expected to occur in how stressors impact steelhead populations from year to year, and natural variation in demographic performance that results from the slightly different phenotypes and genotypes in each population. Because we do not plan to use classical statistical hypothesis testing, the stochastic uncertainty will be addressed by characterizing the range of variation that occurs within and between watersheds. The characterization typically takes the form of establishing statistical distributions (e.g., normal distribution) for various parameters in the system. Characterizing stochastic uncertainty is critical to the use of the LSE technique described above, as it is the range of variability in each of the components of the model, and the covariation among components that allow an estimate of the conceptual model fit, and therefore, the degree of uncertainty in the structural model.

The research outlined in this proposal will generate information not possible to obtain in a simple pilot or implementation project. The reasons for this are 1) some of the hypotheses require manipulation and the control that a laboratory setting will provide, 2) because we employ a watershed approach, we work on a scale that can't be obtained in pilot or implementation projects, and 3) research hypotheses can be refocused to pursue the most promising avenues for research.

We feel that our conceptual models are sufficient to address the major stressors on steelhead, although we will formally review each of the main stressor elements (physical, hydrologic, and chemical) after each field season to determine if the models need revision. What is most likely is that within specific watersheds, we will find that the individual stressors acting singly or in combination will require significant research effort not originally anticipated. This in fact was exactly what happened in our Navarro River watershed project. We initiated the project with the intent of quantifying the impact of storm water runoff (specifically metals and organics) on steelhead, but found within the first year that the impacts were minimal. Our focus shifted instead to understanding the roles of instream flow and sediment on steelhead, specifically how sediment deposition impacts spawning and rearing habitat, how watershed-wide anthropogenic activities cause reductions in groundwater recharge to the streams, and how those impacts result in increased water temperatures which is the proximal cause of steelhead population reduction. The refocusing of our research was the result of 1) maintaining the schedule of research tasks so that critical data are available, and 2) frequent review and preliminary analysis of data. We will perform the proposed project in same manner.

3. Approach

We believe that it is important to maintain continuity in the methodology employed to evaluate the hypotheses and for comparison to past, current, and future investigations. Consequently, we will use the methodology recommended by the CDFG in their California Salmonid Stream Habitat Restoration Manual (Flosi et al 1998), and Measuring the Health of California Streams and Rivers (Harrington and Born 1999). Consequently, we will refer to those measurements without providing details on the methodology. Additionally, all of the techniques for measuring habitat not covered in these manuals are well established and will not be discussed in detail.

Task 8. Project Administration

Prior to initiation of the project we will form a Scientific Advisory Committee using personnel from NMFS and CDFG. This committee will help steer the project through the three years of research. The initial meeting in late spring 2002 will focus on identifying watersheds in which research projects are currently being conducted. Subsequent meetings will occur in the fall after the end of the summer field season and prior to initiation of spawning surveys. SAC meetings will be held twice each year to review progress and evaluate results.

Task 1. Assess the distribution and demographic status of steelhead throughout the Central Valley tributaries.

During the first summer of the project, a survey of all potential steelhead habitat on both the east and west sides of the CV will be performed. We will visit all streams in watersheds not currently under study by other entities (e.g., Mokelomne River). Because we are not sure of the number of steelhead in each watershed, sampling will be done by snorkeling surveys that require the least disruption. It is our experience that 0+, 1+, and 2+ fish can be distinguished by size. In watersheds in which steelhead are found, density estimates for each class will be made. We will return to the same watersheds during the late summer/early fall to perform a second snorkel survey, and we will perform a third survey the following spring as soon as flows allow safe entry into the streams. We will employ the newest modification of the Hankin and Reeves snorkel survey methodology (Hankin and Reeves 1988, Hankin and Mohr 2001). For all watersheds in which steelhead are found and densities are above a threshold established in discussions with the SAC, fish will be seined and scales will be collected for an analysis of age and demographic structure. Also, we are aware that Jennifer Nielsen is performing genetic analyses on Central Valley steelhead and we will contact her and offer to provide her with fin clips from as many fish as we mark if she wants to include them in her analyses. If she does not want the tissue, we reserve the right to perform our own genetic analysis to analyze population structure.

During the second and third summers, we will identify reaches within several watersheds for intensive study. We will select three sites, lower, middle, and upper, in each subwatershed of a major watershed. At each site, we will perform a 3-pass electroshock sampling of the steelhead. Fish are measured, weighed, and if over 60 mm in length, given a PIT tag for monitoring survival and movement of individuals. Data will be recorded on CDFG Electrofishing Field Form and Supplemental Page (CSSHRM 1998).

During the winter, we will perform redd counts in all watersheds in which steelhead were found the previous summer. Streams will be walked at least twice monthly and the location of all redds recorded using GPS. All redds will be measured, as will the habitat characteristics of the sites, and the flows and water depth. We will monitor the emergence success of as many redds as possible using mesh enclosures placed around redds to contain the emerging fry. Visitations every two weeks and continual monitoring of water temperature (see below) will allow us to determine within a short period of time the potential emergence date of the fry from the gravel. When emergence appears to be near, the mesh cages will be placed around a redd and the site will be visited daily. All newly emerged fish will be counted and released at the site. If it appears that there are a substantial number of emerging fry, we will collect 10-15 individuals for heat shock protein (hsp) analysis, see below. If it appears that very few individuals are emerging, all hsp analyses will be performed with hatchery fish. In addition to using fish livers for hsp analysis, we routinely collect otoliths and scales for aging and elemental analysis using the microprobe, muscle tissue for stable isotope and energetics (see below) analyses, and stomachs for gut content analysis. Carcasses are cleared and stained and analyzed for development asymmetry as a measure of stress.

Perhaps the most important biochemical adaptation that organisms use to cope with temperature stress is the production of heat shock proteins (hsp; Somero, 1995). Hsp, in particular the hsp70 protein family, are involved in cellular protein homeostasis and repair and provide a mechanism for organisms to reduce the deleterious effects of heat and various other stressors. Hsp also aid in protecting the host from microbial stress, are involved in immune function and host-pathogen interactions (Polla 1991, Young et al. 1993).

Short-term energetic demands are met through the production and use of molecules such as ATP and phosphocreatine. Long-term energetic demand is met by the storage and mobilization of lipids. Prolonged exposure to higher water temperatures could result in the continued production of hsp, and the concomitant draining of short-term and long-term energetic stores. If fish are stressed energetically, their growth and/or survival can be reduced. Lower growth rates would result in steelhead remaining in the stream system for an additional period of time exposing the fish to the hazards of the freshwater portion of the life cycle. Alternatively, they could out-migrate at a smaller size reducing their ability to compete in the open ocean. Our research in the Navarro watershed indicates that increased levels of hsp70 are correlated with reduced growth and summer survival of steelhead parr suggesting that there is the potential for a tradeoff between production of hsp70 and energy allocation to growth and survival. We are interested in 3 questions concerning hsp induction and energetic demand. The answers to these questions will provide us with information about the potential mechanism for heat stress and more importantly, provide the information about the temperature threshold that must be achieved to eliminate that stress.
1. What is the intensity of the heat shock protein (hsp) response in different populations of steelhead trout in locations across the Central Valley?
2. Is the induction of hsp consistent across stages in the steelhead life cycle?
3. What is the short-term and long-term energetic demand associated with production of hsp?

Hsp70 proteins are analyzed using Western blotting techniques (see Werner et al. 2001). Metabolic responses will be characterized via the quantification of energy-related nucleotides (ATP, ADP, AMP) and phosphocreatine using reverse-phase high-pressure liquid chromatography (Ally and Park, 1992).

Task 2.

Task 2 is aimed at determining the condition of the biotic environment in which steelhead are found. Primary productivity will be measured using the standard diel DO technique (Odum 1956, Marzolf et al. 1994, Bott 1996). Secondary productivity is determined using biomass measures for macroinvertebrates. Macroinvertebrate samples will be collected and processed using the techniques outlined in Harrington and Born (1999). We will employ drift nets to obtain an estimate of the input of terrestrial invertebrates to the system. General trophic structure will be determined using stable isotope analysis. Trophic position is important because we have evidence from the Navarro River watershed that steelhead in slightly different trophic positions also have different growth rates and survival. Finally, the remaining fish in the community will be identified and scales taken for aging in order to characterize the entire community.

Stable isotope analysis (SIA) provides a tool to identify energy sources. Measurements of δ-^{13}C in consumers reflect the δ-^{13}C of their basal carbon sources, and thus provide a natural tracer of basal carbon sources. Ratios of ^{14}N to ^{15}N in the tissues of animals in the food web also provide data for food chain position. Studies across lake ecosystems show that ^{15}N increases in concentration by an average of 3.4 $^{0}/_{00}$ at each step in the food chain. Individuals within the same species that differ in ^{15}N reflect basic differences in diet that are often reflected in growth and survival.

Food quality will be determined by measuring the polyunsaturated fatty acids (PUFA's) in steelhead and their diet. In particular, the long-chain fatty acids eicosapentaenoic acid (EPA 20:5ω3) and docosahexaenoic acid (DHA, 22:6ω3) have been identified as indicators of high quality food in aquatic food webs (Stottrup and Jensen 1990, Brett and Müller-Navarra 1997, Müller-Navarra 1995). Moreover, a deficiency in essential fatty acids has been linked to reduced growth rates, increased mortality, and reduced viability (Olsen 1999). We will analyze the fatty acid content of all trophic levels from primary producers to steelhead in the various watersheds to understand the role of food quality in the growth and survival of steelhead.

Task 3.

Physical habitat measurements and riparian evaluation will be performed on as many reaches as possible for locations not previously evaluated by CDFG. Habitat typing will follow the CSSHRM protocols. In addition to the analyses performed for habitat typing, we will perform more detailed habitat and sediment analyses including measures of bed load, turbidity during different periods of the year, and sediment deposition rate. Fine scale temperature monitoring will be conducted at several reaches using temperature loggers to understand the potential for temperature stratification of pools, and general water temperatures at locations where steelhead are present. DO loggers will be placed in several reaches to determine the DO concentration in streams as the flow declines and water temperature increases. Samples will be collected for analysis of total N and P to determine the role of nutrients in productivity. Currently, there is a hypothesis that reduced survival of early age classes is attributed to a lack of nutrients because fish carcasses that once provided nutrients to the system are no longer present. Once fish die after spawning, the carcasses can become captured by LWD jams and other habitat features and slowly decompose releasing their nutrients to the system, which in turn fuel primary productivity. An alternative hypothesis is that the decomposing carcasses serve as a carbon source for early life stages. Over time as salmonid runs decline, there are fewer and fewer carcasses to provide nutrients. Coupled with lower amounts of LWD to trap carcasses in the streams, it is hypothesized that now there are insufficient nutrients to support salmonids. We will perform experiments in which we anchor carcasses from hatchery brood stock in the stream after their death and monitor the nutrient addition and any change in primary productivity that may occur. We will also monitor survival and growth of fish present in those reaches compared to fish in reaches with no additions. Finally, we will perform modeling with PHABSIM to determine if the results of the modeling correspond to the habitat selection of juvenile steelhead.

Task 4.

We will develop age-based matrix models for the stages of the steelhead populations for which we can obtain data. As part of this project, we can't monitor survival of steelhead once they migrate to the Sacramento or San Joaquin rivers and out to the ocean. Consequently, we can't include all stages of the steelhead life cycle in the models. We will be able to obtain steelhead carcasses and count redds providing an estimate of the number of adults returning to the watersheds each year. (Steelhead and salmon redds are sufficiently different that they can be distinguished relatively well although there are some redds for which differentiation is not possible.) Otolith analysis will allow us to determine the ages of returning fish and microprobe analysis to determine strontium/calcium ratios in the otoliths will allow us to determine if there are any multiple spawners in the system (and also allow us to separate anadromous from native rainbows). We can then work backwards to estimate the survival of fish once they leave the watershed. Because steelhead have longer than a 3-year life span, it will not be possible to follow a cohort throughout its life. We will be able to obtain estimates for the survival of the younger age classes and parameterize the models. It is doubtful that the range of variation seen in the three years of the project will allow realistic variance estimates for the parameters. Large variance estimates reduce the potential utility of the population projections, but more realistic variance estimates can be obtained with additional years of monitoring. The key is to begin to generate the data necessary to build adequate models. Once the models are generated, standard sensitivity analyses can be run to determine how sensitive the population growth rate is to changes in the matrix elements. Once the sensitivities are understood, habitat improvement projects that target those elements can be implemented.

Task 5

The core of the subtask is GIS analysis of the watersheds selected for intensive study and hence the primary work on this task will occur after the first summer of field work. Sediment delivery sites will be catalogued using aerial photo analysis from the most recently available photos. Additionally, we attempt to find a time series of aerial photos to document the change in sediment delivery over time. In the Navarro watershed, we obtained photos from 1936 to 1996. Photos are examined for the presence of landslides and other erosion mechanisms and these sites are placed into a GIS coverage of active erosion source locations. We then will quantify the sediment contribution from hill slopes and relate that contribution to landscape features such as logging roads, landings, other timber harvest activities, agricultural activities, mining sites, and natural erosion processes. Geomorphology field surveys will document channel morphology and sediment storage in order to investigate the effect of hill slope sediment sources on physical habitat. Field work at each reach will include preparation of a geomorphic map, surveying a longitudinal profile and 6 to 10 cross sections, and surface and subsurface sediment analysis. Large woody debris will be catalogued and the relationship of LWD to pool scour and pool water temperatures will be established.

Through the use of classified Landsat imagery and high-resolution digital elevation data, a geospatial stream-shading model will be developed. This effort will use 10-meter digital elevation models, provided by the California Department of Forestry and Fire Protection, as the basis for examining the solar intensity of each reach under a late-seral stage riparian canopy scenario and a current conditions scenario.

Below is a diagram showing the basis of the stream-shading model (Figure 2a). A general hill slope (a.) can be characterized by a Digital Elevation Model (DEM); in our model we use a DEM with a 10 meter cell size resolution and indicated in the diagram (b.). We then add tree heights (c.) to the DEM while masking out stream reaches. We employ a standard shading algorithm that calculates the percent incoming solar radiation for each hour (d) on a given date. Lastly, we sum the hourly values for each reach (e.). One minus the summed percent incoming solar radiation is the stream shade potential. To calibrate the model, the modeled tree heights are used to predict tree heights on the ground with two other variables: elevation and percent slope. We have calibrated this model for the Navarro River. Results for the regression are $r^2 = 0.81$ (F=14.54, p=0.0006, do=3,13, Figure 2b) indicating a good fit.

Instream flows will be evaluated in two ways. Every field visit will include measurements of flow in several cross sections of the stream. Also, we have 10 ISCO water samplers with Doppler acoustic depth and velocity samplers. We will place these at various sections of the stream to measure flow and velocity during times when higher flows would prevent manual measurements. We will place several of these along a single cross section to obtain discharge at several sites in a watershed. Of course, any USGS gauging data will be used preferentially.

Additional stressors in each watershed selected for intensive study will be identified and set into a GIS coverage, if it is not already part of a GIS coverage. The Information Center for the Environment, our GIS partner for this proposal maintains numerous coverages with a large variety of features that can be identified as stressors, e.g., timber harvest, vineyards, mine sites, dams and exotic species. Additional stressors will be identified through the remotely sensed data used for the sediment source identification. Once identified, we will perform a cumulative effects assessment. Cumulative effects assessment (CEA) is a term that is used frequently but not generally understood. Canter (1999) provides a review of the process and provides 11 steps involved in CEA and several rules-of-thumb for working through the steps. In general, these steps involve identifying the geographic and temporal scope of the analysis (watersheds, period required for reversal of effects), characterizing the resource(s) subject to impact (steelhead), characterizing stressors (see above), developing baseline condition (viable populations), identifying cause and effect relationships (structural equation modeling), and estimating the magnitude of the direct and indirect cumulative effects (structural equation modeling). Final steps involve identifying alternatives to avoid, minimize, or mitigate the effects (HI projects-Objective 6), and monitor the effects of the selected projects and adapt management accordingly (performance metrics-Objective 7). Therefore, as we perform the research for this project, we will in essence be performing a cumulative effects assessment. The Linear Structural Modeling technique we employ to estimate direct and indirect effects will allow us to quantify the effects of each stressor that we identify.

Task 6.
ICE is developing a GIS coverage of all of the stream habitat improvement projects in the state and we will use this coverage with the addition of recent projects implemented through various state programs, to map as many projects as possible. The type of project will be determined (e.g., bank stabilization, insertion of LWD) as will the objective of the HI project (e.g., improve spawning habitat). We will then perform all of the habitat and water quality measurements that we used in Task 3 to characterize the actual effects of the HI project. We will then target these sites for observations and monitoring of steelhead to determine if habitat use increases and there are concomitant increases in survival and/or growth. Using a multivariate statistical approach, we will determine the factors (e.g., general landscape features, surrounding riparian or instream habitat, variability in flow) that contribute to the success of HI projects. If we measure success as simply either successful or failure, we will use a multiple logistic regression to perform the analysis. If it appears that we can recover a sufficient number of marked fish during the course of the summer, we will be able to use a continuous variable such as increased length or body mass (or condition factor) as the dependent variable in a classical multiple regression analysis. Once we determine the factors that are important to the success of the HI project, we can search for reaches with those similar combinations of factors as a first cataloguing of potential restoration sites.

Task 7.
A performance metric is an indicator of resource condition that can be applied as a measure of progress toward restoration. They should be sensitive to stress such that they respond rapidly and at very low levels of the stress. Indicators should be reliable, unambiguous (high specificity), and be related to ecosystem structure and function (e.g., Cairns and Pratt 1976, Kelly and Harwell 1989, 1990 Hunsaker and Carpenter 1990).

Murtaugh (1996) provided a framework for evaluating indicators in which he pointed out the four potential outcomes when evaluating condition (see Figure 1 in Murtaugh 1996). The indicator can identify a system as being (1) in good condition when it is in good condition (true positive), (2) in good condition when it is in bad condition (false positive), (3) in bad condition when it is in good condition (false negative), and (4) in bad condition

Figure 2a.

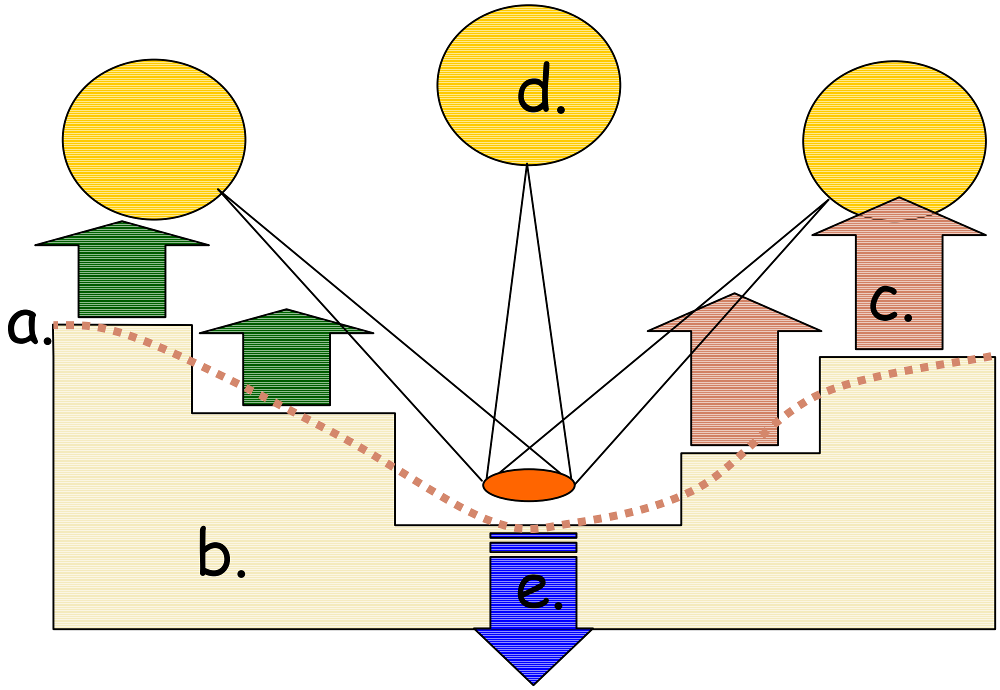
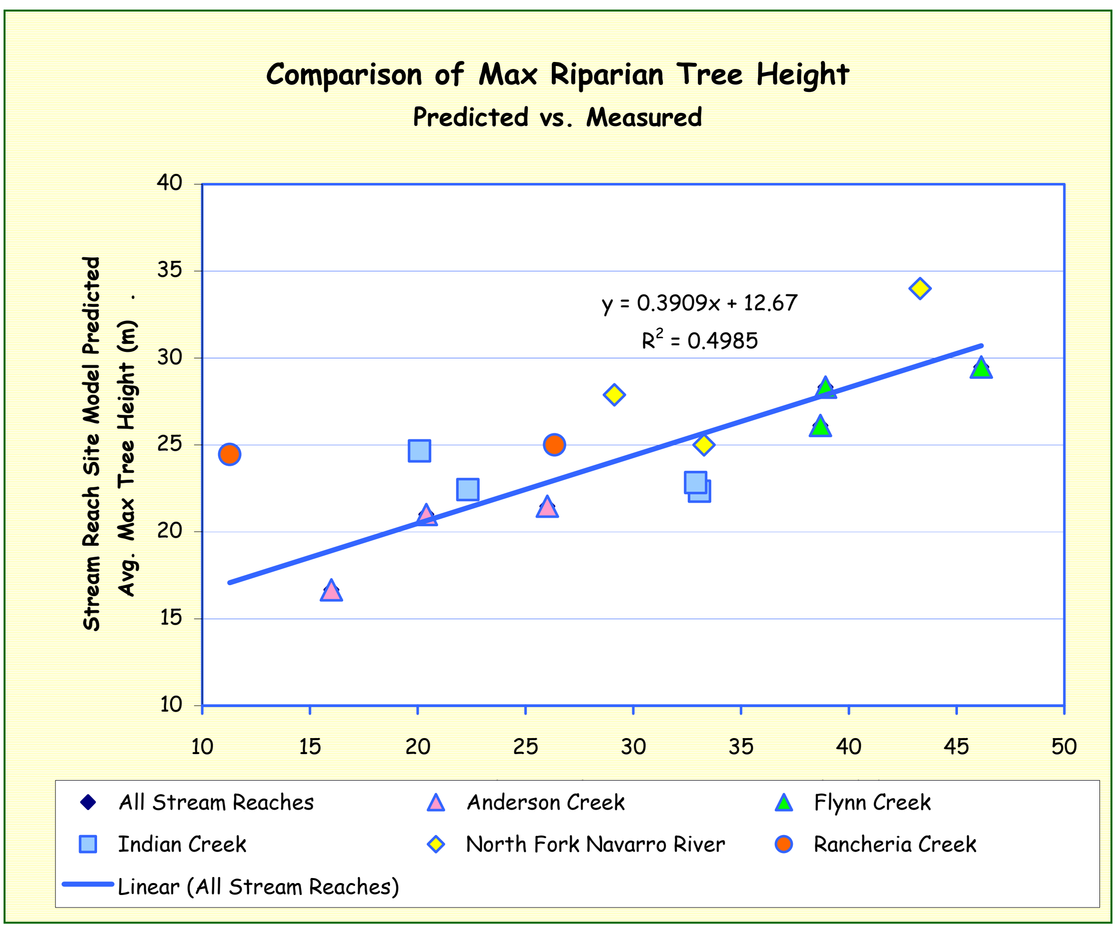


Figure 2b.



when it is in bad condition (true negative). These four potential outcomes lead to two questions that should be asked about any proposed indicator. The first question is determining if the indicator can actually discriminate between two subpopulations, i.e., can the indicator be used to distinguish between those systems that are in acceptable condition (true positives) and those that are in unacceptable condition (true negatives). Once an acceptable indicator is established, the second question is how to fix a decision point to establish the appropriate tradeoff between choices that result in false positives and false negatives. In other words, we wish to minimize the occurrence of decisions in which we accept a resource as being in good condition when it is not, or declare a resource to be in poor condition when it is not.

Receiver Operating Characteristic (ROC) analysis has been proposed as a tool for the quantitative evaluation of candidate indicators (Murtaugh 1996). This tool enables objective assessment of both questions for the majority of indicators, whether they are individual metrics or indices. ROC analysis allows us to measure the sensitivity and specificity of any indicator given a cutoff value c. Once sensitivity and specificity are plotted against each other in phase space, the area under the curve (AUC) can be used to address the first question. The greater the area under the curve, the greater the ability of the indicator to separate systems in acceptable condition from those in unacceptable condition, i.e., the greater the AUC, the better the indicator. Correct location of the cutoff point is based on positive and negative predictive values of the indicator. The positive and negative predictive values are functions of the sensitivity and specificity of the indicators, and the prevalence of healthy populations in nature (Murtaugh 1996). Only if one understands the prevalence of healthy populations in nature can an appropriate cutoff point for the indicator be established.

Our general problem is not identifying candidate indicators, it is eliminating the indicators that do not adequately convey the condition of the resource when its true status is unknown (see for example the indicator identification process initiated by Calfed in 2000). In our proposed research, our survey of steelhead populations and the assessment of their demographic status should provide us with an estimate of the prevalence of healthy populations in the Central Valley. We will then use ROC curve analysis to evaluate the large number of performance metrics that are proposed to indicate good condition of steelhead populations.

4. Feasibility

The project is completely feasible. We have performed all of the field and laboratory analyses proposed for this project as part of our current Navarro River Watershed research. Completion of some tasks does require information from other tasks, e.g., development of population models requires information on survival and reproductive success. However, there are no tasks with a low probability for completion. The greatest difficulty with the project is being able to receive permits in a timely manner, and receiving permission to access property.

5. Performance Measures

Performance measures for research project activities and outcomes include both the quarterly reports to Calfed and DFG, but also the generation of peer-reviewed publications. Unfortunately, the time frame of this project will not allow for the publication of manuscripts in scientific journals and the performance measures will simply be the submission of reports.

6. Data Handling and Storage

For the proposed research, all field samples (e.g., scales, macroinvertebrates), field measurements (e.g., flows, habitat measurements), and laboratory measurements (e.g., PUFA content) will be marked with a bar code tag that can be affixed to sample vials, field and laboratory data sheets. This will insure that all samples are assigned to the correct location. All field samples are catalogued with a chain-of-custody form at time of collection that includes all relevant data.

All data for the project will be kept in either an ArcView GIS database and/or an ACCESS database. The ACCESS database is already developed and will contain information on every aspect of the project including raw data, manipulated data, and results of statistical analyses. Additionally, the database contains SOPs for every field or laboratory sampling technique used in the project, digital photos for documentation, all publications and poster presentations, and cross references to GIS coverages maintained in ArcView. The ArcView database contains all of the coverages generated by the project. Most of the actual raw data generated by the project are included in the ArcView files as attributes. The responsibility of the ACCESS database manager includes conversion of data files to ACCESS, quality control of data, and responding to queries from team members. The database manager for the GIS will maintain the coverages, respond to queries from the group, and do the GIS analyses.

7. Expected Products/Outcomes

The expected product from any research project is new knowledge. The key then is to determine how this new knowledge can most efficiently be communicated with the appropriate groups. We will submit quarterly and annual reports of all activities to Calfed and to the CDFG Steelhead Program Work Team. Quarterly reports will consist of the activities performed during the quarter, and the annual reports will consist of an evaluation of the status of the project, any refocusing or redirection of efforts, and preliminary results of the research.

8. Work Schedule

Tasks 1, 2, 3, 5, 6 and 8 will be conducted every year. Tasks 4 and 7 will be initiated in year two after the first year's data become available. Quarterly reports will be due every quarter and the annual report will be due 30 days after the end of each year of funding.

B. Applicability to CALFED ERP and Science Program Goals and Implementation Plan and CVPIA Priorities

1. ERP, Science Program and CVPIA Priorities.

This project will support ERP Strategic Goals 1 (At-Risk Species), 2 (Ecological Processes), 3 (Harvestable Species), 4 (Habitat), and 6 (Sediment and Water Quality) and will cover two of the five geographic regions of concern to Calfed. This research addresses Science Program Goals MR-6 (conceptual understanding and models that cross multiple regions), SR-3 (adaptive management experiments in regard to natural and modified flows), SR-7 (conceptual models to support restoration), SJ-4 (improve understanding of at-risk species). The proposed research will determine the relationship among steelhead populations, stressors, habitat condition, riparian condition, watershed landscape dynamics, and aquatic communities. All major stream and rivers of the Central Valley will be studied including Battle, Clear, Cottonwood, Deer, Mill, Butte, Big Chico and Antelope creeks, and the Yuba and Feather Rivers, which are identified in Goals SR-3 and 7 as priority streams for studies of salmonid stressors and their effects.

2. Relationship to Other Ecosystem Restoration Projects.
The biological data produced through this study can be used to evaluate existing and future stream restoration projects in both the Central Valley and Sierra Foothills Ecoregions of the Sacramento River watershed.

3. Requests for Next-Phase Funding.
This proposal is not a request for next phase funding.

4. Previous Recipients of CALFED Program or CVPIA Funding.
The applicants have not received previous CALFED Program or CVPIA funding.

5. System-Wide Ecosystem Benefits.
The benefits from this project would apply throughout the Sierra Foothill and Central Valley Ecoregions of the Central Valley watershed.

6. Additional Information for Proposals Containing Land Acquisition.
Not Applicable

C. Qualifications
Michael L. Johnson is an Associate Research Ecologist in the John Muir Institute of the Environment at the University of California, Davis. He received a Ph.D. from the University of Kansas in 1984 and worked with the Kansas Biological Survey on projects related to the effect of agriculture on the aquatic ecosystems of Kansas. He moved to UC Davis in 1992 where he is now the Director of the University of California Toxic Substances Research and Teaching Program's Lead Campus Program in Ecotoxicology. He has worked on a number of projects related to stressor identification and effects on ecosystems, steelhead ecology on the North Coast, and modeling of population dynamics. He is the PI of the Navarro River Watershed project, a $3.5 million multidisciplinary project to identify the stressors on steelhead populations in a North Coast watershed.

Dr. Donald G. Huggins is a Visiting Research Ecologist at the JMIE at UC Davis. He has over 30 years of experience as an aquatic ecologist at the Kansas Biological Survey where he is the Director of the Aquatic Ecotoxicology Program. He is also the Director of the Central Plains Center for Bioassessment in EPA Region VII, a center whose goal is to develop numerical criteria for nutrients and the biological condition of aquatic systems. Dr. Huggins is currently assisting Dr. Johnson on the Navarro River project. His appointment can be extended and he can remain at UCD if this project is funded.

D. Cost

1. Budget.

The detailed budget and budget justification are included in the web forms.

2. Cost Sharing.

N/A.

E. Local Involvement

We have contacted the DFG Native Anadromous Fish and Watershed Branch and have been informed that we will be contacted by Ms. Katie Perry who is the new DFG Statewide Steelhead Specialist. We will work closely with her over the three years of the project.

F. Compliance with Standard Terms and Conditions

All applicants will comply with standard State and Federal contract terms.

G. Literature Cited

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