CALFED BAY-DELTA PROGRAM

CALFED SCIENCE FELLOWS PROGRAM

Sea Grant California

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California Sea Grant College Program

FELLOWSHIP APPLICATION COVER PAGE

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

PROJECT NUMBER _____

PROJECT TITLE Sacramento River steelhead trout: An assessment of behavioral differences and contributions of hatchery and wild stocks

FINANCIAL SUMMARY

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Total CALFED Funds Requested:	$98,750.00
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APPROVAL SIGNATURES

FELLOW:

Name: Philip Sandstrom
Position/Tit Graduate Student Researcher
Departmen John Muir Institute for the Environment
Institution: University of California Davis
Address: One Shields Ave.
City, State & Zip: Davis, CA 95616
Telephone: 803-466-3172
Fax 530-754-9364
E-mail: ptsandstrom@ucdavis.edu

MENTOR/PRINCIPAL INVESTIGATOR:

A. Peter Klimley

Name: A. Peter Klimley
Position/Title: Professor
Department: Wildlife, Fish and Conservation Biology
Institution: University of California Davis
Address: One Shields Ave.
City, State & Zip: Davis, CA 95616
Telephone: 530-752-5830
Fax:
E-mail: apklimley@ucdavis.edu

AUTHORIZED INSTITUTIONAL REPRESENTATIVE:

Danielle Neff 6-5-08

Name: DANIELLE NEFF
Position/Title: CONTRACTS + GRANTS ANALYST
Department: OFFICE OF RESEARCH, SPONSORED PROGRAMS
Institution: REGENTS OF THE UNIVERSITY OF CALIFORNIA, UC DAVIS
Address: 1850 RESEARCH PARK DR, STE 300
City, State & Zip: DAVIS, CA 95618
Telephone: (530) 747-3920
Fax: (530) 747-3937
E-mail: dnneff@ucdavis.edu

Will animal subjects be used? ☒ Yes ☐ No

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

Sacramento River steelhead trout: An assessment of behavioral differences and contributions of hatchery and wild stocks

Introduction:

The recent closure of the ocean sport and commercial salmon fisheries off the California coast emphasizes the importance of understanding migration and mortality in Pacific Salmonids. However, researchers have focused relatively little attention on migratory movements and success of juvenile and adult salmonids in the Central Valley, especially steelhead trout. The unique configurations of the Sacramento River Basin and estuaries require Pacific salmonids to travel farther and through larger and more altered habitat than in most other watersheds. The Sacramento River is heavily managed through the use of dams, water diversions, and levees. Salmonids have lost a large proportion of their native habitat, and the remaining habitat has been heavily altered. Thus, studies specific to the Sacramento River are crucial to advance understanding of the species in this particular ecosystem.

Purpose:

I propose to conduct a comparative study of juvenile and adult steelhead trout, originating both from the wild and a hatchery, that will reveal 1) reach-specific success rates; 2) reach-specific movement rates; 3) environmental and anthropogenic impacts; 4) rates of iteroparity; and 5) behavioral differences.

Need for New Knowledge:

Pacific salmonids are both an important economic and cultural resource of the Central Valley. The migratory movements and success of juvenile steelhead trout and chinook salmon in the Central Valley have significant research interest to a variety of groups, such as fishermen, managers, and water boards, Wild steelhead trout and late-fall Chinook salmon runs are supplemented by the addition of juvenile salmonids from a number of hatcheries, including Coleman National Fish Hatchery, American River Hatchery, Feather River Hatchery, and Comanche Hatchery on the Mokelumne River. Collectively state and federal hatcheries in the Central Valley contribute millions of chinook each year to the watershed. Currently, researchers have little information about the migratory movements of either the wild or hatchery species, although there is currently an ongoing research program, funded by CALFED, to gather this data. To improve the management of each stage of steelhead trout and enhance the success of their various stocks (hatchery and wild), researchers need to learn more about the behavior and migratory success of hatchery and wild fish.

The majority of data collected on migratory movements of juvenile salmonids in the Central Valley is drawn primarily from CWT mark recapture studies (Brandes and McLain 2001; Snider and Titus 2000). New technologies make it possible to repeatedly detect a migrating fish along its path. With the advent of miniature acoustic tags, it is now possible to quantify reach specific rates and migratory pathways for individual fish. This data is especially important for classifying corridors or migratory routes of importance and minimum survival rates in the Sacramento River, San Francisco Bay Estuary, and Sacramento/San Joaquin Delta, an area of high concern for fish survival due

to pumping facilities and predation by invasive species. Ultrasonic tags and automated monitors can be used to perform mark-recapture analysis. Researchers can now record the time a specific fish passes a known location without impeding or handling it in any fashion. Thus, researchers have no influence on the fish's migratory behavior. Moreover, the use of ultrasonic tags and monitors eliminates the need to sacrifice captured CWT fish to gain data. Most crucially, the ultrasonic tags and monitors now make it possible for researchers to reconstruct the timing and pathways of successful fish in order to examine correlations with environmental and physiological variables.

Because salmonids have steadily declined in number over recent years, it is crucial to understand what environmental, physical and anthropogenic processes affect all life histories and stages of these populations. Basic telemetry work can greatly improve our understanding of the behavior and physical processes that govern the movements, success, and survival of Central Valley steelhead trout. Through the use of acoustic telemetry it is possible to reconstruct the migratory routes and reach-specific rates of both smolt and adult life stages of Central Valley steelhead trout. This data, coupled with other data such as habitat type, temperature, flow and dissolved oxygen, will help inform management of the species within the effect of riverine conditions. Further, this data can be used in the development of an age structured model to make predictions regarding the contributions of hatchery and wild stocks of steelhead trout to the population.

California Fish Tracking Consortium:

For the past two years the California Fish Tracking Consortium, formed by a CALFED funded project at UC Davis/NOAA, has successfully tagged more than 700 juvenile steelhead trout and many adult steelhead trout. This project has focused primarily on quantitatively assessing the migratory success of hatchery fish with acoustic telemetry. A large array of more than 200 acoustic monitors is currently deployed throughout the Sacramento/San Joaquin Watershed (Figure 1). Monitors have been deployed in the Sacramento River, Yuba River, Feather River, American River, Cosumnes River, Mokelumne River, San Joaquin River, Delta and San Francisco Estuary. Soon there will be an acoustic array stretching from the coast north of San Francisco to the edge of the continental shelf in order to assess early oceanic movement and survival of this species. This vast infrastructure will make it possible to examine adult and juvenile steelhead trout migratory success and behavior with a nominal investment in tags and labor costs.

Mark-reacapture:

The tags implanted in the adult steelhead will last for more than three years, making it possible to assess the success of each fish over multiple years. The tags implanted in juvenile steelhead will last for 160+ days, allowing assessment of outmigratory success. Tagging returning wild and hatchery steelhead trout in the Sacramento River Watershed will make it possible to assess the success of the fish in relation to physical and anthropogenic effects. Tagging both wild and hatchery fish will yield important data on differentiation in success between the two classes. Our related findings will have important implications for the overall management of the species, particularly by assessing the effect of straying hatchery fish intermingling with wild

stocks in the watershed. If the hatchery fish produce a lower number of kelts than wild fish, then intermingling of genetics could severely impact the fitness of the species.

Understanding the return rates and the proportion of multiple-year spawners (iteroparous steelhead), or kelts, of wild and hatchery steelhead trout is crucial for the recovery this iconic species. The goal of this comparative research is to develop a model that predicts how steelhead success rates fluctuate with river and estuarine conditions, as well as what conditions are most conducive to their success.

In addition to the new data collected from the tagged adult steelhead trout, I will also analyze the data from 300 hatchery and 200 wild acoustically tagged individuals (collected by UC Davis and NMFS as part of a CALFED project). This data will be used to obtain estimates of success and movement rates as well as detection probabilities.

It is critical to determine the proper model to use for mark recapture data, which becomes even more significant when examining multiple data sets related with one another (Burnham et al. 1995). The Cormack-Jolly-Seber model is ideal for examining the survival and recapture probabilities of juvenile chinook salmon and steelhead trout in the Sacramento River Watershed. Survival or recapture probabilities can be functions of external factors in the Cormack-Jolly-Seber models. Bunrham et al. (1995) give several examples such as North's 1979 article including winter conditions, Sandland and Kirkwood's 1981 piece on capture history, and Colbert and Lebreton (1985) animal body condition as an example of another type of covariate.

While the Cormack-Jolly-Seber model is useful for the emigrating chinook in the river, it lacks some desirable features for the steelhead trout throughout the system and chinook salmon in the Delta. In these cases using a multistrata may be more advantageous since the individuals can choose to migrate down different routes when they reach the Delta and have been known to back and forth between sites in tidally influenced areas. In addition the steelhead trout have been observed moving upstream or leaving the area of a monitor for an extended period of time and returning days latter. For this sort system a multistrata model may be more useful since you can include sightings at site "A" then "B" and back to "A" again. Instead of using "1" and "0" the multistate approach uses "A, B, C…" to describe the capture history of the individual, so an individual could have an encounter history such as the one below White et al. (2006):

BCACC

So the fish was detected at site B then C bypassed or went undetected at B and was subsequently detected at A and then at C the next two sampling periods. This sort of analysis is useful in the Delta.

The data collected on juvenile and adult hatchery and wild steelhead trout from the larger CALFED study will be analyzed with Program MARK in a Cormack-Jolly-Seber model to create success and detection probabilities. In the Delta a multistrata model will be used in Program MARK to better assess route selection and movements affected by flow in terms of success and detection probabilities. From this analysis, problematic areas for the fish and potential areas of high mortality can be identified. The environmental data collected at key sites throughout the watershed can then be parameterized and added to improve the model to examine the potential impact of individual variables or combinations of variables. In turn, better informed mitigation actions for the Sacramento River Watershed can be developed.

Finally, data collected from the juvenile and adult steelhead trout can be used to develop an age-based model to better determine the contributions of hatchery and adult steelhead trout to the general population. Tagging wild and hatchery individuals will also give us the opportunity to examine behavioral differences of both classes for juvenile and adult fish, which will give insight into the possible mechanisms behind differences in success rates.

Collaborations:

The proposed research endeavor will promote and enhance collaboration with many groups throughout the Central Valley. For instance, it will build upon and strengthen relationships I have already established with researchers at U.S. Fish and Wildlife Service, California Department of Fish and Game, NOAA, University of California Santa Cruz, University of California Davis, East Bay Municipal Utilities District, E-CORP, Bay Planning Coalition, Department of Water Resources, and the U. S. Army Corps of Engineers. It is also likely to promote collaboration with other groups in the Central Valley, such as SYRCL and Cramer Sciences. In turn, I believe that this project clearly fits both the scientific goals and collaborative goals outlined by CALFED.

Approach/Plan of Work:

I propose to use the extensive array currently in use by researchers at UC-Davis that was developed for the California Fish Tracking Consortium, a CALFED funded project, to study the migratory behavior of both wild and hatchery steelhead trout. Over the past two years I have spent a great deal of time conducting range tests and assisting with tag retention studies and procedures. Through this process we have determined the optimal detection ranges of acoustic monitors throughout various sections of the Sacramento River, San Joaquin/Sacramento Delta, and San Francisco Bay Estuary. We have also determined the optimal tag size for a given sized salmonid allowing us to select tags with the best tag life and signal strength. I will implant 15 wild adult steelhead trout, 15 adult hatchery steelhead trout, 200 juvenile wild steelhead trout, and 300 juvenile hatchery steelhead trout with acoustic tags in 2008/2009.

Acoustic Array:

The development of miniature tags and automated listening stations makes acoustic technologies more applicable to salmonids. Use of this acoustic technology makes it possible to answer many more questions about the movements and reach-specific rates of fish than has been previously possible with any other previous technology. In addition, Vemco's creation of a line of low cost acoustic tags and automated monitors has made such a study cost-effective. The proposed study fits within the category of a mark-recapture study, but the fish are never touched after the surgical procedure and subsequent release, thereby minimizing the effect of handling on tagged fish.

Prior to the deployment of Vemco automated monitors and release of tagged fish, we conducted range tests in the Sacramento River, Sacramento/San Joaquin Delta, and San Francisco Bay to determine the effective coverage area of monitors under various environmental conditions. The tests revealed significantly reduced detection ranges in shallow water (< 2m) and areas of high flow. They also demonstrated that high level,

low frequency noise was capable of blocking tag transmissions to automated monitors. Since 2006, we have strategically placed more than 200 automated monitors at areas that were as acoustically favorable as possible and biologically important (areas of perceived high mortality and confluence) throughout the Sacramento River Watershed. Estuary receivers were deployed in lines or curtains in order to detect fish passing the entire width of the bay, and river monitors were placed in exits and entrances of sloughs and near confluence areas.

The Sacramento River Watershed presents a unique opportunity because of a large infrastructure of acoustic monitors deployed from Redding, CA to the continental shelf break just north of San Francisco, CA. Overall, more than 200 acoustic monitors are now deployed throughout the study region. In the San Francisco Bay Estuary we have deployed "curtain lines" at several choke points to ensure the detection of tagged fish. These lines have been deployed at Rio Vista, Jersey Point, Chipps Island, Benicia Bridge, Carquinez Bridge, San Rafael Bridge, Raccoon Strait, and the Golden Gate Bridge. Since the water is deep and fast moving at the final detection point before fish reach the Pacific Ocean near the Golden Gate Bridge, the curtain line has been deployed as a double and staggered array to ensure passing fish are detected.

In the Delta the acoustic monitors have greatly improved detection ranges compared to other areas of the watershed. Using single monitors at specific sites, such as branching points from the main-stem Sacramento River, it is possible to detect tagged fish and determine route selection. Several branching points in the Delta that have been identified as areas of interest for the survival of fish. Monitors have been placed at Sutter Slough, Steamboat Slough, Miner Slough, Georgiana Slough, the Delta Cross Channel, Three-mile Slough, and several other areas of confluence and branching. These sites make it possible to determine which route a fish utilizes and if the success rate of fish using a specific route is lower than that of fish using another route.

From the city of Sacramento to Cow Creek, a tributary running into the main-stem Sacramento near Redding, CA, monitors have been deployed in pairs. The monitors are offset at least 100 meters upstream or downstream of one another and typically placed on opposite banks. This is done to ensure that fish are detected as they pass by specific locations. Pairing monitors is also a useful way of having duplicate data. This helps protect against data loss from a monitor malfunction, debris causing the loss of a monitor, or in rare instances the vandalism or theft of a monitor. This array is downloaded quarterly and the data is complied in a centralized database at the NMFS office in Santa Cruz.

Study Design:

During the fall/winter of 2008, I will tag 15 returning wild adult steelhead trout and 15 hatchery adult steelhead trout returning to Coleman National Fish Hatchery. Wild steelhead trout will be captured through hook and line sampling, long lining, and gill netting to tag the proposed 15 fish. The Biotelemetry Laboratory has been successful in hook and line sampling for steelhead trout and gill netting and tagging green sturgeon. We also work with other groups that have caught and tagged adult wild steelhead trout. The captured fish will be anesthetized and implanted with acoustic tags and monitored briefly following the surgical procedure to ensure their recovery.

We have extensive experience tagging fish while on the river, in the laboratory and at the hatchery. To date, we have tagged more than 1500 salmonids with acoustic tags. We have conducted tag effect studies and have developed specialized surgical tables to minimize stress to fish during the procedure. Vemco V16 tags (tag life of five years) will be implanted into all the fish. The V16 tag is an optimal tag size (<5% of fish body weight) for adult steelhead trout, has an appropriate tag life, and has a greater detection range than the V7, V9, and V13 tags which will increase our detection probability. The hatchery steelhead will come from Coleman National Fish Hatchery. These fish will also be tagged with V16 tags.

Before surgical procedures begin, tags are activated, weighed, and sterilized. The hatchery fish will be starved for 24 hours prior to surgery and anesthetized with MS-222. Once the fish are anesthetized they are moved to the surgical table where a pump pushes a flow of water containing a low concentration of MS-222, keeping the fish fully anesthetized throughout the surgical procedure. A small incision is made near the mid ventral line in front of the pelvic girdle. The ultrasonic tag is then implanted into the peritoneal cavity of the fish. The incision is closed with two square knots and excess material is cut off, leaving a clean, closed incision. The fish is placed in a recovery tank and observed until it makes a full recovery. During the surgical procedure data is collected on the weight, length, and condition of the fish (eyes, fins, and scales). In addition, a photo and genetic sample is taken from each fish. The protocol for wild fish surgery will be the same, with the exception of not being starved 24 hours prior to surgery and CO_2 will be used as an anesthetic rather than MS-222 so there will be no required holding period.

In the first year of my study, I will look at differences in the movement and success rates of hatchery and wild steelhead trout. Adults tagged at Coleman National Fish Hatchery have shown ~35% rate return the following year (unpublished data, Null). By tagging hatchery and wild adults it will be possible to examine the differences in return rates and proportion of iteroparous steelhead in each stock. In the second year I will look at the number of returning tagged wild and hatchery steelhead and the proportion of fish that outmigrate to sea following their second consecutive year of spawning.

The extensive acoustic array in the Sacramento River Watershed makes it possible to examine differential success rates of fish according to their route in the Delta as they migrate upstream and downstream. I am interested in noting the cues fish use to begin their upstream or downstream migrations. Gathering reach-specific rate data will help us to know if fish are holding in specific reaches because of habitat (restored or natural) available to them, or if the adults are migrating at steady rates.

In the winter of 2008/2009, tagging 300 hatchery juvenile steelhead and 200 wild juvenile steelhead trout will provide the opportunity to monitor outmigratory movement and success rates, along with migratory timing and route selection. These fish will be implanted with V7 and V9 tags which have long enough tag lives to detect fish over their entire emigration to sea. We have had some success with the tags. In our first year of study, 2006, we detected steelhead which moved past the Golden Gate in May of 2007 and then returned to the bay in September of 2007.

This portion of the project, under the direction of Dr. A. Peter Klimley of UC Davis and Dr. Bruce MacFarlane UC Santa Cruz will be run by CALFED funds granted

to monitor the migratory success of juvenile salmonids. The data collected from the 2008/2009 project will be crucial for identifying areas of high mortality and migratory behaviors of hatchery and wild juvenile steelhead trout. Further, it will provide important information for assessing the impact of varying river conditions over consecutive years. We will appraise correlations in juvenile success with environmental and anthropogenic variables in different stretches of the river.

Environmental data will be collected throughout the course of the study. Each automated monitor is equipped with a HOBO tidbit which records temperature at 15 minute time increments. I will also use data collected at USGS stations throughout the Sacramento River and Delta to examine the response of steelhead trout to changing flows and temperature. Precipitation data will be factored to examine the effect of this variable on the success of fish in different reaches of the river.

By tagging wild adult, hatchery adult, wild juveniles, and hatchery juveniles over consecutive years we will be able to develop a more thorough picture of Central Valley steelhead trout life histories. This data could then be used to develop an age-based model to make predictions about populations from year to year in response to varying conditions. This model would be particularly useful for management and mitigation strategies.

Output/Anticipated Products and/or Benefits:

This project addresses several of the CALFED priorities and missions. It will be a collaborative effort between multiple agencies (UC Davis, NOAA, USACE, EBMUD, USFWS, and Cramer Sciences) involving highly qualified scientists with backgrounds in fisheries, statistics, modeling, telemetry, and management. The project will be conducted in collaboration with the CFTC which is comprised of eight agencies. Researchers such as Robert Null, Pat Brandes, Bruce MacFarlane, Peter Klimley, Steven Lindley, and Joe Merz are members of this group. All of these individuals have specialized skills in research areas pertinent to the study.

This research project has the potential to advance the understanding of environmental and anthropogenic factors affecting the success of the different classes of the fishery. The project will yield important data which will have broad use applications. The project will also provide training for numerous scientists and aspiring scientists in telemetric, mark-recapture, calibration, validation, and database management techniques. In addition to the collaborative nature of the project and utility of the data, the research is also a good fit to the priority areas defined by CALFED. The data collected will be useful for addressing trends and patterns of a population in response to changing environmental and anthropogenic effects. The project will also consider the impact of water flow and water quality on the success and behavior of various stocks and life stages of steelhead trout. Finally, it will elucidate direct performance measurements of wild and hatchery populations of steelhead trout in response to environmental factors.

If granted the CALFED fellowship, I would be able to focus on the proposed research project during my final two years of my doctoral studies. The fellowship and the proposed research would also greatly benefit my research and academic career by putting me in direct working relationships with other scientists, fisheries management specialists and providing data for research papers.

Tagging adult steelhead trout in addition to juvenile steelhead trout would open new areas of population assessment to the larger CALFED-funded study. It also has the potential to intersect with other important research. For example, Steven Teo, a post-doctoral researcher at UC Davis, is currently placing archival tags on adult steelhead which are able to geo-locate adults in the ocean. This is exciting research, since there is a dearth of information about the movements of adult steelhead trout in the ocean. Current data on this topic is derived from archival tags and sea surface temperatures. Dr. Teo is hoping that his results will be sufficiently successful to encourage adding the geo-location tags to acoustically-tagged fish. This means there is the potential to assess not only movements of adult steelhead trout within the watershed, but also in the ocean. This data would deepen and extend models of success and movements of adult and juvenile steelhead trout. It would also add a great deal of significant information to the models assessing the contribution of hatchery juveniles and adults along with wild juvenile and adult steelhead.

The project would benefit the UC Davis Biotelemetry Laboratory by supplying a month of salary for a member of the lab each year of the project. It would help to grow the current number of projects and publications produced by the laboratory, and add to an important body of scientific knowledge. This project would also benefit the P.I., Dr. A. Peter Klimley, with the addition of important data concerning the adult life stage of steelhead trout. This data would complement the laboratory's current work on wild and hatchery juvenile steelhead trout. There has also been money written into the budget to help support the laboratory's boat and travel expenses.

Tagging data on adult steelhead trout will help in the assessment and preservation of Central Valley steelhead. The data collected from the adult steelhead trout may also yield information on the success of adult fish in relation to dredging activities and sites in the San Francisco Bay Estuary. This information would be useful to the Biotelemetry Laboratory which is collaborating with USACE in assessing the impact of dredging activities on salmonids.

The community mentor, Joe Merz Ph.D. of Cramer Sciences, has a positive history with the California Fish Tracking Consortium, and will assist on the project. He also has experience capturing and tagging wild steelhead trout. This project will help expand his experience with telemetry work. It will also lead to co-authored publications and presentations. Dr. Merz has worked with salmonids for many years and this project is of great interest to him, adding to the collaboration he would have with the CFTC.

After the first year of study the data from the adult steelhead trout will be analyzed and presented at the CALFED conference. This data will yield results concerning differences in adult wild and hatchery steelhead trout survival and behaviors, including timing reach specific rates, response to environmental cues, and route selection data. It will also tell us about adult escapement rates and the proportion of iteroparous hatchery and wild fish. All of this data will be compared with the river, estuary, and oceanic conditions at the time of residence to examine possible environmental effects.

Upon completion of the second year of research, both years will be analyzed and presented at the CALFED conference and American Fisheries Society meeting. The data will also be worked up and used in a publication comparing the behaviors and success of adult wild and hatchery steelhead trout. This data will be coupled with the data on the

success and behavior of juvenile wild and hatchery steelhead trout in order to develop a stage-based model for publication in scientific literature.

As noted earlier, there is a severe lack of knowledge concerning Sacramento River steelhead trout. The fishery is heavily supported by hatchery stockings. It is crucial that we assess the contribution of both wild and hatchery fish to the population in order to have quality management and mitigation practices which will facilitate the subsistence of this important species.

With the support of this grant, our ability to collect data on a wider range of individual fish will be greatly enhanced. Given a larger pool of data, we will be able to create an age structure model which will allow the development of estimates regarding the contribution of hatchery and wild individuals. We will be able to estimate the success rate of juvenile wild and hatchery steelhead trout as they migrate to the Golden Gate under varying environmental conditions. I would expect the hatchery fish to have a different survival rate then the wild fish.

Another data set gained by tagging wild and hatchery adult steelhead trout would allow us to examine the rate of successful outmigration. The data collected would also be compared with the environmental conditions encountered by the fish along their migratory route. In the subsequent years following the initial tagging it will be possible to examine differences in return rates of adults and the proportion of fish that spawn and successfully emigrate and return the following year. This information is key for assessing the contribution of hatchery and wild fish. If there is a higher proportion of wild fish reaching the ocean and returning from sea, then these stocks could be considered to be more important to the fishery. In addition, if wild adults have a higher rate of return and spawn multiple years more frequently than hatchery fish, they could be crucial for sustaining the population of steelhead trout in the Sacramento River. If we find that wild fish have higher success rates and proportions of repeat spawners then hatchery fish, then mixing of genetics could also pose problems for wild fisheries if the hatchery adults stray.

Along with assessing the performance and patterns of wild and hatchery stocks, acoustic telemetry also offers the opportunity to examine behavioral mechanisms that could explain differences between the fish. Examining timing and cues that might trigger outmigration of hatchery juvenile steelhead trout versus wild juvenile steelhead trout will suggest significant avenues for additional research. With acoustic telemetry and hatchery fish I have observed a near synchronous response of hatchery juvenile steelhead trout to increases in water flow in the upper Sacramento River following precipitation. Less than 35% of the juvenile hatchery fish responded to the precipitation/increase in flow. However, those fish that did respond to this environmental cue comprised 90% of all fish detected at the Golden Gate Bridge during the study. If we are able to conduct the proposed research, we can significantly extend the validity of this finding.

USFWS in Red Bluff has noted that they have an increase in the number of wild steelhead that they capture following precipitation events during the migratory season (pers. comm.. Bill Poytress). Currently we cannot assess the percentage of wild fish responding to this hypothesized cue, but if there is a difference it would suggest a behavioral difference between hatchery and wild fish that could substantially affect success rates. There may be other behavioral differences among wild and hatchery fish, but to date researchers have only tagged hatchery juvenile and adult steelhead trout. By

tagging wild juvenile and adult steelhead trout, it will be possible to gather data concerning environmental cues, behavioral differences, success rates, movement rates, potential areas of high mortality, habitat preferences, and overall contributions of wild and hatchery stocks.

If we are able to collaborate with another project in addition to our current collaboration with the California Fish Tracking Consortium, it may be possible to examine the affect of ocean conditions on adult steelhead trout and determine a general distribution of Sacramento River steelhead trout in the Pacific Ocean. Steve Teo is hoping to deploy archival light sensing tags to determine oceanic positions within ~60km. Data on the distribution of steelhead trout in the ocean is almost non-existent. Some researchers have used small temperature archival tags to try to answer questions, but the data gained leaves a large possible distribution range for the species. The current knowledge of ~35% return rate of hatchery adult steelhead trout suggests that some data can be gleaned from this methodology. This information would be extremely useful for the project in that we would already know success rates of wild and hatchery fish for both juveniles and adults in response to environmental variables within the river and estuary. The estimated survival rates and knowledge of the oceanic conditions in the defined area would assist in assessing the role environmental conditions and habitat play in determining the success of fish.

Additional Collaborative Opportunities:

In addition there is the possibility of collaborating with Steve Teo, post doc at UC Davis, and tagging hatchery fish with light/temperature sensing archival tags that will make it possible to determine where adults are moving when they are in the ocean.

Summary

There is a severe lack of knowledge concerning Sacramento River steelhead trout. The fishery is heavily supported by hatchery stockings. It is crucial that we determine the differences in behavior and success of wild and hatchery fish populations in order to have quality management and mitigation practices which will facilitate the subsistence and recovery of this species. This project would encourage collaboration among many individuals and groups. It would assist in completing the picture for both wild and hatchery stocks of steelhead trout in the Sacramento River and help to develop an assessment of behavioral differences and the contribution of each stock under year to year environmental differences.

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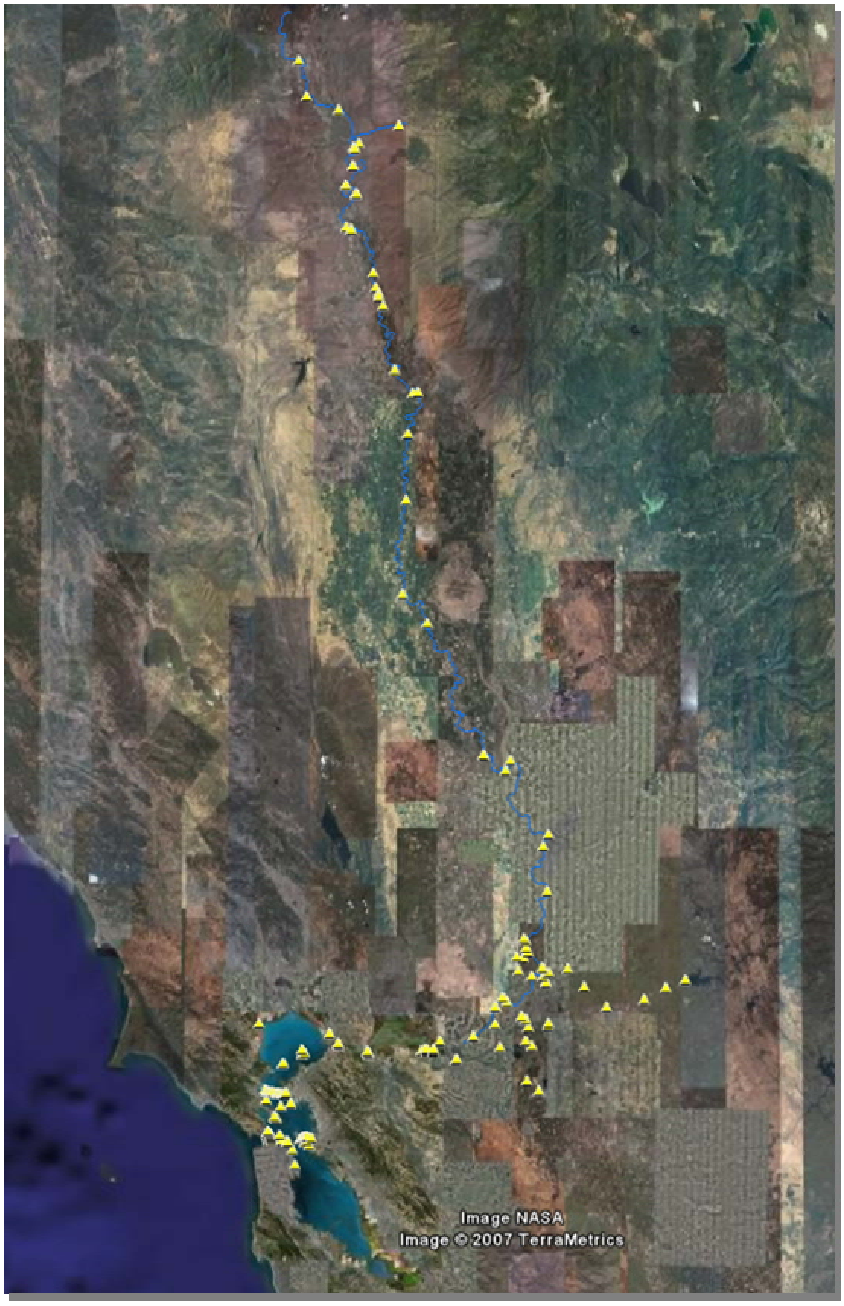

Figure 1: The above map shows the locations of acoustic monitors (yellow triangles) deployed throughout the Sacramento River Watershed as of 2007.