CALFED SCIENCE FELLOWS PROGRAM

In cooperation with the

California Sea Grant College Program

FELLOWSHIP APPLICATION COVER PAGE

APPLICANT TYPE ☐ Postdoctoral Researcher ☒ Ph.D. Graduate Student

PROJECT NUMBER ____________________

PROJECT TITLE Effects of water temperature, streamflow and food availability on the growth, survival and movement of Central Valley juvenile steelhead (Oncorhynchus mykiss) with implications for water management

FINANCIAL SUMMARY

First Year CALFED Funds Requested:	$43,125
Total CALFED Funds Requested:	$129,375
Duration:	36 months
Proposed Start/Completion Dates:	9/1/05-8/31/08

APPROVAL SIGNATURES

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Will animal subjects be used? ☒ Yes ☐ No

APPROVAL DATE: Jan. 2004 PROTOCOL #: casp04.05 PENDING: ____________

Does this application involve any recombinant DNA technology or research? ☐ Yes ☒ No

2) Proposed Research

a) Introduction / Questions / Objectives:

The plasticity of life history trajectories in steelhead (*Oncorhynchus mykiss*) has allowed the persistence of populations in highly variable environments along the Pacific Coast of North America. However, despite this adaptability steelhead populations have suffered severe losses in abundance. In California, all but one Evolutionarily Significant Unit (ESU) of steelhead are currently listed as either threatened or endangered under the Endangered Species Act. In the Central Valley, declines are clearly linked to water management (McEwan 2001). Dam construction throughout the Sacramento and San Joaquin watersheds eliminated approximately 82% of historical spawning and rearing habitat (Yoshiyama et al. 1996 in McEwan 2001) and constrained steelhead to spawning in lower elevations, as is the case with the Mokelumne River. However, the continuing decline of steelhead populations 40+ years after the major period of dam construction suggests that other factors are contributing to population losses. An improved understanding of how environmental factors and water management affect the growth, survival and movement of Central Valley ESU steelhead will greatly improve our ability to understand and predict effects of changing environmental factors on steelhead populations.

My study is designed to be complementary to a new CALFED funded project that will be conducted by Dr. Marc Mangel, Dr. Susan Sogard, and Dr. Robert Titus investigating the Life History Variation in Steelhead in the Mokelumne and American Rivers (Central Valley ESU), and Soquel and Scott Creeks (Central California Coast ESU). My study compliments their project by focusing on the investigation of water management effects upon juvenile steelhead growth, survival, life history pathways and movement. In order to focus on water management implications I have chosen to work on the Mokelumne River (in conjunction with the above project), an altered, highly regulated and managed river, in comparison to the neighboring Cosumnes River (in addition to the above project) with similar watershed characteristics yet relatively unaltered, unregulated, and with no major dams. By comparing these two neighboring watersheds and how different environmental factors affect juvenile steelhead growth, survival, life history trajectories and movement I will be able to identify how different water management regimes affect steelhead population dynamics.

The comparison of the Mokelumne and Cosumnes Rivers provide an excellent natural experiment on the effects of water temperature and streamflow on juvenile steelhead life histories and population dynamics. The Cosumnes River, while actually a slightly smaller rain fed watershed, now potentially has higher flows than the once much larger snow fed river system of the Mokelumne River due to all of the diversions and flow controls. However, the Cosumnes has the potential to dry in areas and has increased probability of elevated water temperatures. Controlled flows in the Mokelumne, while reducing streamflows, may actually work to maintain cooler downstream temperatures due to releases from the bottom of reservoirs. These characteristics make comparisons of the Mokelumne and Cosumnes Rivers excellent field sites for my investigation of how natural and anthropogenic factors affect juvenile steelhead growth, survival and movement.

My project will thus focus on the first two CALFED priority topic areas: 1) water operations and biological resources, and 2) ecological processes and their relationship to water management and key species. Furthermore, my work will provide tools and data to help achieve the CVPIA Section 3406(b)1 objective of doubling populations of naturally produced salmonids. Understanding the environmental conditions necessary for the success of fish adopting different life history strategies is also essential for CVPIA goals of restoring altered habitats and providing water flows of appropriate timing to protect early stages of steelhead. In a system where water supply is insufficient for both human use as well as for fish habitat, determining how the timing of diversions for human use could best benefit fish habitat is critical. Field study results on the Mokelumne will potentially elucidate stressors near "zones of influence" of water diversions, a high priority of CALFED and CBDA. Results on the movement of juvenile steelhead will increase CALFED understanding of impacts from water diversions and the Delta Cross Channel. By directly testing the effects of water temperature and food availability on the growth of Mokelumne stock fish, my lab component will focus on how water management regimes affect juvenile steelhead life histories and success. Results from my project will provide a tool that can be used to plan water management to improve water supply efficiency while maximizing steelhead habitat quality at critical times, and therefore increasing steelhead productivity.

My project will focus on determining and modeling environmental conditions that underlie three pathways available to steelhead in their first year. Prior studies on juvenile salmonids have demonstrated the influence of growth and lipid accumulation, interacting with genetic factors, on timing of life history transitions (Thorpe et al. 1998). Fast growth is typically associated with smolt transformation and emigration at age 1. Fish with poor growth typically remain in fresh water for at least another year. Early maturation may occur in fish that are able to both grow quickly and accumulate high lipid levels. Once initiated, these trajectories may be fixed, with limited opportunity to switch if conditions change. Therefore, major environmental shifts can result in high proportions of fish that have entered an inappropriate pathway. My overall hypothesis is that water temperatures and the temporal pattern of streamflows have a major impact on growth opportunity and life history expression in age-0 steelhead, which will echo through the rest of their life history and population dynamics. Alterations in streamflow patterns potentially disrupt the natural adaptive responses of juvenile steelhead, resulting in reduced survival as fish make crucial mistakes in selecting life history trajectories. In order to reach CVPIA goals of increasing naturally produced salmonids, managers must understand how the environment affects the life history processes and how those processes are echoed through to production.

I will investigate a series of questions concerning the factors determining the growth, survival and movement of juvenile steelhead and the role of the environment, particularly water temperatures and streamflows, in shaping this behavior. These include:

1) How do water temperature and streamflow affect growth, survival and movement of juvenile steelhead of the Central Valley ESU?
2) What information do size distributions and growth rate provide about the probability of different life history pathways?
3) Can we determine life history patterns and habitat parameters for Central Valley ESU steelhead?
4) What are the implications of these results for the effects of water management

and streamflows on steelhead life history pathways, survival and therefore population dynamics?

I will address these questions from approaches of field studies, lab experiments, and modeling.

Background

Steelhead (*Oncorhynchus mykiss*) exhibit a remarkable diversity of life histories. At the end of their first year individual steelhead may follow three different trajectories, they may: 1) remain in freshwater as immature parr, 2) undergo smolt transformation and emigrate to the ocean, or 3) precociously mature. The following year, multiple pathways are again possible, such as emigration to the ocean or continued freshwater residence. Some individuals never emigrate, thus becoming rainbow trout, the non-anadromous form of *O. mykiss*. This complexity of life histories makes understanding population dynamics and environmental effects on steelhead very challenging. For example, fisheries science typically focuses on analyzing annual cohorts (year classes) and how they fare as they progress through their life span. However, steelhead progeny produced in a single year will very likely split into different trajectories, inhibiting the tracking of birth cohorts. Returning runs of adults will be comprised of fish of different ages that have spent varying periods in freshwater and seawater, making linkages of abundance to environmental conditions such as flow rates in the birth year, problematic. In contrast to other Pacific salmonids, steelhead are iteroparous meaning they may spawn over several years, and migrate to the ocean between each spawning.

Experimental studies have elucidated the importance of early growth rates and the position of an individual along an expected growth trajectory in shaping the probability of early maturation and/or migration, as well as the timing of emigration for anadromous individuals (Thorpe et al. 1998). Growth rates of age-0 fishes are presumably driven by the interactions of several factors, including density of conspecifics and potential competitors, water temperature, genetic differences in growth capacity, and food availability. I assume that smolt transformation and subsequent emigration depend on the physiological state of an individual at some time in advance of the actual initiation of the required physiological transformations; once this decision is made an individual fish is committed to a particular developmental pathway.

Poff and Ward (1989) emphasize the importance of stability in flow patterns for the productivity of stream fish. Drifting terrestrial invertebrates are a rich and preferred prey type for juvenile steelhead, and increase in abundance as water velocity increases (Smith and Li 1983). Seelbach (1993) found that stable flows were associated with high survival of steelhead through their first winter. Management decisions that alter the natural patterns of flow rates thereby have the potential to alter growth rates and, consequently, life history pathways of steelhead. For example, if the emigration decision window occurs prior to a period of normally high flow, disruption of streamflow and therefore of food delivery may have a negative impact on fish that have adopted an early emigration trajectory. I do not know of any data linking these growth components on a seasonal basis and thereby addressing the issue of growth potential for steelhead in different seasons.

The central role of early growth in determining life history trajectories provides a tractable means of generating the empirical data necessary to develop life cycle models for Central Valley steelhead and for using these models to understand the effects of water policy on steelhead population dynamics. My overall focus is to understand the mechanisms underlying variability in potential growth rates and how different factors impact growth and consequent life history pathways. I believe management decisions affecting the growth environment, including habitat availability, food delivery via drift, and physical conditions such as temperature, all of which are dependent upon streamflow, can dramatically alter the natural distribution of life history patterns exhibited in steelhead populations. Development of appropriate, well-supported life history models for steelhead will be useful for both improved management of water resources for threatened populations and improved predictive capabilities for future environmental impacts such as global warming and drought regimes.

Preliminary results:

NMFS Santa Cruz has focused and long-term research and monitoring results for similar field and laboratory studies in streams draining into the Monterey Bay in the Central Coast California ESU. Dr. Sogard has preliminary results showing that growth is inhibited in the summer and accelerated in the winter/spring when temperatures are mild and food availability presumably increases due to higher flows for her Soquel Creek study, opposite to published results found for Atlantic salmon (Thorpe et al. 1998). From his work on the American and Mokelumne Rivers, Dr. Merz (2002, Merz and Vanicek 1996) has documented relationships of feeding activity with temperature and flow rates. Merz (2002) observed higher gut fullness levels in winter than other seasons for steelhead in the Mokelumne River. This fits with my predictions for the Mokelumne and Cosumnes Rivers based upon similar temperature and flow regimes to the coastal streams, i.e. high flows and low temperatures in winter, with low flows and elevated temperatures in the late summer / early fall. I hypothesize that variability in water flow is a major determinant of food availability through the delivery of insect prey, resulting in a direct relationship of flow with growth potential.

Hypotheses to be tested:

Fieldwork will be guided by the following hypotheses:

H1: Age-0 steelhead exhibit bimodal size distributions in the winter, reflecting a split into emigrating and non-emigrating trajectories.

H2: Availability of insect prey differs among stream systems and seasonally.

H3: Prey delivery via drift is a function of flow rate.

H4: Growth and survival of age-0 steelhead is an interactive function of streamflow, temperature, prey density, and competitor density.

Laboratory work will be guided by the following hypotheses:

H6: Growth rates and body condition establish the life history pathway selected by an individual fish.

H7: Altered temperature regimes influence the proportion of fish adopting different life history pathways.

H8: Behavior varies as a function of life history pathway and temperature.

Models developed cooperatively with the full three years of laboratory and fieldwork will be guided by the following hypothesis:

H9: Life history trajectories may be predicted based upon environmental and physiological conditions during a decision window.

b) Approach / Plan of Work:

Field component

The field component will address the following questions:

1. How do juvenile steelhead growth rate and survival vary within and between the Mokelumne and Cosumnes Rivers?
2. How do different environmental factors, specifically water temperature and streamflow, affect juvenile steelhead growth rate and survival?
3. How does food availability vary through time for the Mokelumne and Cosumnes Rivers?
4. How does food variability affect growth rates, survival and other population dynamics of juvenile steelhead?
5. How do different water management and streamflow management regimes affect juvenile steelhead growth rates, survival, movement and other population dynamics?

Field studies will focus on evaluating seasonal patterns in growth potential for steelhead populations in the Mokelumne River and the Cosumnes River. These two different yet comparable, neighboring watersheds of the Central Valley flow directly into the Sacramento-San Joaquin delta system. The Mokelumne River has 16 major hydroelectric, irrigation and water supply dams and is a primary water source for the East Bay Municipal Utilities District (EBMUD), which serves approximately 1.3 million people. In contrast, the neighboring Cosumnes River, a tributary to the Mokelumne, is the only undammed river on the west slope of the Sierras and has portions within a preserve with multi-agency management by a cooperation between The Bureau of Land Management, California Department of Fish and Game, Ducks Unlimited, California Department of Water Resources, Sacramento County Department of Regional Parks Open Space and Recreation, The Nature Conservancy, and the Wildlife Conservation Board. Little research has been conducted on steelhead of the Cosumnes River so any increase in knowledge will greatly benefit CALFED. The Cosumnes River with its less altered and less managed flow regime will be a good comparison to the highly regulated flow regime of the Mokelumne River. Both have histories of habitat restoration and habitat improvement.

Within each stream system I will establish four 100 m reaches for sampling. My focus will be to select sampling sites that cover a range of conditions and habitats currently being used by age-0 *O. mykiss* in each system. My goal is to examine the variability in juvenile steelhead growth potential and life history trajectories as a function of different environmental conditions, especially in relationship to different streamflow water management regimes. Physical parameters of temperature and flow will be monitored on a continuous basis. Temperatures will be recorded using Onset TidBits placed in housings at each site. Water flow data will be obtained from existing flow monitoring stations and models on both the Cosumnes and Mokelumne rivers from past and continuing CALFED, EBMUD and other research. Flows at the 8 individual sampling sites will be periodically calibrated against these values with a hand held stream flow meter.

Documenting seasonal patterns of food abundance will be a key component of my field research and one of the most time intensive efforts. It is also a vital information gap, as relatively little effort has been expended to address the annual variability of prey in natural steelhead waters. The diet of age-0 and age-1 steelhead is comprised primarily of insect larval and adult stages (Merz & Vanicek 1996). Insect prey for young steelhead is derived from in situ (benthic) sources and delivered via drift from upstream sources. I expect availability of prey to be highly variable depending on seasonal cycles of production and fluctuating delivery via drift. To sample these two components I will use benthic samplers (Surber or modified Hess) and stream drift nets, deployed according to standard protocols. Collected organisms will be identified to broad taxa and categorized as potential prey for either age-0 or age-1 steelhead. Dr. Joe Merz (EBMUD) has agreed to assist with training in identification of stream invertebrates, and the processing of benthic and drift samples will take place in his laboratory. Sampling will be conducted at the 8 sites on a seasonal basis (four time periods per year). In addition, I will examine variability in food availability on a diel basis by sampling across a 48-hour time period at one site in each stream per season. To provide more detailed comparisons of prey abundance with flow rates, I will conduct sampling on an opportunistic basis as water flows vary within a season. I expect this variability to be expressed primarily during fall and winter in association with rainstorms. Standard parametric statistics will be used to evaluate differences in food abundance between sites, between rivers, and as a function of season and flow rate.

Fish density estimates, steelhead size distributions, and the species composition of potential predators and competitors will be determined using snorkeling observations. Standard snorkeling transects will be conducted along the 100 m reach during four time periods (spring, summer, fall, winter) each year. Abundance and size distribution of *O. mykiss* and other fish species present in each reach will be recorded. Roni and Fayram (2000) found that nighttime observations provided estimates comparable to electrofishing for small salmonids, whereas daytime snorkeling underestimated abundance, particularly at low water temperatures (small fish are more likely to feed at night and hide during the daytime). I will conduct preliminary tests to determine if night snorkeling counts exceed day counts and plan further sampling accordingly. Low water clarity may inhibit snorkeling surveys. In this case, the fish community will be sampled with seines and trawls to provide a coarse estimate of fish density and potential competitors and predators. If low flow rates prevent snorkeling, density estimates will be conducted by a backpack electrofishing 3 pass regression model.

Growth rates will be monitored indirectly using the time series of length-frequency estimates derived from density sampling and directly using mark and recapture methods at the same eight sites. During the late spring or early summer sampling of each year, steelhead will be caught via seining or electrofishing. Fish < 65 mm fork length (FL) (all presumed to be age-0) will be tagged with different colors of fluorescent elastomer (Northwest Marine Technology) for each series of 10 mm size classes. Fish > 65 mm will be tagged with PIT (Passive Induced Transponder, Allflex corporation) tags, which provide a unique identifier for each individual. Subsequent recaptures at each sampling site during the four seasonal efforts will provide data on growth rates within each season. As fish attain the 65 mm target, they will be PIT tagged, providing increasing sample sizes for tracking of individual growth rates. These methods have proven to be highly effective in evaluating growth in studies on Soquel Creek (Central California Coast ESU).

Emigration of PIT tagged steelhead from Scott Creek is currently being monitored by the Salmon Ecology Team, NMFS Santa Cruz, using a stream wide antenna/reader system with continuous logging as tagged individuals move past the reader. I will design a PIT tag reader to integrate into EBMUD's existing fish traps and weirs on the Mokelumne River and expect to be able to develop something similar for the Cosumnes River to continuously monitor movement of tagged fish out of the river systems and into the Bay Delta area. Timing of emigration will be compared with age, size and growth data for tagged steelhead.

All of the field studies will be conducted across the full 3 years of the project. I expect to encounter a broad range of environmental conditions across this time, providing the opportunity to evaluate the variability in growth potential experienced by natural steelhead populations in the watersheds. This intensive effort will provide a wealth of data on the physical environment, food availability, and fish density across seasons in two different stream systems that feed into the Bay Delta area. Growth rate measurements will elucidate the interactive effects of these factors and any population differences potentially attributable to water management regimes. All results will be statistically analyzed and fed directly into a modeling component of this project for CALFED management use.

Lab component

Laboratory experiments will address the following questions:

1. How do variations in water temperature and food availability affect juvenile steelhead growth and survival?
2. How does fish behavior vary as a function of physiological and environmental conditions?

The California Department of Fish and Game and the East Bay Municipal Utilities District operate a hatchery on the Mokelumne River to mitigate the loss of anadromous habitat caused by dams on the river. By using juvenile steelhead from this hatchery I will be testing the above processes on fish from the Mokelumne system, and specific to the Bay Delta area. The Cosumnes River is a tributary of the Mokelumne River directly adjacent to the North with similar environmental conditions and likely similar genetics. Hatchery staff will use standard egg and sperm removal and incubation procedures from aggregated males and females to ensure a varied mix of lineages. Under a cooperative agreement with the hatchery, I will collect progeny just prior to the first feeding stage and transport them to aquarium facilities at the NMFS Santa Cruz lab for subsequent growth experiments. The fry will likely be ready for transfer some time in May. This timing will allow us to have full control over the food availability and water temperatures experienced by different treatments of fish.

Laboratory experiments will take place during the third year of the project. In the laboratory, fish will be randomly assigned in groups of 20 fish to one of four treatments, with four replicate tanks for each. The treatments will investigate the effects of elevated water temperatures and food availability on juvenile steelhead growth.

For the first set of two treatments water temperatures will follow the mean weekly temperature for the Mokelumne River from historical data collected by EBMUD. Within this set, treatments will differ in feeding regimes between "high" (ad libitum) and "low" (3% body weight d^{-1} based upon wet weight). In the second set of treatments, water temperatures will follow the record high experienced in that week by either the

Mokelumne or the Cosumnes Rivers. Once again treatments will be "high" and "low" feeding rations. Food provided will be a standard hatchery pellet, BioDiet. Growth and condition indices will be monitored by measuring and weighing all fish on a weekly basis between temperature changes. Prior studies have demonstrated a marked capacity in Scott Creek populations (Central California Coast ESU) to capitalize on these feeding opportunities with accelerated growth rates (exceeding 1 mm d^{-1}), and I expect the Mokelumne population to respond similarly.

Behavior of fish in each treatment will be examined in late winter and early spring to determine any differences associated with growth rates or life history trajectory and temperature regime. Pairs of fish from each tank will be placed in circular tanks with overhead video cameras and filmed for 4-hour periods during the day and at night. A PVC shelter will be placed in the middle of the tank. General motor activity, shelter use, and aggressive interactions will be quantified and compared among treatments and between day and night.

Fish will be maintained under a photoperiod natural to the Mokelumne River. Fish will be photographed periodically throughout the experiments to assess changes in coloration to potentially assess treatment effects on life history trajectories. I will monitor physiological condition of the fish in my experiments by measuring swimming capability and metabolic rate in a swim tunnel respirometer once a month, using a representative sample of fish from each treatment to test treatment effects upon metabolism.

Being ectothermic, fish metabolism and activity are related to water temperature. I expect fish growth to increase with increased water temperatures, within a performance and survival threshold, so long as there is ample food supply. In past experiments, (Sogard and Olla 2001) fish growth increased with water temperature to a survival threshold. There may be circumstances in which low ration fish in the cooler temperature regime grow more, or maintain body condition than those in the elevated temperature regime due to conservation of energy. By continual growth and condition monitoring compared between two different temperature arrays I will determine how water temperature affects Central Valley ESU juvenile steelhead growth, a previously untested parameter.

Modeling Component:

An initial framework for a growth model to characterize anticipated and actual life history trajectories can be developed from existing models (Weatherley and Gill 1981, Weatherley and Gill 1995, Hill and Grossman 1993, Elliott 1994, Elliott et al. 1996, West et al. 2001, Forseth et al. 2001), parameterized initially with the data in Shapovalov and Taft (1954) and refined through Mangel's empirical work:

$$\frac{dW}{dt} = q\Phi(T(t))W^{a} - \alpha e^{0.071T(t)}W^{b}$$

Where W(t) is mass at time t, q is maximum food assimilation efficiency and related to the abundance of food, $\Phi(T(t))$ characterizes the temperature dependence of food assimilation, a and b are allometric parameters (a=2/3, b=1 corresponds to von Bertalanffy growth), and α is a measure of standard metabolic rate. The maximum food assimilation efficiency q and water temperature at time t, T(t), behave in predictable manners with respect to water flow (e.g. with other factors remaining constant, reduced flow will reduce q and increase T).

By specifically manipulating water temperature and food availability in my lab component I will be directly testing their effects upon juvenile steelhead growth and survival. Similarly, by comparing habitat parameter and the resulting growth, survival and movement of juvenile steelhead between the Mokelumne and Cosumnes rivers I will be specifically addressing the effects of water temperature, streamflow and water management on juvenile steelhead population dynamics. My modeling efforts will thereby provide a tool to EBMUD and CALFED for the forward projection of steelhead growth survival, and population dynamics in relation to streamflow and water management regimes. Furthermore, additions of my results into the modeling efforts of Dr. Mangel and Dr. Sogard, will increase the accuracy and utility of their models of life history variation in steelhead and the implications for water management.

In previous work, Dr. Mangel and Dr. Sogard have demonstrated the feasibility of each component of the project (laboratory studies, field studies and modeling). Preliminary studies have been conducted for all major aspects of the project . Initial lab results have allowed the fine tuning of experimental protocols for manipulating growth rates and for measuring behavioral responses and physiological changes associated with smolting.

c) Output / Anticipated Products or Benefits:

- *To the fellow*

This project fits well with and draws from my extensive experience in steelhead monitoring and watershed management in relation to municipal water use and sensitive species and resources. I have been out of the academic realm for nine years, working on steelhead population and habitat monitoring projects, other wildlife projects, restoration ecology, and as a Watershed Planning Analyst, writing a watershed management plan for the San Lorenzo Valley Water District. I am ready and eager to return to the academic arena. During my time since my undergraduate career I have fine-tuned what I want to gain out of graduate school. I designed this project to incorporate all of those skills and knowledge areas into my graduate experience. This project works with steelhead, a species I am passionate about with ten years experience, expands upon my experience in field methodologies, develops lab techniques and experience, strengthens my use of statistics, introduces me to the utility of modeling, and further develops skills in communication and dissemination of results. I plan on publishing the results in a co-authorship with the collaborators in one or more peer-reviewed journals. I will also present the results at different scientific conferences and to CALFED / California Bay-Delta Authority Science Conferences as desired. Furthermore, this project further develops my relationship with NMFS Santa Cruz and initiates a working relationship with CALFED and the California Bay-Delta Authority.

- *To the research mentor*

This project expands upon and further focuses Dr. Susan Sogard's CALFED grant. It overlaps with her proposed work on the Mokelumne River, but introduces the Cosumnes River as a comparison of a highly water managed river to one with a more natural flow regime. My project specifically questions the effects of temperature and food availability on juvenile steelhead, providing an expansion on her proposed project of life history variation in steelhead, while mutually benefiting her project and CALFED with its utility for water management. This project continues and expands upon work that Dr. Sogard has conducted at NMFS Santa Cruz on the juvenile stage of steelhead, and directly addresses questions that she is interested in researching. Dr. Sogard will co-author publication(s) in peer reviewed journal(s).

- *To the community mentor(s)*

This project will directly benefit Dr. Joe Merz in several manners. It is a continuation and expansion of existing research and monitoring Dr. Merz has conducted on the Mokelumne River. My remote, instream PIT tag sensors that I design and incorporate into EBMUD fish traps and weirs will provide long-term data on the movement of steelhead in and out of the Mokelumne River, a question of particular interest to EBMUD and Dr. Merz. Dr. Merz will co-author the publication(s) in peer reviewed journal(s). The results of this project will directly benefit Dr. Merz and EBMUD with their management of the Mokelumne Watershed to increase steelhead habitat quality and population numbers while maximizing efficiency of water supply to their customers.

- *to the CALFED priorities and mission*

This project fulfills the goals of the CBDA Science Fellows program by promoting scientific partnerships across agencies and research institutions to provide training and development of scientists working in multidisciplinary, field oriented research supporting resource management, and to bring together world-class scientific talent to advance scientific knowledge on ecosystems and water management in watersheds draining into the Sacramento-San Joaquin Delta and San Francisco Bay. Results of this project will directly benefit the first two CALFED priority topic areas of: “Linkages between water operations and biological resources, particularly at-risk species” and “Ecological processes and their relationship to water management and key species conservation;” as well as three of the four main objectives of CALFED to: 1) Improve Ecosystem Quality, 2) Improve Water Supply Reliability, and 3) Improve Water Quality. I will present results to CALFED and the CBDA at CALFED Science Conferences, and at other CALFED conferences, training sessions or workshops as CALFED desires. I will also present results at several national scientific conferences, and will publish results in peer-reviewed journals, all of which provide CALFED decision-making requirements of clearly articulating the state of knowledge through unbiased peer review of world-class scientific research conducted through a multi-agency cooperation through CALFED and CBDA.

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