Implementation of the California Coastal Salmonid Monitoring Plan in the Russian River

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EXECUTIVE SUMMARY

As stated in the California Coastal Salmonid Population Monitoring Plan (CMP, Adams et al. 2011), there is an immediate need to provide monitoring data in order to measure progress toward recovery of California- and federal-ESA listed salmonids as well as to meet related management objectives. In 2013, the Sonoma County Water Agency (Water Agency) received funds through the Fisheries Restoration Grants Program (FRGP) to implement the CMP in the Russian River watershed. The University of California Cooperative Extension/California Sea Grant (UC) is contributing their expertise and experience to help achieve that end. This Russian River CMP monitoring plan will serve as a guide for monitoring coho salmon, steelhead, and Chinook salmon populations and their habitat in the Russian River, though Chinook monitoring will not be paid for with FRGP funds. This monitoring plan (and the methods described herein) will be updated and improved with direction from the Russian River CMP Technical Advisory Committee, a body of fisheries experts tasked with providing guidance and technical advice related to CMP implementation in the Russian River. The plan is organized around the four key population characteristics listed in Adams et al. (2011): abundance, productivity, spatial structure, and diversity. In addition to these key population characteristics, Adams et al. (2011) state the importance of life cycle monitoring (LCM) for effective interpretation of observed variation in adult abundance.

Abundance and productivity monitoring will consist of dispersed redd surveys (see Gallagher and Gallagher 2005, Gallagher et al. 2007, Gallagher et al. 2010), augmented with adult to redd ratios estimated from LCM stations. Surveys will be conducted in a probabilistic, spatially-dispersed fashion by taking a generalized random tessellation stratified (GRTS) sample from a sample frame consisting of all coho salmon habitat in the Russian River basin. Snorkel surveys for spatial structure monitoring will be conducted for coho salmon and steelhead in GRTS-sampled reaches from the coho salmon sample frame. Snorkel surveys will follow the procedures described in O'Neal (2007) and Garwood and Ricker (2013). Spatial structure of Chinook will be estimated from spawner surveys conducted over the entire Chinook sample frame. Diversity monitoring will consist of tissue sampling for genetic analysis. Samples will be taken from adult coho and steelhead carcasses encountered during redd surveys and live juvenile coho and steelhead caught during electrofishing surveys. Life cycle monitoring for coho and steelhead will be conducted in dry creek. Adults will be sampled with a DIDSON/digital video system at the mouth of dry creek and spawner surveys throughout the dry creek watershed. Adult counts at the DIDSON/digital video counting station will be combined with redd estimates from spawner surveys to provide a spawner: redd ratio for the Russian River. Smolt population monitoring will employ downstream migrant traps, PIT antenna arrays, summer snorkel surveys and fall electrofishing surveys. We will employ a "population modeling" approach to estimating coho and steelhead smolt abundance. The approach consists of (1) estimating the standing crop of all juvenile steelhead in the fall; (2) estimating stream- and/or reach-specific survival of fish that were PIT-tagged in the fall to the smolt stage; and (3) applying the fall to smolt survival estimates for PIT-tagged fish to the estimated reach-specific standing crop of all juveniles in the fall. We believe this approach will improve smolt estimates by accounting for smolt emigration during times of high flow when downstream migrant trapping is dangerous to crews and fish. Life cycle monitoring for Chinook will be conducted in the Russian river mainstem. Adults will be sampled with a DIDSON/digital video system at Mirabel dam, below the vast majority of Chinook spawning habitat in the watershed. Smolts will be sampled with downstream migrant traps at the same location. Because this smolt monitoring will occur upstream of the mouth of the Russian river, smolt mortality between the LCM station and the mouth will be estimated using PIT antennas at multiple points in the Russian river estuary.

INTRODUCTION

As stated in the California Coastal Salmonid Population Monitoring Plan (CMP, Adams et al. 2011), there is an immediate need to provide monitoring data in order to measure progress toward recovery of California- and federal-ESA listed salmonids as well as to meet related management objectives. The CMP goes further to state the importance of standardizing data collection methods so that data across drainages is comparable. In 2013, the Sonoma County Water Agency (Water Agency) received funds through the FRGP (FRGP grant # P1230413) to implement the CMP in the Russian River watershed. The University of California Cooperative Extension/California Sea Grant (UC) is contributing their expertise and experience to help achieve that end. One of the primary tasks of CMP implementation in the Russian River Watershed is to create a basin-wide monitoring plan within the first six months of implementation of the CMP. This document is intended to meet that task.

This plan will serve as a guide for monitoring coho salmon, steelhead, and Chinook salmon populations and their habitat in the Russian River. We are including Chinook monitoring in this monitoring plan in order to provide a more complete picture of all of the salmonid monitoring that will take place in the Russian River if CMP monitoring continues. Though Chinook monitoring is a major part of the work outlined in the CMP, we are not using FRGP funding for any of the Chinook monitoring described below; instead, Chinook monitoring in the Russian River has been and will continue to be funded entirely by the Water Agency.

Here we outline a starting point for CMP monitoring in the Russian River watershed. As methods improve, the sample frame is refined and finalized, new information is gathered, and goals change, there will likely be modifications to monitoring approaches outlined in this plan. A deliverable under FRGP grant # P1230413 is the formation of the Russian River CMP Technical Advisory Committee (here after “Committee”) to provide guidance and technical advice related to CMP implementation in the Russian. The Water Agency will convene annual meetings of the Committee to evaluate the effectiveness of current methods of data collection and consider new approaches or modifications to existing approaches. The Water Agency will work closely with our FRGP contract manager to ensure that any new or modified approaches are consistent with the goals and objectives of the Statewide CMP Technical Team.

Our proposed fisheries monitoring for the Russian River is organized around the four key population characteristics listed in Adams et al. (2011): abundance, productivity, spatial structure, and diversity (McElhaney et al. 2000). High abundance buffers a population against both ‘normal’ and catastrophic variation due to environmental conditions and loss due to anthropogenic factors. High productivity will lead to more certain replacement when populations are placed under either natural or anthropogenic stress. Wide spatial structure (measured as high levels of occupancy throughout the species habitat) reduces extinction risk due to catastrophic events and provides pathways for recolonization. Diversity in life history traits (e.g., time of spawning, juvenile life history, adult fish size, age structure, degree of anadromy, etc.) provides resilience against extinction risk from changing conditions.

Key population characteristics and their associated methods described in this monitoring plan and Adams et al. (2011) are:

Abundance and productivity- Dispersed redd surveys augmented with LCM data from life cycle monitoring stations (LCS);

Spatial structure- Juvenile snorkeling surveys (coho salmon and steelhead) and spawner surveys (Chinook salmon);

Diversity- Local evaluation of life history.

In addition to the key population characteristics listed above, Adams et al. (2011) state the importance of LCM for effective interpretation of observed variation in adult abundance. LCM data also play a central role in translating redd estimates to spawner estimates and providing the primary data for characterizing diversity.

METHODS

1. Abundance and productivity (adult monitoring)

Adult monitoring will consist of dispersed redd surveys (see Gallagher and Gallagher 2005, Gallagher et al. 2007, Gallagher et al. 2010), augmented with adult to redd ratios estimated from LCM stations. Surveys will be conducted in a probabilistic, spatially-dispersed fashion. The deliverable for the FRGP contract will consist of an electronic version of the data set arising from basin-wide sampling that is compatible with the statewide CMP database.

a) GRTS draw

In 2012, the Water Agency, UC, CDFW, NMFS and other professionals familiar with anadromous salmonid habitat in the Russian River began a series of meetings to define the spawning and juvenile rearing habitat for coho, steelhead, and Chinook in the Russian River basin. Streams were included in this list only if they contained habitat and were downstream of known barriers to upstream migration (**Figure 1**). This desktop exercise resulted in a sampling universe that served as the basis for creating a sample frame (e.g., the sampling universe broken into sampling reaches). Existing spawning and juvenile rearing reaches that have been surveyed over multiple years by UC were incorporated into the sample frame. The sampling reaches were then ordered in a specific manner (see Garwood and Ricker 2011 for details) to allow for a random, spatially-balanced (GRTS) sample of reaches to survey for redds and juveniles.

The current draft, expert opinion-based sampling frame for the Russian River watershed contains 402 reaches that are considered to be spawning and/or juvenile rearing habitat for one or more of the three anadromous salmonid populations in the watershed. There are 108 reaches in 40 streams that contain both coho and steelhead habitat and 241 reaches in 97 streams that contain only steelhead habitat. As field reconnaissance of these reaches occurs over time, adjustments to the sampling frame will most likely be necessary (S. Gallagher, personal communication). In that case, we will work closely with the Committee to ensure that the statistical integrity of the GRTS approach is maintained. Adams 2011, describes methods for dividing sample reaches into rotating panels to provide for simultaneous status and trend estimation. At the suggestion of the Committee, we will not fit the GRTS draw to a rotating panel until the sample frame is finalized. The sample frame will be resized based on field verification over the first three years of monitoring. When the sample frame accurately reflects the core salmonid spawning habitat in the basin, we will fit it to a 1 year, 3 year, 12 year, and 30 year rotating panel. However, depending on the total number of reaches in the final sample frame and whether or not we secure funding to monitor more than coho space (e.g. the entirety of the steelhead habitat in the Russian River) we may fit it to a different rotation scheme.

A significant challenge facing full implementation of the CMP in the Russian River for steelhead is securing adequate resources to successfully sample all steelhead habitat in the watershed. Along with the logistical challenges presented by the spatial extent of steelhead in the basin, statistical sampling challenges arise as the result of unequal distribution of coho habitat as compared to steelhead habitat, the difference in the diversity strata for the two species in the Russian River, and the fact that while 100% of coho habitat is steelhead habitat less than 100% of steelhead habitat is coho habitat (**Figure 1**). We have received input from the Committee on this issue and have decided to initially sample in the coho sample frame only. Gallagher et al. (2010) concluded that 41 reaches is the number of reaches necessary to achieve an acceptable tradeoff between precision (±30%) and effort. Therefore, although we will continue to aim to sample 41 reaches, resources will not be available in 2014-15 to accomplish that. Until additional resources become available, we intend to sample as many reaches as possible.

b) Coho salmon and steelhead

The GRTS reaches containing spawning habitat for both coho and steelhead will serve as the basis for spawner surveys. Repeat visits to these reaches that follow the protocols of Gallagher et al. (2007, 2010) will allow annual estimates of redd abundance in the GRTS reaches and allow discrimination of redd species (Gallagher and Gallagher 2005). The number of coho and steelhead redds in sampled reaches will be expanded to the coho universe following Adams et al (2010). Finally, spawner: redd ratio estimates from the Dry Creek LCS (see Life Cycle Monitoring section below) will be used to convert annual redd estimates to an annual adult estimate for both species. Data collection will begin in the late fall/early winter each year (once flows in tributary streams become connected) and continue through the end of steelhead spawning in mid-April.

2. Spatial structure

Spatial structure sampling will be used to assess whether the population distribution is expanding, contracting, or remaining constant. Spatial structure monitoring will be conducted for juvenile coho salmon throughout the entire coho universe. According to Adams et al. (2011), "spatial monitoring for steelhead is a lower priority because they are more widely distributed than coho and Chinook." Therefore, we will limit steelhead spatial structure monitoring to the coho universe since all streams in the coho universe are expected to contain steelhead habitat as well. The FRGP contract deliverable will consist of an electronic version of the spatial structure data that is compatible with the statewide CMP database.

a) Coho salmon and steelhead

Our aim will be to conduct summer snorkel surveys in at least 30% of the ordered reaches comprising the sample frame. Initially, reaches from the spawner survey sample frame will be used; however, we plan to consider the validity of the coho spawner sample frame for juveniles as new information is gained. The actual number of reaches snorkeled will depend on landowner access and available funds. Snorkel surveys will follow the procedures described in O'Neal (2007) and Garwood and Ricker (2013). The accuracy of snorkel counts will be assessed by resampling (making 2 independent snorkel passes) in 10-20% of pool habitat units. The primary metric estimated will be coho salmon and steelhead occupancy rates (MacKenzie et al 2002; Nichols et al 2008; Garwood and Ricker 2013). Presence/absence snorkeling data collected within GRTS-drawn sample reaches will be used to estimate the proportion of pool habitat units occupied within each sample reach. To expand this proportion to the remainder of the coho universe, we will estimate the proportion of sample reaches occupied within the sampling universe. Over time, these annual estimates of basin-wide occupancy can be used to assess changes in spatial structure.

b) Chinook salmon

In the Russian River watershed, Chinook salmon spawn in well-defined areas and out-migrate in the spring before juvenile surveys take place. For this reason, Adams et al. (2011) state that information on Chinook spatial structure should come from adult monitoring. We plan to conduct a single annual spawner survey in the mainstem of the Russian River from the City of Ukiah to the downstream extent of mainstem spawning habitat upstream of the Mirabel Dam. We will use redd counts from this spawner survey to estimate Chinook occupancy at the universe scale. The Water Agency has been conducting Chinook spawner surveys in this portion of the mainstem since 2004 and operating the adult counting station at Mirabel since 2000. Over that period we have been largely successful in combining these two data sources to ensure that mainstem spawner surveys coincide with the peak of Chinook spawning (mid- to late- November, Manning and Martini-Lamb 2012). Exceptions are when heavy early rains have precluded our ability to conduct spawner surveys. As stated previously, with the exception of mainstem Dry Creek, Chinook can only access tributary streams in years when early rains connect surface flows in those tributaries. Typically that does not occur until late in the Chinook migration period if at all. Therefore, because our surveys most often coincide with the peak of spawning, they allow depictions of the spatial distribution of Chinook spawning that accurately reflect the spatial structure of the adult population.

3. Diversity

The purposes of diversity monitoring are to: 1) establish and maintain genetic baselines for coho and steelhead in the Russian River Basin, and 2) identify life history characteristics of specific populations within each ESU that can be measured as part of existing field surveys at life cycle monitoring stations (see Life Cycle Monitoring section below) and at hatcheries, or for other diversity traits for which specific data collection still needs to be designed (Adams et al. 2011).

Tissues for genetic analysis will be collected from all coho and steelhead carcasses encountered during spawner surveys. Tissues will also be collected from a portion of fish caught during electrofishing. Tissue collection and archiving will follow protocols established by NOAA Fisheries SWFSC's as part of the Coastal Salmonid Tissue Archive and CDFW's Central Valley Anadromous Salmonid Tissue Archive. We will also collect seasonal abundance data at life cycle monitoring stations (see below) to evaluate smolt and adult run timing (Adams et al. 2011).

4. Life Cycle Monitoring (*freshwater & marine survival/redd correction*)

The primary purpose of life cycle monitoring is to provide adult and smolt estimates at life cycle monitoring stations (LCS) in order to provide abundance estimates of "fish in" (adults) and "fish out" (smolts). When these estimates are viewed over multiple years, trend analyses may indicate responses to changing ocean conditions and/or responses to population recovery measures. An additional objective of LCM is to provide annual estimates of redds in the life cycle monitoring watershed in order to develop a ratio of the number of adults to the number of redds for calibration of spawner surveys conducted in other portions of the Russian River watershed where such calibration ratios are unavailable. LCM data are also ideal for conducting recovery-oriented research such as habitat-productivity relationships and evaluations of habitat enhancement effectiveness (Adams et al. 2011).

That portion of the Russian River watershed upstream of the Mirabel Dam on the mainstem Russian River (river km 39. 7) was selected as the LCS for Chinook salmon while Dry Creek was selected as the LCS for coho salmon and steelhead (**Figure 1, Figure 2**). The FRGP contract deliverable will result in a dataset consisting of counts of adult salmonids returning to each LCS in a format that is compatible with the statewide CMP database. LCM for each LCS is described below.

a) *Coho salmon and steelhead life cycle station (Dry Creek)*

Adult abundance. We will employ a combination of two methods to estimate the number of adults returning to Dry Creek each year: DIDSON and continuous underwater video monitoring (**Figure 2, Figure 3**).

A fixed adult counting station near the mouth of mainstem Dry Creek (river km 0.4, downstream of all tributaries to Dry Creek) will employ a DIDSON system to provide annual counts of adult salmonids returning to Dry Creek. In addition to coho salmon and steelhead, a significant number of Chinook salmon is known to spawn in mainstem Dry Creek. Because of overlap in the timing of adult returns to the system for all three species, DIDSON alone will be insufficient for distinguishing among species. Therefore, review of underwater video footage collected simultaneous to DIDSON footage at the same location will be used to prorate species by time thereby overcoming the species identification issue. For example, if 100 individuals are counted on the DIDSON in a given time period and 20 individuals are identified to species on the video during that same time period, the species composition of those "known species" (video) individuals would be applied to the 100 "unknown species" (DIDSON) individuals. The proration will be particularly important for differentiating coho from steelhead which exhibit a higher degree of overlap in run timing than either species does with Chinook.

Adult LCM will also include spawner surveys throughout all available habitat in the Dry Creek watershed in order to estimate the number of redds for both coho and steelhead. In conjunction with the estimated number of returning adults, spawner data will facilitate species-specific estimates of spawner: redd ratios for use in expanding data from coho and steelhead spawner surveys outside of the Dry Creek system.

<u>Smolt abundance.</u> Smolt population monitoring will employ downstream migrant traps and PIT antenna arrays on mainstem Dry Creek and Mill Creek (**Figure 2, Figure 3**), summer snorkel surveys (Dry Creek tributaries) and fall electrofishing surveys (mainstem Dry Creek and tributaries). This deliverable will consist of an electronic version of the smolt abundance portion of the LCM data set that is compatible with the statewide CMP database.

The Water Agency has been operating a rotary screw trap on mainstem Dry Creek at river km 3.3 since 2009. This effort has resulted in captures of over 20,000 salmonid smolts in some years and trapping efficiency averages of approximately 10% (Manning and Martini-Lamb 2012). UC has been operating a downstream migrant trap near the mouth of Mill Creek at river km 2.00 since 2005; estimated trap efficiencies for coho smolts at that site average approximately 70%. From these and similar downstream migrant trapping efforts elsewhere in the Russian River watershed, there is a wealth of evidence that unlike steelhead, coho salmon have a relatively fixed smolt age (age 1) and migration period. This experience has given us confidence that capture-mark-recapture estimates for coho smolts developed at these sites (e.g., from program DARR (Bjorkstedt 2005)) are a reliable method for estimating smolt abundance. Because the location of the Dry Creek trap is upstream of Mill Creek, an important coho- and steelhead-producing tributary in the system (the river km on Dry Creek at the confluence with Mill Creek is 1.1), our approach to estimating coho salmon smolt abundance from the Dry Creek watershed will be to combine mark-recapture population estimates constructed on mainstem Dry Creek with mark-recapture population estimates constructed on Mill Creek.

Several years of fisheries monitoring data in the Russian River and tributaries shows that steelhead smolt migration can occur any time between January and June with the peak usually occurring in February or March (Water Agency, unpublished data). More recent data from PIT antenna arrays has shown that some fish may be migrating out of their tributary of origin even earlier than January. Our experience has also proven that operation of downstream migrant traps during the winter months can be extremely unsafe for personnel, fish and equipment. For these reasons we propose an alternative approach to estimating steelhead smolt abundance as compared to that outlined in Adams et al. (2011). Generally, this "population modeling" approach relies less on downstream migrant trapping and more on the PIT antenna detections of smolts that were previously PIT-tagged as juveniles. The approach consists of (1) estimating the standing crop of all juvenile steelhead in the fall; (2) estimating stream- and/or reach-specific survival of fish that were PIT-tagged in the fall to the smolt stage; and (3) applying the fall to smolt survival estimates for PIT-tagged fish to the estimated reach-specific standing crop of all juveniles in the fall (**Figure 4**).

Conceptually, fall to smolt survival in the Dry Creek watershed is simply the proportion of fish that are PIT-tagged in the fall that are estimated leaving Dry Creek as smolts. This concept is illustrated in step 9 of **Figure 4**. The Dry Creek PIT antenna array will consist of two arrays of three, 20 foot antennas lying flat on the bottom of the stream and configured in such a way that each array of three antennas spans the width of Dry Creek (**Figure 3**). The antennas will be operated year-round. Because detection efficiency at the PIT antenna site is unknown and can vary over time, it will be estimated. In a paired antenna array, antenna efficiency for smolts can be estimated as the number of fish detected on both antenna arrays divided by the total number of detections on the downstream antenna (Zydlewski et al. 2006). By dividing the antenna efficiency estimate into the total number of detections on the upper antenna, an estimate of the total number of PIT-tagged smolts swimming past the paired array can be generated (e.g., Dry Creek smolt production). One drawback to this approach is that it does not allow for an explicit estimate of variance for either the survival estimate or the smolt abundance estimate on which it is based. A preferred approach that we will use in the Dry Creek LCS is based on an adaptation of the multistate capture-mark-recapture model (Hestbeck et al. 1991) that allows for emigration (Horton et al. 2011). When applied in Dry Creek, this model will allow annual point and variance estimates of PIT-tagged smolt survival that are independent of annual estimates of the probability of emigrating (smolting). Because the location of the PIT antenna array in Dry Creek is downstream of all smolt production habitat in the Dry Creek watershed, annual estimates of the survival of PIT-tagged fish will be used in steps 9 and 10 of **Figure 4**.

The population modeling approach described here offers several distinct advantages over complete reliance on downstream migrant trapping. First, it saves on labor by obviating the need to operate downstream migrant traps during winter months when trapping conditions can be unsafe and data gaps would be common due to gear wash-outs; however the approach still allows incorporation of downstream migrant trapping data during periods when traps can be operated. Second, there are increases in data efficiency because the summer/fall data for juveniles necessary for the population model are also necessary for depicting spatial structure. Third, individual data from PIT-tagged fish provide information on smolt age which is important for depiction of diversity. Finally, these data inform a more detailed picture of freshwater survival which is important for identifying impediments to recovery and for providing a broader context when validating the effectiveness of recovery measures.

Potential pitfalls of greater reliance on steelhead smolt survival estimates from PIT-tagged fish and PIT antennas comes about as the result of spatial variability in juvenile survival and variability in smolt age. In the Russian River, there is evidence that steelhead may smolt at age 1, 2 or >2 and, depending on the year, season, and location (e.g., stream, reach). A juvenile of a given size may vary in age by as much as one year. This variation limits the interpretation of the survival estimate described above (step 9 in **Figure 4**) unless consideration is also given to the probability of smolting. For example, the pre-smolt survival for individuals tagged at age-0 that smolt at age-1 is not comparable to fish that are tagged at age-0 and smolt at age-2. Data from individually PIT-tagged fish help to overcome this problem by allowing us to incorporate the aforementioned probability of smolting obtained from stream- and/or reach-specific estimates of survival and emigration from the multistate emigration model into the population model.

<u>Spawner: redd ratio.</u> The Dry Creek LCS will provide the data necessary to estimate spawner: redd ratios for coho and steelhead which will, in turn, facilitate expansion of redd estimates into adult estimates outside the LCS. Surveys will be conducted every 7-14 days in all coho- and steelhead-bearing tributaries in the Dry Creek watershed (**Figure 1**) following the protocols in Gallagher et al.

(2007, 2010). It is likely that denial of landowner access will prevent us from surveying 100% of the habitat. In that event, we will work with the RRCMPT to address that issue.

Because direct counts of adult Chinook returning to the Russian River watershed are possible (see the following section), there is no need to estimate Chinook adult abundance by redd count expansion. However, it is still important to obtain accurate counts of adult Chinook and redds in Dry Creek so that a Chinook spawner: redd ratio can be estimated for use in applying to other coastal California river systems where these data are scarce (S. Gallagher, CDFW, personal communication). Therefore, spawner surveys in mainstem Dry Creek will be conducted every 7-14 days throughout the Chinook spawning season (October through December).

b) Chinook salmon life cycle station and monitoring (mainstem Russian River and Dry Creek)

Adult abundance. The adult Chinook salmon monitoring station on the mainstem Russian River at the Water Agency's inflatable dam site in Forestville (river km 39.7) will employ a continuous underwater video monitoring system combined with DIDSON monitoring to obtain annual counts of Chinook adults returning to the Russian River basin upstream of the Mirabel dam. This site is downstream of approximately 95% of the Chinook spawning habitat in the basin (Chase et al. 2007). The monitoring system consists of an underwater video camera and DIDSON camera at the upstream end of each of two fish ladders located on either side of the inflatable dam (**Figure 5**). Underwater video monitoring at Mirabel has occurred each year since 2000 with installation occurring in early September prior to the onset of adult migration and removal typically occurring near or after the end of adult Chinook migration in mid-December. Of the 14 years of adult monitoring at this site, video monitoring gear has been operational for at least 95% of the Chinook migration period in most years. Exceptions are brief periods when early rain caused high flows and decreased water clarity to the point where fish could not be accurately discerned on the video and two years when we had to deflate the dam and remove the cameras early (2012: removal in late November after a record count of 6,696 Chinook adults; 2001: removal in early November after a count of 1,383 Chinook adults). To assist in overcoming the water clarity issue during periods when video counts are infeasible, DIDSON cameras (on loan from CDFW) were installed in 2011. Comparison of DIDSON counts to video counts during periods of good video-visibility has shown near perfect correlation. For these reasons, Chinook counted as they swim past the Mirabel LCS can effectively be interpreted as a census of the adults making it back to the spawning habitat in most years (**Figure 1**). Although adult coho and steelhead are counted at this site each year, the run timing and habitat preferences of these species are such that the monitoring gear must be removed prior to the onset of large winter storms which unfortunately often coincide with the onset of the majority of coho and steelhead migration in the Russian River. However, the video system does allow us to distinguish the three species during that period when the run timing of multiple species does overlap.

Smolt abundance. The Chinook smolt LCS on the mainstem Russian River is located at the same site as the Chinook adult LCS at the Water Agency's Mirabel inflatable dam site in Forestville (river km 39.7). This site, which has been operational since 2000, will continue to employ rotary screw trapping as a way to estimate smolt production from the Russian River basin (**Figure 5**). We will continue to use the one-trap capture-recapture approach and estimator in DARR (Bjorkstedt 2005) to obtain estimates of Chinook smolts produced from that portion of the basin that is upstream of the trap site. As mentioned above, this site is downstream of the vast majority of Chinook spawning habitat in the basin (Chase et al. 2007); therefore, the Chinook smolts swimming past that site can effectively be interpreted as the total number escaping to the ocean (irrespective of migration mortality downstream of the dam [discussed in detail in the next section]). In order to coincide with the

Chinook smolt emigration period, data will be collected during the early-spring through early-summer time periods each year of the project period.

c) Migration mortality

Because of the distance of the Dry Creek LCS (~55 km) and Mirabel LCS (~40 km) from the ocean, it is likely that smolt and adult migration mortality is occurring in that portion of the system downstream of each LCS. For this reason, we plan to incorporate detections of PIT-tagged fish at a paired PIT antenna array located at the upstream end of the Russian River estuary (river km 10.5 in Duncans Mills). The estuary PIT antenna system will consist of two arrays of 12, 16 foot antennas lying flat on the bottom of the river and configured in such a way that each set spans the width of the river (**Figure 6**). The antenna array was successfully operated at flood stage in 2012 and our intention is to continue operation on a year-round basis into the future[1].

When detections from the paired Duncans Mills PIT antenna array are combined with data from upstream monitoring locations, migration mortality of PIT-tagged salmonid smolts through lower Dry Creek and mainstem Russian River can be directly estimated using the multistate emigration model (Horton et al. 2011). Based on simulations using observed Duncans Mills detection probabilities and previously-estimated ranges of pre-smolt survival for coho and steelhead in tributaries of the Russian River, the numbers of juveniles necessary to PIT tag in order to obtain reasonably precise (coefficient of variation <10%) estimates of true survival (as opposed to the confounded probabilities of true survival and fidelity) is fewer than 500 individuals per species (UC and Water Agency, unpublished data). In the case of coho salmon and steelhead and depending on the tributary, fish that are ≥60 mm may be PIT-tagged several months prior to smolting either in the hatchery before stocking (coho) or upon capture in the wild (coho and steelhead). For those stream reaches where PIT-tagged fish are at large, this will allow stream-specific estimation of true survival throughout the freshwater portion of the life-cycle from PIT-tagging as a young-of the-year to estuary entry as a smolt as well as to intervening detection points along the way. For Chinook, smolts are currently only tagged at the Dry Creek downstream migrant trap. Therefore, detection of PIT-tagged individuals may occur at the mouth of Dry Creek (~3 km downstream), Mirabel downstream migrant trap (~15 km downstream) and Duncans Mills (~45 km downstream). By incorporating all of these detections into the multistate emigration model, estimates of true survival between detection points will be possible (**Figure 7**).

The Water Agency and UC recently developed the structure of the multistate emigration model necessary for estimating the combined probabilities of surviving estuarine migration as a smolt and ocean survival as a post-smolt back through the estuary to Duncans Mills (post-estuarine survival) (**Figure 7**). This structure is being adopted as the primary approach for incorporating detections of PIT-tagged adult coho at Duncans Mills necessary for estimating hatchery-origin coho salmon returns. With a relatively modest expansion of Chinook salmon PIT-tagging beyond Dry Creek, reasonable estimates of post-estuarine survival should be attainable. Given the low ocean survival common for salmonids, and the current relatively low numbers of steelhead PIT-tagged in the system, it is questionable whether estimates of post-estuarine survival from the multistate emigration model will be of much utility for steelhead.

[1]The equipment and the cost of operating the Duncans Mills antenna system is not being paid for with FRGP funds.

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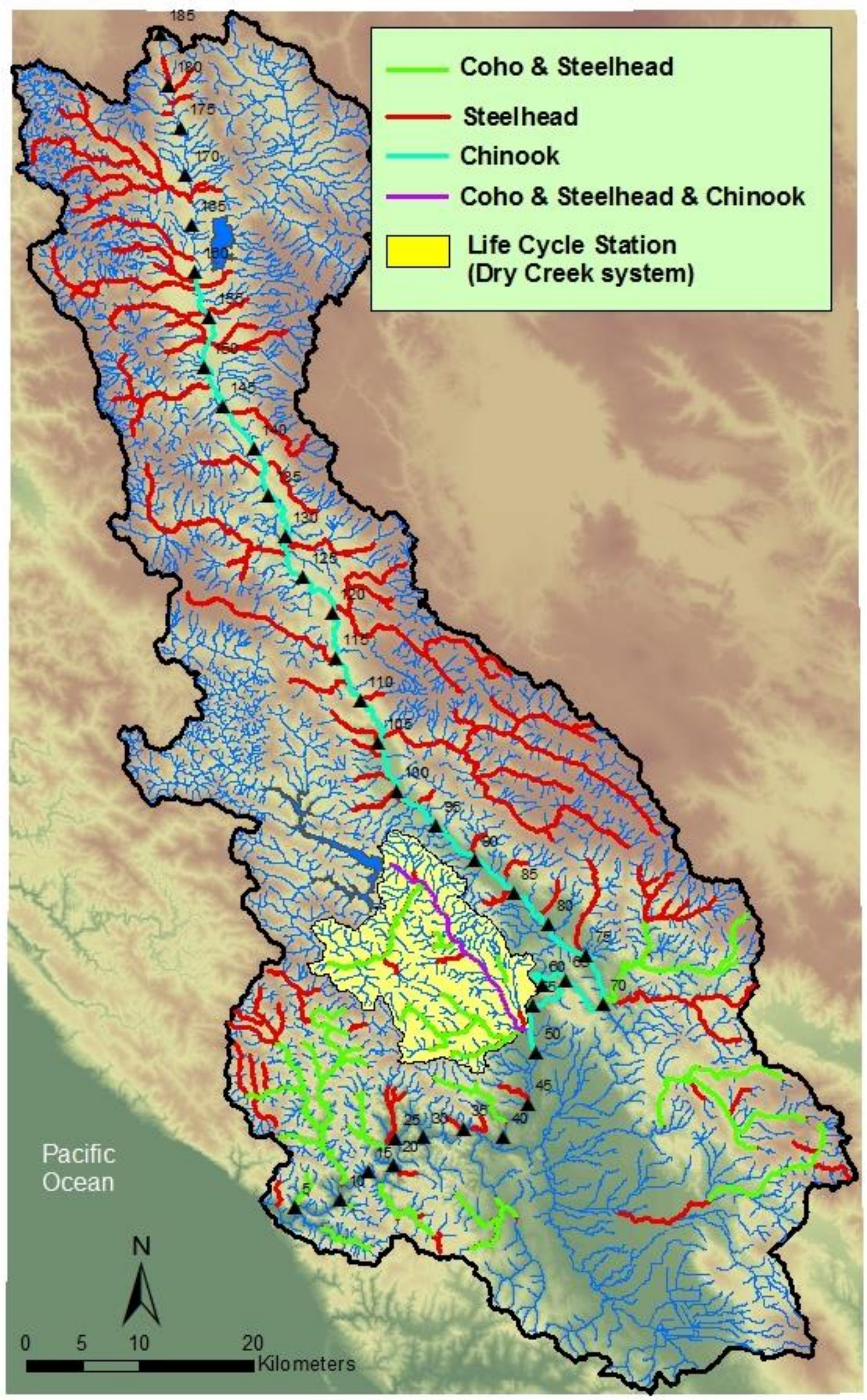


Figure 1. Species-specific spawning universes in the Russian River watershed. Numbered triangles represent distance in river km from the mouth of the stream.

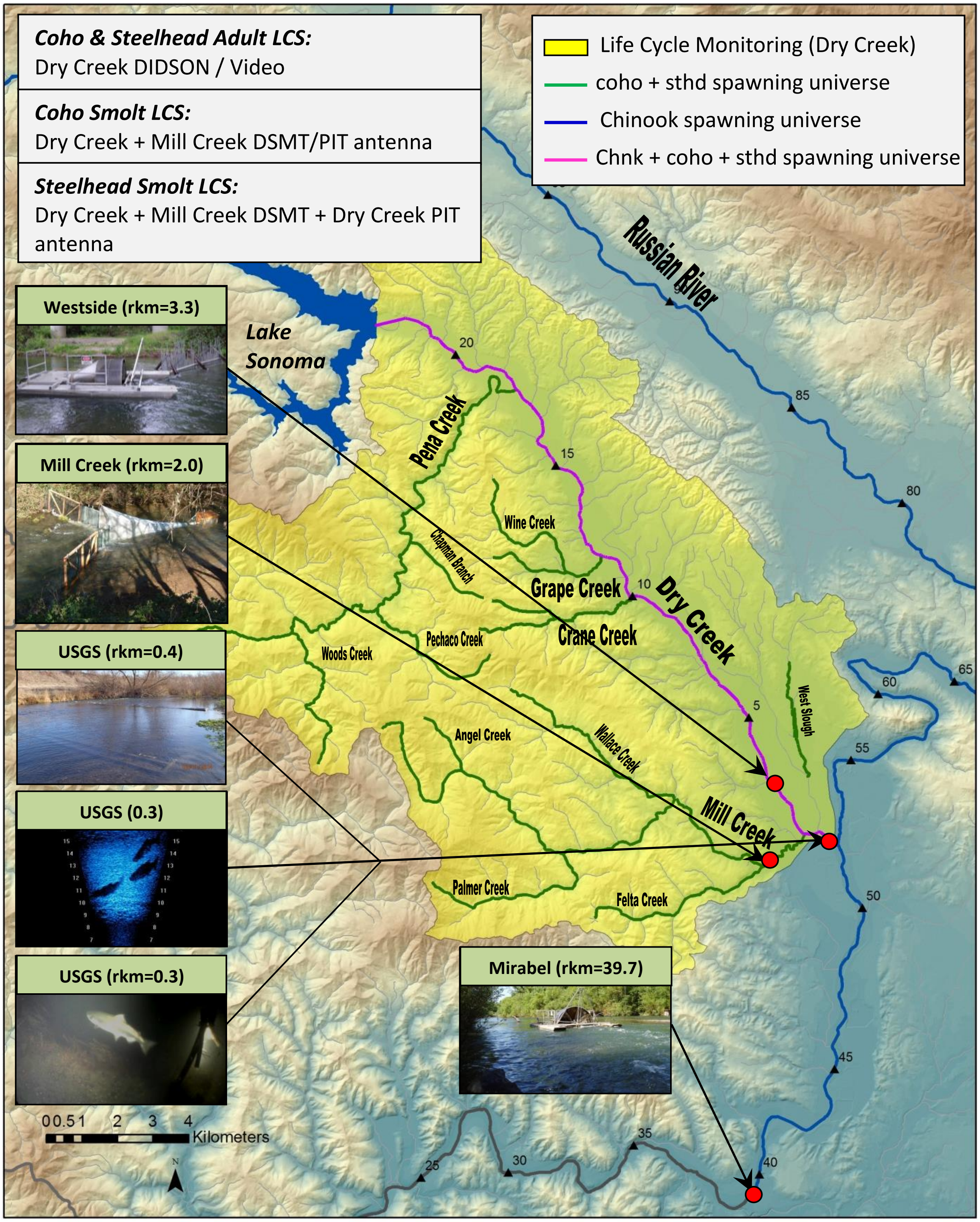


Figure 2. Life cycle stations for coho salmon and steelhead smolts (Dry Creek + Mill Creek), coho and steelhead adults (Dry Creek, USGS) and Chinook salmon (mainstem Russian River at Mirabel dam). Numbered triangles represent distance in river km from the mouth of the stream.

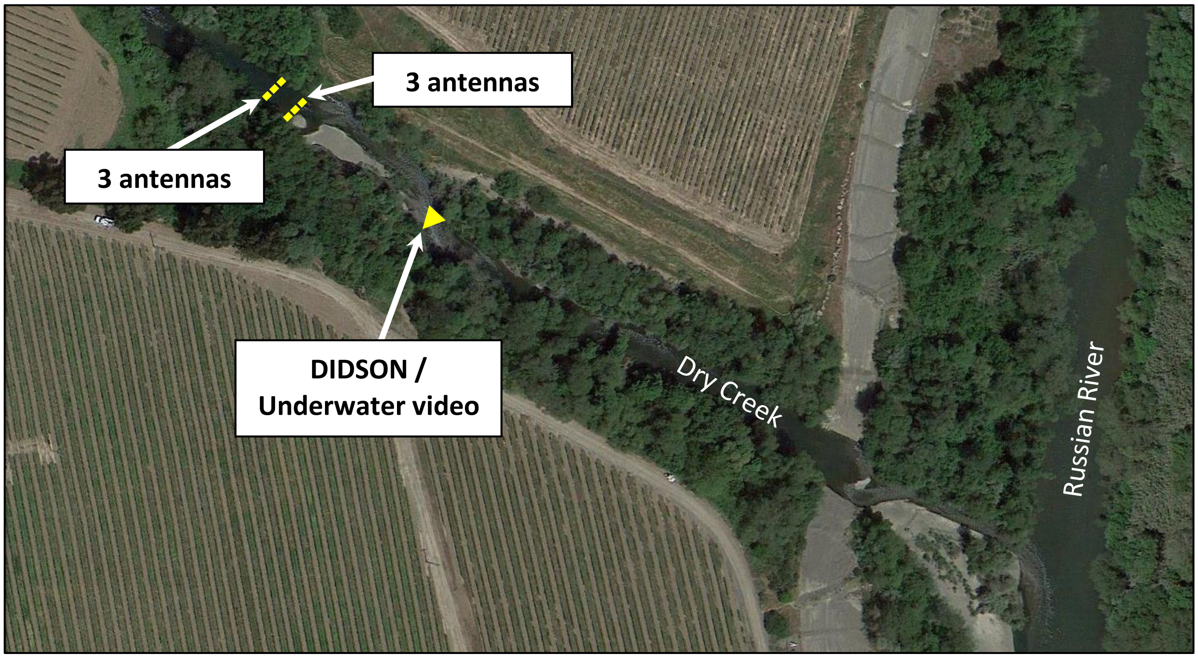


Figure 3. Location of Dry Creek PIT antenna array (river km 0.4) DIDSON/underwater video (river km 0.3) and confluence of Dry Creek with the mainstem Russian River (river km 52.04)

(1) Summer Available Habitat

(a) Habitat unit inventory (pool, flat, riffle)

(2) Summer Distribution / Minimum Count

(a) Single pass snorkel counts in every other pool, every snorkleable flatwater, no riffles

(3) Habitat Specific Snorkeling Efficiency

(a) Group every 10 contiguous pools into discrete "EF groups"

(b) Electrofishing depletion estimate for 1 pool, 1 flat, 1 riffle in each EF group

(c) Same day snorkel count in each depletion pool and flat that could be snorkeled

(d) Reach specific snorkeling efficiency = sum(snorkel counts) / sum(depletion estimates)

(4) Habitat Specific Oversummer Survival

(a) Reach specific oversummer survival = sum(Count in fall in calibration units) / sum(Count in summer in calibration units)

(5) Reach & Habitat Specific Adjustments to Snorkeling Counts

(a) Summer snorkel count = sum(unit level snorkel counts in summer)

(b) Calibration corrected summer snorkel count = Summer snorkel count / Snorkeling efficiency

(c) Summer mortality corrected fall snorkel count = Calibration corrected summer snorkel count * Oversummer survival

(6) Fall Total Abundance

(a) Reach and habitat specific average fish per unit = Calibration & summer mortality corrected fall snorkel count / # of units snorkeled in summer

(b) Reach and habitat specific fall abundance = Reach and habitat specific average fish / unit * Total # of units

(c) Fall total abundance = sum(Reach and habitat specific fall abundance)

(7) Fall PIT Abundance

(a) During fall electrofishing, PIT tag based on portion of fish in each EF group from distribution during summer snorkeling

(8) Smolt PIT Abundance (PIT)

(a) PIT detections at PIT antenna array and/or downstream migrant trap adjusted for detection / trap efficiency

(9) PIT to Smolt Survival

(a) PIT detections at PIT antenna array and/or downstream migrant trap adjusted for detection / trap efficiency

(10) Smolt Total Abundance

(a) Smolt abundance = Fall total abundance * PIT to smolt survival

Figure 4. Steps to estimate the abundance of steelhead smolts produced from tributaries to Dry Creek.

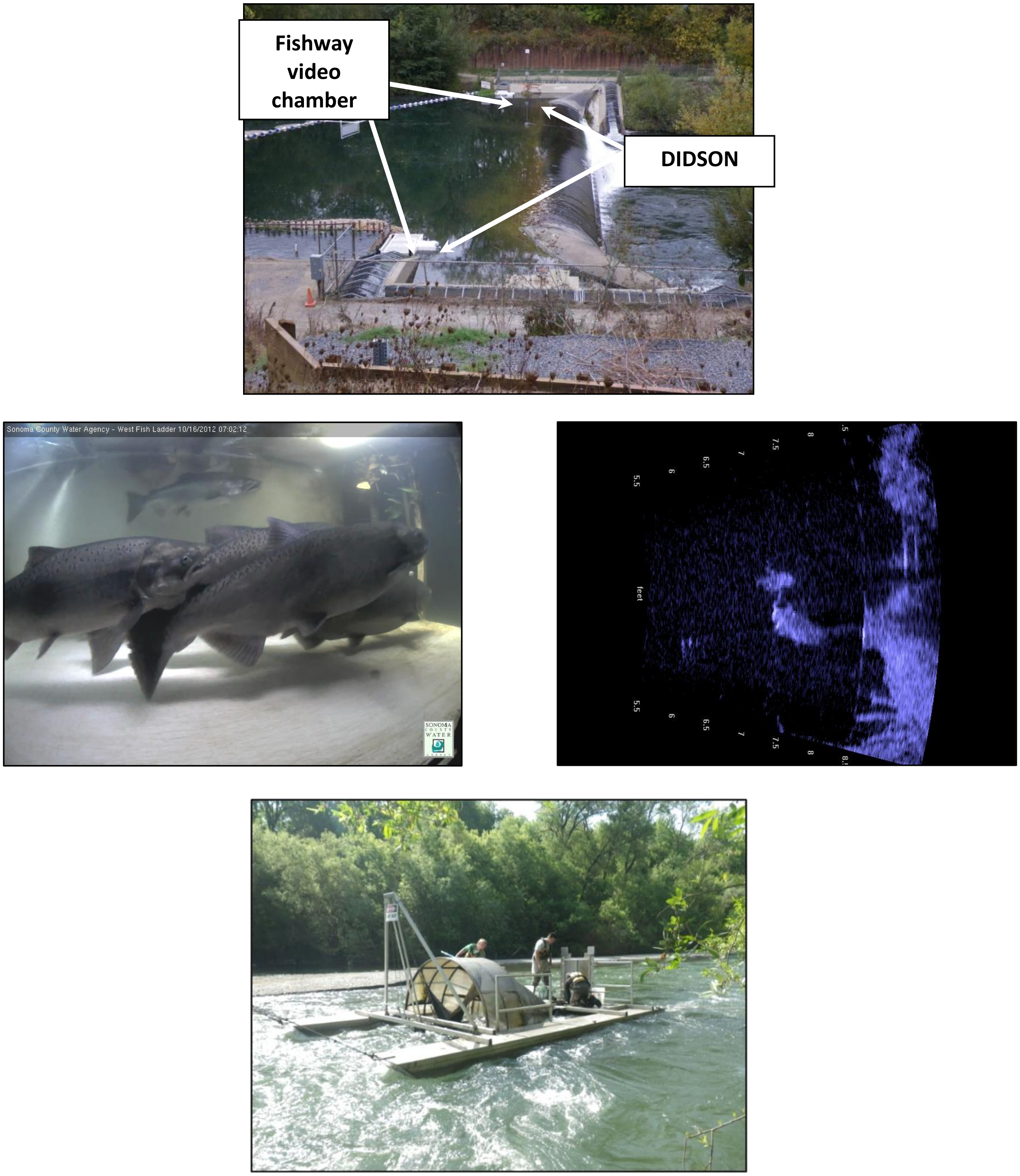


Figure 5. Chinook LCS at Mirabel on the mainstem Russian River: adult underwater video and DIDSON monitoring at fish ladders associated with the Mirabel dam (upper panels) and downstream migrant trap.

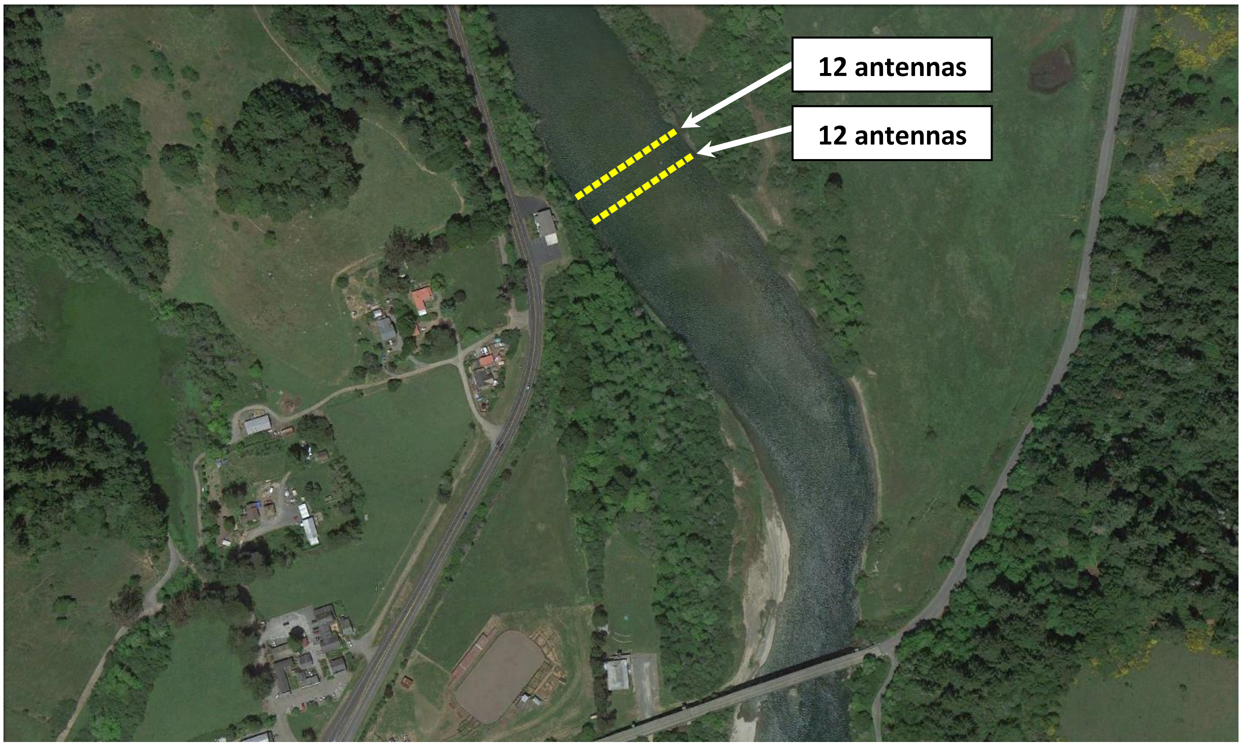
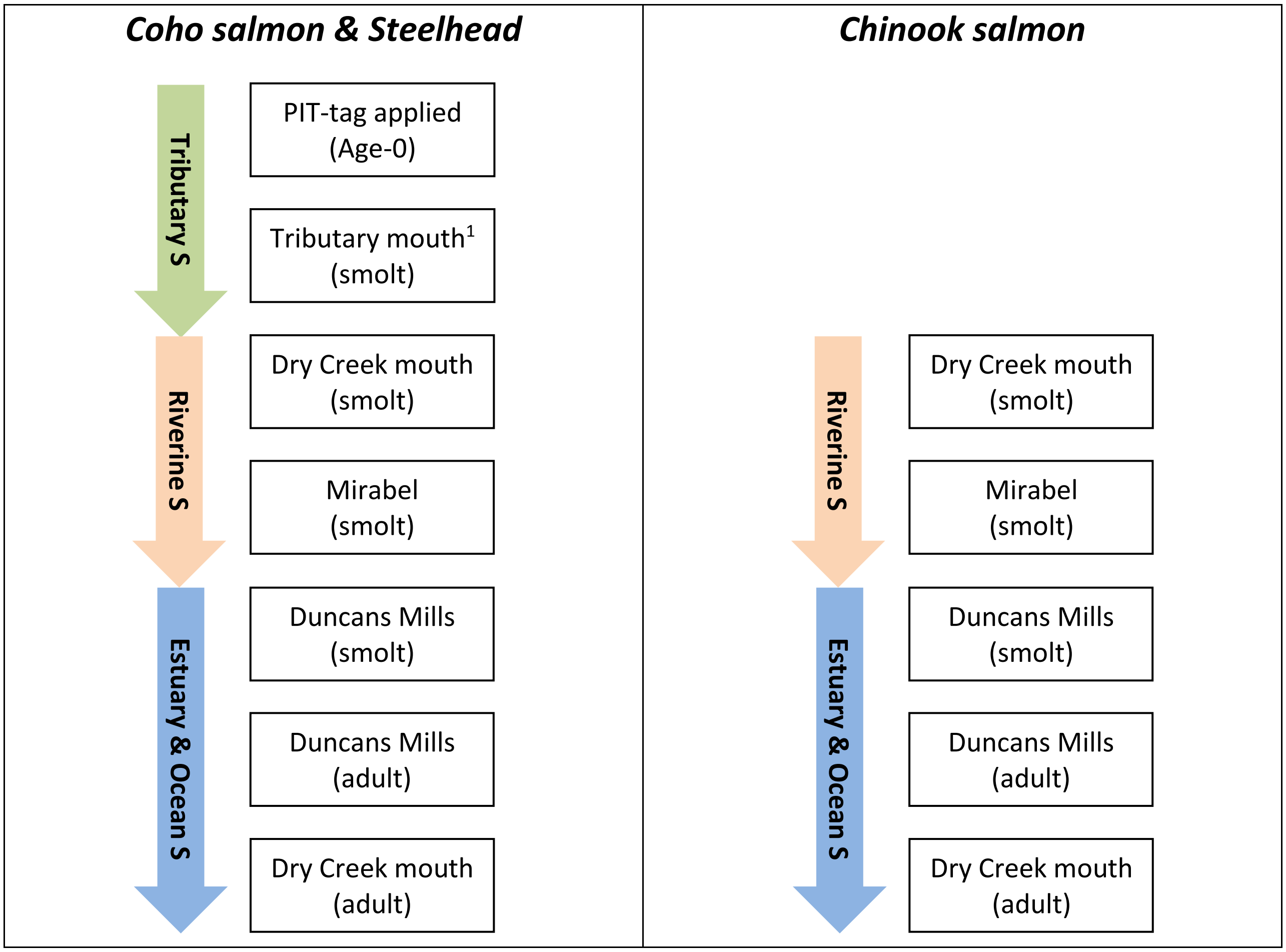


Figure 6. Paired flat plate PIT antenna array at the upstream end of the Russian River estuary (river km 10.5) in Duncans Mills.



[1]Only possible if a downstream migrant trap and/or PIT antenna array is operated at the tributary mouth.

Figure 7. Stage- and habitat-specific true survival (as opposed to apparent survival, the confounded estimate of true survival and fidelity) estimates possible from the multistate emigration model (provided a large enough number of fish is PIT-tagged) for the three salmonid species monitored in the Russian River watershed