

# Monitoring Steelhead Populations in the San Joaquin Basin - *Oncorhynchus mykiss* Monitoring and Research Gap Analysis

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## Introduction

*Oncorhynchus mykiss* are distributed throughout most watersheds in the California Central Valley (Williams 2006). Although the effective population size of California Central Valley *O. mykiss* is still relatively high with significant genetic structure among populations (Nielson et al. 2003), the proportion of fish that adopt an anadromous life-history (i.e., steelhead) has steadily declined over past decades (Williams et al. 2016). Indeed, the anadromous form of this species is often in low abundance throughout the Central Valley, particularly in the San Joaquin Basin (Williams et al. 2016), which led to their listing as threatened under the Endangered Species Act (ESA) in 1998 (Volume 63 Federal Register, 13347-13371) and reaffirmed in 2006 (Volume 71 Federal Register, 834-862).

The continued decline of steelhead population numbers highlights the need for coordinated research and monitoring of *O. mykiss*. Towards this aim, the California Department of Fish and Wildlife led an effort in 2008 to characterize historical and ongoing *O. mykiss* monitoring programs in the California Central Valley (Eilers 2010). Through this review, Eilers (2010) identified a suite of monitoring programs generating data on *O. mykiss*, but determined that monitoring was not standardized, often designed for Chinook salmon (*Oncorhynchus tshawytscha*) populations, and inadequate for assessing population viability (Lindley et al. 2007). Specifically, a total 63 *O. mykiss* monitoring programs were identified during the review, but only eight projects were reported to monitor *O. mykiss* with meaningful confidence, and none could generate abundance or production estimates for juvenile *O. mykiss*. Overall, monitoring coverage was generally limited to streams that also supported populations of Chinook salmon. As

a result, the Central Valley Steelhead (*O. mykiss*) Monitoring Plan was developed to identify actions needed to provide population data for the assessment of steelhead recovery (Eilers et al. 2010). Recommendations included adult abundance monitoring in the mainstem Sacramento River, distribution monitoring using spatially balanced sampling across the Central Valley, and monitoring in priority streams within the Northwestern California, Basalt and Porous Lava, Northern Sierra Nevada, and Southern Sierra Nevada Diversity Groups (NMFS 2014).

Several years after the completion of the Central Valley Steelhead Monitoring Plan, a series of related monitoring projects, identified as the Central Valley Steelhead Monitoring Program (CVSMP), were initiated on the Sacramento River and its tributaries. These projects include the mainstem Sacramento River mark-recapture project, Sacramento River tributary mark-recapture monitoring, upper Sacramento River tributary escapement monitoring, and hatchery broodstock and angler harvest sampling. The program utilizes a variety of methods including large wire fyke traps, rotary screw traps, Passive Integrated Transponder (PIT) tag arrays, acoustic monitoring, resistance board weirs, and hook and line sampling with the goals of establishing Sacramento River basin-wide adult abundance estimates for wild and hatchery origin *O. mykiss*, producing adult *O. mykiss* abundance estimates for select streams, and determining the spatial distribution of *O. mykiss* in the Central Valley. In addition, many population monitoring projects in priority streams outside of the CVSMP continue and in some cases have been expanded to encompass the entire *O. mykiss* immigration and spawning period.

In the fall of 2020, a small group of state and federal scientists initiated a follow-up review from Eilers 2010. The primary purpose of this review is to identify where gaps in our monitoring network and approach have been filled and where gaps persist (i.e., '2020 gap analysis'). These gaps may represent physical monitoring elements like infrastructure (e.g., rotary screw traps [RST], PIT tag antennas), gaps in spatial or temporal scope of monitoring, and/or intellectual gaps (e.g., theoretical drivers of life-history expression). Identifying persistent gaps in our monitoring network will enable managers to optimize resource allocation, thus strengthening our system-wide *O. mykiss* research and monitoring program.

The 2020 gap analysis team contacted over 50 researchers with knowledge of *O. mykiss* research and monitoring that has been, or is currently being, implemented in over 30 Central Valley streams and rivers (Figure 1, Appendix A). This effort enabled the gap analysis team to characterize new *O. mykiss* monitoring in Sacramento and San Joaquin tributaries (Appendix A), and initiate data compilation from Central Valley hatchery programs (Table 1) and ongoing monitoring programs (see example below). The majority of the new research and monitoring effort stems from the initiatives outlined in the CVSMP as described above. However, over the last decade new research and

monitoring has been implemented or planned in several San Joaquin tributaries including the Calaveras and Stanislaus Rivers (Appendix A).

Table 1. California Central Valley hatchery trapping data gathered for 2020 *O. mykiss* gap analysis organized by Diversity Group and Johnson et al. 2017 regions (see maps below). The California Central Valley Steelhead Distinct Population Segment (DPS) includes steelhead from the Coleman National Fish Hatchery Program, the Feather River Fish Hatchery Program, and the Mokelumne River Hatchery Program.

| <b>Diversity Group/Region</b> | <b>Hatchery Name</b>           | <b>Hatchery Location</b> | <b>Life stage</b> | <b>Duration</b> |
|-------------------------------|--------------------------------|--------------------------|-------------------|-----------------|
| Southern Sierra Nevada        | Mokelumne River Fish Hatchery  | Lower Mokelumne River    | Adult             | 1964-2001       |
| Southern Sierra Nevada        | Mokelumne River Fish Hatchery  | Lower Mokelumne River    | Juvenile & Adult  | 2002-present    |
| American River Mainstem       | Nimbus Fish Hatchery           | Lower American River     | Adult             | 1955-1986       |
| American River Mainstem       | Nimbus Fish Hatchery           | Lower American River     | Juvenile & Adult  | 1986-present    |
| Feather River Mainstem        | Feather River Fish Hatchery    | Lower Feather River      | Adult             | 1968-1999       |
| Feather River Mainstem        | Feather River Fish Hatchery    | Lower Feather River      | Juvenile & Adult  | 2000-present    |
| Basalt and Porous Lava        | Coleman National Fish Hatchery | Battle Creek             | Adult             | 1990-present    |

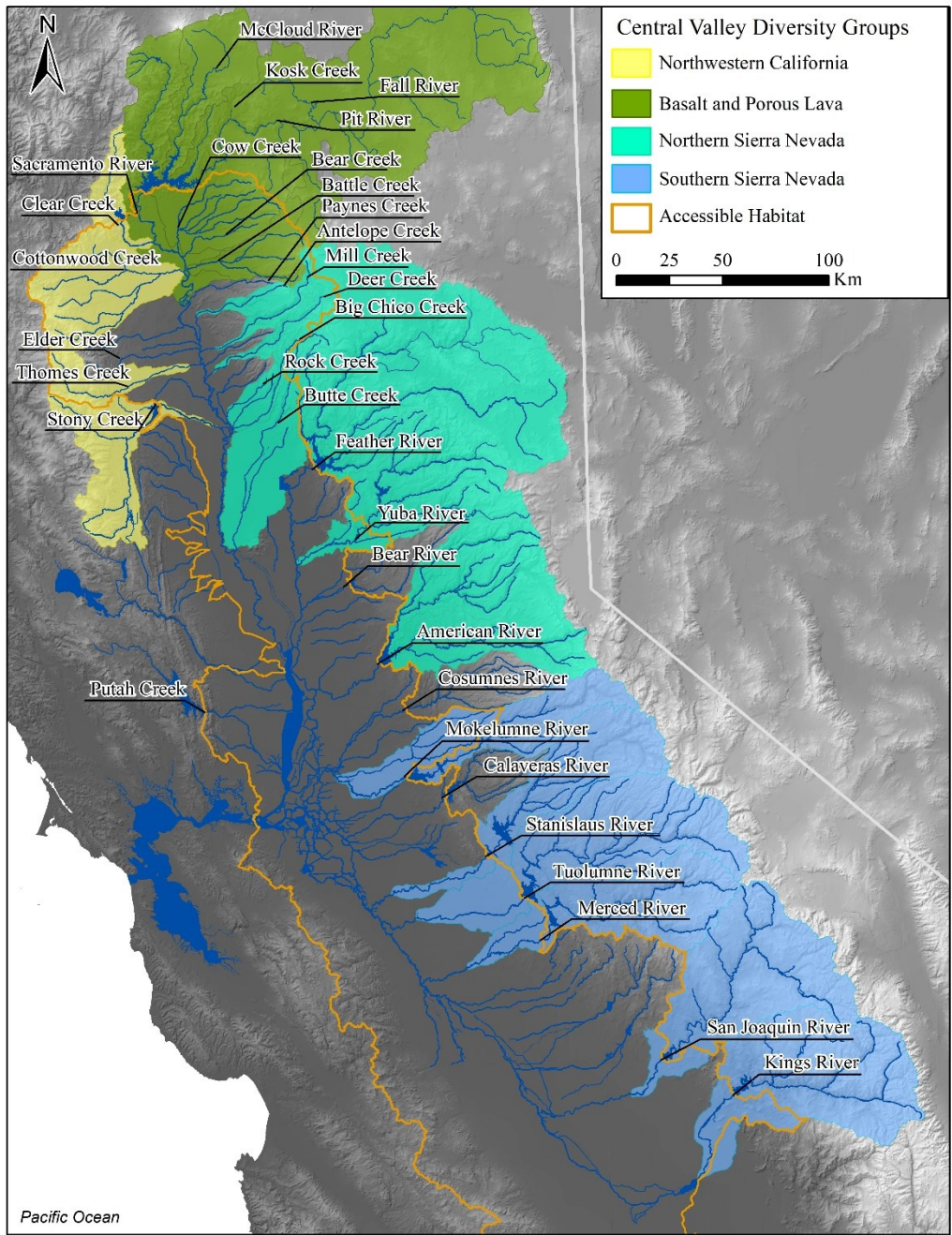


Figure 1. Map illustrating the location of target watersheds in the 2020 gap analysis and distribution within Central Valley diversity groups. For a complete list of watersheds and monitoring activities see Appendix A.

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## Knowledge gaps and next steps

Although progress has been made towards coordinating Central Valley *O. mykiss* research and monitoring, our ability to quantify demographics and vital rates, or generate a steelhead juvenile production estimate remains limited. Current monitoring efforts are skewed towards watersheds in the Northern Sierra Nevada, and Basalt and Porous Lava Diversity Groups (Figure 1, Appendix A). Although there are new monitoring efforts underway in the San Joaquin Basin and Southern Sierra Nevada Diversity Group, these programs have been developed and implemented independent of one another. Further, the data generated from these programs is often difficult to access by the public and/or is unavailable. As such, there is a clear need to develop a plan for coordinating *O. mykiss* research and monitoring in this region and integrating the data they generate.

Integrating *O. mykiss* monitoring datasets across regions and programs will foster and accelerate learning opportunities. For example, the 2020 gap analysis provided an opportunity to compile and conduct preliminary analyses on monitoring data from the U.S. Fish and Wildlife Service Delta Juvenile Fish Monitoring Program (DJFMP). These survey data were used to assess the seasonal presence of *O. mykiss* in the Bay-Delta. In this example, the likelihood of *O. mykiss* presence in the DJFMP surveys was compared over space and time (Figure 2). Likelihood of presence is defined here as the proportion of years in which a survey caught *O. mykiss* in a given month. Data were compared before and after the implementation of 100% hatchery marking in 1998. Collectively, *O. mykiss* are most likely present in the Delta from January through May and least likely present from July through December (especially after 1998). While these data have had minimal processing (i.e., no efficiency work has been conducted with *O. mykiss*), interesting spatial patterns emerge. For instance, we see a protracted presence of *O. mykiss* in the northern and central Delta (Sacramento and Chipps Island trawls, and Lower Sacramento, Northern Delta, and Southern Delta seine regions) where there have been individuals caught almost year-round. Compare this to the southern Delta and San Joaquin River where *O. mykiss* were observed mainly from March through May with very low presence surrounding those months. Since 1998, these surveys have remained relatively consistent with year-round sampling, so differences in presence observed in Figure 2 are not a result of differences in sampling schedules. However before implementing year-round sampling in the mid-1990s (except at the Mossdale trawl site, which started in 2003), interpreting the likelihood of *O. mykiss* presence outside of the Chinook migratory season should be done with caution. An interesting extension to this work would be to compare the temporal presence of *O. mykiss* along the migratory pathways. Differences between the Sacramento and San Joaquin River basins should be evident and could help elucidate important drivers of *O. mykiss* outmigration in the Central Valley using more appropriate analytical techniques that account for detection, such as occupancy modeling.

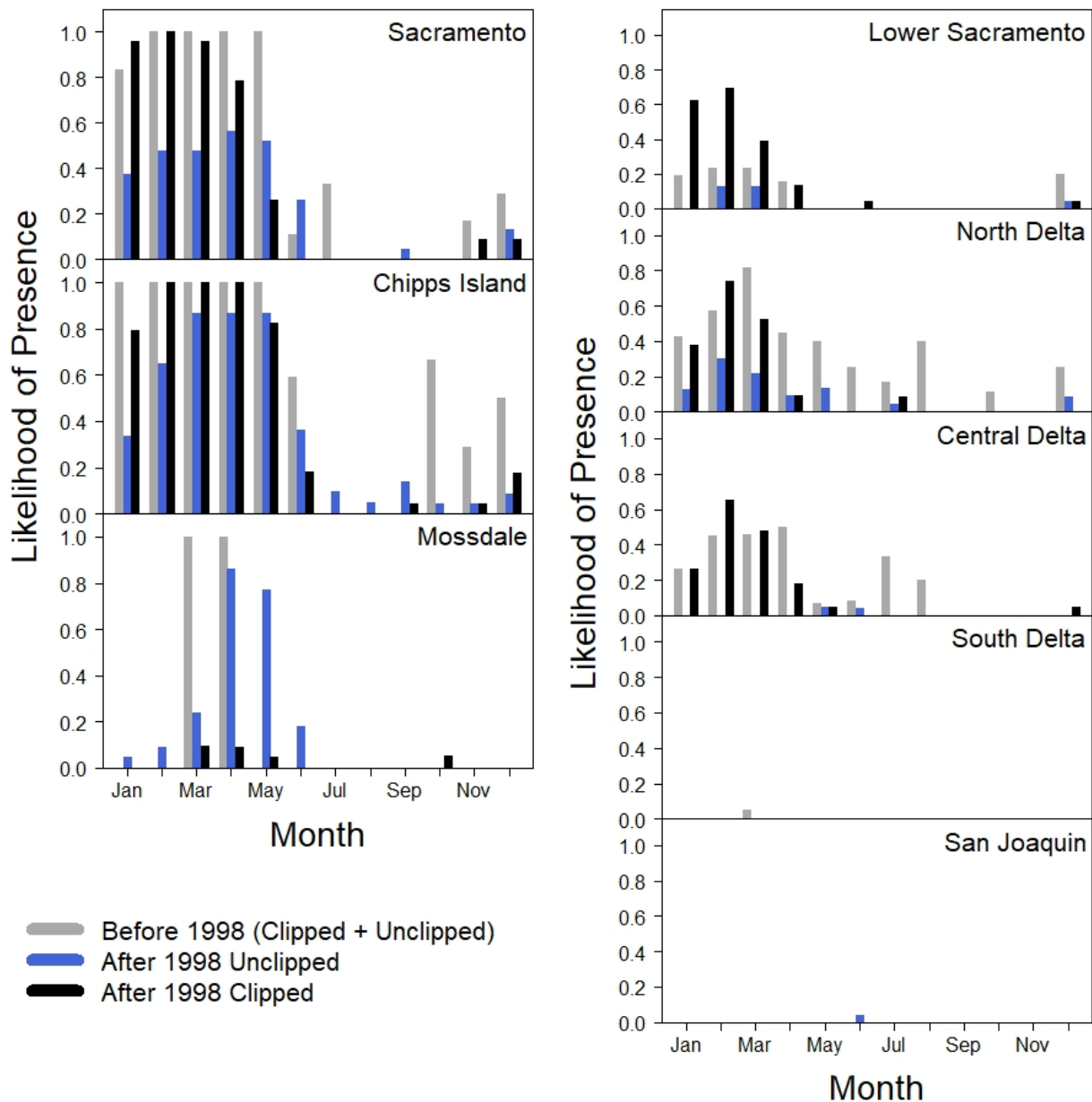


Figure 2. Likelihood of *O. mykiss* presence in the DJFMP surveys before and after implementation of 100% marking of hatchery releases in 1998. Sample stations are ordered from north to south, left panels are trawl locations and right panels are beach seine regions. Likelihood of presence is defined here as the proportion of years in which a survey caught *O. mykiss* in a given month. Please note that in years before 1998 surveys were often not conducted year-round (see Table and text).

Figure 2 is an eight-panel figure of the likelihood of *O. mykiss* presence in the DJFMP surveys before 1998 (implementation of 100% marking of hatchery releases) after 1998 unclipped (wild) and after 1998 clipped (hatchery origin). Left panels are trawl locations (Sacramento, Chipps and Mosssdale) and right panels are beach seine regions (Sacramento River, North, Central and South Delta, and San Joaquin River).

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## Appendices

Appendix A. Preliminary compilation of sampling efforts identified during the 2020 O. mykiss gap analysis. The table is organized by NOAA Diversity Group and Johnson et al. 2017 regions for the mainstem Sacramento River. Note the NMFS 2014 Recovery Plan sometimes lists Mokelumne River in the Northern Sierra Nevada diversity group, but it is considered to be in the Southern Sierra Nevada Diversity Group.

| Diversity Group/Region | Location         | Core Population | Life stage          | Sampling Method         | Duration                         |
|------------------------|------------------|-----------------|---------------------|-------------------------|----------------------------------|
| Southern Sierra Nevada | Calaveras River  | Core 1          | Juvenile & Subadult | Rotary Screw Trap       | 2002 – present                   |
| Southern Sierra Nevada | Calaveras River  | Core 1          | Adult               | Video                   | 2017 – present                   |
| Southern Sierra Nevada | Calaveras River  | Core 1          | Adult               | Redd Surveys            | 2014 – present                   |
| Southern Sierra Nevada | Calaveras River  | Core 1          | Juvenile & Adult    | Snorkel Surveys         | 2011 – present                   |
| Southern Sierra Nevada | Calaveras River  | Core 1          | Juvenile & Subadult | Angling (Hook & Line)   | 2019 – present                   |
| Southern Sierra Nevada | Calaveras River  | Core 1          | Juvenile & Subadult | Backpack Electrofishing | 2019 – present                   |
| Southern Sierra Nevada | Calaveras River  | Core 1          | Juvenile & Subadult | Seine                   | 2019 – present                   |
| Southern Sierra Nevada | Tuolumne River   | Core 2          | Juvenile & Adult    | Seine                   | 1986 – present                   |
| Southern Sierra Nevada | Tuolumne River   | Core 2          | Juvenile & Adult    | Rotary Screw Trap       | 1995 – present                   |
| Southern Sierra Nevada | Tuolumne River   | Core 2          | Juvenile & Adult    | Weir                    | 2009 – present                   |
| Southern Sierra Nevada | Tuolumne River   | Core 2          | Juvenile & Adult    | Redd Survey             | 2012 – present                   |
| Southern Sierra Nevada | Tuolumne River   | Core 2          | Juvenile & Adult    | Snorkel Survey          | 1982 – present                   |
| Southern Sierra Nevada | Stanislaus River | Core 2          | Juvenile            | Rotary Screw Trap       | 1993, 1995, 1996, 1998 – present |



| <b>Diversity Group/Region</b> | <b>Location</b>                     | <b>Core Population</b> | <b>Life stage</b> | <b>Sampling Method</b>  | <b>Duration</b>          |
|-------------------------------|-------------------------------------|------------------------|-------------------|-------------------------|--------------------------|
| Southern Sierra Nevada        | Stanislaus River                    | Core 2                 | Juvenile & Adult  | Weir                    | 2003 – present           |
| Southern Sierra Nevada        | Stanislaus River                    | Core 2                 | Juvenile & Adult  | Snorkel Surveys         | 2002 – present           |
| Southern Sierra Nevada        | Merced River                        | Core 2                 | Juvenile & Adult  | Snorkel Survey          | 2014 – 2015              |
| Southern Sierra Nevada        | Merced River                        | Core 2                 | Juvenile          | Weir                    | 2012                     |
| Southern Sierra Nevada        | Merced River                        | Core 2                 | Juvenile          | Rotary Screw Trap       | 1999 – 2006              |
| San Joaquin River             | Mossdale                            | NA                     | Juvenile          | Trawl                   | 1988 – present           |
| San Joaquin River             | upstream of Merced River Confluence | NA                     | Adult             | Electrofishing          | 2012 – 2014, 2017 – 2020 |
| San Joaquin River             | upstream of Merced River Confluence | NA                     | Adult             | Fyke Trap               | 2012 – 2014, 2017 – 2020 |
| Tidal Delta, Estuary & Bays   | Napa River                          | NA                     | Juvenile          | Rotary Screw Trap       | 2009 – present           |
| Tidal Delta, Estuary & Bays   | Napa River                          | NA                     | Juvenile          | PIT Tagging             | 2013 – present           |
| Tidal Delta, Estuary & Bays   | Alameda Creek                       | NA                     | Adult             | Redd Survey             | 2000 – present           |
| Tidal Delta, Estuary & Bays   | Alameda Creek                       | NA                     | Juvenile          | Rotary Screw Trap       | 2013 – present           |
| Tidal Delta, Estuary & Bays   | Alameda Creek                       | NA                     | Juvenile & Adult  | Fyke Trap               | 2013 – present           |
| Tidal Delta, Estuary & Bays   | Alameda Creek                       | NA                     | Juvenile & Adult  | Snorkel Survey          | 2000 – present           |
| Tidal Delta, Estuary & Bays   | Alameda Creek                       | NA                     | Juvenile & Adult  | Electrofishing          | 2000 – present           |
| Tidal Delta, Estuary & Bays   | Alameda Creek                       | NA                     | Juvenile & Adult  | PIT Tagging             | 2013 – present           |
| Tidal Delta, Estuary & Bays   | Alameda Creek                       | NA                     | Juvenile & Adult  | Scale & Tissue Sampling | 2002, 2004 –present      |
| Tidal Delta, Estuary & Bays   | Alameda Creek                       | NA                     | Adult             | Mark Recapture          | 2003, 2009, 2018         |
| Tidal Delta, Estuary & Bays   | Alameda Creek                       | NA                     | Juvenile & Adult  | Predation               | 2004, 2005               |

| <b>Diversity Group/Region</b> | <b>Location</b>       | <b>Core Population</b> | <b>Life stage</b> | <b>Sampling Method</b>                  | <b>Duration</b>                             |
|-------------------------------|-----------------------|------------------------|-------------------|---|---|
| Tidal Delta, Estuary & Bays   | Suisun Creek          | NA                     | Juvenile & Adult  | Electrofishing                          | 1999 – 2001, 2016 – 2020                    |
| Northwestern California       | Putah Creek           | Core 2                 | Juvenile & Adult  | Snorkel Survey                          | 2016, 2018, 2020                            |
| Northwestern California       | Putah Creek           | Core 2                 | Juvenile & Adult  | Electrofishing                          | 1991, 1993 – 2000, 2001 – 2008, 2010 – 2020 |
| Northwestern California       | Putah Creek           | Core 2                 | Juvenile & Adult  | Rotary Screw Trap                       | 2016 – 2019                                 |
| Northwestern California       | Putah Creek           | Core 2                 | Juvenile          | Fyke Trap                               | 2020  |
| Tidal Delta, Estuary & Bays   | Yolo Bypass           | NA                     | Juvenile          | Rotary Screw Trap                       | 1998 – present                              |
| Tidal Delta, Estuary & Bays   | Yolo Bypass           | NA                     | Juvenile          | Beach Seine                             | 1998 – present                              |
| Tidal Delta, Estuary & Bays   | Yolo Bypass           | NA                     | Adult             | Fyke Trap                               | 1998 – present                              |
| Tidal Delta, Estuary & Bays   | Green Valley Creek    | NA                     | Juvenile & Adult  | Electrofishing                          | 1999 – 2001, 2016 – 2020                    |
| Tidal Delta, Estuary & Bays   | San Leandro Creek     | NA                     | Juvenile          | TBD                                     | TBD   |
| Tidal Delta, Estuary & Bays   | Delta                 | NA                     | Juvenile          | Beach Seine                             | 1976 – present                              |
| Tidal Delta, Estuary & Bays   | Chippis Island        | NA                     | Juvenile          | Trawl                                   | 1976 – present                              |
| Tidal Delta, Estuary & Bays   | Sherwood Harbor       | NA                     | Juvenile          | Trawl                                   | 1988 – present                              |
| Tidal Delta, Estuary & Bays   | Delta                 | NA                     | Juvenile          | Acoustic Telemetry                      | 2010 – 2016                                 |
| Tidal Delta, Estuary & Bays   | Delta                 | NA                     | Juvenile          | Electrofishing                          | 2017 – present                              |
| Tidal Delta, Estuary & Bays   | Delta                 | NA                     | Juvenile          | Trawl (Enhanced Delta Smelt Monitoring) | 2016 – present                              |
| Tidal Delta, Estuary & Bays   | Suisun Marsh          | NA                     | TBD               | TBD                                     | TBD   |
| Tidal Delta, Estuary & Bays   | Cache-Lindsey Complex | NA                     | Juvenile          | Electrofishing                          | TBD   |
| Middle Sacramento River       | GCID                  | NA                     | Juvenile          | Rotary Screw Trap                       | 2013 – present                              |

| <b>Diversity Group/Region</b> | <b>Location</b>         | <b>Core Population</b> | <b>Life stage</b> | <b>Sampling Method</b> | <b>Duration</b>             |
|-------------------------------|-------------------------|------------------------|-------------------|------------------------|-----------------------------|
| Middle Sacramento River       | Knight's Landing        | NA                     | Juvenile          | Rotary Screw Trap      | 1996 – present              |
| Middle Sacramento River       | Tisdale Weir            | NA                     | Juvenile          | Rotary Screw Trap      | 2010 – 2018                 |
| Middle Sacramento River       | Tisdale Bypass          | NA                     | Juvenile & Adult  | Fish Rescue            | 2016 – present              |
| Basalt and Porous Lava        | Bear Creek              | NA                     | Adult             | Video                  | 2016 – present              |
| Basalt and Porous Lava        | Cow Creek               | Core 2                 | Adult             | Video                  | 2011 – present              |
| Basalt and Porous Lava        | Red Bluff Diversion Dam | NA                     | Juvenile          | Rotary Screw Trap      | 1994 – present              |
| Northern Sierra Nevada        | Antelope Creek          | Core 1                 | Adult             | Redd Survey            | 2012, 2017, 2018            |
| Northern Sierra Nevada        | Antelope Creek          | Core 1                 | Adult             | Video                  | 2013 – 2015                 |
| Northern Sierra Nevada        | Mill Creek              | Core 1                 | Adult             | Video                  | 2008 – present              |
| Northern Sierra Nevada        | Mill Creek              | Core 1                 | Juvenile          | Rotary Screw Trap      | 1994 – present              |
| Northern Sierra Nevada        | Deer Creek              | Core 1                 | Adult             | Video                  | 2014 – present              |
| Northern Sierra Nevada        | Deer Creek              | Core 1                 | Juvenile          | Rotary Screw Trap      | 1994 – present              |
| Northern Sierra Nevada        | Butte Creek             | Core 2                 | Adult             | Vaki                   | 2014 – 2016, 2019 – present |
| Northern Sierra Nevada        | Butte Creek             | Core 2                 | Juvenile          | Rotary Screw Trap      | 1995 – present              |
| Northern Sierra Nevada        | Butte Creek             | Core 2                 | Juvenile          | Fyke Trap              | 1995 – present              |
| Northern Sierra Nevada        | Big Chico Creek         | Core 2                 | Juvenile          | Rotary Screw Trap      | 1995 – 2006                 |
| Northern Sierra Nevada        | Big Chico Creek         | Core 2                 | Juvenile          | Fyke Trap              | 1995 – 2006                 |
| Northern Sierra Nevada        | Yuba River              | Core 2                 | Adult             | Vaki                   | 2003 – present              |
| Northern Sierra Nevada        | Yuba River              | Core 2                 | Adult             | Redd Survey            | 2008 – present              |
| Northern Sierra Nevada        | Yuba River              | Core 2                 | Juvenile          | Rotary Screw Trap      | 1999 – present              |

| <b>Diversity Group/Region</b> | <b>Location</b> | <b>Core Population</b> | <b>Life stage</b> | <b>Sampling Method</b>          | <b>Duration</b>                          |
|-------------------------------|-----------------|------------------------|-------------------|---------------------------------|--|
| Southern Sierra Nevada        | Mokelumne River | Core 2                 | Adult             | Video                           | 1991 – present                           |
| Southern Sierra Nevada        | Mokelumne River | Core 2                 | Adult             | Redd Survey                     | 1994 – present                           |
| Southern Sierra Nevada        | Mokelumne River | Core 2                 | Juvenile          | Rotary Screw Trap & Bypass trap | 1991 – present                           |
| Southern Sierra Nevada        | Mokelumne River | Core 2                 | Juvenile & Adult  | Electrofishing                  | 1997 – 2016                              |
| Southern Sierra Nevada        | Mokelumne River | Core 2                 | Juvenile          | Beach Seine                     | 1997 – 2016                              |
| Northern Sierra Nevada        | Bear River      | Core 3                 | TBD               | TBD                             | TBD                                      |
| Northern Sierra Nevada        | Feather River   | Core 2                 | Juvenile          | Rotary Screw Trap               | 1996 – present                           |
| Northern Sierra Nevada        | Feather River   | Core 2                 | Juvenile          | Beach Seine                     | 1999 - 2001, 2008 - 2019                 |
| Northern Sierra Nevada        | Feather River   | Core 2                 | Juvenile          | Electrofishing                  | 2000 – 2001, 2020                        |
| Northern Sierra Nevada        | Feather River   | Core 2                 | Juvenile & Adult  | Snorkel Survey                  | 1998 – present                           |
| Northern Sierra Nevada        | Feather River   | Core 2                 | Adult             | Redd Survey                     | 2003, 2005, 2008 – present               |
| Northern Sierra Nevada        | Feather River   | Core 2                 | Juvenile & Adult  | Tissue Collection               | TBD                                      |
| Northern Sierra Nevada        | Feather River   | Core 2                 | Juvenile & Adult  | Angling (Hook & Line)           | 2016 – present                           |
| Northern Sierra Nevada        | Feather River   | Core 2                 | Juvenile & Adult  | Telemetry                       | 2010 – 2015, 2016 – 2019, 2020 – Present |
| Northern Sierra Nevada        | Feather River   | Core 2                 | Juvenile & Adult  | PIT Tagging                     | 2009 – 2011, 2014, 2015, 2016 – present  |
| Northern Sierra Nevada        | Feather River   | Core 2                 | Juvenile          | Fish Rescue                     | 2000 – 2007, 2013 – 2014, 2017           |
| Northern Sierra Nevada        | American River  | Core 2                 | Adults            | Redd Survey                     | 2002 – 2005, 2007, 2009 –present         |
| Northern Sierra Nevada        | American River  | Core 2                 | Juvenile          | Rotary Screw Trap               | 1992 – present                           |
| Northwestern California       | Clear Creek     | Core 1                 | Adult             | Video                           | 2011 – present                           |

| <b>Diversity Group/Region</b> | <b>Location</b>    | <b>Core Population</b> | <b>Life stage</b> | <b>Sampling Method</b>  | <b>Duration</b>  |
|-------------------------------|--------------------|------------------------|-------------------|-------------------------|--|
| Northwestern California       | Clear Creek        | Core 1                 | Adult             | Redd Survey             | 2003 – present   |
| Northwestern California       | Clear Creek        | Core 1                 | Juvenile          | Rotary Screw Trap       | 1998 – present   |
| Northwestern California       | Cottonwood Creek   | Core 2                 | Adult             | Video                   | 2012 – present   |
| Basalt and Porous Lava        | McCloud River      | NA                     | Juvenile & Adult  | Angling (Hook & Line)   | 1998, 2013   |
| Basalt and Porous Lava        | McCloud River      | NA                     | Juvenile & Adult  | Weir Counts             | 1984 – 1987  |
| Basalt and Porous Lava        | McCloud River      | NA                     | Juvenile & Adult  | Creel Census            | 1981, 1982   |
| Basalt and Porous Lava        | McCloud River      | NA                     | Juvenile & Adult  | Angler Survey           | 1990 – present   |
| Basalt and Porous Lava        | Squaw Valley Creek | NA                     | Juvenile & Adult  | Direct Observation      | 2013, 2014   |
| Basalt and Porous Lava        | Squaw Valley Creek | NA                     | Juvenile & Adult  | Backpack Electrofishing | 1986, 1990, 2002                                       |
| Basalt and Porous Lava        | Squaw Valley Creek | NA                     | Juvenile & Adult  | Angling (Hook & Line)   | 2014   |
| Basalt and Porous Lava        | Pit River          | NA                     | Juvenile & Adult  | Angling (Hook & Line)   | TBD  |
| Basalt and Porous Lava        | Pit River          | NA                     | Juvenile & Adult  | Angler Survey           | 1993 – present   |
| Basalt and Porous Lava        | Pit River          | NA                     | Juvenile & Adult  | Direct Observation      | 1993, 1995, 1997 – 1999, 2001, 2004, 2007 – 2010, 2012 |
| Basalt and Porous Lava        | Fall River         | NA                     | Juvenile & Adult  | Direct Observation      | 1993, 1995, 1997 – 1999, 2001, 2004, 2007 – 2010, 2012 |
| Basalt and Porous Lava        | Fall River         | NA                     | Juvenile & Adult  | Creel Census            | 1983, 1988, 1993, 2012                                 |
| Basalt and Porous Lava        | Fall River         | NA                     | Juvenile & Adult  | Boat Electrofishing     | 1980 – 1986, 1988, 1993                                |
| Basalt and Porous Lava        | Fall River         | NA                     | Juvenile & Adult  | Angler Survey           | 2003 – present   |
| Basalt and Porous Lava        | Hat Creek          | NA                     | Juvenile & Adult  | Boat Electrofishing     | 1980 – 1984, 1988, 1991, 1993, 2012                    |

| <b>Diversity Group/Region</b> | <b>Location</b>                  | <b>Core Population</b> | <b>Life stage</b> | <b>Sampling Method</b>  | <b>Duration</b>                            |
|-------------------------------|----------------------------------|------------------------|-------------------|-------------------------|--|
| Basalt and Porous Lava        | Hat Creek                        | NA                     | Juvenile & Adult  | Direct Observation      | 1993, 1995, 1997 – 1999, 2001, 2003 – 2012 |
| Basalt and Porous Lava        | Hat Creek                        | NA                     | Juvenile & Adult  | Creel Census            | 1983, 1988, 1993, 2012                     |
| Basalt and Porous Lava        | Hat Creek                        | NA                     | Juvenile & Adult  | Angler Survey           | 1990 – present                             |
| Basalt and Porous Lava        | Rock Creek                       | NA                     | Juvenile & Adult  | Direct Observation      | 2013                                       |
| Basalt and Porous Lava        | Rock Creek                       | NA                     | Juvenile & Adult  | Backpack Electrofishing | 2018                                       |
| Basalt and Porous Lava        | Potem creek                      | NA                     | Juvenile & Adult  | Backpack Electrofishing | 2018                                       |
| Basalt and Porous Lava        | Kosk Creek                       | NA                     | Juvenile & Adult  | Backpack Electrofishing | 2018                                       |
| Basalt and Porous Lava        | Burney Creek                     | NA                     | Juvenile & Adult  | Direct Observation      | 1985, 1994, 1995, 1996, 2006, 2015         |
| Basalt and Porous Lava        | Burney Creek                     | NA                     | Juvenile & Adult  | Backpack Electrofishing | 1985                                       |
| Basalt and Porous Lava        | Burney Creek                     | NA                     | Juvenile & Adult  | Angler Survey           | 1996 – present                             |
| Basalt and Porous Lava        | McGill creek                     | NA                     | Juvenile & Adult  | Backpack Electrofishing | 1981, 2018                                 |
| Basalt and Porous Lava        | Screwdriver Creek                | NA                     | Juvenile & Adult  | Backpack Electrofishing | 2018                                       |
| Basalt and Porous Lava        | Sacramento River (Shasta County) | Core 1                 | Juvenile & Adult  | Direct Observation      | 1992 – 1999, 2007, 2008, 2018              |
| Basalt and Porous Lava        | Sacramento River (Shasta County) | Core 1                 | Juvenile & Adult  | Boat Electrofishing     | 1980, 1993 – 1998                          |
| Basalt and Porous Lava        | Sacramento River (Shasta County) | Core 1                 | Juvenile & Adult  | Creel Census            | 1980, 1986, 1994 – 1997                    |
| Basalt and Porous Lava        | Sacramento River (Shasta County) | Core 1                 | Juvenile & Adult  | Angler Survey           | 1994 – present                             |
| Basalt and Porous Lava        | Scott Camp Creek                 | NA                     | Juvenile & Adult  | Backpack Electrofishing | 2018                                       |
| Basalt and Porous Lava        | Campbell Creek                   | NA                     | Juvenile & Adult  | Backpack Electrofishing | 2018                                       |

| <b>Diversity Group/Region</b> | <b>Location</b>  | <b>Core Population</b> | <b>Life stage</b> | <b>Sampling Method</b>  | <b>Duration</b> |
|-------------------------------|--|------------------------|-------------------|-------------------------|-----------------|
| Basalt and Porous Lava        | Middle Salt Creek  | NA                     | Juvenile & Adult  | Backpack Electrofishing | 2018            |
| Basalt and Porous Lava        | Dog Creek  | NA                     | Juvenile & Adult  | Backpack Electrofishing | 2018            |
| Basalt and Porous Lava        | North Fork Slate Creek                                     | NA                     | Juvenile & Adult  | Backpack Electrofishing | 2018            |
| Basalt and Porous Lava        | Castle Creek   | NA                     | Juvenile & Adult  | Backpack Electrofishing | 2018            |
| Basalt and Porous Lava        | North, Mid & South Fork Sacramento River (Siskiyou County) | NA                     | Juvenile & Adult  | Backpack Electrofishing | 2018            |
| Basalt and Porous Lava        | Fawn Creek   | NA                     | Juvenile & Adult  | Backpack Electrofishing | 2018            |
| Basalt and Porous Lava        | Gumboot Creek  | NA                     | Juvenile & Adult  | Backpack Electrofishing | 2018            |
| Basalt and Porous Lava        | Soapstone Creek  | NA                     | Juvenile & Adult  | Backpack Electrofishing | 2018            |
| Basalt and Porous Lava        | South Fork Slate Creek                                     | NA                     | Juvenile & Adult  | Backpack Electrofishing | 2018            |
| Basalt and Porous Lava        | Castle Lake Creek  | NA                     | Juvenile & Adult  | Angling (Hook & Line)   | 1977            |
| Basalt and Porous Lava        | Castle Lake Creek  | NA                     | Juvenile & Adult  | Backpack Electrofishing | 2018            |
| Basalt and Porous Lava        | Battle Creek   | Core 1                 | Adult             | Video & Sorting         | 1998 – present  |
| Basalt and Porous Lava        | Battle Creek   | Core 1                 | Juvenile          | Rotary Screw Trap       | 1998 – present  |