REVIEW OF PRESENT STEELHEAD MONITORING PROGRAMS IN THE CALIFORNIA CENTRAL VALLEY

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Introduction
History

California Central Valley (CV) anadromous rainbow trout (*Oncorhynchus mykiss*) (commonly known as steelhead) were listed as threatened under the Endangered Species Act (ESA) in 1998 (Volume 63 *Federal Register*, 13347-13371); threatened status was reaffirmed in 2006 (Volume 71 *Federal Register*, 834-862). Steelhead included in this listing consist of all naturally-produced steelhead in the Sacramento and San Joaquin rivers and their tributaries, excluding steelhead originating from San Francisco and San Pablo Bays and their tributaries (Volume 71 *Federal Register*, 834-862). Steelhead populations in other evolutionarily significant units (ESU) in California are also protected by the ESA; steelhead in the Northern California, Central California Coast, and South-Central California Coast ESUs are threatened, those in the Southern California Coast ESU are endangered. Steelhead populations in the Klamath Mountains Province ESU in Northern California and Oregon are stable and not warranted for listing under the ESA at this time. In response to a need for improved effectiveness and efficiencies and improvement in CV steelhead monitoring, the Interagency Ecological Program Steelhead Project Work Team (Steelhead PWT) was formed.

Steelhead were historically distributed throughout California's CV, with populations ranging from the Pit River in the northern part of the state to the Kings River in the south (Figure 1) (Lindley et al. 2006). Population estimates prior to European settlement are not available, but may have approached 1 to 2 million adults annually (McEwan 2001). Counts of fish migrating upstream of Red Bluff Diversion Dam from 1967 – 1991 indicate a decline from nearly 20,000 adults in 1968 to less than 1000 fish in 1991. Numerous anthropological impacts including the construction of impassible dams, water diversions, gravel mining, stream sedimentation, water pollution, introduction of non-indigenous species, and the conversion of riparian zones to agricultural and urban land-uses are likely causes of these population declines (Lindley et al. 2006). Remnant steelhead populations are presently distributed through the mainstem of the Sacramento and San Joaquin Rivers, as well as many of the major tributaries (Figure 2) of these rivers. Steelhead presence in highly variable "flashy" streams and creeks in the CV depend primarily on water flow and temperature, which can change drastically from year to year (McEwan and Jackson 1996). It is estimated that 80% of historical steelhead spawning and rearing habitat is now located above impassible dams (Lindley et al. 2006).

O. mykiss have highly variable life histories, with freshwater resident (DFG refer to as rainbow trout) and anadromous (DFG refer to as steelhead) forms (in some cases it is possible for one form to produce progeny of the opposite form) (McEwan 2001). Juvenile anadromous *O. mykiss* in the CV may spend one to three years rearing in fresh water before migrating to the ocean (McEwan and Jackson 1996). They may remain in the ocean for up to four years before returning to their natal streams as adults to spawn (Shapovalov and Taft 1954).

Figure 1. Historic distribution of steelhead in the Central Valley of California. The lines represent rivers and creeks where steelhead are thought to have existed prior to construction of terminal dams throughout the valley. The current Central Valley steelhead ESU (see Figure 2) is outlined in red. Adapted from Lindley et al. (2006).

Figure 2. Current distribution of steelhead in the Central Valley of California. Blue lines represent rivers and creeks where steelhead are known to exist. The dams indicated on the map block all fish access to areas upstream. The distribution is bordered by the National Marine Fisheries Service Central Valley steelhead evolutionarily significant unit (ESU).

Although there were once two different runs of steelhead (summer run and winter run) in the CV (McEwan and Jackson 1996), the summer run has been all but extirpated due to a lack of suitable holding and staging habitat, such as coldwater pools in the headwaters of CV streams, presently located above impassible dams (Lindley et al. 2006). Throughout the CV (and in particular the Merced River, Tuolumne River, and upper Sacramento River) it is difficult to discriminate between adult anadromous and resident forms of *O. mykiss*, as well as their progeny (McEwan 2001), further complicating our understanding of steelhead distribution in the CV.

Restoration of California's anadromous fish populations are mandated by the *Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988*, which directed the Department of Fish and Game to develop a program to double naturally spawning fish populations by the year 2000 (Fish and Game Code Sections 6900-6924). Additionally, the *Central Valley Project Improvement Act* enacted in 1992 (Public Law 102-575) required the Department of Interior to develop and implement a program that ensured the long term sustainability and viability of anadromous fish in the CV, at population levels not less than twice the average levels from 1967 – 1991 (Section 3406(b)(1)).

Current steelhead monitoring programs throughout the CV lack statistical power (the ability to assign confidence levels), are not standardized throughout the region, and in many cases lack dedicated funding. The monitoring programs in the CV are focused on Chinook salmon (*O. tshawytscha*) due to their commercial importance and to address specific regulatory requirements such as those under ESA. These programs are designed to monitor Chinook salmon abundance, and production levels. These programs are inadequate for monitoring steelhead populations due to differences in steelhead and Chinook life history. Although determining "abundance" is an objective for many of the programs listed in this review, current sampling methods are inadequate for monitoring steelhead population levels and trends.

This effort identifies and reviews all steelhead monitoring programs in the CV to identify information gaps and provide suggestions for future monitoring. This review effort is the basis for the development of a comprehensive CV monitoring plan that is based on sound science, technically and procedurally adequate, utilizes latest information, and demonstrates a statistical approach, that when implemented provides fisheries managers the data necessary to assess steelhead population status and trends as well as habitats that support them. These data will aid in the decision-making process to lead to recovery of steelhead populations.

Steelhead populations in the CV are critically depressed in most if not all rivers and streams. In many cases, particularly in the San Joaquin Basin, anadromy in *O. mykiss* populations may be nonexistent or too low to detect while resident *O. mykiss* populations in the same rivers have remained strong. Because resident and anadromous *O. mykiss* juveniles can be difficult to differentiate, monitoring programs in these rivers typically report steelhead/rainbow trout captures as *O. mykiss*, rather than identifying the particular life history strategy of individual fish. This monitoring concern is reflected in the summary below.

Estimates of the numbers of adult steelhead returning to CV streams have been made since the 1950s (Hallock 1989). Adult estimates provide information on the size of fish populations and predictors for future production. Numerous methods can be employed to estimate adult steelhead populations, although each method is limited by the assumptions and biases inherently present in the sampling design and method.

Juvenile monitoring has been conducted in the CV since the 1920s (CDFG 1929) and has evolved over the years, particularly in response to regulatory requirements and the development of technologies. Today juvenile monitoring is conducted primarily to monitor juvenile emigration with some limited rearing and growth studies. As with adult monitoring, the juvenile program design, methods, and sampling gear may create biases that are problematic to data analyses.

Sampling Techniques

Angler surveys and catch record cards are useful tools for estimating harvest and/or catch per unit effort of adult fishes. On-site angler surveys are also a source for tag recoveries and obtaining data (size, sex, condition, age) of fish kept. Surveys must be designed so that sampling location and time are random (to allow for expansion of data) and yet also cover the spatial and temporal components of site use and angling activities. Catch record cards have inherent biases, in that successful anglers are more likely to report catches whereas unsuccessful anglers are more likely to be non-responsive.

Visual counts at temporary weirs are often able to provide the most reliable counts regarding the number of returning adult fish, making this method more accurate than methods that estimate fish populations. However, the integrity of the weir and quality control must be assured if absolute counts are to be assumed. "Fish-tight" weirs are more typically the exception than the rule. Weirs may incorporate fish traps that allow capture of fish for tagging, collection of biological material and population parameters (i.e. genetic samples, broodstock, age structure determination, spawning condition, sex ratio, etc.). Weirs provide suitable recapture sites for basin-wide mark-recapture studies. Unfortunately, they block migration routes, easily clog with debris, cause navigation hazards to boats and swimmers, and are often limited to small streams due to the high initial cost and problems related to construction (e.g. a lack suitable substrate for anchoring weir). Weirs are also limited to streams that have relatively stable flow regimes, as streams with highly variable flow conditions tend to either cut channel banks to bypass weirs or destroy the weir (through the sheer force of the water or large debris washing downstream) (Zimmerman and Zabkar 2007).

Video monitoring is usually paired with weirs (and work best in these settings) as a method of enumerating migrating adult fish. Traditional video monitoring programs use underwater cameras and video cameras, often in combination with digital video recorders. These programs are very cost effective after the initial investment, and can be automated with motion sensors to reduce recording when fish are not present. Video monitoring provides a permanent record that can be re-analyzed at a later date. As video processing software is continually developed, systems are able to more effectively identify fish to species, differentiate hatchery fish from naturally produced fish, accurately measure fish, and calculate sex ratios (in sexually dimorphic species). Video monitoring systems have also been developed that can be deployed in remote areas and powered via solar, wind, or hydropower sources. Video monitoring efforts are best suited to clear, narrow, shallow streams that have low turbulence (to maximize visibility). Night video monitoring may be impossible if the intense lighting required for video monitoring deters or impedes fish movement (O'Neal 2007b). Issues with human bias need to be accounted for (especially identification of fish species in turbid systems, and discrimination between resident and anadromous *O. mykiss*). There exists counting issues with double counting and single counting when multiple fish are present, as well as how to interpret the incidence of fish falling back (or migrating downstream). Compared to traditional video monitoring, the development of alternative ("Vaki" or "DIDSON") monitoring systems have streamlined fish measurement and enumeration using methods

similar to video monitoring. Because these systems use alternative technology to create silhouette images of fish (Vaki systems use infrared light, DIDSON uses SONAR), it is more difficult to assign fish to species, particularly if multiple species are migrating upstream or the timing of migration overlaps. Though much more costly than traditional video monitoring equipment, Vaki and DIDSON systems are often able to detect fish passage in streams and rivers when conditions (turbid water) prevent the use of traditional video monitoring equipment.

As an extension of visual surveys for adult fish, redd surveys share many of the same assumptions. Unlike other visual surveys, redd surveys provide an index or estimate of the effective population size (the number of female fish in the population that are breeding), rather than a simple count of upstream migrants (as not all fish that migrate upstream will successfully spawn). Redd surveys are less intrusive than other methods, and surveys are relatively easy to design and implement. One problem with redd surveys is that it can be difficult to identify redds to species, so the survey may be limited to streams with spatially or temporally isolated spawning populations. Redds are also temporally "unstable" and the ability to detect and identify redds declines as the redd ages (Gallagher et al. 2007). It may be difficult to determine super-imposed redds. It may be necessary to conduct additional research to determine the number of fish present at each redd. Furthermore, fish may construct redds but not deposit eggs if the substrate or flow patterns are unsuitable. It may be difficult to distinguish these "false" redds from "true" redds; if "false" redds are included in the count, the population may be overestimated (Gallagher et al. 2007). Some fish may also construct and deposit eggs in more than one redd.

Snorkel surveys can be developed for both adult and juvenile monitoring studies. One of the main strengths of snorkel surveys is that they do not require a large initial investment, can be conducted in remote areas (no large equipment to move, gear is easily packable), and can be conducted by agencies with small budgets. Snorkel surveys are less intrusive than weir or video monitoring, and allow for researchers to investigate fish-fish and fish-habitat interactions. The biologists and field technicians involved need to be at a higher level of skill and knowledge. It is also important to realize that fish movement and behavior is affected by the observers, time of day, habitat type, and water temperature; snorkel surveys should be conducted with this in mind (O'Neal 2007a).

Rotary screw traps are primarily used to estimate juvenile abundance, allowing biologists to parse out mortality between freshwater and marine life stages. Rotary screw traps in the Sacramento and San Joaquin river valleys are commonly deployed to monitor water diversions, provide marked fish recapture sites, assess fish presence or absence, estimate production, estimate emigration between two points, and estimate predation. Trapping efforts may be complicated by several issues. Screw traps are often size selective, with larger fish avoidance (Volkhardt et al. 2007). Trapping efficiency is also related to stream flow, and efficiency drops when flow decreases. In high flow conditions, traps may become filled with debris or be washed downstream. Traps also provide navigation hazards to boaters and swimmers.

Beach seining is an effective method of sampling fish communities in shallow near shore areas. Seines are relatively inexpensive, easy to use, and may be purchased with various mesh sizes depending on the study objectives. As seines capture live fish, they may be used in studies interested in tagging fish for mark-recapture studies or studies that rely on the collection of genetic materials. Relative abundance of fish species can be estimated based on the number of fish captured in each seine haul. Seines are most useful for capturing small fish (juveniles), as larger fish are more likely to detect and avoid the net Hahn et al. 2007). The ability of a seine to capture fish is related to the size of the mesh that the net is composed of – small fish may be able to escape the net if the mesh is too large (Hahn et al. 2007). Seines are used most effectively in shallow areas (depth less than the net height) with smooth bottoms. Uneven substrates, vegetation, and coarse woody debris can all snag the seine, lift it off the bottom, and allow fish to escape. Seines are species selective, tending to capture fewer demersal fish (Hahn et al. 2007).

Although carcass surveys are a reliable means of determining Chinook salmon abundance in the Sacramento and San Joaquin river valleys, carcass surveys are not reliable estimators of steelhead abundance. Unlike Chinook salmon, steelhead are iteroparous and capable of spawning multiple times (Hayes et al. 2008). Even though repeat spawning in subsequent years is relatively low for adult steelhead (less than 30 percent, typically), it is uncommon to find carcasses near spawning sites. Most adults begin downstream migration shortly after spawning has been completed.

Fyke nets are passive capture gear types, meaning that the fish need to swim into the net to be captured. Like other net types, the mesh size of the net plays an important role in the size of fish that can be captured. Fyke nets are an effective gear type especially in complex habitat types (dense vegetation, coarse woody debris, marshes). Because the nets need to be securely anchored into the substrate, they are primarily used in lakes and reservoirs, but may also be used in low velocity streams, backwater areas in large rivers, and sloughs. Fyke nets are species selective and tend to capture fish that are associated with complex habitat types (Hubert 1996). All passive net types may cause fish mortality; fish may become gilled in the mesh or predated by larger fish also present in the net. Damaged nets can allow fish to escape, biasing abundance estimates.

Electrofishing may be a live capture technique that can be used to obtain population estimates, length-weight relationships, and age and growth parameters in most systems. Electrofishing tends to be size-selective; larger fish are more likely to be susceptible to the electric fields generated by the gear (Temple and Pearsons 2007). These biases can be accounted for and minimized by properly calibrating and testing the settings so that the electric field generated is capable of capturing small fish (NMFS guidelines and procedures are available) (NMFS 2000). Efficiency varies widely with water conductivity, temperature, depth, and water clarity. Electrofishing techniques are effective in large boulder-rubble substrate, aquatic vegetation, and undercut bank habitat types, which can bias other population estimation methods (Temple and Pearsons 2007). Proper staff training is required to eliminate potential risks to fish and operators, as the batteries and generators used in electrofishing gear are capable of inducing respiratory arrest, asphyxia, and ventricular fibrillation in humans. Electrofishing can also cause

internal trauma (hemorrhaging, broken bones) in fish, though this can be mitigated by changing electrofishing settings (cycle frequency, voltage, etc.). Electrofishing gear is available in boat mounted and backpack style configurations, allowing the use of electrofishing gear in wadeable streams, shallow navigable rivers, and in the littoral zone of lakes and reservoirs.

Suitable for use in large rivers, trawls sample a discrete area or volume over time, allowing quantitative indices of species abundance to be easily calculated. Trawl nets equipped with live boxes may provide live fish samples and therefore are suitable for mark-recapture studies, genetic material collection, and other studies that require the use of live fish. The required use of a boat and the towed net precludes sampling in shallow areas, areas with high macrophyte densities, and through areas where the net may snag on boulders or submerged woody debris (Hayes et al. 2007). Similar to other studies that use nets to capture fish, the size of fish in the catch is greatly related to mesh size. Trawl tow durations should be kept short; the probability of fish being injured is increased the longer fish are confined in the net (Hayes et al. 1996).

EXISTING PROGRAM MONITORING EFFORTS IN THE CENTRAL VALLEY

Central Valley Wide

Program Title: Central Valley Steelhead Angler Survey

Program Manager (PI): Rob Titus
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Target Species and Lifestage: Adult Chinook salmon (all runs) and adult steelhead

Stream Reach(es): Anadromous waters of the Sacramento, American, Feather, Yuba, San Joaquin, and Mokelumne Rivers.

Objective(s): The primary objectives of this program are to estimate angler effort and harvest of CV Chinook salmon and steelhead to provide the data necessary aid in the determination of angler impact on ESA listed species and angler compliance with fishing regulations.

Methodology(ies): A stratified random sample design is used to select sample days (including weekends) and river reaches. Sampling start time and river section are randomly selected. In the field, one pass of the survey (river) reach is conducted to count anglers and determine the number of anglers that can feasibly be interviewed. Angler interviews are conducted during a second pass of the survey reach.

Anglers are interviewed to determine the number of hours they have fished, fishing method, the number of anglers in a group, target species, river mile location, the angler's home zip code, whether the trip was completed, and the number of fish kept and released by species. Lengths of all individuals of the nine target species or group (Chinook salmon, steelhead, resident rainbow trout, striped bass, white sturgeon, American shad, catfish, sunfish, and black bass) are recorded. Salmon and steelhead are checked for adipose fin presence or absence.

Data Retrieval: Data is stored in excel spread sheet format at Fisheries Branch, contact Rob Titus.

Data Analysis: Angler effort (per location and time spent) and harvest are used to calculate harvest estimates in the form of fish per angler-hour (catch per effort).

Reporting: Annual summary reports are filed with the Fisheries Branch, California Department of Fish and Game (CDFG) the year following the survey year.

Program History: Starting in 1990, the initial project ran through 2002. This project was re-initiated in 2007.

Funding: Sport Fish Restoration Act and Bay-Delta Enhancement Stamp funds.

Program Strengths and Weaknesses: This program benefits from a twelve year dataset, comprehensive spatially and temporally. The survey design allows an estimation of angler harvest, effort, and angler contact with steelhead when fishing for other species (striped bass, salmon). This project can only collect limited data on juvenile steelhead (it is difficult to differentiate between juvenile steelhead and resident rainbow trout). Anglers that fish with the intent of releasing all fish may not check for the presence or absence of an adipose fin, limiting this survey's ability to estimate angler contact with hatchery and naturally produced fish. The survey relies on human interpretation of harvest information. Sample bias is also of concern (successful anglers are more likely to report data, fish that are not retained by anglers cannot be positively identified, checked for marks, measured, etc.).

Potential Monitoring Improvements: Add additional streams and reaches (Stanislaus River, Calaveras River, etc.), provide data online for other uses, initiate data sharing with Bay-Delta Authority sturgeon and striped bass angler survey (anglers in the delta targeting sturgeon and striped bass may encounter steelhead).

Existing Monitoring Efforts in the Central Valley

Central Valley Wide

Program Title: Steelhead Fishing Report and Restoration Card

Program Manager (PI): Terry Jackson
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Target Species and Lifestage: Adult steelhead

Stream Reach(es): The program covers public access, anadromous waters in the state, excluding the upper Sacramento River between Deschutes Bridge (near Anderson, CA) and Keswick Dam, which is managed for trophy rainbow trout.

Program Objective(s): The steelhead report card program is comprised of two main goals, to gather data related to angler effort, harvest mortality, and monitor catch trends, and generate revenue specifically dedicated for funding projects that contribute to the restoration of steelhead habitat in California.

Methodology(ies): Implemented in 1993, the steelhead report card is required of all anglers 16 years and older when fishing for steelhead (approximately 50,000 anglers annually). Beginning in 2008, all steelhead anglers, are required to record their California steelhead fishing efforts and catches. The angler is required to record all steelhead fishing efforts (date and water fished), regardless of success, and record all steelhead (wild and hatchery) caught. For the purposes of this requirement, a steelhead is considered any rainbow trout greater than 16 inches in length in anadromous waters (excluding the upper Sacramento River described above). The card is required to be turned back into the DFG at the end of the license year.

Data Analysis: The data generated through the steelhead report card is used to estimate angler effort throughout the state, harvest estimates and catch and release estimates (wild and hatchery), and angler catch per effort. Trends and run timing for each stream are also deciphered from these data. In addition, steelhead angler demographics are available.

Data Retrieval: Contact Terry Jackson

Reporting: A report is submitted to the California state legislature every five years. The most recent report was filed in July 2007; the next report is due July 2012.

Program History: Since inception in 1993, the Steelhead Report Card program has evolved to allow for better collection of data. Initially, the program depended on

voluntary card returns and average response rates were low. In addition to the voluntary return, a subset of 10,000 report card purchasers was surveyed with a stratified random sampling method. This resulted in improved average response rates and improved statistical validity of voluntary returns. Though the voluntary return and stratified random sampling methods were successful at developing reliable harvest estimates for some streams, return rates were much too low to develop catch estimates for the majority of California's streams. Starting in 2003, the program opted for mandatory return of steelhead cards. Though the theoretical 100% return has not been achieved, return rates have markedly improved (roughly 50%) and catch estimates for the majority of California's steelhead streams is now possible.

Funding: The steelhead report card program is fully funded through the revenue that is generated by the steelhead report card program.

Program Strengths and Weaknesses: The project is capable of generating revenue to continually support its existence. Since the implementation of 100% marking of hatchery steelhead, this project has become a useful tool for managing ESA listed steelhead stocks. As the project collects data from streams and stream reaches individually, the DFG is able to evaluate angling pressure and management strategies for individual streams. One potential weakness of this project is that it relies on angler compliance to collect data. Since the Report Card is sold on calendar year, two calendar years are required to record a steelhead season/run information – i.e., November-April. Anglers are often leisurely to return their data to CDFG, resulting in a delay of months, to possibly years, between angling information for a season and analyses.

Existing Monitoring Efforts in the Central Valley
Central Valley Wide

Program Title: Central Valley Steelhead Assessments- Adult Scale Reading

Program Manager (PI): Rob Titus
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Target Species and Lifestage: Adult steelhead

Stream Reach(es): Anadromous waters of the Feather, American, and Mokelumne Rivers.

Program Objective(s): The objectives of these investigations are to use scales from adult steelhead to address a variety of life history questions as reflected in the growth history of individual fish. Specific objectives include determining the following: age structure of adult CV steelhead; relative contribution of hatchery and natural production to adult populations; back-calculated size at previous age and at ocean entry; residence time of juvenile steelhead in different parts of the CV (e.g., riverine vs. delta rearing), and frequency of anadromy.

Methodology(ies): Adult steelhead returning to Feather, Nimbus, and Mokelumne Hatcheries are enumerated, measured (fork length), aged, and sexed. Scales are collected for length at age analysis and age at emigration.

Data Analysis: Fish data (counts, length composition, age composition, sex composition, and length at age and at emigration) are summarized. Temporal and spatial trends are identified.

Data Retrieval: Contact Rob Titus

Reporting: Annual summary reports, the first available in fall of 2008

Program History: Project initiated in 2007.

Funding: Ongoing, funded through Sport Fish Restoration Act grants

Program Strengths and Weaknesses: Hatchery returns are one of the most reliable sources for collection of biological data on salmonids as many return to their natal streams to spawn. The sampling site is also spatially fixed. One potential problem with this project is that it assumes all adipose clipped fish are hatchery produced. Hatchery fish with partially clipped adipose fins may be mistaken for naturally produced fish. It is

recommended that clip efficiencies be carefully evaluated by the marking program on a yearly basis to validate this assumption.

Potential Monitoring Improvements: Collaborate with Coleman National Fish Hatchery in future investigations, compare results at Coleman National Fish Hatchery to results at Feather, Nimbus, and Mokelumne Hatcheries. A second project could involve tagging spawned fish to determine the contribution of repeat spawners to steelhead populations in the CV.

Upper Sacramento Basin
Keswick Dam to Butte Creek Confluence

Program Title: Ladder Counts at Red Bluff Diversion Dam

Program Manager (PI): Doug Killam
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Target Species and Lifestage: Adult Chinook (all runs), adult steelhead

Stream Reach(es): Upper Sacramento River at Red Bluff Diversion Dam

Program Objective(s): Estimate numbers of Chinook salmon and steelhead passing the dam.

Sampling Time: May 15 through September 15

Methodology(ies): The fish ladder at the Red Bluff Diversion Dam is equipped with video equipment that allows biologists to observe fish real-time or from video tape.

Data Analysis: Passage estimates are generated from the actual number of fish observed plus night and other adjustments (applicable if river turbidity, floods, or open dam gates interrupt video monitoring).

Data Retrieval: Contact Doug Killam

Reporting: The Annual Sport Fish Restoration Act Report is made available in September of the year following data collection.

Program History: Ladder counts at Red Bluff Diversion Dam were the primary means of estimating salmonid escapement in the upper Sacramento River from 1967 –2000. Prior to 1967, a trap and weir at Ball's Ferry (near Anderson, CA) was operated for two years in the 1950s to estimate salmonid escapement.

Funding: Video monitoring at Red Bluff Diversion Dam is funded (75%) through a Sport Fish Restoration Act grant through 2008. The remaining 25% is funded through a CDFG matching grant from non-dedicated Fish and Game Preservation and State General Funds.

Program Strengths and Weaknesses: Video monitoring at Red Bluff Diversion Dam generates accurate counts of steelhead passing upstream of the dam from May through September. However, due to concerns that diversion gates at Red Bluff were impeding the upstream migration of endangered winter-run Chinook salmon, dam operations were

changed in 1987. The new operating regime consisted of opening the diversion gates from approximately September 15 through May 15 each year. With gates in the open position, fish are free to swim through the dam and the fish ladder (where video monitoring occurs) is non-operational. As the majority of steelhead pass Red Bluff Diversion Dam during this time, monitoring efforts are unable to effectively assess steelhead passage.

Potential Monitoring Improvements: Video monitoring stations are already in place to monitor fall-run Chinook on Battle, Cow, Cottonwood, and Bear Creeks. It may be possible to expand the objectives of these programs to monitor steelhead. Deer, Beegum, Thomes, Paynes, Stillwater, Churn, Clover, Ash, Olney, and Sulphur Creeks are also recommended for future video monitoring programs.

Upper Sacramento Basin
Keswick Dam to Butte Creek Confluence

Program Title: Juvenile Chinook and Steelhead Emigration Monitoring at Red Bluff Diversion Dam

Program Manager (PI): Bill Poytress
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Target Species and Lifestage: Emigrating juvenile Chinook (all runs), juvenile steelhead

Stream Reach(es): Upper Sacramento River at Red Bluff Diversion Dam

Program Objective(s): Determine juvenile production indices, emigration timing,

Sampling Time: Year round

Methodology(ies): Four eight foot diameter rotary screw traps are employed to monitor juvenile salmonid emigration. Traps remain in the river year round, and are fished 24 hours per day. Captured salmonids are counted, identified, and measured (fork length). When the trap is emptied, water temperature, river depth, the depth of the rotating cone, water velocity, and water turbidity are measured. Accumulated debris type and volume in the live box is also recorded. Trap efficiency is estimated using mark-recapture methods.

Data Analysis: Juvenile production indices are calculated daily, weekly, monthly, and annually from mark-recapture trap efficiency data. Spatial and temporal emigration is plotted for each species, as well as length frequency distributions. Physical river parameters are summarized.

Data Retrieval: Contact Bill Poytress

Reporting: Annual report to CDFG.

Program History: July 1994-July 2000, October 2001 – June 2009

Funding: Previously funded by California Bay-Delta Authority. Currently funded through the CDFG.

Program Strengths and Weaknesses: This project has a long term dataset with a fixed sampling location. Continual development of the dataset has allowed summarized data

reporting in real time, with minimal error. A major weakness of the program is the use of Chinook capture efficiencies to determine juvenile steelhead production indices.

Potential Monitoring Improvements: Radio, acoustic, or PIT tagging of adult steelhead migrating upstream to determine spawning sites and distribution of fish through the tributaries upstream of Red Bluff Diversion Dam.

Upper Sacramento Basin
Keswick Dam to Butte Creek Confluence

Program Title: Rotary Screw Trapping at GCID Diversion Dam

Program Manager (PI): Diane Coulon
CDFG
GCID Fish Screen Facility
P.O. Box 117
Hamilton City, CA 95951
(530) 865-9331
dcoulon@dfg.ca.gov

Target Species and Lifestage: Emigrating juvenile Chinook (all runs), juvenile steelhead

Stream reach: Upper Sacramento River at Glenn-Colusa Irrigation District Diversion Dam

Program Objective(s): Determine migration timing, length distributions, relative abundance, assess steelhead presence/absence, and assess year to year trends. Determine the number of juvenile Chinook and steelhead passing the fish screens at GCID Diversion Dam.

Sampling Time: Year round

Methodology(ies): One eight foot diameter rotary screw trap located downstream of GCID fish screens is operated continuously year round. Trap is emptied once per day, and more often if warranted. Fish are counted, identified, and the first 10 steelhead are measured (fork length, nearest mm). Chinook are subsampled (approximately 50) and measured (fork length, nearest mm). All salmon not measured are grouped by size and counted. Fish are checked for adipose fin clips to identify fish origin (hatchery or naturally produced). Water temperature, turbidity, and velocity are recorded. The amount of debris in the trap is estimated and categorized. Percent cloud cover is estimated.

Data Analysis: Collected data is used for real-time management of the delta water project operations for protection of juvenile anadromous fish.

Data Retrieval: Contact Diane Coulon

Reporting: Annual reports to the department of Fish and Game are available from 2000-2004. Monthly summary reports available from 1996 - present.

Program History: Variable and inconsistent sampling efforts using beach seines and fyke nets have been conducted at this site since the 1920s. The current project has been on-going with similar protocols year round since 1991.

Funding: Funded through the CDFG and California Bay-Delta Program.

Program Strengths and Weaknesses: The long term dataset is most useful for data trend analysis such as changes in migration timing or length distributions. Low steelhead capture rates prevent calculation of population estimates with meaningful confidence.

Potential Monitoring Improvements: The addition of a second rotary screw trap on the mainstem of the Sacramento River would allow determination of fish screen efficiency at GCID Diversion Dam. It may also be possible change sampling protocols so that all juvenile steelhead are measured.

Upper Sacramento Tributaries
Basin Wide

Program Title: Upper Sacramento River Basin Snorkeling Surveys

Program Manager (PI): Doug Killam
CDFG
P.O. Box 578
Red Bluff, CA 96080
(530) 527-8893
dkillam@dfg.ca.gov

Target Species and Lifestage: Adult Steelhead

Stream Reach(es): Various reaches throughout Beegum, Thomes, Paynes, Antelope, Mill, and Deer Creeks

Program Objective(s): Determine steelhead presence and absence

Sampling Time: Intermittent and opportunistic

Methodology(ies): Survey reaches are sampled intermittently and opportunistically as funding, personnel, and weather allow. Sampling is conducted from upstream to downstream sites, if fish are seen, the snorkeler notifies his/her partner to verify and determine fish numbers. Redd locations (GPS marked if possible) and sizes are noted. Observations are documented in the field and entered electronically upon return to the office.

Data Analysis: Data is descriptive only. Surveys are not conducted in a manner that is able to be analyzed statistically.

Data Retrieval: Contact Doug Killam

Reporting: Field notes filed with the CDFG, Red Bluff Field Office.

Program History: Surveys conducted opportunistically as weather allows.

Funding: No funding exists for this project.

Program Strengths and Weaknesses: Snorkeling surveys allow the steelhead surveys on small streams that may preclude the use of other techniques. Presence and absence data is useful for determining identifying previously unknown steelhead streams and adds to our knowledge of steelhead distribution throughout the CV. The lack of a sampling structure precludes the statistical analysis of data.

Potential Monitoring Improvements: These creeks have the potential to be equipped with video monitoring equipment that would expand our knowledge of steelhead populations in these streams and allow population estimates.

Upper Sacramento Tributaries
Clear Creek

Program Title: Juvenile Chinook salmon and steelhead Rotary Screw Trap

Program Manager (PI): Matt Brown
U.S. Fish and Wildlife Service
10950 Tyler Road
Red Bluff, CA 96080
(530) 527-3043
matt_brown@fws.gov

Target Species and Lifestage: Emigrating juvenile Chinook (all runs), juvenile steelhead

Stream Reach(es): Clear Creek, river mile 1.7 to Whiskeytown Dam

Program Objective(s): Determine an annual juvenile passage index for salmon and steelhead juveniles for inter-year comparisons, obtain juvenile salmonid life history information (length distributions, migration timing, condition, emergence timing, and factors that limit survival at various life stages), and collect tissue samples for genetic and otolith analyses.

Sampling Time: October through June

Methodology(ies): Two rotary screw traps are used to capture emigrating juvenile salmonids in the Clear Creek watershed. One trap (the upper trap) is located at river mile 8.3, the lower trap at river mile 1.7. The lower trap is operated year round, the upper trap from October to June. Traps are checked daily; fish are counted, identified, and measured. Otolith samples are collected from steelhead. Weekly mark-recapture trials are conducted to measure trap efficiencies. Daily water temperature and turbidity are recorded. Up to 100 fish per year are sacrificed for otolith collection to determine maternal origin and migratory history.

Data Analysis: Population indices are calculated using daily catch and mark-recapture trap efficiencies.

Data Retrieval: Contact Matt Brown

Reporting: Annual reports to California Bay-Delta Authority, see also http://www.fws.gov/redbluff/cvpia.html

Program History: This project has been in existence since 1998.

Funding: California Bay-Delta Authority and Central Valley Project Improvement Act

Program Strengths and Weaknesses: Numerous efficiency trials are conducted to calibrate the Clear Creek trap, but these efficiency estimates are calculated using juvenile Chinook salmon because captures of steelhead juveniles are too low. Because capture efficiencies are not determined for steelhead, production estimates are questionable.

Potential Monitoring Improvements: A juvenile Chinook salmon habitat use study is currently conducted on Clear Creek to determine the effect of habitat enhancement projects on salmon abundance in enhanced and un-enhanced reaches. This study could be adapted to determine steelhead habitat use, but is currently not feasible due to low numbers of juvenile steelhead observed in the study reaches.

Upper Sacramento Tributaries
Clear Creek

Program Title: Late-fall Chinook and Steelhead Kayak Redd Survey

Program Manager (PI): Matt Brown
U.S. Fish and Wildlife Service
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Red Bluff, CA 96080
(530) 527-3043
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Target Species and Lifestage: Adult late-fall Chinook, adult steelhead

Stream Reach(es): Clear Creek, river mile 1.7 to Whiskeytown Dam

Program Objective(s): Determine annual relative abundance, evaluate temporal and spatial spawning distributions, and evaluate relationships between environmental conditions (water temperature, flow, physical barriers, and spawning substrate) and *O. mykiss* redd abundance in Clear Creek.

Sampling Time: December through April

Methodology(ies): Surveys are conducted monthly from December to April. Steelhead redds are counted and marked using GPS. Redd dimensions are measured along with water depth, water velocity, and substrate size. Water temperature and turbidity are also recorded. A redd snorkeling survey is conducted once per year to compare to kayak surveys.

Data Analysis: Steelhead redd counts are used to generate escapement estimates. Spatial and temporal spawning distributions are plotted. Results from the kayak surveys are calibrated using snorkeling surveys. Flow data, water temperature, water turbidity, and redd size are summarized (mean and range).

Data Retrieval: Contact Matt Brown

Reporting: Periodic internal reports filed with U.S. Fish and Wildlife Service, see also http://www.fws.gov/redbluff/cvpia.html

Program History: Project ongoing from 1999 - Present

Funding: California Bay-Delta Authority and Central Valley Project Improvement Act

Program Strengths and Weaknesses: Positive identification of steelhead redds is possible due to extensive staff experience and spatial differences in spawning elevation and location within the channel between steelhead and late-fall run Chinook salmon.

Steelhead redd surveys are always subject to water turbidity and stream flow. Kayak surveys tend to under-represent the number of redds compared to snorkel surveys.

Potential Monitoring Improvements: Although a counting weir equipped with video monitoring gear may be applicable in Clear Creek, such a monitoring project is not desired at this time. A picket weir is currently installed to provide separation between spring and fall-run Chinook salmon spawning grounds; this weir may be modified to allow monitoring of steelhead in upper Clear Creek.

Upper Sacramento Tributaries
Battle Creek

Program Title: Adult Salmonid Monitoring at Coleman National Fish Hatchery

Program Manager (PI): Matt Brown
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Red Bluff, CA 96080
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Kevin Niemela
U.S. Fish and Wildlife Service
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Red Bluff, CA 96080
(530) 527-3043
kevin_niemela@fws.gov

Target Species and Lifestage: Adult Chinook, adult steelhead

Stream Reach(es): Battle Creek at Coleman National Fish Hatchery

Program Objective(s): Estimate steelhead abundance in Battle Creek, collect eggs and sperm for Coleman National Fish Hatchery steelhead propagation.

Sampling Time: Year round

Methodology(ies): A weir and fish trap located on Battle Creek near Coleman National Fish Hatchery blocks the upstream migration of salmon and steelhead on Battle Creek. During broodstock collection (approximately August – March), fish are diverted from the weir to the hatchery. In the hatchery, fish are sorted by origin; hatchery fish are spawned or stripped (if egg quotas have already been met) and released into a hatchery pond for reconditioning. After reconditioning, hatchery fish are released downstream of the weir. A small proportion of wild fish are spawned with the hatchery fish, but most are allowed to re-enter Battle Creek upstream of the weir. All hatchery and wild fish entering the hatchery during egg collection are enumerated.

When the hatchery is not actively collecting broodstock (approximately March – August), the weir and trap is operated so that wild fish are passed upstream of the weir and allowed to spawn naturally. All wild fish passed upstream of the weir are identified, measured (fork length, nearest 0.5 cm) and enumerated. Hatchery steelhead are checked for the presence of a CWT; tagged fish are sacrificed for CWT recovery. Weather conditions, water temperature, and water depth are recorded. Trapping ceases when water temperatures exceeded 60° F, to minimize stress and handling effects on fish. The

weir and trap is equipped with a video recording system to monitor fish passage when water temperatures exceed 60° F. Overhead lighting allows 24 hour video monitoring.

Data Analysis: Passage estimates are calculated for hatchery and natural origin steelhead. Migration timing, and length, age, and sex compositions are determined.

Data Retrieval: Contact Matt Brown for trap and video data, contact Kevin Niemela for hatchery counts.

Reporting: Annual U.S. Fish and Wildlife Service reports, see also http://www.fws.gov/redbluff/cvpia.html

Program History: Sparse hatchery counts available since 1947. More robust hatchery counts are available after 1990. Trap data available since 1995.

Funding: Funded through California Bay-Delta Authority grants.

Program Strengths and Weaknesses: The barrier weir and trap offer strong monitoring of anadromous fish moving into Battle Creek. The weir offers a fixed sampling location with strong standardized historical datasets that can be compared year to year. A potential weakness of the sampling site is that heavy creek flows following storms can cause water to bypass or pass over the weir and allow fish to bypass the trap. Planned improvements to the weir structure will remedy this problem. Additionally, video monitoring that occurs when the trap is closed is not able to accurately measure fish, which can cause problems when trying to differentiate between steelhead and resident rainbow trout.

Potential Monitoring Improvements: A project designed to determine steelhead in-river spawning estimates is desired on Battle Creek. Redd surveys were conducted from 2001-2006 on Battle Creek but discontinued due to problems with feasibility. Acoustic or PIT tagging efforts could allow for estimates of in-river spawning.

Upper Sacramento Tributaries
Battle Creek

Program Title: Juvenile Chinook Salmon and Steelhead Rotary Screw Trapping

Program Manager (PI): Matt Brown
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10950 Tyler Road
Red Bluff, CA 96080
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matt_brown@fws.gov

Target Species and Lifestage: Emigrating juvenile Chinook (all runs), juvenile steelhead

Stream Reach(es): Two screw traps on Battle Creek. The upper trap is located at river mile 5.9, the lower trap at river mile 2.8.

Program Objective(s): Determine annual juvenile passage indices for Chinook and steelhead for inter-year comparisons, obtain juvenile life history information (length distribution, emergence and migration timing, condition, determine potential factors limiting survival at various life stages, collect tissue samples for genetics and otolith analyses.

Sampling Time: Year round

Methodology(ies): Rotary screw traps are operated continuously year round. Each day, traps are checked and all captured steelhead are identified, measured (fork length, nearest mm), and enumerated. Steelhead greater than 50 mm are weighed (nearest 0.1 g) for CDFG's Stream Evaluation Program. Fish are released downstream of the trap. Weekly mark-recapture trials are used to estimate trap efficiency. Water temperature and turbidity are also recorded. Up to 100 fish per year are sacrificed for otolith collection to determine maternal origin and migratory history.

Data Analysis: Population indices are generated using daily catch and weekly trap efficiencies. Annual passage indices are calculated, as well as length frequency and distribution, emigration timing, mark-recapture trap efficiencies, and water temperature, turbidity, and discharge are summarized.

Data Retrieval: Contact Matt Brown

Reporting: Annual U. S. Fish and Wildlife Service reports, reports to the California Bay-Delta Authority, see also http://www.fws.gov/redbluff/cvpia.html

Program History: Two rotary screw traps have been in use on Battle Creek continually since 1998. A third rotary screw trap was added at river mile 7.5 for the 2005-2006 sampling season.

Funding: Funding provided through California Bay-Delta Authority

Program Strengths and Weaknesses: Passage estimates generated in this project are calculated using trap efficiency trials, which are very robust and calculated on a weekly or twice weekly basis. However, efficiency estimates are calculated only for juvenile Chinook salmon and nay not be applicable to juvenile steelhead.

Potential Monitoring Improvements: Additional monitoring of Battle Creek is not recommended at this time.

Upper Sacramento Tributaries
Antelope Creek

Program Title: Antelope Creek Video Monitoring

Program Manager (PI): Doug Killam
CDFG
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Red Bluff, CA 96080
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dkillam@dfg.ca.gov

Target Species and Lifestage: Adult spring-run Chinook, adult steelhead

Stream Reach(es): Lower Antelope Creek (40.1873252, -122.1347026).

Program Objective(s): Enumerate steelhead entering Antelope Creek; determine diel patterns, and migration timing.

Sampling Time: December through July (or until river discharge is too low for fish to migrate).

Methodology(ies): Four video cameras (one overhead and three underwater) installed on Antelope Creek record all fish passing 24 hours per day. On-site digital video recorders allow the capture of high resolution video that can then be analyzed using motion sensing software. The use of motion sensing software greatly reduces the number of hours needed to review recorded video. Fish are identified and counts verified by more than one independent reviewer for quality control. Overhead lighting allows 24 hour monitoring.

Data Analysis: Fish counts are used to generate diel movement patterns, migration timing, and population estimates.

Data Retrieval: Contact Doug Killam

Reporting: Not yet available

Program History: Antelope Creek was first monitored for steelhead using video techniques starting in December 2007. Previous monitoring included opportunistic and periodic snorkel surveys (see pages 22-23).

Funding: Funded through California Bay-Delta Authority Ecosystem Restoration Program and CDFG through 2009.

Program Strengths and Weaknesses: Video monitoring techniques are very cost effective and high quality equipment can be reused over several field seasons. Video monitoring

may not be applicable in “flashy” systems where high flow events can flood out systems, allowing fish to bypass the cameras. “Flashy” streams such as Antelope Creek can also become very turbid and limit camera visibility.

Potential Monitoring Improvements: Video, Vaki, or DIDSON monitoring on nearby tributaries (Mill, Deer, Cow, Paynes, Thomes, Cottonwood, Beegum, Sulphur, Bear, Stillwater, Churn, Clover, Ash, and Olney Creeks).

Upper Sacramento Tributaries
Mill Creek

Project Title: Mill Creek Video Monitoring

Contact: Doug Killam
California Department of Fish and Game
P.O. Box 578
Red Bluff, CA 96080
(530) 527-8893
dkillam@dfg.ca.gov

Target Species/Lifestage: Adult spring-run Chinook, adult steelhead

Stream Reach: Lower Mill Creek (40.0459382, -122.0946912).

Project Objectives: Enumerate steelhead entering Mill Creek; determine diel patterns, and migration timing.

Sampling Time: March though June (or until stream turbidity prevents video monitoring).

Methodology: Four video cameras (one overhead and three underwater) installed on Mill Creek record all fish passing 24 hours per day. On-site VCRs allow the capture video that can then be analyzed using motion sensing software. The use of motion sensing software greatly reduces the number of hours needed to review recorded video. Fish are identified and counts verified by more than one independent reviewer for quality control. Overhead lighting allows 24 hour monitoring. A DIDSON system is also being used in tandem with video monitoring equipment in 2008 as part of a feasibility study.

Data Analysis: Fish counts are used to generate diel movement patterns, migration timing, and population estimates.

Data Retrieval: Contact Doug Killam

Reporting: Annual reports available the year following data collection. Reports also available online at:
http://www.calfish.org/IndependentDatasets/CDFGRedBluff/tabid/126/Default.aspx

Project History: Mill Creek was first monitored for steelhead using video techniques starting in 2007. Previous monitoring included opportunistic and periodic snorkel surveys (see pages 22-23).

Funding: Funded through California Bay-Delta Authority Ecosystem Restoration Program and California Department of Fish and Game through 2009.

Project Strength/Weaknesses: Video monitoring techniques are very cost effective and high quality equipment may last several field seasons. Turbid water during Mill Creek high flows limits visibility and ability of reviewers to identify and count fish.

Recommended Future Projects: Video, Vaki, or DIDSON monitoring on nearby tributaries (Mill, Deer, Cow, Paynes, Thomes, Cottonwood, Beegum, Sulphur, Bear, Stillwater, Churn, Clover, Ash, and Olney Creeks). Additional projects could include mark recapture tagging efforts throughout the upper Sacramento River basin to determine proportional distribution of steelhead throughout the basin.

Upper Sacramento Tributaries
Mill Creek

Program Title: Rotary Screw Trapping on Mill Creek

Program Manager (PI): Colleen Harvey-Arrison
CDFG
P.O. Box 578
Red Bluff, CA 96080
(530) 527-9490
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Target Species and Lifestage: Emigrating juvenile spring-run Chinook, juvenile steelhead

Stream Reach(es): Rotary screw trap located at river mile 6 in Mill Creek (40.0548205, -122.0296572).

Program Objective(s): Determine emergence and migration timing, length frequency distributions, relative abundance of emigrating smolts, steelhead presence or absence.

Sampling Time: October though May

Methodology(ies): One rotary screw trap is installed at river mile 6 in Mill Creek and is operated from October through May. The trap is emptied on a daily basis during sampling season. All captured fish are counted, measured, and identified to species and lifestage. Water temperature, flow, and turbidity also recorded.

Data Analysis: Fish counts are summarized, lifestage and length distributions determined on a bimonthly basis.

Data Retrieval: Contact Colleen Harvey-Arrison

Reporting: Biennial reports to the Fish and Game Commission, weekly reports to the Interagency Ecological Program's Juvenile Chinook Salmon Protection Process.

Program History: This project has been conducted on Mill Creek from 1994 – Present.

Funding: Currently funded through the Interagency Ecological Program

Program Strengths and Weaknesses: This project benefits from its long term dataset that is useful for assessing trends in steelhead populations. Trapping ceases in June on Mill Creek to prevent mortality of captured fish due to warm water conditions. Traps are also not fished during periods of high flow. As steelhead emigrate during all months, and particularly during high flow events, a significant number of steelhead could be moving out of the system when traps are not operating. Trap catches between years cannot be compared because of the lack of continuous fishing by the traps.

Potential Monitoring Improvements: Mill Creek would benefit from a study designed to assess adult steelhead returning to the system. A DIDSON feasibility study was conducted on Mill Creek to monitor Chinook salmon in 2007. This research may be applicable for monitoring adult steelhead in Mill Creek. The "flashy" nature of Mill Creek limits the type of monitoring efforts that can be conducted (weirs may wash out or become damaged in high flows, traps can wash downstream).

Upper Sacramento Tributaries
Mill Creek

Program Title: Upper Mill Creek Salmonid Hatching and Rearing Study

Program Manager (PI): Colleen Harvey-Arrison
CDFG
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Red Bluff, CA 96080
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Target Species and Lifestage: Juvenile spring-run and fall-run Chinook, juvenile steelhead

Stream Reach(es): Upper Mill Creek - the lowest monitoring point is "Black Rock" (40.1836740, -121.710036), the highest monitoring point is "Hole-in-Ground Camp" (40.3096529, -121.558839).

Program Objective(s): Determine juvenile salmonid emergence timing and assess rearing conditions. Estimate relative growth during sampling period.

Sampling Time: January through June

Methodology(ies): Electrofishing gear and beach seines are used to capture a representative sample of fish. Surveys are conducted bi-monthly. Up to 20 steelhead juveniles are measured and lifestage and smolt condition is recorded.

Data Analysis: Fish abundances, length distributions, and smolt condition are summarized.

Data Retrieval: Contact Colleen Harvey-Arrison

Reporting: Annual reports to CDFG

Program History: These surveys were initiated in 2007. Redd surveys were conducted in 2006 to determine spawning reaches for spring and fall-run Chinook. Counts of upstream migrants were attempted in the 1990s using electronic fish counters, but estimates were too low to be conclusive.

Funding: Funding through Federal Aid in Sport Fish Restoration Grants and Central Valley Bay-Delta Branch Interagency Ecological Program Grants.

Program Strengths and Weaknesses: Data collected in this program can be used to infer steelhead growth and emigration timing, as well as identify critical habitat types and conditions for juvenile steelhead. This project is primarily conducted to determine

relative growth of Chinook in discrete sections of the Creek that correspond to spawning reaches determined in 2006. All steelhead data is collected opportunistically and cannot be used to estimate abundance or production.

Potential Monitoring Improvements: Mill Creek would benefit from a study designed to assess adult steelhead returning to the system. A DIDSON feasibility study was conducted on Mill Creek to monitor Chinook salmon in 2007. This research may be applicable for monitoring adult steelhead in Mill Creek. The "flashy" nature of Mill Creek limits the type of monitoring efforts that can be conducted (weirs may wash out or become damaged in high flows, traps can wash downstream).

Upper Sacramento Tributaries
Deer Creek

Program Title: Rotary Screw Trapping on Deer Creek

Program Manager (PI): Colleen Harvey-Arrison
CDFG
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Red Bluff, CA 96080
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Target Species and Lifestage: Emigrating juvenile spring-run Chinook, juvenile steelhead

Stream Reach(es): Rotary screw trap located at river mile 11 in Deer Creek (40.0097674, -121.9614964).

Program Objective(s): Determine emergence and migration timing, length frequency information, relative abundance of emigrating smolts, steelhead presence or absence.

Sampling Time: October through May

Methodology(ies): One rotary screw trap is installed at river mile 11 in Deer Creek and is operated from October through May. The trap is emptied on a daily basis during sampling season. All captured fish are counted, measured, and identified to species and lifestage. Water temperature, flow, and turbidity also recorded.

Data Analysis: Fish counts are summarized, lifestage and length distributions determined on a bimonthly basis.

Data Retrieval: Contact Colleen Harvey-Arrison

Reporting: Biennial reports to the Fish and Game Commission, weekly reports to the Interagency Ecological Program's Juvenile Chinook Salmon Protection Process.

Program History: This project has been conducted on Deer Creek from 1994 – Present.

Funding: Currently funded through the Interagency Ecological Program

Program Strengths and Weaknesses: This project benefits from its long term dataset that is useful for assessing trends in steelhead populations. Trapping ceases in June in Deer Creek to prevent mortality of captured fish due to warm water conditions. As steelhead emigrate during all months, a significant number of steelhead could be moving out of the system when traps are not operating.

Potential Monitoring Improvements: Deer Creek would benefit from a study designed to assess adult steelhead returning to the system. A DIDSON feasibility study was conducted on Mill Creek to monitor Chinook salmon in 2007. This research may be applicable for monitoring adult steelhead in Deer Creek. The "flashy" nature of Deer Creek limits the type of monitoring efforts that can be conducted (weirs may wash out or become damaged in high flows, traps can wash downstream).

Upper Sacramento Tributaries
Deer Creek

Program Title: Upper Deer Creek Salmonid Hatching and Rearing Study

Program Manager (PI): Colleen Harvey-Arrison
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Red Bluff, CA 96080
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Target Species and Lifestage: Juvenile spring-run and fall-run Chinook, juvenile steelhead

Stream Reach(es): Upper Deer Creek - lowest monitoring point is "Ponderosa Way": 40.0704858, -121.7035629. The highest monitoring point is "Red Bridge": 40.1729754, -121.5548729.

Program Objective(s): Determine juvenile salmonid emergence timing and assess rearing conditions. Estimate relative growth during sampling period.

Sampling Time: January through June

Methodology(ies): Electrofishing gear and beach seines are used to capture a representative sample of fish. Surveys are conducted bi-monthly. Up to 20 steelhead juveniles are measured and lifestage and smolt condition is recorded.

Data Analysis: Fish abundances, weight - length information, and smolt condition are summarized.

Data Retrieval: Contact Colleen Harvey-Arrison

Reporting: Annual reports to CDFG

Program History: These surveys were initiated in 2007. Redd surveys were conducted in 2006 to determine spawning reaches for spring and fall-run Chinook. Counts of upstream migrants were attempted in the 1990s using electronic fish counters, but estimates were too low to be conclusive.

Funding: Funding through Federal Aid in Sport Fish Restoration Grants and Central Valley Bay-Delta Branch Interagency Ecological Program Grants.

Program Strengths and Weaknesses: Data collected in this program can be used to infer steelhead growth and emigration timing, as well as identify critical habitat types and conditions for juvenile steelhead. This project is primarily conducted to determine

relative growth of Chinook in discrete sections of the Creek that correspond to spawning reaches determined in 2006. All steelhead data is collected opportunistically and cannot be used to estimate abundance or production.

Potential Monitoring Improvements: Deer Creek would benefit from a study designed to assess adult steelhead returning to the system. A DIDSON feasibility study was conducted on Mill Creek to monitor Chinook salmon in 2007. This research may be applicable for monitoring adult steelhead in Deer Creek. The "flashy" nature of Deer Creek limits the type of monitoring efforts that can be conducted (weirs may wash out or become damaged in high flows, traps can wash downstream).

Upper Sacramento Tributaries
Stony Creek

Program Title: Lower Stony Creek Fish Monitoring Study

Program Manager (PI): Richard Corwin
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Target Species and Lifestage: Emigrating juvenile Chinook (all runs), juvenile steelhead, and all endemic and introduced species.

Stream Reach(es): Lower Stony Creek, multiple sampling reaches between river mile 14 and river mile 19.5.

Program Objective(s): Determine presence or absence of ESA listed special status anadromous fish, measure and enumerate captured fish, and determine fish community with an emphasis on endemic and introduced species.

Sampling Time: March – June.

Methodology(ies): Beach seines are used to capture fish daily from March – June annually. Monthly seining efforts were conducted from June – November from 2001 – 2003. Fish are enumerated, identified, and measured (fork length, nearest mm). All salmonids are fully processed. Additional (non-salmonid) individuals of each fish species are counted and recorded as extras.

Fyke nets are deployed upstream of the mouth of Stony Creek (2001 – 2003), downstream of the Constant Head Orifice (CHO) within the Tehama-Colusa Canal, and within the North Canal (downstream of the canal intake). Fish sampling protocols follow those used for beach seining. Fyke nets are operated within the CHO from April 1 through May 15 and from approximately March 15 to June 15 in the North Canal.

Water temperature, turbidity, dissolved oxygen, and stream discharge are recorded each sample day.

Data Analysis: Data analysis of the catch data for the fyke nets located at the CHO is expressed as CPUE (catch per unit effort) based on the number of fish caught within the fyke nets and the volume of water fished. Length distributions are generated, physical data summarized, and the number of introduced species are reported.

Data Retrieval: Contact Richard Corwin

Reporting: Data is reported to the California Department of Fish and Game and National Oceanic and Atmospheric Administration, National Marine Fisheries Service, in accordance to Streambed Alteration Agreement II-93-99 and Reclamation's Lower Stony Creek Water Management Biological Opinion, respectively.

Program History: Project duration 2001 – Present. Previous sampling efforts have incorporated additional fyke nets near the mouth of Stony Creek, electrofishing surveys, aerial surveys, water quality monitoring and spawning substrate composition studies.

Funding: Funded by the U.S. Bureau of Reclamation.

Program Strengths and Weaknesses: Monitoring of Stony Creek is recommended by a biological opinion issued by the National Marine Fisheries Service. This project is capable of estimating fish entrainment into the Tehama-Colusa Canal and North Canal and results may be applicable to other water diversion projects. Due to the low numbers of steelhead that are typically captured, this project has limited application aside from presence and absence data.

Potential Monitoring Improvements: Adult monitoring (weir counts) at the mouth of Stony Creek should be conducted to enumerate the number of adult salmonids entering Stony Creek to spawn. Also, juvenile monitoring should be conducted to enumerate the ratio of non-natal to natal juveniles within lower Stony Creek. There is strong evidence that juvenile salmonids use lower Stony Creek as rearing habitat. A study to investigate salmonid losses to Sacramento pikeminnow predation is also of interest.

Upper Sacramento Tributaries
Butte Creek

Program Title: Spring-run Chinook Salmon and Steelhead Snorkel Survey

Program Manager (PI): Tracy McReynolds
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Target Species and Lifestage: Adult spring-run Chinook salmon, adult steelhead

Stream Reach(es): Quartz Bowl Pool (39.854587, -121.633791) downstream to Honey Run Covered Bridge (39.729245, -121.703475) in Butte Creek.

Program Objective(s): Estimate spawner escapement, age at spawning, contribution to the fishery, and straying estimates for spring run Chinook salmon. Estimate steelhead escapement, presence and absence of steelhead

Sampling Time: October through June

Methodology(ies): Snorkeling surveys are conducted to count adult fish holding in pools prior to spawning. Each pool in the reach is sampled once by up to four independent surveyors. In addition to snorkeling surveys, mark-recapture carcass surveys and juvenile tagging programs are used to produce Chinook salmon estimates.

Data Analysis: Independent estimates are averaged with the total annual escapement estimate, which is calculated by summing the averages for all survey reaches.

Data Retrieval: Contact Tracy McReynolds or Clint Garman

Reporting: Annual administrative reports to the CDFG.

Program History: This project began in 1995. Similar surveys were conducted on Big Chico Creek from 1995 – 2006.

Funding: Funding provided by California Bay-Delta Authority, Federal Aid in Sport Fish Restoration, and through a grant provided by a partnership between CDFG and Pacific Gas and Electric.

Program Strengths and Weaknesses: Steelhead data is collected opportunistically and reliable for determining steelhead presence or absence. This project focuses on monitoring and estimating escapement of spring-run Chinook salmon.

Potential Monitoring Improvements: Reinitiate surveys on Big Chico Creek; modify study design for more statistically sound steelhead data collection. Parrott-Phelan Diversion Dam and Durham-Mutual Dam are equipped with fish ladders that are used by adult Chinook salmon and steelhead as they migrate upstream. Either of these facilities would be an adequate site for the installation of video monitoring equipment (pending landowner permission). The installation of video monitoring equipment would provide a better understanding of steelhead populations in Butte Creek (existing programs in Butte Creek are unable to adequately determine steelhead population status, see pages 48-49)

Upper Sacramento Tributaries
Butte Creek

Program Title: Butte Creek Spring and Fall-run Chinook Salmon and Steelhead Rotary Screw Trap

Program Manager (PI): Tracy McReynolds
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Clint Garman
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Target Species and Lifestage: Juvenile spring and fall-run Chinook salmon, juvenile steelhead

Stream Reach(es): The rotary screw trap is located at Parrott-Phelan Diversion Dam (39.709750, -121.750417).

Program Objective(s): Monitor time of alevin emergence, monitor size at emigration, develop an estimate of juvenile abundance, and document rearing and emigration patterns.

Sampling Time: October through June

Methodology(ies): Fish captured in the trap are identified, enumerated, and measured (fork length, nearest mm). Traps are checked and emptied daily. Water temperature, turbidity, and velocity are also recorded.

Data Analysis: Fish counts, length distributions, and juvenile abundances are summarized. Physical river conditions are summarized.

Data Retrieval: Contact Tracy McReynolds or Clint Garman

Reporting: Annual California Fish and Game report,

Program History: 1995 – present. Similar surveys were conducted on Big Chico Creek from 1995 – 2006.

Funding: Provided by California Bay-Delta Authority, Federal Aid in Sport Fish Restoration, and through a grant provided by a partnership between the CDFG and Pacific Gas and Electric.

Program Strengths and Weaknesses: Steelhead juveniles are collected opportunistically and data is reliable for determining steelhead presence and absence. Trap efficiencies cannot be estimated due to highly variable flow conditions in Butte Creek. The main purpose of this project is to identify spring-run Chinook life history patterns and capture fish for the spring Chinook coded wire tag marking program in Butte Creek. The trap is located at the downstream entrance of the fish ladder at Parrott-Phelan Diversion Dam. It is likely that the majority of juvenile steelhead emigrating in Butte Creek are able to bypass the screw trap by moving over the dam (in the overflow) or are large enough to avoid the screw trap as they migrate down through the fish ladder.

Potential Monitoring Improvements: Reinitiate trapping on Big Chico Creek. It is possible that sampling methodologies may be able to be changed or expanded upon to better estimate juvenile steelhead abundance and understand life history patterns in Butte Creek.

Lower Sacramento Mainstem
Downstream of Butte Creek Confluence to American River Confluence

Program Title: Rotary Screw Trapping at Knight's Landing

Program Manager (PI): Joe Johnson
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Robert Vincik
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Target Species and Lifestage: Emigrating juvenile Chinook (all runs), juvenile steelhead

Stream Reach(es): The lower Sacramento River at Knight's Landing

Program Objective(s): Estimate juvenile salmonid emigration annually in the lower Sacramento River, evaluate temporal distribution, relationships to environmental conditions, and population characteristics (length distribution, age, health, and smolt index).

Sampling Time: October through June

Methodology(ies): Two eight foot diameter rotary screw traps are used to capture emigrating salmonids. Traps are checked daily or twice daily as needed. Trap efficiencies are estimated for Chinook salmon using a mark-recapture method. Captured fish are identified, enumerated, measured (nearest mm, fork length), and weighed (nearest 0.1 g). Smolt indices are recorded for each fish. Temperature, turbidity, water velocity, and stream flow are also recorded.

Data Analysis: Juvenile emigration estimates, length distribution frequencies, temporal emigration distribution, smolt indices, and physical data are summarized. Fish condition is determined using weight-length relationships.

Data Retrieval: Contact Joe Johnson or Robert Vincik

Reporting: Annual reports to the CDFG.

Program History: 1994 - Present

Funding: Funded through the CDFG and the Interagency Ecological Program

Program Strengths and Weaknesses: Unlike many of the other rotary screw trapping programs throughout the CV, the traps at Knight's Landing are able to capture large numbers of emigrating naturally and hatchery produced steelhead. Fall-run Chinook trap efficiencies are applied to steelhead smolts to determine steelhead abundance.

Potential Monitoring Improvements: Monitoring of the Sacramento River between Glenn-Colusa Irrigation District Diversion Dam and Knight's Landing to evaluate losses of steelhead smolts in this reach. Releases of marked steelhead smolts in the mainstem of the lower Sacramento River during March, April, and May (when naturally produced fish are emigrating) would allow calculation of steelhead trap efficiencies.

Lower Sacramento Mainstem
Downstream of the American River

Program Title: Sacramento-San Joaquin Delta Juvenile Chinook Salmon Kodiak and Midwater Trawl at Sacramento

Program Manager (PI): Paul Cadrett
U. S. Fish and Wildlife Service
4001 N. Wilson Way
Stockton, CA 95205
(209) 946-6400 x312

Target Species and Lifestage: Emigrating juvenile Chinook (all runs)

Stream Reach(es): Three river miles downstream of Sacramento.

Program Objective(s): Monitor long term abundance and distribution of all runs of juvenile salmonids entering the Sacramento-San Joaquin Delta from upstream, create an index of relative abundance, monitor long term abundance and distribution of special status fish, sport fish, native fishes, and non-native fishes.

Sampling Time: Year round

Methodology(ies): Mid-water and Kodiak trawls are used to capture fish in the Sacramento River before the move downstream into the delta. Fish are identified, enumerated, and measured (nearest mm, fork length). Capture efficiencies are estimated using 24 hour efficiency trawls following Feather River Hatchery releases. Water turbidity, conductivity, and temperature at time of sampling are measured.

Data Analysis: Relative abundance is estimated in the form of a catch per effort index based on the volume of water sampled. Relative abundance is determined weekly, monthly, and annually. Length-frequency distributions are created for each species and run, and fish data and physical river conditions are summarized.

Data Retrieval: Contact Paul Cadrett, data posted on Bay-Delta and Tributaries (BDAT) website.

Reporting: Annual U.S. Fish and Wildlife reports, Interagency Ecological Program Newsletter articles, technical reports, and journal articles.

Program History: 1976 – 1981, 1988 – Present.

Funding: Continued funding available through the Interagency Ecological Program

Program Strengths and Weaknesses: This project is strengthened by its strong historical dataset and spatially and temporally comprehensive sampling protocols. This project was

designed for the explicit purpose of determining abundance of Chinook salmon through the delta. Larger fish (steelhead smolts) are less susceptible to trawling techniques and may not accurately be represented in trawl tows.

Potential Monitoring Improvements: Conduct capture efficiency trials on marked steelhead to strengthen relative abundance estimates and evaluate estimate confidence.

Lower Sacramento River Tributaries
Feather River

Program Title: Hatchery Returns to Feather River Hatchery

Program Manager (PI): Judy Urrutia
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Target Species and Lifestage: Adult steelhead

Stream Reach(es): Feather River at Feather River Hatchery

Program Objective(s): Collect eggs and sperm for propagation, enumerate steelhead spawned at the hatchery.

Methodology(ies): Fish are collected in a trap located in the fish ladder leading into the hatchery.

Data Analysis: Weekly, monthly, and annual trap counts.

Data Retrieval: Contact Judy Urrutia

Reporting: Weekly reports submitted to the CDFG for weeks when trap is operating.

Program History: The Feather River Hatchery has collected data on the number of fish returning to the facility since construction in 1967.

Funding: CDFG

Program Strengths and Weaknesses: The hatchery provides a reliable, spatially fixed sampling site. A large proportion of the fish returning to the hatchery are hatchery produced; little knowledge of wild steelhead populations can be extrapolated from this dataset.

Potential Monitoring Improvements: N/A

Lower Sacramento River Tributaries
Feather River

Program Title: Lower Feather River Steelhead Redd Survey

Program Manager (PI): Jason Kindopp
California Department of Water Resources
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(530) 534-2381

Target Species and Lifestage: Adult steelhead

Stream Reach(es): Various transects through the high and low flow channels (river mile 45-67).

Program Objective(s): Determine adult abundance and spawning distribution of steelhead in the Feather River.

Sampling Time: January through April

Methodology(ies): Spawning transects are conducted weekly. When located, GPS coordinates, in-river location, distance from the bank, water depth, water velocity, redd length, redd width, substrate type, and cover type around the redd are recorded.

Data Analysis: Minimum numbers of spawning steelhead are determined, redds are mapped spatially using GIS techniques.

Data Retrieval: Contact Jason Kindopp

Reporting: The year following the survey year, available online at: http://orovillerelicensing.water.ca.gov/wg-reports_envir.html

Program History: Steelhead redd surveys are conducted annually if possible (dependent on streamflow). Surveys were conducted in 2003, 2005, and 2008.

Funding: Ongoing funding through California Department of Water Resources.

Program Strengths and Weaknesses: The redd survey is very conservative and redds are only positively identified as steelhead redds if steelhead are observed holding on the redd. Redds are also not visible if they are located in water deeper than 1.5 meters. Both of these factors under-represent the actual number of steelhead spawning in the Feather River. Surveys are not conducted every year (due to high flow conditions).

Potential Monitoring Improvements: The installation of a weir (pages 61-62) on the Feather River will allow better estimates of adult steelhead escapement in the Feather River.

Lower Sacramento River Tributaries
Feather River

Program Title: Feather River Juvenile Salmon and Steelhead Rotary Screw Trap

Program Manager (PI): Jason Kindopp
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Target Species and Lifestage: Emigrating fall and spring-run Chinook salmon, steelhead

Stream Reach(es): Feather River below Oroville Dam, one trap is located at river mile 59 and two traps located at river mile 44.

Program Objective(s): Determine emigration timing, salmonid abundance, understand emigration timing and cues.

Sampling Time: December through June

Methodology(ies): Traps are checked daily, fish identified, enumerated, measured. Fifty salmonids of each species or run are sub-sampled, and smolt index is assessed for measured individuals. Traps are operated from December – June when possible (low flows or high water temperatures may shorten sampling). Trap efficiencies are conducted using mark-recapture methods. Water temperature and turbidity are recorded at the time of sampling.

Data Analysis: Emigration estimates are calculated and regression analyses used to determine the physical conditions that influence emigration. Length frequencies and fish counts are summarized.

Data Retrieval: Contact Jason Kindopp

Reporting: Annual reports to the California Department of Water Resources, FERC relicensing reports. Available online at:
http://orovillerelicensing.water.ca.gov/wg-reports_envir.html

Program History: 1996 - Present

Funding: Ongoing funding through California Department of Water Resources.

Program Strengths and Weaknesses: The long term standardized dataset allows for year to year trend comparisons. However, this program is designed to monitor Chinook salmon production and is not specifically designed to capture juvenile steelhead. Trap

efficiencies calculated for Chinook salmon are not applicable to juvenile steelhead. Steelhead capture numbers are too low to determine steelhead abundance estimates with reasonable confidence.

Potential Monitoring Improvements: Conduct trap efficiencies for juvenile steelhead when captures allow. This may need to be done using hatchery reared fish. Alter sampling protocols and seasonal monitoring to capture steelhead emigrating at all times of the year (when flows and water temperatures allow). Captured juvenile steelhead should be marked for use in mark-recapture studies (growth, distribution, abundance estimates).

Lower Sacramento River Tributaries
Feather River

Program Title: Feather River Juvenile Steelhead Growth and Habitat Utilization

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Target Species and Lifestage: Juvenile steelhead

Stream Reach(es): Feather River below Oroville Dam, between the fish barrier dam (river mile 67) and Honcut Creek (river mile 43).

Program Objective(s): Understand and evaluate steelhead distribution, abundance, habitat use, and growth.

Sampling Time: June through September

Methodology(ies): Snorkeling surveys and electrofishing surveys are used to estimate fish habitat use and growth. Snorkeling surveys are conducted at three spatial scales- broad, intermediate, and fine. In the broad scale, fish observations are recorded as well as water temperature, substrate, cover, and habitat type. Intermediate and fine scale snorkeling surveys expand upon the broad scale surveys by including depth and velocity. Electrofishing and beach seining are used to capture juvenile steelhead for a mark-recapture study. Captured fish are measured and marked with unique tags. Recaptured fish are measured to estimate individual growth rates.

Data Analysis: Individual growth rates, fish condition, distribution, and habitat use in different sections of the Feather River is summarized.

Data Retrieval: Contact Jason Kindopp or Ryon Kurth

Reporting: Annual reports to National Marine Fisheries Service in February, FERC relicensing reports as necessary. Available online at:
http://orovillerelicensing.water.ca.gov/wg-reports_envir.html

Program History: 1999 - Present

Funding: Funded through the California Department of Water Resources

Program Strengths and Weaknesses: Snorkeling surveys are successful, but few fish are observed during surveys. Backpack electrofishing surveys are limited to side channels of the Feather River, as the river is too big to sample effectively using backpack electrofishing gear.

Potential Monitoring Improvements: Boat mounted electrofishing units would allow more thorough sampling of the Feather River. Future habitat restorations (boulder, coarse woody debris, and spawning gravel enhancements) should be monitored to evaluate steelhead habitat use.

Lower Sacramento River Tributaries
Feather River

Program Title: Lower Feather River Count Weir

Program Manager (PI): Jason Kindopp
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(530) 534-2381

Target Species and Lifestage: Adult steelhead, spring and fall-run Chinook

Stream Reach(es): Lower Feather River (river mile 61).

Program Objective(s): Determine temporal trends of both adult steelhead and fall and spring-run Chinook salmon, obtain accurate counts of both adult steelhead and Chinook salmon (hatchery and in-river), determine origin of steelhead and Chinook salmon, collect tissues and mark both adult steelhead and Chinook salmon for aging and DNA testing.

Methodology(ies): Two upstream and one downstream opening in the weir will direct fish through a counting area. Although video counting is the preferred method of counting individuals, a combination of the video counting system and live-box trapping is set up at each opening. During video counting, each individual is digitally recorded and later identified to species and enumerated by DWR personnel. When turbidity levels are too high for video counting, salmon and steelhead are trapped in live boxes and enumerated by hand. Equipment for detecting tags placed in fish will also be installed in the passage chute (e.g. passive integrated tags (PIT), coded wire tags (CWT), radio/acoustic tags). Trap sampling depends on the number of fish passing. Trapping is ceased once water temperature exceeds 68° F (20°C). Snorkel surveys conducted at regular intervals downstream determine if fish are delayed below the weir.

Data Analysis: Immigration timing, fish count, and fish origin data are summarized.

Data Retrieval: Contact Jason Kindopp

Reporting: Initial weir report due in 2008-2009.

Program History: The weir will be installed in 2008 or 2009.

Funding: Funded through the California Department of Water Resources.

Program Strengths and Weaknesses: The weir will allow good estimates steelhead and Chinook escapement and abundance for the first time in the Feather River. A potential

problem with the weir is that proposed placement in the low flow channel may not be able to monitor all steelhead (particularly if steelhead spawn downstream in the high flow channel).

Potential Monitoring Improvements: Proposed and current projects to evaluate the distribution and behavior of steelhead smolts should be assessed to determine steelhead smolt life history decisions in the Feather River. California's Department of Water Resources has also collected genetic tissue and otolith samples that could be used to determine parentage of steelhead/rainbow trout in the Feather River, but funding has not been secured for analysis of these materials.

Lower Sacramento River Tributaries
Yuba River

Program Title: Yuba River Juvenile Chinook Salmon and Steelhead Rotary Screw Trap

Program Manager (PI): Duane Massa
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Target Species and Lifestage: Emigrating fall, late-fall and spring-run Chinook salmon, and steelhead

Stream Reach(es): Trap is located at river mile 6 (near Hallwood Boulevard, east of Marysville, CA).

Program Objective(s): Estimate annual salmonid emigration, temporal distribution, determine relationships of physical conditions to emigration, population characteristics, and evaluate the effects of in-stream flow requirements.

Sampling Time: Year round

Methodology(ies): Traps are operated from October through the end of June, and traps are checked daily during the sampling season. Fish captured in the trap are identified and enumerated. The first 10 of each non-salmonid species are measured (nearest mm, fork length) and released. The first 50 of each salmonid species are measured (nearest mm, fork length) and a second subsample of 30 of fish greater than 40 mm are weighed and checked for smolt condition. Mark-recapture methods are used to estimate trap efficiency. Water temperature, turbidity, and discharge are recorded.

Data Analysis: Emigration timing, abundance estimates, length frequency distributions, relative weight, and smolt indices are summarized for each species and run. Physical stream data is summarized.

Data Retrieval: Contact Duane Massa

Reporting: Annual report to CDFG available in December.

Program History: 1999 – Present. Previous methods included seine surveys and fish collection at the Hallwood-Cordua fish screen.

Funding: Anadromous Fish Restoration Program, CDFG.

Program Strengths and Weaknesses: This project is designed for the capture of emigrating Chinook salmon, and may not be able to adequately assess downstream migration of steelhead smolts, especially if steelhead grow large enough to avoid the trap prior to emigration. Mark-recapture efficiency trials are conducted using Chinook salmon. The assumption that juvenile steelhead and juvenile Chinook are equally susceptible to the rotary screw trap has not been validated.

Potential Monitoring Improvements: Conduct mark-release steelhead capture efficiency trials to better estimate juvenile steelhead abundance. Numerous screened water diversions near Daguerre Point Dam (Hallwood-Cordua North Canal, South Yuba/Brophy South Canal, and Browns Valley Diversion) have the potential to entrain large numbers of juvenile salmonids. Monitoring of fish return pipes may allow collection of greater numbers of juvenile fish for mark-recapture studies, movement studies, and allow collection of genetic materials. Mortalities should be collected and archived for future otolith microchemistry and genetic research.

Lower Sacramento River Tributaries
Yuba River

Program Title: Yuba River Fall, Late-Fall, Spring-Run, and Steelhead Passage at Daguerre Point Dam

Program Manager (PI): Duane Massa
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Target Species and Lifestage: Adult fall, late-fall, and spring-run Chinook salmon, adult steelhead

Stream Reach(es): Yuba River at Daguerre Point Dam (river mile 12)

Program Objective(s): Provide continuous monitoring of adult salmonid passage through Daguerre Point Dam's two fish ladders. Evaluate temporal distribution, relationships to environmental conditions, and population characteristics of immigrating adult salmonids.

Sampling Time: Year round

Methodology(ies): A Vaki Riverwatcher installed at the site uses infra-red imaging to create silhouettes of fish passing through the fish ladders. The silhouette images are used to enumerate fish, estimate fish length, age class, and determine origin (hatchery or naturally produced) of fish passing through fish ladders. Because silhouettes cannot be used to positively identify fish to species; a second camera integrated into the Vaki system captures still images for fish identification. Water temperature and flow data are also recorded.

Data Analysis: Escapement estimates and total annual passage of all anadromous fish through Daguerre Point Dam are determined. Temporal distribution, length frequency distribution, sex composition, fish origin, and physical stream conditions are summarized.

Data Retrieval: Contact Duane Massa

Reporting: Annual report to the CDFG available in June. Escapement estimates available in February for the previous year (March – February).

Program History: 2003 – Present.

Funding: Currently funded through the Anadromous Fish Restoration Program and the CDFG. Future funding is unsecured.

Program Strengths and Weaknesses: Because the Vaki system uses infra-red light to capture a silhouette of the passing fish, it is applicable in settings where highly turbid water conditions prohibit the use of more traditional video monitoring efforts. Fish measurements and observations can be made remotely, 24 hours per day. However, because the system relies on still images for fish identification, fish passing the Riverwatcher in high flow or highly turbid conditions can only be measured and checked for origin. They cannot be positively identified to species. Because adult steelhead tend to migrate during high flow conditions in turbid water, this technique may underestimate the number of steelhead passing Daguerre Point Dam.

Potential Monitoring Improvements: Daguerre Point Dam is one of the few impoundments in the CV that allows fish passage upstream of the facility. Owned and operated by the U. S. Army Corps of Engineers, the dam is a good candidate location for the installation of PIT tag detectors, which would allow passive detection of fish moving through the facility. As PIT tags uniquely identify fish, a PIT tagging efforts can be used to evaluate fish growth and other life history events (emigration to ocean, return from ocean, repeat spawning migrations, etc.). The implementation of a project like this would only be feasible if other dams and water diversion sites throughout the CV were equipped with PIT tag detectors. A large scale tagging effort would be needed to tag either emigrating juvenile steelhead or immigrating adults.

Lower Sacramento River Tributaries
American River

Program Title: Hatchery Returns to Nimbus Hatchery

Program Manager (PI): Judy Urrutia
CDFG
830 "S" Street
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Target Species and Lifestage: Adult steelhead

Stream Reach(es): American River at Nimbus Hatchery

Program Objective(s): Collect eggs and sperm for propagation, enumerate steelhead spawned at the hatchery.

Methodology(ies): Fish are captured in a trap located in the fish ladder leading into the hatchery.

Data Analysis: Weekly, monthly, and annual trap counts are recorded.

Data Retrieval: Data is maintained in electronic format by Judy Urrutia

Reporting: Weekly reports submitted to CDFG Fisheries Branch for weeks when trap is operating.

Program History: Nimbus Hatchery has collected data on the number of fish returning to the facility since construction in 1954.

Funding: Funded annually by CDFG

Program Strengths and Weaknesses: The hatchery provides a reliable, spatially fixed sampling site. A large proportion of the fish returning to the hatchery are hatchery produced; little knowledge of wild steelhead populations can be extrapolated from this dataset.

Potential Monitoring Improvements: Collect tissue samples from naturally produced fish for genetic analysis, collect general fish health information on naturally produced fish.

Lower Sacramento River Tributaries
American River

Program Title: American River Juvenile Fall-Run Chinook and Steelhead Rotary Screw Trap

Program Manager (PI): Mike Healey
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Target Species and Lifestage: Emigrating fall-run Chinook salmon, steelhead

Stream Reach(es): The American River downstream of the Watt Avenue bridge (river mile 6.5) in Sacramento, CA.

Program Objective(s): Estimate juvenile salmonid emigration; evaluate temporal distribution, determine emigration relationships to environmental conditions, and population characteristics annually in the lower American River. The information gained is used to adaptively manage water operations in the American River.

Sampling Time: January through June

Methodology(ies): Two rotary screw traps (consisting of paired four foot diameter cones) are operated on the American River from January through the end of June. Sampling is conducted daily. Fish are enumerated by species, measured (nearest mm, fork length), weighed (nearest 0.1 gram), and smolt index is recorded. Physical river conditions (temperature, flow, and turbidity) are recorded. Mark-recapture methods are used to estimate trap efficiency.

Data Analysis: Passage estimates, temporal distributions, length-frequency distributions, smolt indices, and physical data are summarized. Fish condition factors are determined through weight-length relationship equations.

Data Retrieval: Contact Mike Healey.

Reporting: Passage estimates available in July. Annual report to the CDFG available in December.

Program History: 1993 – Present, previous methods used beach seining to estimate emigration timing and abundance.

Funding: Funding provided through the CDFG.

Program Strengths and Weaknesses: This project is able to adequately evaluate the impact that adult spawning times have on juvenile emergence. Passage estimates generated in this project are robust for Chinook salmon due to the high number of fish captured. Juvenile steelhead in the river typically grow large enough to avoid rotary screw traps before they emigrate (resulting in low capture efficiencies and abundance estimates that lack confidence).

Potential Monitoring Improvements: Additional sampling techniques that are capable of capturing large juvenile steelhead need to be evaluated in the lower American River. Mark-recapture methods could add confidence to steelhead abundance estimates. Tagging juvenile fish with coded wire tags could be used to estimate ocean survival and recruitment to adult life stages.

Lower Sacramento River Tributaries
American River

Program Title: American River Steelhead Spawning Survey

Program Manager (PI): John Hannon
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Sacramento, CA 95825
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jhannon@mp.usbr.gov

Target Species and Lifestage: Adult steelhead

Stream Reach(es): The American River from Howe Avenue (river mile 5) to Nimbus Dam (river mile 23).

Program Objective(s): Estimate the number of adult steelhead spawning in the American River, determine spatial spawning distribution and timing, and estimate the proportion of hatchery and natural origin steelhead spawning in the river annually.

Sampling Time: December through April

Methodology(ies): Sampling is conducted every two weeks from December 20 through the first week in April. When redds are located, the fish species is identified (steelhead, lamprey, Chinook, sucker, Sacramento pikeminnow, etc.), fish length is estimated (if fish are present on redd), fish origin is determined, fish injuries are documented, and whether fish were holding on the redd or not. Scales and biological tissue are collected from steelhead carcasses. Water depth, velocity, substrate, and water clarity are measured at the redd site. The location of the redd is recorded using GPS, and redd dimensions and age are recorded.

Data Analysis: In river escapement estimates are determined using redd surveys and fish counts; the results of each estimate are compared. Spatial and temporal spawning distributions are determined, the physical characteristics of redds are summarized, the proportion of hatchery and natural origin spawners is determined, and the effects of river flow management on egg survival and redd dewatering is evaluated.

Data Retrieval: Contact John Hannon

Reporting: Annual U. S. Bureau of Reclamation reports (available September 30)

Program History: Surveys have been conducted 2001 – present.

Funding: Funding provided through the U. S. Bureau of Reclamation's Science and Technology Program.

Program Strengths and Weaknesses: This project currently produces the best in-river escapement estimates for natural origin fish on the American River. Redds in the American River are not always able to be identified to species. Although the majority of Chinook spawning has ceased before steelhead begin redd construction, some Chinook activity is still observed late in the year. Pacific lamprey redds may also be misclassified as steelhead redds. Steelhead redds in the American River may not remain distinguishable for long after construction due to the impact that warm water temperatures and high nutrient loads have on epilithic algae growth.

Potential Monitoring Improvements: Additional work could include a mark-recapture program to help estimate total steelhead escapement. Methodology for such a project could follow methods reported in Hallock (1989) in the lower Sacramento River.

Lower Sacramento River Tributaries
American River

Program Title: Life History Variation in Steelhead Trout and the Implications for Water Management

Program Manager (PI): Rob Titus
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Target Species and Lifestage: young-of-year *O. mykiss*

Stream Reach(es): The American and Mokelumne Rivers, additional coastal watersheds (Soquel and Scott Creeks).

Program Objective(s): Determining and modeling environmental factors that contributes to *O. mykiss* life history variation.

Methodology(ies): Field studies focus on evaluating seasonal and spatial variations in *O. mykiss* growth, fish densities, size distribution, and potential *O. mykiss* predators and competitors using snorkeling, electrofishing, and seining techniques. Fish larger than 65 mm are tagged with PIT tags so that growth rates can be estimated for recaptured fish. Larger naturally produced smolts are targeted using angling and seining techniques; these fish are tagged with surgically implanted acoustic tags (see pages 127-128). Placement of hydrophones throughout the lower American River, Mokelumne River, and the Sacramento-San Joaquin Delta will monitor the downstream migration of tagged fish (emigration timing and path through the delta). Physical river conditions are recorded (temperature, stream flow). Macroinvertebrate density, abundance, and species composition are determined for each river and used to estimate potential age-0 *O. mykiss* prey.

Data Analysis: Individual growth rates are determined; fish length distributions, density, abundance, and river conditions are summarized. Modeling methods relate physical river conditions and prey availability to individual fish growth parameters in order to: estimate the thresholds that determine variation in *O. mykiss* life history, project time from emergence to smolting, project size at smolting, determine expected reproductive success, and project population dynamics.

Data Retrieval: Contact Rob Titus

Reporting: Not yet available. Once available, reports can be downloaded at:
http://www. soe.ucsc.edu/~msmangel or
http://www. soe.ucsc.edu/~msmangel/CSTAR.html

Program History: Project was initiated in 2006, work is scheduled to continue through May 2009.

Funding: Funding provided through California Bay-Delta Authority and Steelhead Restoration and Report Card funds.

Program Strengths and Weaknesses: The modeling aspects of this project will likely be applicable to other streams in the CV and throughout California. Certain aspects of the project (acoustic tagging) are limited by low numbers of captured fish.

Potential Monitoring Improvements: Determine if modeling results are applicable to other river systems in the CV. Of particular interest is the relationship between water temperature, flow regime, and variation in life history.

Sacramento-San Joaquin Delta and Tributaries
Delta-wide

Program Title: Sacramento – San Joaquin Delta Juvenile Chinook Salmon Beach Seine Surveys

Program Manager (PI): Paul Cadrett
U. S. Fish and Wildlife Service
4001 N. Wilson Way
Stockton, CA 95205
(209) 946-6400

Target Species and Lifestage: Emigrating spring, fall, late-fall, and winter-run Chinook salmon.

Stream Reach(es): Lower Sacramento River (between Colusa and Elkhorn)
Sacramento River at Sacramento (between Verona and Clarksburg)
North Delta (Discovery Park to Antioch)
Central Delta (between the Sacramento and San Joaquin Rivers
South Delta (adjacent to and south of the San Joaquin River)
San Joaquin River (between Mossdale and the Tuolumne River)
San Francisco and San Pablo Bays (between Pittsburg and Tiburon)

Program Objective(s): Monitor long term abundance and distribution, create an index of relative abundance, and monitor the emigration paths of juvenile Chinook salmon and other special status fish entering the delta.

Sampling Time: Dependent on reach, see below

Methodology(ies):
Lower Sacramento River is sampled once a week, year round,
Sacramento River at Sacramento is sampled 3-7 times per week, October – February,
North Delta is sampled once a week, year round,
Central Delta is sampled 1-2 times per month, year round,
South Delta is sampled 1-2 times per month, year round,
San Joaquin River is sampled once per week, January – June, and
San Francisco and San Pablo Bays are sampled once per week, November – July.

Captured fish are enumerated, identified, and the first 50 fish of each species are measured (nearest mm, fork length). Remaining fish are identified to species and counted.

Data Analysis: Relative abundance is determined using catch-per-effort based on the volume of water sampled in each haul. Mean catch-per-effort per species is reported by week, month, and year. Length frequency distributions and fish count are broken down by species and run.

Data Retrieval: Contact Paul Cadrett

Reporting: Annual reports to the Interagency Ecological Program and U. S. Fish and Wildlife Service.

Program History: Sampling has been continuous since 1976.

Funding: Continued funding available through the Interagency Ecological Program

Program Strengths and Weaknesses: This project is strengthened by its strong historical dataset and spatially and temporally comprehensive sampling protocols. This project was designed for the explicit purpose of determining abundance of Chinook salmon through the delta. Larger fish (steelhead smolts) are less susceptible to seining techniques and may not accurately be represented in seine hauls.

Sacramento-San Joaquin Delta and Tributaries
Delta-wide

Program Title: Sacramento-San Joaquin Delta Juvenile Chinook Salmon Mid-water Trawl at Chipps Island

Program Manager (PI): Paul Cadrett
U. S. Fish and Wildlife Service
4001 N. Wilson Way
Stockton, CA 95205
(209) 946-6400

Target Species and Lifestage: Emigrating juvenile Chinook (all runs)

Stream Reach(es): The Sacramento-San Joaquin Delta near Chipps Island.

Program Objective(s): Monitor long term abundance and distribution of all runs of juvenile salmonids entering the Suisun Bay from the delta, create an index of relative abundance, and monitor long term abundance and distribution of special status fish, sport fish, native fishes, and non-native fishes.

Sampling Time: April through May

Methodology(ies): Mid-water and Kodiak trawls are used to capture fish as they move into Suisun Bay from the delta. Trawls are conducted 3-7 days per week year round, with efforts doubled (twice per day, seven days per week) during the Vernalis Adaptive Management Program salmon releases (April – May). Fish captured are identified, enumerated, and the first 50 individuals of each species are measured (nearest mm, fork length). Water clarity and temperature at time of sampling are recorded.

Data Analysis: Relative abundance is estimated in the form of a catch per effort index based on the volume of water sampled. Relative abundance is determined weekly, monthly, and annually. Survival estimates are calculated based on the number of fish captured, the number released, the proportion of the channel sampled, and the amount of time from first to last sampling date. Length-frequency distributions are created for each species and run, and fish data and physical river conditions are summarized.

Data Retrieval: Contact Paul Cadrett, data posted on Bay-Delta and Tributaries (BDAT) website (http://bdat.ca.gov/).

Reporting: Annual U.S. Fish and Wildlife reports, Interagency Ecological Program Newsletter articles, technical reports, and journal articles.

Program History: 1976 – Present

Funding: Funded through the Interagency Ecological Program.

Program Strengths and Weaknesses: This project is strengthened by its strong historical dataset and spatially and temporally comprehensive sampling protocols. This project was designed for the explicit purpose of determining abundance of Chinook salmon through the delta. Larger fish (steelhead smolts) are less susceptible to seining techniques and may not accurately be represented in seine hauls.

Sacramento-San Joaquin Delta and Tributaries
Mokelumne River

Program Title: Hatchery Returns to Mokelumne River Hatchery

Program Manager (PI): Judy Urrutia
CDFG
830 "S" Street
Sacramento, CA 95814
(916) 445-3462
jurrutia@dfg.ca.gov

Target Species and Lifestage: Adult steelhead

Stream Reach(es): Mokelumne River at Mokelumne River Hatchery

Program Objective(s): Collect eggs and sperm for propagation, enumerate steelhead spawned at the hatchery.

Methodology(ies): Fish are collected in a trap located in the fish ladder leading into the hatchery.

Data Analysis: Weekly, monthly, and annual trap counts.

Data Retrieval: Contact Judy Urrutia

Reporting: Weekly reports submitted to the CDFG for weeks when trap is operating.

Program History: Mokelumne River Hatchery has collected data on the number of fish returning to the facility since construction in 1963.

Funding: CDFG

Program Strengths and Weaknesses: The hatchery provides a reliable, spatially fixed sampling site. A large proportion of the fish returning to the hatchery are hatchery produced; little knowledge of wild steelhead populations can be extrapolated from this dataset.

Potential Monitoring Improvements: N/A

Sacramento-San Joaquin Delta and Tributaries
Mokelumne River

Program Title: Mokelumne River Fall-run Chinook and Steelhead Redd Survey

Program Manager (PI): Michelle Workman
East Bay Municipal Utility District
1 Winemasters Way Suite K
Lodi, CA 95240
(209) 365-1486
mworkman@ebmud.com

Target Species and Lifestage: Adult fall-run Chinook salmon, steelhead

Stream Reach(es): Redd surveys are conducted from Camanche Dam downstream to the town of Lockeford (Elliott Road bridge). Data collection is broken down into two reaches (Camanche Dam to Mackville Road and Mackville Road to Elliott Road).

Program Objective(s): Determine in-river spawner and redd counts, describe relationships between environmental factors and Chinook salmon and steelhead immigration, provide annual escapement estimates, assess use of spawning gravel enhancement projects, and assess distributions of spawning fish.

Sampling Time: September through March

Methodology(ies): Surveys are conducted weekly from September through March (depending on upstream migration of Chinook and steelhead). Redds are identified to species, enumerated, and marked in a GIS database.

Data Analysis: Redds are enumerated, percent in-river spawning, sex ratio, the number of redds per female, proportion within enhancement reaches, temporal distributions and spatial redd distributions are determined. Distributions and habitat use are analyzed in GIS databases.

Data Retrieval: Contact Michelle Workman

Reporting: Internal reports to East Bay Municipal Utility District

Program History: This project has been conducted since 1990, successful surveys depend on river flow conditions.

Funding: Ongoing funding provided by East Bay Municipal Utility District

Program Strengths and Weaknesses: This program is strengthened by its long term standardized data set which allows comparisons to be made from year to year. Steelhead

redds may be difficult to differentiate from Chinook redds. Steelhead redd surveys can only be conducted in years when stream flow conditions are adequate for surveys.

Potential Monitoring Improvements: Future efforts on the Mokelumne River should focus on using genetics studies and otolith analysis to determine parentage of resident fish and the proportion of the population (steelhead and rainbow trout) that still exhibits anadromy.

Sacramento-San Joaquin Delta and Tributaries
Mokelumne River

Program Title: Mokelumne River Fall-run Chinook and Steelhead Passage

Program Manager (PI): Michelle Workman
East Bay Municipal Utility District
1 Winemasters Way Suite K
Lodi, CA 95240
(209) 365-1486
mworkman@ebmud.com

Target Species and Lifestage: Adult fall-run Chinook salmon, steelhead

Stream Reach(es): Video monitoring and live trapping are conducted at Woodbridge Irrigation District Dam.

Program Objective(s): Monitor fish passage at Woodbridge Irrigation District Dam, describe relationships between environmental factors and Chinook salmon and steelhead immigration, provide annual escapement estimates, and assess distributions of spawning fish.

Sampling Time: Year round

Methodology(ies): Video monitoring is conducted 24 hours per day, 7 days per week, year round. Through 2003, trapping was conducted at a fish trap located in a fish ladder at Woodbridge Dam 2-4 weeks in November, with traps checked 2-6 times per day (depending on passage) 7 days per week. During video monitoring and trapping, fish are identified, measured, sex is determined, origin is determined by examining adipose fin presence or absence, and fish are checked for injuries.

Data Analysis: Video monitoring and live trapping fish data are analyzed to determine total escapement estimates of adults and grilse, immigration timing, weekly age and sex composition of the run, length frequency distributions, and diurnal and nocturnal passage. Physical river conditions are summarized and compared to run timing. The proportion of fish with injuries or anomalies is determined.

Data Retrieval: Contact Michelle Workman

Reporting: Internal reports to East Bay Municipal Utility District

Program History: This project has been conducted since 1992. Construction on Woodbridge Dam has interrupted video monitoring since fall of 2005, but will be re-initiated upon completion of construction.

Funding: Ongoing funding provided by East Bay Municipal Utility District

Program Strengths and Weaknesses: This program is strengthened by its long term standardized data set which allows comparisons to be made from year to year. Low steelhead captures prohibit abundance estimates with meaningful confidence.

Potential Monitoring Improvements: Future efforts on the Mokelumne River should focus on using genetic studies and otolith analysis to determine parentage of resident fish and the proportion of the population (steelhead and rainbow trout) that still exhibits anadromy.

Sacramento-San Joaquin Delta and Tributaries
Mokelumne River

Program Title: Mokelumne River Juvenile Fish Community Seine and Electrofishing

Program Manager (PI): Michelle Workman
East Bay Municipal Utility District
1 Winemasters Way Suite K
Lodi, CA 95240
(209) 365-1486
mworkman@ebmud.com

Target Species and Lifestage: All fish species present in the sampling reaches.

Stream Reach(es): The river is broken into six sampling reaches from the river mouth to Camanche Dam:
1. Mouth of the Mokelumne River to the Cosumnes River confluence;
2. Cosumnes confluence to Woodbridge Irrigation District Dam;
3. Woodbridge Dam to the Highway 99 bridge;
4. Highway 99 to Elliott Road bridge;
5. Elliott Road to Mackville Road bridge;
6. Mackville Road to Camanche Dam.

Program Objective(s): Provide year-round monitoring of the fish community of the lower Mokelumne River, document invasions of non-native species, and monitor salmonid abundance, growth, feeding habits, and emigration timing.

Sampling Time: Electrofishing in January, May, July, and October; seining January though June

Methodology(ies): Fish are collected using beach seines and backpack and boat electrofishing gear. Electrofishing is conducted four times annually (January, May, July, and October), seining is conducted monthly (January – June). Fish are identified to species, enumerated, measured, weighed, and lifestage is recorded (fry, parr, smolt, etc.). *O. mykiss* captured are PIT tagged. Fish injuries and physical anomalies are also recorded. Habitat type, depth, river velocity, water temperature, dissolved oxygen, and the area sampled are recorded.

Data Analysis: Catch per effort is used to determine relative abundance, and species diversity and species richness are calculated.

Data Retrieval: Contact Michelle Workman

Reporting: Internal reports to East Bay Municipal Utility District

Program History: 1992 – Present

Funding: Funded through East Bay Municipal Utility District

Program Strengths and Weaknesses: PIT tagging of *O. mykiss* allows estimation of anadromy present in the *O. mykiss* population in the Mokelumne River. Currently there are no autonomous detectors on the river, limiting the effectiveness of PIT tag detections for monitoring fish movements (all PIT tag readings need to be collected using hand-held detectors).

Potential Monitoring Improvements: Install additional PIT tag readers where possible (Woodbridge Irrigation District Diversion Dam, tributary braches of the Mokelumne, Mokelumne River Hatchery, etc). Future efforts on the Mokelumne River should focus on using genetics studies and otolith analysis to determine parentage of resident fish and the proportion of the population (steelhead and rainbow trout) that still exhibits anadromy.

Sacramento-San Joaquin Delta and Tributaries
Mokelumne River

Program Title: Mokelumne River Juvenile Chinook Salmon and Steelhead Rotary Screw Trapping

Program Manager (PI): Michelle Workman
East Bay Municipal Utility District
1 Winemasters Way Suite K
Lodi, CA 95240
(209) 365-1486
mworkman@ebmud.com

Target Species and Lifestage: Emigrating juvenile fall-run Chinook salmon, steelhead

Stream Reach(es): Mokelumne River immediately downstream of Woodbridge Irrigation District Dam.

Program Objective(s): Monitor the abundance and immigration patterns of naturally produced anadromous salmonids downstream of Woodbridge Irrigation District Dam.

Sampling Time: December through July

Methodology(ies): Through 2007, 1 or 2 rotary screw traps were used to capture fish emigrating past Woodbridge Dam (river kilometer 63) daily from mid-December through July. Beginning in 2008 one trap operates at river kilometer 63 and one trap at river kilometer 87. The traps are checked daily. Fish captured are identified to species, measured (nearest mm, fork length), weighed, and lifestage is determined for the first 50 of each salmonid captured. The remaining fish are identified and enumerated. Physical river and weather conditions are also recorded (temperature, dissolved oxygen, turbidity, cloud cover, wind speed, precipitation, and flow velocity). Cone rotation per minute is used to calculate catch-per-effort and relative abundance. Capture efficiencies are determined from Mokelumne River Fish Hatchery release data.

Data Analysis: Estimates of abundance and passage are generated from capture efficiency tests and catch-per-effort data. Environmental variables and fish capture numbers are used in regression analyses. Condition factor is determined for different lifestages (fry, parr, smolt, etc.) for each species. Seasonal data is compared to historical data. Diurnal and nocturnal passages are determined and compared.

Data Retrieval: Contact Michelle Workman

Reporting: Annual reports published internally, available in September. Emigration estimates are available annually in August.

Program History: Continuous since 1990, previous methods used fyke nets to capture fish.

Funding: Internally funded through East Bay Municipal Utility District.

Program Strengths and Weaknesses: This program is strengthened by its long term standardized data set which allows comparisons to be made from year to year. Capture efficiencies calculated using juvenile Chinook salmon are not explicitly applicable to juvenile steelhead.

Potential Monitoring Improvements: Future efforts on the Mokelumne River should focus on using genetics studies and otolith analysis to determine parentage of resident fish and the proportion of the population (steelhead and rainbow trout) that still exhibits anadromy.

Lower San Joaquin Mainstem

Program Title: San Joaquin River Juvenile Chinook Salmon and Steelhead Kodiak Trawl at Mossdale

Program Manager (PI): Tim Heyne
CDFG
737 North Old La Grange Road
La Grange, CA
(209) 853-2533
theyne@dfg.ca.gov

Target Species and Lifestage: Juvenile fall-run Chinook salmon

Stream Reach(es): The San Joaquin River near Mossdale Landing County Park (sampling reach is from the mouth of the Old River to two miles upstream of the confluence).

Program Objective(s): Estimate the number of Chinook smolts entering the Sacramento-San Joaquin Delta from the San Joaquin River. Determine the spatial and temporal distribution of Chinook smolts, relationship of emigration timing to environmental conditions, and estimate production of Chinook smolts in the San Joaquin Basin.

Sampling Time: April through June

Methodology(ies): A Kodiak trawl is used to capture juvenile Chinook daily from April through mid-June. Sampling days consist of 15 tows at 20 minutes per tow. Fish captured are identified, enumerated, and the first 20 of each species in each tow are measured (nearest mm, fork length). All Chinook juveniles are checked for the presence or absence of an adipose fin to determine fish origin (hatchery or natural). Water temperature, turbidity, and weather conditions are recorded at the beginning of each tow.

Data Analysis: Numbers of unmarked Chinook smolts caught per tow are adjusted using vulnerability indices calculated from recaptures of marked fish in release groups. These adjusted estimates are then extrapolated to 5-hour, 24-hour, and seasonal passage estimates. Results include smolt production estimates for the entire San Joaquin Basin, a determination of emigration timing, and the proportion of emigrants protected by the Vernalis Adaptive Management Plan. Physical river conditions are summarized.

Data Retrieval: Contact Tim Heyne

Reporting: Annual CDFG reports, annual Sport Fish Restoration Act grant reporting.

Program History: 1988 – Present.

Funding: Currently funded by Sport Fish Restoration Act grants through June of 2009.

Program Strengths and Weaknesses: This project is strengthened by its strong historical dataset and spatially and temporally comprehensive sampling protocols. This project was designed for the explicit purpose of determining abundance of Chinook salmon moving into the delta. Larger fish (steelhead smolts) are less susceptible to trawling techniques and may not accurately be represented in trawl tows. Another weakness of the project is the small number of steelhead smolts captured annually.

Potential Monitoring Improvements: This project could easily be modified to better assess emigrating steelhead populations in the San Joaquin Basin (such as year round sampling, determination of steelhead capture efficiencies).

San Joaquin River Tributaries
Calaveras River

Program Title: Calaveras River Juvenile Chinook Salmon and Steelhead Rotary Screw Trap

Program Manager (PI): Michele Palmer
FISHBIO Environmental
670 Hi-Tech Parkway, Suite A
Oakdale, CA 95361
(530)-343-2101
michelepalmer@fishbio.com

Target Species and Lifestage: Emigrating juvenile Chinook salmon (all runs), juvenile *O. mykiss*

Stream Reach(es): The trap is located immediately upstream of the Shelton Road bridge at river mile 28.

Program Objective(s): Determine abundance and estimate the number of juvenile Chinook migrating out of the Calaveras River, monitor environmental variables that influence emigration size, timing, and number of migrants.

Sampling Time: December though May

Methodology(ies): Sampling is conducted 4-7 times per week December through May. Fish captured are identified and enumerated, and the first 50 salmonids and the first 20 non-salmonids of each species are measured (fork length, nearest mm). Each week, up to 50 *O. mykiss* and Chinook are weighed (nearest 0.1 g). Smolt indices are recorded for each salmonid. Physical conditions (water temperature, turbidity, and water velocity) are recorded, as well as the number of cone revolutions per minute.

Data Analysis: Chinook counts are converted to abundance (catch-per-effort) and passage data using trap efficiency data. Steelhead migration timing and counts are summarized. Environmental river conditions are summarized and compared to emigration estimates and timing.

Data Retrieval: Chrissy Sonke
670 Hi-Tech Parkway, Suite A
Oakdale, CA 95361
(209) 614-0813
sonke@comcast.net

Raw data are also available through the Calaveras River Fish Group website: http://www.delta.dfg.ca.gov/crfg/data.asp

Reporting: Annual internal reports, also available through the Calaveras River Fish Group, Stockton East Water District Calaveras River Fisheries, and San Joaquin Basin websites:
http://www.sanjoaquinbasin.com/fishbio-san-joaquin-basin-newsletter.html
http://www.calaverasriver.com/sewd_fisheries_reports.htm

Program History: 2002 – Present.

Funding: Funding provided through Stockton East Water District

Program Strengths and Weaknesses: Steelhead data is limited to summarized presence and absence data, emigration timing and smolt indices. Too few steelhead smolts are captured to be able to determine trap efficiencies using mark-recapture techniques.

Potential Monitoring Improvements: additional monitoring efforts should focus on determining adult steelhead abundance and escapement in the Calaveras River.

San Joaquin River Tributaries
Stanislaus River

Program Title: Stanislaus River Juvenile Fall-run Chinook and *O. mykiss* Rotary Screw Trap at Oakdale.

Program Manager (PI): Michele Palmer
FISHBIO Environmental
670 Hi-Tech Parkway, Suite A
Oakdale, CA 95361
(530)-343-2101
michelepalmer@fishbio.com

Target Species and Lifestage: Emigrating juvenile fall-run Chinook salmon, juvenile *O. mykiss*

Stream Reach(es): The trap is located at river mile 40.

Program Objective(s): Determine abundance and estimate the number of juvenile Chinook migrating out of the Stanislaus River, monitor environmental variables that influence emigration size, timing, and number of migrants. Compare production estimates at Oakdale to estimates at Caswell State Park (river mile 9) to obtain survival indices through the Stanislaus River.

Sampling Time: December through June

Methodology(ies): Sampling is conducted 4-7 times per week December through mid-June. Fish captured are identified and enumerated, and the first 50 salmonids and the first 20 non-salmonids of each species are measured (fork length, nearest mm). Each week, up to 50 *O. mykiss* and Chinook are weighed (nearest 0.1 g). Smolt indices are recorded for each salmonid. Chinook trap efficiencies are conducted weekly using mark-recapture techniques. Physical conditions (water temperature, turbidity, and water velocity) are recorded, as well as the number of cone revolutions per minute.

Data Analysis: Chinook counts are converted to abundance (catch-per-effort) and passage data using trap efficiency data. Steelhead migration timing and counts are summarized. Environmental river conditions are summarized and compared to emigration estimates and timing.

Data Retrieval: Chrissy Sonke
670 Hi-Tech Parkway, Suite A
Oakdale, CA 95361
(209) 614-0813
sonke@comcast.net

Raw data are also available through the Stanislaus River Fish Group website: http://www.delta.dfg.ca.gov/srfg/data.asp

Reporting: Annual internal reports, also available at the San Joaquin Basin website http://www.sanjoaquinbasin.com/fishbio-san-joaquin-basin-newsletter.html

Program History: 1993 – Present.

Funding: Funding provided through Tri-Dam Project, Oakdale Irrigation District, and the South San Joaquin Irrigation District.

Program Strengths and Weaknesses: Steelhead data is limited to summarized presence and absence data, emigration timing and smolt indices. Too few steelhead smolts are captured to be able to determine trap efficiencies using mark-recapture techniques.

Potential Monitoring Improvements: Investigate the feasibility of additional projects (mark-recapture, weir installations) that allow better estimates of juvenile and adult abundance.

San Joaquin River Tributaries
Stanislaus River

Program Title: Stanislaus River Juvenile Fall-run Chinook and *O. mykiss* Rotary Screw Trap at Caswell State Park

Program Manager (PI): Clark Watry
Cramer Fish Sciences
636 Hedburg Way #22
Oakdale, CA 95361
(209) 847-7786
clarkw@fishsciences.net

Target Species and Lifestage: Emigrating fall-run Chinook salmon, *O. mykiss*

Stream Reach(es): Trap is located on the Stanislaus River near Caswell State Park (river mile 9).

Program Objective(s): Estimate juvenile salmon emigrants annually in the lower Stanislaus River, evaluate emigration patterns and examine the relationships between environmental conditions and emigration timing, fish length, and fish abundance. Compare abundance estimates at this site to abundance estimates at Oakdale (river mile 40) to calculate an index of survival through the river.

Sampling Time: January through June

Methodology(ies): Sampling is conducted 4-7 days per week from mid-January through mid-June. All fish are enumerated and identified to species, the first 25 fish of each salmonid species are measured (fork length, nearest mm), weighed (nearest 0.1 g), and have scales collected on a daily basis. All salmonids are checked visually for disease, abnormalities, and marks (fin clips, color implants), and are assigned a smolt index. Trap efficiency trials are conducted for Chinook salmon on a weekly basis. Physical conditions are recorded (water temperature, turbidity, velocity) and cone revolutions per minute are recorded.

Data Analysis: Daily trap captures are extrapolated to weekly, monthly, and annual passage based on trap efficiency trials. Steelhead passage estimates are not determined. Relative abundance in the form of catch-per-effort is generated for steelhead and salmon.

Data Retrieval: Contact Clark Watry
Raw data are also available through the Stanislaus River Fish Group website:
http://www.delta.dfg.ca.gov/srfg/data.asp

Reporting: Annual internal reports, reports to the U. S. Fish and Wildlife Service, Anadromous Fish Restoration Program (AFRP).

Summary reports available on the Cramer Fish Sciences website:
http://www.fishsciences.net/projects/stanislaus/caswell%20outmigration/index.htm

Program History: 1996 – Present. Previous sampling methods involved measuring the first 50 individuals of each salmonid species per week and weighing and collecting scale samples from 50 individuals of each species per week.

Funding: Ongoing project funded through the U. S. Fish and Wildlife Service (AFRP).

Program Strengths and Weaknesses: The project provides a long term dataset with results comparable from year to year. Abundance and passage estimates are robust for Chinook, but not calculated for steelhead because Chinook capture efficiencies are not necessarily applicable to steelhead. Steelhead capture efficiencies are not calculated due to low numbers of fish captured.

Potential Monitoring Improvements: Determining steelhead trap efficiencies would allow calculation of abundance and passage estimates. Additional work should focus on determining *O. mykiss* life history strategies through genetics and otolith microchemistry studies, when possible. The installation of barrier weirs and fish traps on all CV streams is also desirable where applicable (streams with highly variable flows or lack of public access may not be feasible). Adult fish data collected at the weirs should include total immigration/emigration estimates, sex ratios, fish origin, immigration timing, and length frequency distributions. The weirs also provide mark-recapture sites (for PIT, CWT, or acoustic/radio tagging) and tissue and otolith collection sites. Additional work in the San Joaquin Basin needs to be done to investigate mixing between anadromous and resident *O. mykiss* populations and determine incidences of repeat spawning in steelhead.

San Joaquin River Tributaries
Stanislaus River

Program Title: Stanislaus River Juvenile Fall-run Chinook and Steelhead Snorkel Survey

Program Manager (PI): John Hannon
U. S. Bureau of Reclamation, MP-150
2800 Cottage Way
Sacramento, CA 95825
(916) 978-5524
jhannon@mp.usbr.gov

Target Species and Lifestage: Juvenile Fall-run Chinook salmon and steelhead

Stream Reach(es): Multiple sampling reaches from Goodwin Canyon to the Oakdale Recreation Area.

Program Objective(s): Determine spatial and temporal distribution of juvenile salmonids through the Stanislaus River. Evaluate salmonid response to in-river flow management actions such as the Vernalis Adaptive Management Plan. Evaluate juvenile salmonid use of gravel restoration projects.

Sampling Time: Year round, bi-monthly

Methodology(ies): Snorkel surveys are conducted bi-monthly on a year-round basis. Fish observed are identified and counted. Observed fish numbers are converted into densities based on reach. Fish lengths are estimated. Water temperature, turbidity, and flow data are recorded.

Data Analysis: Spatial and temporal densities are determined, compared between and within reaches, and between gravel enhancement sites and non-enhancement sites. Physical river conditions (flow, temperature, turbidity) are related to fish densities.

Data Retrieval: Sampling is contracted to The Fishery Foundation of California:

Trevor Kennedy
The Fishery Foundation of California
Elk Grove Office
8698 Elk Grove Blvd. Suite 3
Elk Grove, CA 95624
(209) 649-8914
cosumnes@surewest.net

Raw data are also available through the Stanislaus River Fish Group website:
http://www.delta.dfg.ca.gov/srfg/data.asp

Reporting: Annual reports available in March. Data reports available monthly.

Program History: 2002 – 2007, previous sampling efforts used seine surveys to collect fish.

Funding: Funding provided through the U. S. Bureau of Reclamation

Program Strengths and Weaknesses: Snorkeling surveys are able to observe fish in microhabitat types where other sampling gear may be less effective. The project is limited by potential misidentification of fish species and length estimates.

Potential Monitoring Improvements: Additional monitoring efforts on the Stanislaus River are not recommended at this time.

San Joaquin River Tributaries
Stanislaus River

Program Title: Stanislaus River Fall-run Chinook and Steelhead Passage (Alaskan Weir)

Program Manager (PI): Andrea Fuller
FISHBIO Environmental
P.O. Box 342
MiWuk Village, CA 95346
(209) 586-4509

Target Species and Lifestage: Adult fall-run Chinook salmon and steelhead

Stream Reach(es): The weir is installed at river mile 31.5 on the Stanislaus River.

Program Objective(s): Determine adult escapement, determine relationships between environmental variables and run timing and escapement.

Sampling Time: September through December/January

Methodology(ies): A Vaki Riverwatcher installed at the site uses infra-red imaging to create silhouettes of fish passing through the weir. The silhouette images are used to enumerate fish, estimate fish length, age class, and determine origin (hatchery or naturally produced) of fish passing through the weir. Because silhouettes cannot be used to positively identify fish to species; a second camera integrated into the Vaki system captures still images for fish identification. Sampling with the Vaki system is continuous day and night from September through December/January.

A fish trap incorporated into the weir is operated to capture steelhead when turbidity exceeds 4 NTU. Length, weight, and scale samples are collected from all trapped salmonids. Steelhead carcasses that wash into the weir are collected for scale and otolith analysis. Snorkel surveys are conducted to assess fish species composition above and below the weir. Water temperature, turbidity, dissolved oxygen, and flow data are recorded.

Data Analysis: Total escapement is determined from September through April, environmental data (water temperature, dissolved oxygen, turbidity, and stream flow) are summarized, and biological parameters (sex ratios, length frequency distributions, fish origin, species composition, fish weight) are summarized.

Data Retrieval: Chrissy Sonke
FISHBIO Environmental
670 Hi-Tech Parkway, Suite A
Oakdale, CA 95361
(209) 614-0813
sonke@comcast.net

Raw data are also available through the Stanislaus River Fish Group website:
http://www.delta.dfg.ca.gov/srfg/data.asp

Reporting: Annual escapement estimates are generated and submitted to U. S. Fish and Wildlife Service. Online reports available at the following websites:
http://www.fishsciences.net/postcards/postcards.htm
http://www.sanjoaquinbasin.com/newsletter.php

Program History: 2002 – Present. Currently, the weir and Vaki are on loan from USFWS to the Tri-Dam Project, and are being operated by FISHBIO.

Funding: Funding provided through the U. S. Fish and Wildlife Service's Anadromous Fish Restoration Program and California Bay-Delta Authority.

Program Strengths and Weaknesses: An Alaskan style weir provides flexibility in the fact that it allows biologists to monitor movements of fish, particularly the upstream migration of adult salmonids without presenting an obstacle to boaters using the river for recreational purposes. The center of the weir is designed to collapse so that boats can easily pass over the weir, after which the center panels return to their original position. Furthermore, during high flow conditions after storms and during heavy spring runoff, resistance boards on the weir can be removed, causing the weir to lay flat against the river bottom, reducing the likelihood that it will be damaged by debris washing downstream.

The weir is currently the only way to monitor adult salmonid immigration timing and abundance in the Stanislaus River and allows fish measurements and observations to be made remotely, 24 hours per day. The weir is currently operated from September through December or January (through the end of fall-run Chinook migration), although it has been operated through June in the past. Because monitoring currently ends in December or January, steelhead that enter the Stanislaus River later in the year may not be sampled by this project (steelhead migrations and spawning are protracted and may extend from September through April).

Potential Monitoring Improvements: Investigate the feasibility of weir installation on additional CV streams and rivers to monitor adult salmonid escapement.

San Joaquin River Tributaries
Stanislaus River

Program Title: Discharge to Habitat Relationships for Anadromous Salmonid Juveniles in the Stanislaus River

Program Manager (PI): Mark Bowen
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Target Species and Lifestage: Juvenile Chinook salmon and juvenile *O. mykiss*.

Stream Reach(es): Goodwin Dam (river mile 58) to the confluence with the San Joaquin River (river mile 0).

Program Objective(s): Determine fish habitat selectivity and mesohabitat responses to different operational flows from New Melones Dam into the lower Stanislaus River. Conduct a preliminary investigation to test survey methods, validate the data analysis approach, and determine how to best expand efforts throughout the lower Stanislaus River (Goodwin Dam to the San Joaquin confluence).

Sampling Time: Fish sampling in February and May (2008).

Methodology(ies): Fish habitat use is determined using snorkeling (primary method, when visibility allows), seining, and electrofishing surveys. Daily observations (or catch) are recorded and converted to densities, water temperature is recorded, as well as depth, water velocity, shear, distance to cover, and distance to edge. Aerial LiDAR techniques are used for large scale habitat mapping.

Data Analysis: Habitat availability at five different discharge levels (200, 300, 700, 1200, and 1500 cfs) is compared using statistical methods (two-way ANOVA) to changes in fish density at each habitat level (micro and mesohabitat).

Data Retrieval: Contact Mark Bowen.

Reporting: Report forthcoming (2010).

Program History: Project initiated in 2005, in-stream habitat mapping ongoing since September 2007, fish sampling conducted in February and May 2008. Six miles of in-stream habitat has been mapped for one discharge level.

Funding: Funding provided through the USBR S&T Program and Central California Area Office of the USBR.

Program Strengths and Weaknesses: The potential to determine critical steelhead habitat at various discharge levels has great implications on water use and flow regime. Habitat mapping at each discharge level is dictated by Central Valley Project operations and are dependent on yearly precipitation. Low numbers of steelhead are present in the Stanislaus River. Juvenile rainbow trout may be mistaken for juvenile steelhead.

Potential Monitoring Improvements: The current project only investigates how discharge affects fish density. The relationship between discharge and residualization rate of juvenile *O. mykiss* in the Stanislaus River is another important aspect that should be investigated.

San Joaquin River Tributaries
Tuolumne River

Program Title: Tuolumne River Fall-run Chinook and Steelhead Passage (Alaskan Weir)

Program Manager (PI): Michele Palmer
FISHBIO Environmental
670 Hi-Tech Parkway, Suite A
Oakdale, CA 95361
(530)-343-2101
michelepalmer@fishbio.com

Target Species and Lifestage: Adult fall-run Chinook salmon and steelhead

Stream Reach(es): Tentative installation at river mile 2.5.

Program Objective(s): Determine adult escapement, determine relationships between environmental variables and run timing and escapement.

Sampling Time: Not yet available

Methodology(ies): A Vaki Riverwatcher installed at the site uses infra-red imaging to create silhouettes of fish passing through the weir. The silhouette images are used to enumerate fish, estimate fish length, age class, and determine origin (hatchery or naturally produced) of fish passing through the weir. Because silhouettes cannot be used to positively identify fish to species; a second camera integrated into the Vaki system captures still images for fish identification.

A fish trap incorporated into the weir is operated to capture steelhead when turbidity exceeds 3 NTU (which prevents accurate identification of fish using the underwater camera). Length, weight, and scale samples are collected from all trapped salmonids. Steelhead carcasses that wash into the weir are collected for scale and otolith analysis.

Data Analysis: Total escapement is determined from September through April, environmental data (water temperature, dissolved oxygen, turbidity, and stream flow) are summarized, and biological parameters (sex ratios, length frequency distributions, fish origin, species composition, fish weight) are summarized.

Data Retrieval: Chrissy Sonke
FISHBIO Environmental
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Oakdale, CA 95361
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sonke@comcast.net

Reporting: Not yet available

Program History: The weir will be installed in 2008

Funding: Funding provided through the Turlock Irrigation District

Program Strengths and Weaknesses: An Alaskan style weir provides flexibility in the fact that it allows biologists to monitor movements of fish, particularly the upstream migration of adult salmonids without presenting an obstacle to boaters using the river for recreational purposes. The center of the weir is designed to collapse so that boats can easily pass over the weir, after which the center panels return to their original position. Furthermore, during high flow conditions after storms and during heavy spring runoff, resistance boards on the weir can be removed, causing the weir to lay flat against the river bottom, reducing the likelihood that it will be damaged by debris washing downstream. The weir is currently the only way to monitor adult salmonid immigration timing and abundance in the Tuolumne River and allows fish measurements and observations to be made remotely, 24 hours per day (using the Vaki Riverwatcher).

Potential Monitoring Improvements: Investigate the feasibility of weir installation on additional CV streams and rivers to monitor adult salmonid escapement.

San Joaquin River Tributaries
Tuolumne River

Program Title: Tuolumne River Juvenile Fall-run Chinook Salmon and *O. mykiss* Rotary Screw Trap

Program Manager (PI): Tim Ford
Turlock Irrigation District
P. O. Box 949
Turlock, CA 95381
(209) 883-8275

Target Species and Lifestage: Juvenile fall-run Chinook salmon and steelhead

Stream Reach(es): One trap is located near Waterford (river mile 30) and a set of two traps (lower traps) are located at Grayson (river mile 5).

Program Objective(s): Determine abundance and estimate the number of juvenile Chinook migrating out of the Tuolumne River, monitor environmental variables that influence emigration size, timing, and number of migrants.

Sampling Time: January through June

Methodology(ies): Sampling is conducted daily January through June. Fish captured are identified and enumerated, measured (fork length, or standard length, as applicable, nearest mm), and weighed (nearest 0.1 g). Smolt indices are recorded for each salmonid. Chinook trap efficiencies are conducted. Environmental conditions (water temperature, flow, turbidity, and water velocity) are recorded.

Data Analysis: Chinook counts are converted to abundance (catch-per-effort) and passage data using trap efficiency data. Steelhead migration timing and counts are summarized. Environmental river conditions are summarized and compared to emigration estimates and timing.

Data Retrieval: Sampling is contracted to FISHBIO Environmental:
Chrissy Sonke
FISHBIO Environmental
670 Hi-Tech Parkway, Suite A
Oakdale, CA 95361
(209) 614-0813
sonke@comcast.net

Reporting: Annual reports to the Turlock Irrigation District, online reporting available at the San Joaquin Basin website:
http://sanjoaquinbasin.com/tuolumne-river-archives.html
http://sanjoaquinbasin.com/fishbio-san-joaquin-basin-newsletter.html

Program History: Similar monitoring has occurred on the Tuolumne since 1995. CDFG operated the lower traps (Grayson) from 1995-2003. Methodology for the 1995-2003 Grayson traps follows that outlined for the Hagaman trap on the Merced River (see pages 111-112). The upper trap (Waterford) has been in use since 2006. Prior to installation of rotary screw traps, monitoring was conducted using fyke nets to capture fish emigrating out of the Tuolumne River

Funding: Currently funded through Turlock Irrigation District.

Program Strengths and Weaknesses: Steelhead presence and absence is able to be determined through this project. Depressed *O. mykiss* populations in the Tuolumne River limit robustness of abundance estimates. Differentiation of resident from anadromous *O. mykiss* is difficult in the Tuolumne River.

Potential Monitoring Improvements: Additional work on the Tuolumne River should focus on determining *O. mykiss* life history strategies through genetics and otolith microchemistry studies.

San Joaquin River Tributaries
Tuolumne River

Program Title: Tuolumne River Juvenile Fall-run Chinook and *O. mykiss* Beach Seine and Snorkeling Survey.

Program Manager (PI): Tim Ford
Turlock Irrigation District
P. O. Box 949
Turlock, CA 95381
(209) 883-8275

Target Species and Lifestage: Juvenile fall-run Chinook salmon and *O. mykiss*

Stream Reach(es): Seining reach extends from La Grange Dam downstream to the San Joaquin River (two sampling sites are in the San Joaquin River). The snorkeling reach extends from La Grange Dam downstream to Waterford (river mile 30).

Program Objective(s): Monitor juvenile salmonid abundance, distribution, timing, and length distribution of naturally produced Chinook salmon and *O. mykiss.*

Sampling Time: January though May

Methodology(ies): Seining is conducted every two weeks from January through May. Fish captured are identified, enumerated, and measured (fork length, nearest mm). Smolt indices are also recorded for all salmonids captured. Snorkeling surveys are conducted in June and September. All fish observed are identified and length is estimated. Environmental conditions (flow, water temperature, turbidity, conductivity, and dissolved oxygen) are recorded at the time of sampling.

Data Analysis: Fish collection data (length frequency distributions, relative abundance, passage, emigration timing) is summarized, statistical analyses are used to compare fish abundance and timing to environmental conditions.

Data Retrieval: Contact Tim Ford

Reporting: Annual FERC reports in March.

Program History: Seining surveys have been conducted on the Tuolumne River since 1997, and similar methods were used from 1986-1996. Snorkel surveys have been conducted since 2001, with intermittent sampling occurring from 1982-2000.

Funding: Funded through Turlock and Modesto Irrigation Districts

Program Strengths and Weaknesses: Steelhead presence and absence is able to be determined through this project. Depressed *O. mykiss* populations in the Tuolumne River limit robustness of abundance estimates. Differentiation of resident from anadromous *O. mykiss* is difficult in the Tuolumne River.

Potential Monitoring Improvements: Additional work on the Tuolumne River should focus on determining *O. mykiss* life history strategies through genetics and otolith microchemistry studies.

San Joaquin River Tributaries
Merced River

Program Title: Merced River Juvenile Fall-run Chinook Rotary Screw Trap at Hopeton

Program Manager (PI): Dave Vogel
Natural Resource Scientists, Inc.
P. O. Box 1210
Red Bluff, CA 96080
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Target Species and Lifestage: Emigrating juvenile fall-run Chinook salmon

Stream Reach(es): Two 8 ft. rotary screw traps are located on the Merced River near Hopeton, CA.

Program Objective(s): Develop early life history information on fall-run Chinook salmon in the Merced River, identify, quantify, and evaluate numbers of Chinook salmon emigrating from the Merced Basin, identify emigration timing in relation to flow pulse events and estimate survival of emigrant Chinook salmon.

Sampling Time: January through June

Methodology(ies): Sampling is conducted seven days per week January through June. All fish captured are identified and enumerated, and the first 50 salmonids are measured (fork length, nearest mm). Captured fish are marked for use in mark-recapture tests used to estimate Chinook survival. Periodic trap efficiencies are conducted using marked fish. Environmental parameters (water temperature, turbidity, velocity, river stage, and cone revolutions per minute) are recorded.

Data Analysis: Fish passage data is compiled, summarized, and related to environmental conditions. Survival estimates are determined using mark-recapture estimates, trap efficiencies are used to extrapolate daily captures to seasonal passage estimates.

Data Retrieval: Contact Dave Vogel

Reporting: Annual data reporting to the CDFG, monthly reporting to Merced Technical Advisory Committee, reports also available online: http://www.resourcescientists.com

Program History: This monitoring effort has been conducted since 1999.

Funding: Funded through the Merced Irrigation District

Program Strengths and Weaknesses: Currently this project can only determine *O. mykiss* presence or absence in the Merced River. This project is focused entirely on determining

emigration parameters for fall-run Chinook salmon. Very few *O. mykiss* captured in the Merced River can be positively identified as the progeny of steelhead, or determined to be smolting.

Potential Monitoring Improvements: Additional work on the Merced River should focus on determining *O. mykiss* life history strategies through genetic and otolith microchemistry studies.

San Joaquin River Tributaries
Merced River

Program Title: Merced River Juvenile Fall-run Chinook Rotary Screw Trap at Hatfield State Park

Program Manager (PI): John Montgomery
Cramer Fish Sciences
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Target Species and Lifestage: Juvenile fall-run Chinook, *O. mykiss*

Stream Reach(es): Two 8 ft. diameter screw traps located in the Merced River near Hatfield State Park (river mile 2)

Program Objective(s): Provide an estimate of the abundance of juvenile salmonids that move through the lower Merced River, determine and evaluate patterns of fish migration timing, length at emigration, and fish abundance relative to stream flow, water temperature, and other environmental conditions, and determine indices of survival for juvenile salmonids in the Merced River.

Sampling Time: January through June

Methodology(ies): Sampling is conducted 7 days per week, January through June. All captured fish are identified to species, enumerated, and the first 50 salmonids each day are measured (fork length, nearest mm). Marked fish are in mark-recapture tests to determine survival estimates and trap efficiencies. Environmental river conditions (water temperature, stream flow, turbidity, water velocity) are recorded at the time of sampling.

Data Analysis: Fish passage data is compiled, summarized, and related to environmental conditions. Survival estimates are determined using mark-recapture estimates, trap efficiencies are used to extrapolate daily captures to seasonal passage estimates.

Data Retrieval: Contact John Montgomery

Reporting: Data is submitted annually to CDFG, additional real-time reporting available at the Cramer Fish Sciences Website:
http://www.fishsciences.net/projects/merced/index.htm

Program History: Project initiated in 2006.

Funding: Funded through the U. S. Fish and Wildlife Service's Comprehensive Assessment and Monitoring Program (CAMP) and the Anadromous Fish Restoration Program (AFRP).

Program Strengths and Weaknesses: Currently this project can only determine *O. mykiss* presence or absence in the Merced River. This project is focused entirely on determining emigration parameters for fall-run Chinook salmon. Very few *O. mykiss* captured in the Merced River can be positively identified as the progeny of steelhead, or determined to be smolting.

Potential Monitoring Improvements: Additional work on the Merced River should focus on determining *O. mykiss* life history strategies through genetics and otolith microchemistry studies.

San Joaquin River Tributaries
Merced River

Program Title: Merced River Rotary Screw Trap at Hagaman Park

Program Manager (PI): Dennis Blakeman
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Target Species and Lifestage: Juvenile fall-run Chinook, *O. mykiss*

Stream Reach(es): Two eight foot rotary screw traps operated near Hagaman Park (river mile 7).

Program Objective(s): The objectives of this study were to estimate the production of juvenile Chinook salmon and determine the timing of juvenile Chinook salmon migration.

Sampling Time: April through June

Methodology(ies): Trap checks were performed on a daily basis, two times per day. Captured fish were identified, enumerated, and the first 100 salmonids were measured (fork length, nearest millimeter). Up to 100 salmonids of each species were measured, the remaining after were counted and recorded as plus counts. A smoltification index code (as specified in the Interagency Ecological Program Steelhead Project Work Team, Steelhead Life-stage Assessment Protocol) was assessed for every measured salmonid and recorded. Non-salmonid fish captures were identified to species and a maximum of 20 individuals measured with extras recorded as plus counts. Air and water temperatures (°C), water turbidity, water velocity and conductivity data were collected for each trap check. Trap efficiency test were conducted weekly through the sampling period.

Data Analysis: Fish passage data is compiled, summarized, and related to environmental conditions. Survival estimates are determined using mark-recapture estimates, trap efficiencies are used to extrapolate daily captures to seasonal passage estimates.

Data Retrieval: Contact Dennis Blakeman

Reporting: Final report available, contact Dennis Blakeman

Program History: Project conducted from 1998 - 2003

Program Strengths and Weaknesses: Low captures of steelhead smolts in the Merced River prevents steelhead capture data from being used to determine abundance or trends. Capture efficiencies were only calculated for Chinook salmon smolts.

Potential Monitoring Improvements: It is recommended that future projects focus on enumerating the number of adult steelhead that spawn annually in the Merced River. Additional work should also focus on determining *O. mykiss* life history strategies through genetics otolith microchemistry studies, and whether steelhead and rainbow trout populations in the river are reproductively isolated or are interbreeding.

Steelhead Research in California's Central Valley

The projects listed in this section of the review are those that are not designed to monitor steelhead population status or trends, but are important contributions to our understanding of steelhead biology in the Central Valley.

Central Valley Wide

Program Title: Maternal origin and migratory history of *Oncorhynchus mykiss* captured in rivers of the Central Valley, California

Program Manager (PI): George Edwards
CDFG
830 S Street
Sacramento, CA 95811
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Target Species and Lifestage: natural origin *O. mykiss* juveniles and adults

Stream Reach(es): Upper Sacramento River, Deer Creek, Yuba River, Calaveras River, San Joaquin River, Stanislaus River, Tuolumne River, and Merced River

Program Objective(s): Use otolith composition to assess the proportion of *O. mykiss* populations that exhibit anadromous or resident life history strategies.

Methodology(ies): Otolith samples collected from fish captured using beach seines, rotary screw traps, hook and line, electrofishing, and carcass surveys. Otoliths were sectioned and Ca:Sr ratios were analyzed using an electron microprobe. Because the concentration of strontium is typically higher in seawater than in freshwater, Ca:Sr ratios in the otolith can be used to describe the migratory history of a fish. Furthermore, because the primordia of the otolith forms while the fish is still consuming its yolk sac, Ca:Sr ratios in the primordia reflect the migratory history of the maternal parent.

Data Analysis: Otoliths analyzed to determine fish migration patterns and migration history of the maternal parent.

Data Retrieval: Contact George Edwards

Reporting: Final report to the CDFG available.

Program History: Otoliths collected from 2001-2007

Funding: Provided through the United States Fish and Wildlife Service Anadromous Fish Restoration Program and the United States Geological Survey.

Program Strengths and Weaknesses: Using otolith microchemistry to determine *O. mykiss* migration histories is one of the only accurate methods to determine the life history strategies (anadromous vs. resident) used by fish in many of the CV watersheds. Identification of streams with high populations of anadromous *O. mykiss* is critical to steelhead management. A potential weakness of this study design is that the fish must be sacrificed, which can be a limiting factor when studying a threatened species.

Central Valley Wide

Program Title: Central Valley Rainbow Trout Population Genetic Evaluation Sampling Plan

Program Manager (PI): George Edwards
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830 S Street
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Target Species and Lifestage: *O. mykiss* juveniles and adults

Stream Reaches: North Fork American River, Middle Fork American River, lower American River, upper Stanislaus River, lower Stanislaus River, upper Tuolumne River, lower Tuolumne River, upper Yuba River, lower Yuba River, North Fork Feather River, lower Feather River, and upper Kings River

Program Objective(s): Use genetic analysis to compare *O. mykiss* populations above and below migration barriers in California's CV.

Methodology(ies): Genetic samples collected from fish captured using beach seines, rotary screw traps, hook and line, electrofishing, and carcass surveys were analyzed and above barrier and below barrier populations were compared. Archived tissue samples were used whenever possible. All upper sampling locations were within the historical steelhead distribution described by Yoshiyama et al. (1996). Samples were also compared to known *O. mykiss* strains propagated at the American River Hatchery (Nimbus Hatchery) and Hot Creek Hatchery.

Data Analysis: Bootstrap consensus neighbor-joining trees used to assign groups, regression of genetic distance (F-stat), population structure determined.

Data Retrieval: Contact George Edwards. Tissue samples archived with the CDFG Salmonid Tissue Archive.

Reporting: Final report to the CDFG forthcoming (2008).

Program History: Samples collected from July 2005 – May 2007.

Funding: Funded through a CALFED Bay Delta Program grant.

Program Strengths and Weaknesses: Using genetic analysis to assign *O. mykiss* populations to groups has great implications for conservation of "pure" (strains that have not been affected by hatchery introgression) *O. mykiss* strains in the CV. Because

resident fish may be able to produce anadromous progeny, these “pure” strain populations could be used to re-establish steelhead downstream populations.

Central Valley Wide

Program Title: Survival and migratory Patterns of Central Valley Juvenile Salmonids

Program Manager (PI): Peter Klimley
Director, Biotelemetry Laboratory
Department of Wildlife, Fish, and Conservation Biology
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University of California – Davis
Davis, California 95616
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Target Species and Lifestage: Juvenile hatchery reared steelhead smolts

Stream Reaches: The Sacramento River from just upstream of Battle Creek downstream to the Sacramento-San Joaquin Delta, through the San Francisco Bay Estuary and into the Pacific Ocean.

Program Objective(s): Describe reach-specific rates of survival and movement from the upper Sacramento River to the Pacific Ocean and explain variations in these rates based on natural and anthropogenic variables (including reach length, water velocity, water temperature, bank condition, the presence of structures, predation, the magnitude of screened and unscreened diversions, and estuarine and ocean conditions).

Methodology(ies): Tags surgically implanted into the peritoneal cavity of juvenile steelhead allow the fish to be detected remotely by receiver arrays as the fish migrates downstream through the Sacramento River towards the Pacific Ocean. Over 150 receivers have been deployed to date throughout the system.

Data Analysis: Survival rates within discrete reaches are examined by comparing the numbers of fish that enter a reach to those that enter the next downstream reach. In reach mortality rates are compared to physical river attributes using regression (ANCOVA) techniques.

Data Retrieval: Contact Pete Klimley

Reporting: Not yet available

Program History: Project initiated in January 2007.

Funding: Funded through a CALFED Science Program grant.

Program Strengths and Weaknesses: The acoustic arrays are spaced through the Sacramento River and through the Sacramento-San Joaquin Delta to allow high-resolution tracking and provide comprehensive evaluations of areas with increased

mortality, indicate reaches that are important to the animal's life history (nursery, rearing, or holding areas), and allow investigations of the environmental factors that influence survival and movement (water project activities, natural factors).

This project was designed with the intent of cooperation and collaboration between different agencies. Any agency that tags fish with tags compatible with the existing acoustic receiver arrays is welcome to query the database for their tag codes. New programs are encouraged to use and expand upon the existing arrays (i.e. a fish tagging program in the Yuba River can gain access to the main database and track their fish using arrays operated by other agencies).

Central Valley Wide

Program Title: Evaluation of Fish Entrainment in Unscreened Diversions on the Sacramento and Feather Rivers.

Program Manager (PI): Dave Vogel
Natural Resource Scientists, Inc.
P. O. Box 1210
Red Bluff, CA 96080
(530) 527-9587
dvogel@resourcescientists.com

Target Species and Lifestage: Juvenile winter-run and spring-run Chinook salmon, juvenile steelhead, and juvenile green sturgeon (*Acipenser medirostris*)

Stream Reaches: Three unscreened diversions on the Sacramento River: Tyndall Mound Diversion (38.908219, -121.811636), Howell's Landing Diversion (38.929011, -121.837155), Boyer's Bend Diversion (38.954197, -121.840836), and one unscreened diversion on the Feather River: Feather Water District North Diversion (39.045569, -121.610311).

Program Objective(s): Improve understanding of how unscreened diversions impact ESA listed species, provide knowledge that will assist in future fish restoration projects (efficient allocation of expenditures for screening remaining unscreened diversions). Salvage listed species from diversion facilities and return live fish to the river (to the greatest extent practicable).

Sampling Time: April through October 2007 and 2008 (the primary irrigation season).

Methodology(ies): Fyke nets (on the Sacramento River diversions) and a water filtration box (on the Feather River diversion) are used to capture fish that have been diverted out of the Sacramento (or Feather) River through irrigation pumps. Fish collected are identified to species, enumerated, and measured. Dead or moribund fish are returned to the diversion; live fish returned to the river. Diversions are sampled once daily, seven days per week for the time period between April 1 - October 31, 2007 and April 1 - October 31, 2008. Flow rates through the diversion are recorded. Fish carcasses may be retained at the request of fishery resource agencies for inclusion in tissue archives or otolith microchemistry analysis.

Data Analysis: Determine mortality for fish diverted into unscreened irrigation canals, determine the fish assemblages, length frequency distribution, and number of listed fish entrained by irrigation pumps.

Data Retrieval: Contact Dave Vogel

Reporting: Not yet available (annual and final project reports forthcoming).

Program History: Project initiated in April 2007.

Funding: Funded through the Unites States Bureau of Reclamation and Anadromous Fish Screen Program grants.

Program Strengths and Weaknesses: This project will offer a better understanding of how small diversions (less than 250 cfs) impact listed fish species. The use of data generated through this project should provide direction for allocation of funds to screen the remaining unscreened diversions in the CV. As all large diversions (greater than 250 cfs) have been screened or will be screened in the foreseeable future, this project will examine the benefits of screening such smaller diversions.

Feather River

Program Title: Movement of wild and hatchery origin Feather River *O. mykiss*

Program Manager (PI): Ryon Kurth
Department of Water Resources
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Oroville, CA 95966
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Target Species and Lifestage: Juvenile and adult *O. mykiss*

Stream Reach(es): The lower Feather River and tributaries.

Program Objective(s): Examine the movement patterns of Feather River steelhead trout (*O. mykiss*), of natural ("wild") and hatchery origin, through the lower Feather River and the Sacramento-San Joaquin Delta using ultrasonic telemetry. Receiver stations have been set up from the base of the Fish Barrier Dam downstream to the confluence with the Sacramento River. These stations are in addition to the receiver grid already in place throughout the Sacramento-San Joaquin river system to help understand habitat use and movement of various steelhead life histories as well as the differences in hatchery and natural fish behavior.

Main objectives are to: (1) determine the dominant life history patterns for hatchery and wild *O. mykiss*; (2) and compare and contrast movement of hatchery and wild steelhead at various life stages.

Methodology(ies): Twenty four receiver stations will be deployed in the lower Feather River from the Fish Barrier Dam (river kilometer 108) downstream to the confluence with the Sacramento River (river kilometer 0). An additional 3 receivers will be placed in the Yuba River, a major tributary of the Feather River.

From December 2007 through May 2008, Vemco acoustic tags will be surgically implanted into the peritoneal cavity of wild and hatchery *O. mykiss* captured in the lower Feather River. Adults (> 380 mm) will be tagged with V13 tags and juveniles (150 – 379 mm) will be tagged with V9 tags. In February 2008, tags will also be implanted into hatchery smolts. All fish tagged in the river will be released at the capture location, while the hatchery smolts will be transported approximately 71 river kilometers downstream and released (RKM 36).

Data Analysis: Yearling and adult *O. mykiss* of hatchery and wild origin movement patterns will be summarized and rate and length of residency will be determined. The relationship between residency/anadromy and various biological (i.e. age, condition) and physical conditions (i.e. water temperature, season) will be investigated.

Data Retrieval: Contact Ryon Kurth

Reporting: Annual report available in 2008

Program History: Project initiated in 2007

Funding: Funded through the California State Water Project

Program Strengths and Weaknesses: Collaboration with multi agency consortium provides monitoring of fish movements for not only the Feather River but throughout the Sacramento-San Joaquin Delta and into San Francisco Bay. Information gained from this study will help determine the gross movement patterns for fish in the Feather River as well as contribute to the understanding of *O. mykiss* movement in the CV. A potential weakness will be low sample size for the various study categories (life-stage and origin).

Potential Monitoring Improvements: Addition of a weir would allow determination of population size, run timing, and return rates for natural spawners. Analysis of genetic and otolith samples would enable determination of parentage and the proportion of the *O. mykiss* population that exhibits anadromy.

Yuba River

Program Title: Monitoring movement patterns of steelhead/rainbow trout on the lower Yuba River using acoustic telemetry.

Program Manager (PI): Jonathan Nelson
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CDFG
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Target Species and Lifestage: Juvenile and adult steelhead/rainbow trout

Stream Reach(es): Yuba River from Englebright Dam downstream to the Sacramento River, through the Sacramento-San Joaquin Delta, through San Francisco Bay, and into the Pacific Ocean.

Program Objective(s): Pilot study to assess equipment and resource needs to monitor local movements of juvenile and adult steelhead and rainbow trout within the lower Yuba River. Monitor smolt migration towards the Pacific Ocean.

Methodology(ies): Acoustic and PIT tags will be surgically implanted in both juvenile (minimum 200 mm fork length) and adult *O. mykiss* in the Yuba River. Fish will be captured primarily using hook and line, but will be tagged opportunistically at the Yuba River rotary screw trap (see pages 63-64) if necessary. Receivers placed through the Yuba River record the date and time as fish pass, along with the transmitter code that allows each transmitter to be uniquely identified. Data will be retrieved from acoustic receivers at a minimum of four times per year.

Data Analysis: Data will be analyzed to determine local movements through the river, to identify preferred habitat types, determine movement above and below Daguerre Point Dam, identify movement into and through the Feather and Sacramento rivers, identify seasonal migration timing, distances moved per day, movement direction and path, residence time, and survival estimates (overall and reach specific). Movements will be analyzed in relation to flow and water temperature conditions in the Yuba River.

Data Retrieval: Contact Jonathan Nelson or Roger Bloom

Reporting: Summary report in January 2009

Program History: Pilot study initiated in March 2008

Funding: Funded through the Steelhead Report and Restoration Card through June 2009

Program Strengths and Weaknesses: Collaboration with multi agency consortium provides monitoring of fish movements for not only the Yuba River but throughout the Sacramento-San Joaquin Delta and into San Francisco Bay. Information gained from this study will contribute to the understanding of *O. mykiss* movement in the CV.

Putah Creek

Program Title: Fish assemblages in lower Putah Creek

Program Manager (PI): Peter Moyle
Department of Wildlife, Fish, and Conservation Biology
1369 Academic Surge
University of California – Davis
Davis, California 95616
(530) 752-6355
pbmoyle@ucdavis.edu

Target Species and Lifestage: All species present

Stream Reaches: Multiple sampling locations between Putah Diversion Dam and Mace Boulevard

Program Objective(s): Determine effects of flow regime on native and introduced species present in lower Putah Creek, describe spatial and temporal changes in fish assemblages.

Sampling Time: Late spring and early fall

Methodology(ies): Fish assemblages were sampled using beach seines, gill nets, and backpack electrofishing gear. Captured fish are identified, counted, and measured. Environmental variables (streamflow, depth, turbidity, surface temperature, conductance, percent canopy cover, in-stream cover, substrate size, and habitat type) were also recorded at each site.

Data Analysis: Fish assemblages and environmental variables analyzed using canonical correspondence analysis

Data Retrieval: Contact Peter Moyle or Pat Crain

Pat Crain
Department of Wildlife, Fish, and Conservation Biology
1363 Academic Surge
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Reporting: Peer-reviewed papers available, annual reports to finding agencies.

Program History: Ongoing since 1980, with more intense sampling from 1995-present.

Funding: Putah Creek Council, Solano Water Agency, UC Davis Putah-Cache Bioregion Project, Putah creek Coordinating Committee

Program Strengths and Weaknesses: Putah Creek likely does not support a steelhead population. It is possible that during wet years steelhead will be able to ascend Putah Creek and spawn. This project may be able to detect juvenile steelhead (presence or absence), but positive identification is hampered by the large rainbow trout population located between Putah Diversion Dam and Monticello Dam (these fish may move downstream).

Mokelumne River

Program Title: Acoustic Tagging of Juvenile Steelhead on the Mokelumne River

Program Manager (PI): Rob Titus
California Fish and Game
8175 F Alpine Avenue
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(916) 227-6390
rtitus@dfg.ca.gov

Walter Heady
University of California, Santa Cruz
(831) 234-2942
heady@biology.ucsc.edu

Target Species and Lifestage: Naturally produced ("wild") steelhead smolts

Stream Reach(es): Mokelumne River from Camanche Dam downstream to the Sacramento-San Joaquin Delta, and through the San Francisco Bay to the Pacific Ocean.

Program Objective(s): Determine when steelhead smolts leave the lower Mokelumne River; determine migration routes through the Sacramento-San Joaquin Delta and San Francisco Bay to the Pacific Ocean. Determine migration rates, mortality rates, positive habitat associations, monitor in-river habitat associations, in-river movement, site fidelity, territorial interactions between resident and anadromous life histories, and population level consequences.

Methodology(ies): Fish are surgically tagged with acoustic transmitters that allow monitoring of fish movement within the Mokelumne River, through the Sacramento-San Joaquin Delta, and into the San Pablo and San Francisco Bays. Fish are captured using rotary screw traps operated by the East Bay Municipal Utility District (see pages 85-86), measured, weighed, sexed, life stage is determined, and a scale and tissue samples are collected. Additional fish may be captured using boat electrofishing, seine netting, and hook and line sampling.

Data Analysis: Data will be analyzed to determine steelhead smolt emigration timing, emigration rate, emigration direction and pathways, residence times, survival rates, habitat associations, mortality within discrete reaches, territorial interactions, home-range sizes, in-stream movement, site fidelity, and how these interactions affect life history, movement, and survival.

Data Retrieval: Contact Walter Heady

Reporting: Project summary report and doctoral dissertation forthcoming

Program History: Project initiated in 2007

Funding: Funded through the California Urban Water Agency (2007), Steelhead Report and Restoration Card (2008-2009), CALFED Science Doctoral Fellowship Program.

Program Strengths and Weaknesses: Collaboration and data sharing between the U. S. Fish and Wildlife Service and other agencies has allowed monitoring of fish movements through the Sacramento-San Joaquin Delta and into San Francisco Bay. This project answers a major question in determining the movement paths of age 1 hatchery steelhead through the Mokelumne River and Sacramento-San Joaquin Delta, as well as determining the proportion of naturally produced fish that exhibit anadromy. This project was developed in collaboration with work conducted by James Smith, EBMUD (pages 129-130).

Mokelumne River

Program Title: Mokelumne River Steelhead Movement Study

Program Manager (PI): Jim Smith
East Bay Municipal Utility District
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jsmith@ebmud.com

Target Species and Lifestage: Juvenile steelhead

Stream Reach(es): The entire Mokelumne River downstream of Camanche Dam.

Program Objective(s): Determine movement and emigration patterns of natural and hatchery produced age 1 steelhead. Determine emigration patterns of post-spawn adult steelhead. Evaluate the effect of hatchery planting location on fish movement patterns and ultimately on returns to Mokelumne River Hatchery. Determine causes of losses of planted hatchery steelhead in the Mokelumne River.

Methodology(ies): Fish are surgically tagged with acoustic transmitters that allow monitoring of fish movement within the Mokelumne River, through the Sacramento-San Joaquin Delta, and into the San Pablo and San Francisco Bays. Hatchery (n = 60) and naturally produced fish (n = 64) and post-spawn adults (n = 10) were tagged in 2007. Tagging in 2008 will focus entirely on hatchery fish age 1 (n = 95), and post spawn adults (n = 10).

Data Analysis: Movement patterns, determination of losses of fish to predators in the Mokelumne River, and determination of residency rates.

Data Retrieval: Contact Jim Smith

Reporting: Annual report available in 2008

Program History: Project initiated in 2007

Funding: Funded through the California Urban Water Agency (2007), the U. S. Fish and Wildlife Service (2008), and CDFG (2008). Future funding is unsecured.

Program Strengths and Weaknesses: Collaboration and data sharing between the U. S. Fish and Wildlife Service and other agencies has allowed monitoring of fish movements through the Sacramento-San Joaquin Delta and into San Francisco Bay. This project answers a major question in determining the movement paths of age-1 hatchery steelhead through the Mokelumne River and Sacramento-San Joaquin Delta, as well as determining the proportion of naturally produced fish that exhibit anadromy. This project was

developed in collaboration with work conducted for Walter Heady's doctoral dissertation at UCSC (pages 127-128).

Potential Monitoring Improvements: Potential Monitoring Improvements: Future efforts on the Mokelumne River should focus on using genetics studies and otolith analysis to determine parentage of resident fish and the proportion of the population (steelhead and rainbow trout) that still exhibits anadromy.

Merced River

Program Title: Merced River Restoration Evaluation and Monitoring

Program Manager (PI): Steve Zeug
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Target Species and Lifestage: All species present in restored and unrestored reaches.

Stream Reach(es): The Merced River (throughout restored and unrestored reaches)

Program Objective(s): Determine spatial and temporal variability in the habitat conditions and environmental variables that influence the structure of native fish communities in the Merced River and provide insights into factors limiting the successful establishment of native fish communities in unrestored reaches.

Sampling Time: January through July

Methodology(ies): Methodology consists of a series of seine hauls every two weeks in randomly selected pool habitats in both restored and unrestored reaches (6 pools per reach). In addition to seining, backpack electrofishing and minnow traps are used to sample fishes from complex habitats that are not effectively sampled with beach seines. Sampling effort is increased to three times weekly from January through July to evaluate patterns of habitat use of juvenile Chinook salmon. Environmental and habitat variables are recorded to associate fish community structure and Chinook abundance.

Data Analysis: Comparisons between restored and unrestored reaches to determine limitations to the development of fish communities. Fish abundance is determined using catch-per-effort as an indicator, and species richness and diversity will be determined and compared between reaches.

Data Retrieval: Contact Steve Zeug

Reporting: Annual California Bay-Delta reports, will be published in peer-reviewed journals at end of study.

Program History: Project initiated in 2008.

Funding: Funded through a California Bay-Delta Authority grant through 2010.

Program Strengths and Weaknesses: Cannot be assessed until sampling begins. Initial plans are hampered by low numbers of anadromous fish in the Merced River.

Potential Monitoring Improvements: Determine the proximate and ultimate causes of salmonid declines in the CV.

Summary

Although steelhead monitoring sites are present on many of the rivers and creeks in the CV (Figure 3), many of these sites are sampled intermittently and the sampling protocols are designed primarily to monitor Chinook salmon populations. For example, the Stanislaus River weir (pages 97-98) is operated to determine Chinook escapement. The weir is in operation from September through January, which encompasses the majority of the fall run Chinook immigration. The weir is capable of generating steelhead passage during this time period, but because steelhead immigration and spawning takes place over a protracted period (typically September through April), the weir is not capable of monitoring the entire run. Sixty-three monitoring programs are identified in this report that have the potential to monitor steelhead populations. Of these programs, only nine (14%) specifically targeted steelhead.

Of the 63 programs identified in this review, 21 projects are designed to monitor adult abundance and trends, although only eight of these 21 projects monitor steelhead with meaningful confidence. The remaining programs cannot calculate and do not report confidence intervals or standard errors associated with estimates, so the accuracy of the estimate is uncertain and statistical power of trend detection is unknown. Three of these eight programs draw upon a historical dataset (Mokelumne River video monitoring, pages 81-82; Ladder counts at RBDD, pages 16-17; and the Vaki system on the Yuba River, pages 65-66). The remaining five programs are in various phases of development and implementation (Tuolumne River weir, pages 101-102; Feather River Weir, pages 61-62) or have very limited datasets (Stanislaus Weir, pages 97-98; Antelope Creek video monitoring, pages 32-33; Mill Creek video monitoring, pages 34-35).

Although 36 of the 63 programs listed in this review are designed to monitor juvenile anadromous fish, none of these programs are capable of generating abundance, production estimates, or trend data for juvenile steelhead. These data are required to adequately assess progress towards recovery goals mandated by the *Central Valley Project Improvement Act, Salmon, Steelhead Trout and Anadromous Fisheries Act*, *California Endangered Species Act*, and the federal *Endangered Species Act*. Captures of juvenile steelhead are too low (resulting in low confidence in the estimate) throughout the CV for a meaningful assessment of production or trends. Low capture numbers likely result from a low number of juvenile steelhead present in the river and larger emigration size (larger fish can more easily avoid sampling gear). Sampling gear efficiency cannot be calibrated for juvenile steelhead for similar reasons. These programs (although incapable of monitoring steelhead populations) continue to exist today primarily to monitor Chinook salmon populations.

Currently, coverage of steelhead monitoring is limited to rivers and streams that also support populations of Chinook salmon. Monitoring efforts should be extended to smaller headwater streams that may be used as spawning and rearing habitat. These areas may be located above natural barriers and inaccessible to Chinook salmon but which are accessible to steelhead (steelhead possess superior jumping ability and migrate during higher flows, which may facilitate navigation around barriers).

Please refer to Appendix A for a summary of steelhead related monitoring sites in the Central Valley.

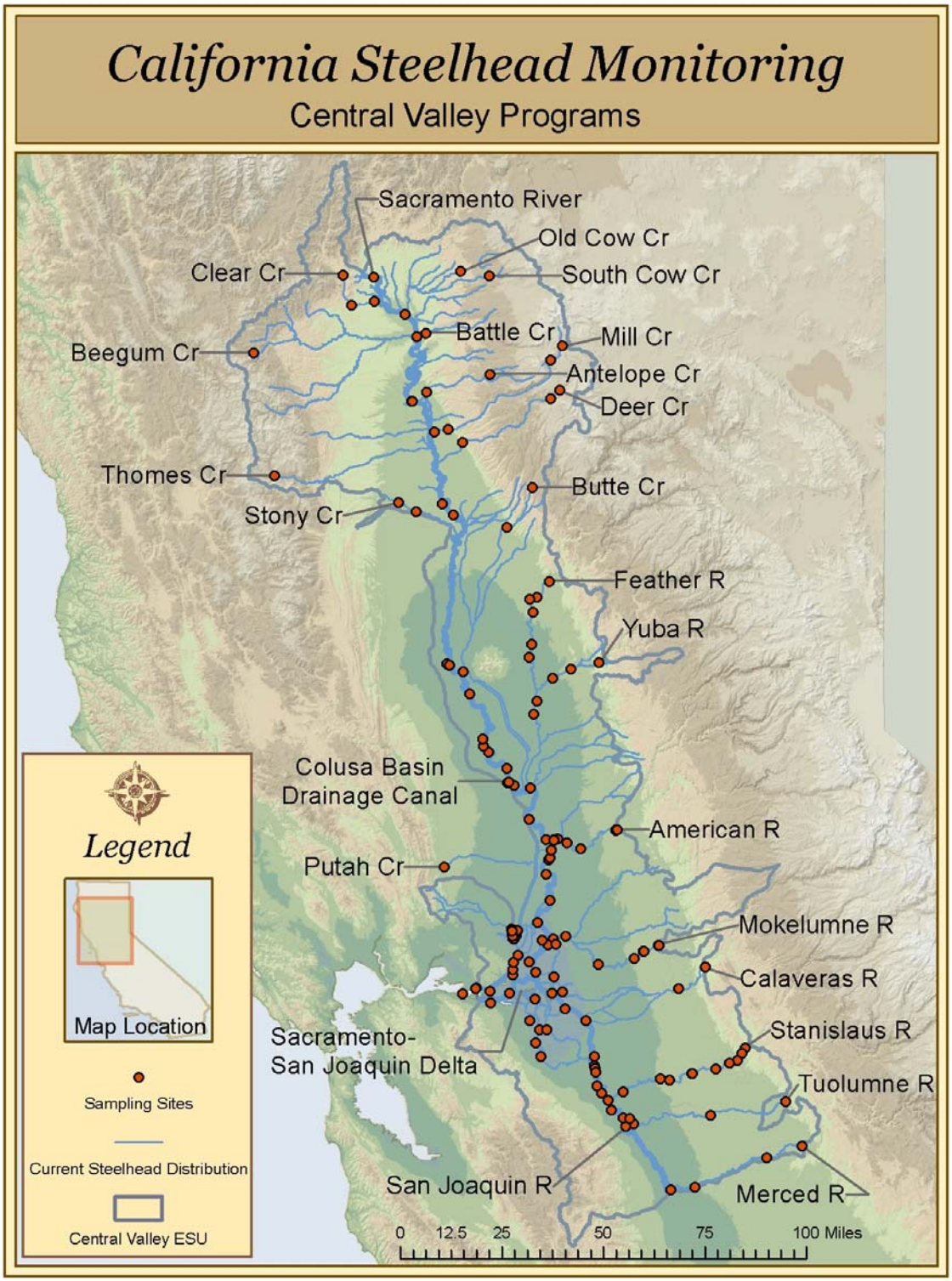

Figure 3. Existing (2007-2008) anadromous fish sampling sites in the Central Valley that may provide steelhead data. Red points indicate sampling sites. Although many of the major rivers and streams throughout the valley are represented, these programs are inadequate for determining steelhead abundance and population trends.

APPENDICES

APPENDIX A

SUMMARY STEELHEAD PROGRAMS IN CALIFORNIA'S CENTRAL VALLEY

Table 1. Adult steelhead monitoring programs in the Central Valley.

Stream	Target Species	Monitoring Method	Variables Measured	Agency	Contact
Sacramento, American, Feather, Yuba, San Joaquin, and Mokelumne Rivers	All Chinook runs, steelhead	Angler Survey	Angler effort and harvest	CDFG	Rob Titus (916) 227-6390
All anadromous waters in the state	Steelhead	Steelhead report card	Angler effort and harvest	CDFG	Terry Jackson (916) 327-8855
Feather, American, and Mokelumne Rivers	Steelhead	Hatchery returns	Abundance, life history patterns	CDFG	Rob Titus (916) 227-6390
Feather, American, and Mokelumne Rivers	Steelhead	Hatchery returns	Escapement	CDFG	Judy Urrutia (916) 445-3462
Upper Sacramento River	All Chinook runs, steelhead	Video	Abundance, immigration timing	CDFG	Doug Killam (530) 527-8893
Old Cow, South Cow, Beegum, Thomes, Paynes, Antelope, Mill, and Deer Creeks	Steelhead	Snorkel surveys	Presence/absence	CDFG	Doug Killam (530) 527-8893
Clear Creek	All Chinook runs, steelhead	Redd survey	Abundance, escapement	USFWS	Matt Brown (530) 527-3043
Battle Creek	All Chinook runs, steelhead	Hatchery returns, fish trap, video monitoring	Abundance, escapement, migration timing	USFWS	Matt Brown & Kevin Niemela (530)527-3043
Antelope Creek	Spring run Chinook, steelhead	Video	Abundance, escapement, migration timing	CDFG	Doug Killam (530) 527-8893

Table 1. Continued.

Stream	Target Species	Monitoring Method	Variables Measured	Agency	Contact
Mill Creek	Spring run Chinook, steelhead	Video	Abundance, escapement, migration timing	CDFG	Doug Killam (530) 527-8893
Butte Creek	Spring run Chinook, steelhead	Snorkel surveys	Escapement, presence/absence	CDFG	Tracy McReynolds (530) 895-5111 & Clint Garman (530) 895-5110
Feather River	Steelhead	Redd survey	Abundance, escapement	DWR	Jason Kindopp (530) 534-2381
Feather River	Steelhead, spring and fall-run Chinook	Trap and weir	Immigration timing, escapement, abundance	DWR	Jason Kindopp (530) 534-2381
Yuba River	All Chinook runs, steelhead	Video and Vaki	Migration timing, escapement, abundance	CDFG	Duane Massa (530) 895-5005
American River	Fall-run Chinook, steelhead	Snorkel survey, redd survey	Distribution, density	USFWS	John Hannon (916) 978-5524
Mokelumne River	Fall-run Chinook, steelhead	Redd survey	Escapement, habitat use	EBMUD	Michelle Workman (209)365-1486
Mokelumne River	Fall-run Chinook, steelhead	Video, fish trap	Escapement, immigration timing, passage estimates	EBMUD	Michelle Workman (209)365-1486
Stanislaus River	Fall-run Chinook, steelhead	Video and Vaki, weir and fish trap	Escapement, immigration timing, passage estimates	USFWS, FISHBIO	John Wikert (209) 334-2968
Tuolumne River	Fall-run Chinook, steelhead	Video and Vaki, weir and fish trap	Escapement, immigration timing, passage estimates	TID, FISHBIO	Michele Palmer (530) 343-2101

Table 2. Juvenile steelhead monitoring programs in the Central Valley.

Stream	Target Species	Monitoring Method	Variables Measured	Agency	Contact
Mainstem Sacramento River	All Chinook runs, steelhead	Rotary screw trap	Abundance, outmigrant timing	USFWS	Bill Poytress (530)527-3043
Mainstem Sacramento River	All Chinook runs, steelhead	Rotary screw trap	Abundance, outmigrant timing	CDFG	Diane Coulon (530)865-9331
Clear Creek	All Chinook runs, steelhead	Rotary screw trap	Abundance, outmigrant timing	USFWS	Matt Brown (530)527-3043
Battle Creek	All Chinook runs, steelhead	Rotary screw trap	Abundance, outmigrant timing	USFWS	Matt Brown (530)527-3043
Mill Creek	Spring-run Chinook, steelhead	Rotary screw trap	Abundance, outmigrant timing	CDFG	Colleen Harvey Arrison (530)527-9490
Mill Creek	Spring and fall-run Chinook, steelhead	Electrofishing, seining	Abundance, emergence timing	CDFG	Colleen Harvey Arrison (530)527-9491
Deer Creek	Spring-run Chinook, steelhead	Rotary screw trap	Relative abundance, outmigrant timing	CDFG	Colleen Harvey Arrison (530)527-9490
Deer Creek	Spring and fall-run Chinook, steelhead	Electrofishing, seining	Abundance, emergence timing	CDFG	Colleen Harvey Arrison (530)527-9491
Stony Creek	All Chinook runs, steelhead	Beach seine, fyke net	Presence/absence	USBR	Richard Corwin (530)528-0512
Butte Creek	Spring-run Chinook, steelhead	Rotary screw trap	Abundance, outmigrant timing	CDFG	Tracy McReynolds (530) 895-5111 Clint Garman (530) 895-5110
Lower Sacramento River	All Chinook runs, steelhead	Rotary screw trap	Abundance, outmigrant timing	CDFG	Robert Vincik (916) 227-6842

Table 2. Continued.

Stream	Target Species	Monitoring Method	Variables Measured	Agency	Contact
Lower Sacramento River	All Chinook runs, steelhead	Kodiak/mid-water trawl	Spatial / temporal distribution, outmigration timing	USFWS	Paul Cadrett (209)946-6400
Sacramento River and Feather River	Winter-run and spring-run Chinook, steelhead	Fyke nets and filtration boxes on diversions	Diversion mortality	NRS	Dave Vogel (530) 527-9587
Feather River	Fall and Spring-run Chinook, steelhead	Rotary screw trap	Abundance, outmigrant timing	DWR	Jason Kindopp (530) 534-2381
Feather River	Steelhead	Snorkel, electrofishing, enclosures	Distribution, abundance, habitat use, growth	DWR	Jason Kindopp (530) 534-2381,
Yuba River	Fall-run, spring-run Chinook, steelhead	Rotary screw trap	Abundance, outmigrant timing	CDFG	Duane Massa (530) 895-5005
American River	Fall-run Chinook, steelhead	Rotary screw trap	Abundance, outmigrant timing	CDFG	Mike Healey (916) 358-4334
American and Mokelumne Rivers	Steelhead	Angling, seining, PIT tagging, acoustic tagging, electrofishing	Environmental variables related to fish emigration	CDFG, UCSC, NMFS	Rob Titus (916) 227-6390
Putah Creek	All species present	Electrofishing	Fish assemblages, environmental variables	UCD	Peter Moyle (530) 752-6355
Lower Sacramento River, Lower San Joaquin River, North Delta, Central Delta, South Delta, San Francisco/San Pablo Bays	All Chinook runs	Beach seine	Abundance, outmigrant timing, recovery of marked smolts	USFWS	Paul Cadrett (209)946-6400
Suisun Bay	All Chinook runs	Mid-water trawl	Abundance, outmigrant timing, recovery of marked smolts	USFWS	Paul Cadrett (209) 946-6400

Table 2. Continued.

Stream	Target Species	Monitoring Method	Variables Measured	Agency	Contact
Mokelumne River	Fall-run Chinook, steelhead	Seining and electrofishing	Distribution, abundance	EBMUD	Michelle Workman (209)365-1486
Mokelumne River	Fall-run Chinook, steelhead	Rotary screw trap	Abundance outmigrant timing	EBMUD	Michelle Workman (209)365-1486
Mokelumne River	Steelhead	Acoustic tagging	Migration timing and paths, residency rates	EBMUD	Jim Smith (209) 365-1467
San Joaquin River	Fall-run Chinook, steelhead	Kodiak trawl at Mossdale	Abundance outmigrant timing	CDFG	Tim Heyne (209) 853-2533
Calaveras River	Fall-run Chinook, steelhead	Rotary screw trap	Abundance outmigrant timing	FISHBIO	Michele Palmer (530) 343-2101
Stanislaus River	Fall-run Chinook, steelhead	Rotary screw trap	Abundance outmigrant timing	FISHBIO	Michele Palmer (530) 343-2101
Stanislaus River	Fall-run Chinook, steelhead	Rotary screw trap	Abundance outmigrant timing	USFWS CFS	Clark Watry (209) 847-7786
Stanislaus River	Fall-run Chinook, steelhead	Snorkel survey	Spatial/temporal distribution, density	USBR	John Hannon (916)978-5524
Stanislaus River	Chinook and steelhead	Snorkel (primary) seining, electrofishing	Abundance, environmental variables	USBR	Mark Bowen (303) 445-2222
Tuolumne River	Fall-run Chinook, steelhead	Rotary screw trap	Abundance, outmigrant timing, recovery of marked smolts	TID	Tim Ford (209)883-8275
Tuolumne River	Fall-run Chinook, steelhead	Beach Seining, snorkel surveys	Abundance, outmigrant timing, recovery of marked smolts	TID	Tim Ford (209)883-8275

Table 2. Continued.

Stream	Target Species	Monitoring Method	Variables Measured	Agency	Contact
Merced River	Fall-run Chinook, O. mykiss	Rotary screw trap	Abundance, outmigrant timing, presence and absence	NRS, MID	Dave Vogel (530) 527-9587
Merced River	Fall-run Chinook, O. mykiss	Rotary screw trap	Abundance, outmigrant timing, presence/absence	USFWS CFS	John Montgomery (209) 847-7787
Merced River	Fall-run Chinook, O. mykiss	Rotary screw trap	Abundance, outmigrant timing	CDFG	Dennis Blakeman (209) 853-2533
Merced River	Fall-run Chinook, O. mykiss, all other species present	Beach seine, electrofishing, minnow traps	Species richness, species diversity, habitat use	UCSB	Steve Zeug (805) 893-4989

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