Porter Creek Streamflow Enhancement Plan

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Prepared By:

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Table of Contents

EXECUTIVE SUMMARY

Since 2017, a collaborative team from Trout Unlimited, Sonoma Resource Conservation District, California Sea Grant, University of California Berkeley, and E & J Gallo has been managing, monitoring, and studying a streamflow augmentation project on Porter Creek, a tributary of the Russian River in Sonoma County, CA. The augmentation project is designed to release water from an off-stream pond on E & J Gallo's MacMurray Ranch through two pipes into the stream channel of Porter Creek. The objectives of streamflow augmentation in Porter Creek are to: (1) increase streamflow connectivity and salmon (*Oncorhynchus sp.)* escapement during spring smolt outmigration window (March-June), and (2) improve rearing habitat and juvenile salmon survival during summer low-flow conditions (June-October). This Streamflow Enhancement Plan provides an overview of the studies conducted at Porter Creek, reports key findings, and establishes recommendations for the future operation and maintenance of the streamflow augmentation system. Data presented include augmentation timing and rate (p 19-22); precipitation (p 29-31); streamflow (p 32-39); water temperature (p 39-42); smolt outmigration (p 42-51); wet-dry mapping (p 51-53); hydraulic habitat (p 52-59); water quality (p 52-59); invertebrates (p 52-59); salmonid movement (p 57-59); and over summer survival (p 57-59).

Summary of Findings: When timed appropriately, flow releases have been successful in establishing and maintaining surface water connectivity between Porter Creek and the Russian River during the spring smolt outmigration period. Photo-monitoring of the mouth of Porter Creek using cellular cameras has been found to be the most effective way to time flow augmentation during the spring smolt migration. Monitoring of smolt movement with Passive Integrated Transponder (PIT) tags suggest that hundreds of smolts that otherwise would have been trapped were able to successfully outmigrate because of the flow augmentation in Porter Creek. During the dry season, flow augmentation generally improved habitat connectivity, elevated dissolved oxygen levels, and resulted in improved over-summer survival of juvenile salmonids. However, the benefits of flow augmentation varied by water year type. In dry years, flow augmentation significantly improved dissolved oxygen and habitat connectivity at sites > 1.5 km downstream from the point of augmentation, but had a marginal warming effect on stream temperature. During wetter year, both dissolved oxygen and water temperature effects were negligible. In both years, augmentation had a small but positive effect on invertebrate drift in summer. Inter-pool movement of juvenile steelhead *(Oncorhynchus mykiss*) and stocked Coho Salmon (*O. kisutch*) increased due to augmentation during the dry summer. Perhaps the most consequential finding of this study was the significant increase in over-summering survival due to augmentation for both juvenile coho salmon (+24%) and steelhead (+20%) in 2020 and for juvenile coho (+11%) in 2019. A permanent gaging station in Porter Creek allows operators to time dry season flow augmentation for maximum benefit.

Long-term water release protocol: This streamflow enhancement plan includes a decision tree to guide ongoing flow augmentation in Porter Creek, including during the spring smolt outmigration window (p 63) and the summer dry season (p 65). While these guidelines incorporate the best available science from studies described in this report, we recommend that augmentation operators regularly communicate with regulatory agencies (such as CDFW and NOAA) to ensure that the recommendations within this Streamflow Enhancement Plan remain suitable for the current year's conditions and follow best practices for restoring salmonid populations in Porter Creek. This plan was written with the intent to inform annual water releases for the benefit native salmonids in Porter Creek, but we realize due to environmental conditions beyond our control, there may be instances where these recommendations should not be followed.

I. INTRODUCTION

Purpose

The primary purpose of the Porter Creek Streamflow Enhancement Plan is to provide recommendations for the long-term management of the Porter Creek Streamflow Augmentation System (SAS), located on the E & J Gallo MacMurray Ranch property in the Porter Creek watershed, tributary to the Russian River in northern California. The SAS was constructed in 2017 with funding from the Wildlife Conservation Board's Streamflow Enhancement Program. Since that time, intensive monitoring has been conducted in Porter Creek to understand the effects of water releases from the SAS on habitat for Central California Coast (CCC) coho salmon (*Oncorhynchus kisutch*) and CCC steelhead trout (*Oncorhynchus mykiss*). This document provides an overview of the studies conducted at Porter Creek, summarizes key findings, and establishes recommendations for the future operation and maintenance of the SAS. We recognize that environmental conditions in Porter Creek will change with time, which will necessitate revisiting the recommendations in this document to ensure that operations of the SAS are providing optimal benefits and avoiding adverse effects.

Watershed Overview

Located in Sonoma County, California, Porter Creek is a small tributary to the Russian River (Figure 1). The Porter Creek is a second order stream that is approximately 7 miles long and has a watershed area of 7.3 square miles (CDFG 2006). Information extracted[1] from the 2019 County of Sonoma parcel geographic information system data shows the watershed is almost entirely privately owned and primary land uses include pasture, vineyard, and hardwood/chaparral forest. The Porter Creek watershed has a characteristically Mediterranean climate — with warm, dry summers and cool, wet winters. Precipitation occurs almost exclusively as rainfall, mostly during the wet winter months (November through April).

Like many streams in the Russian River, Porter Creek historically supported spawning and rearing habitat for coho salmon and steelhead trout, in addition to high-quality habitat for many other aquatic species. Up until the early 1900s, salmonids were abundant within Russian River tributaries. Due to a multitude of factors, these populations have steadily declined. The construction of dams, logging, water use and diversions to satisfy residential and agricultural needs, introduction of non-native species, changes to stream morphology for flood control, and regional land use change have all contributed to declining salmonid populations in Russian River tributaries (Steiner Environmental Consulting 1996). The decline of salmon populations in the Russian River watershed tracks similar declines throughout the state (Moyle 2017).

In Russian River tributaries, low summer streamflow has been documented as a primary limiting factor for juvenile coho oversummer survival (Obedzinski 2018) and low spring streamflow has been identified as a potential bottleneck to coho salmon smolts migrating from tributaries through the Russian River to the ocean (Coho Partnership 2015). California's recent drought years have exacerbated the impacts of low streamflow on salmonid populations.

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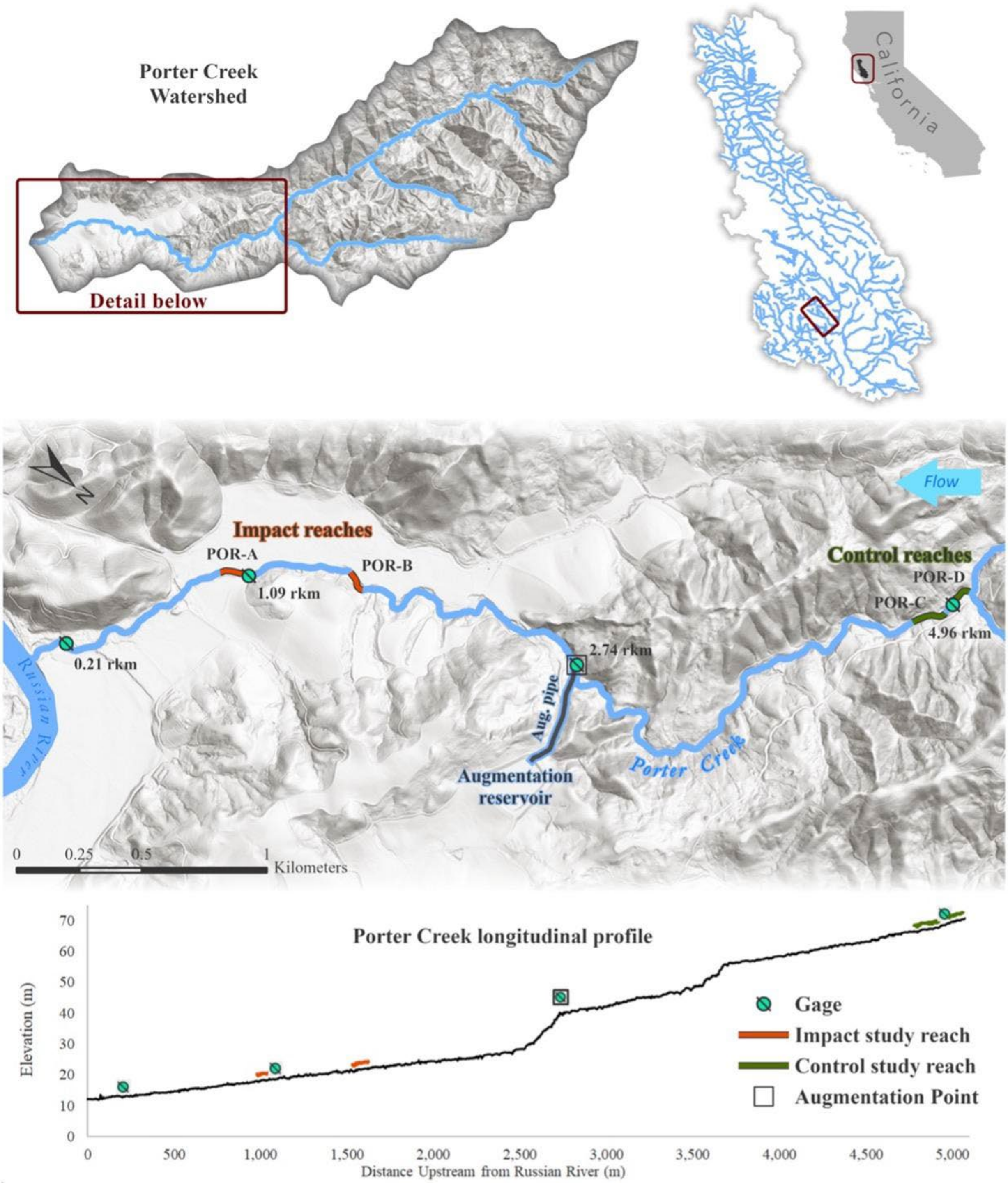

Figure 1. Porter Creek watershed (top left), located in the Russian River watershed in Northern California (top right). The study area map of lower Porter Creek (middle) indicates flow gaging sites, control and impact study reaches, the off-channel pond, and augmentation pipe (dark blue line). The longitudinal profile (bottom) shows the relative location of gaging stations, the augmentation point, and the control and impact study reaches.

Salmonid Populations and Impacts of Low Streamflow

This project focused on improving streamflow conditions for the benefit of the Central California Coast (CCC) Evolutionary Significant Unit (ESU) of coho salmon (*Oncorhynchus kisutch*) and for CCC ESU steelhead trout (*Oncorhynchus mykiss*). CCC coho salmon are listed as endangered under both the federal Endangered Species Act and the California Endangered Species Act and CCC steelhead are listed as threatened under the federal Endangered Species Act. As anadromous fishes, these species inhabit freshwater streams during much of their juvenile life stages. Adults return from the ocean to spawn in winter where juveniles will emerge from gravels during spring through early summer. Juveniles then rear in the stream throughout the summer, fall, and subsequent winter until they outmigrate to the ocean the following spring, just over a year from the time of their hatching (Wilson 1997). During this juvenile life stage, salmonids are dependent on high-quality freshwater habitat for summer rearing and sufficient flows to allow passage through the stream corridor on their way to the ocean as smolts. Low streamflow conditions can negatively affect both juvenile over-summer survival and the ability of smolts to outmigrate.

The 2016 *Volume IV: Central California Coast Steelhead* of the NOAA Fisheries Coastal Multispecies Plan identify recovery strategies that focus on improving migration for salmonid smolts as well as efforts to restore habitat complexity to improve juvenile summer rearing habitat. The Plan also suggests that recommended best management practices will "mitigate ongoing effects from residential development and associated water diversions on water quality and hydrology." Similarly, in the 2012 NMFS *Final Recovery Plan for the Evolutionary Significant Unit of Central California Coast Coho Salmon*, adequate quantities of water and the absence of barriers to migrations (such as stream disconnection) are called out as conditions required to switch the trajectory of CCC coho salmon from extinction to recovery. The lack of water is deemed a "severe limiting factor" for the survival of coho salmon across life stages, particularly for juvenile rearing habitat in the dry season. For example, Obedzinski et al. (2018) showed that juvenile salmonid survival in other Russian River tributaries was strongly influenced by periods of flow disconnection. They found that the greater the length of time that pools are disconnected from surface flow, the more likely it is that juvenile salmonids will perish. The study also showed that juvenile salmonid survival was positively associated with streamflow magnitude, wetted volume, and dissolved oxygen – all factors that can be improved with flow releases.

Ecological Objectives from Streamflow Augmentation Releases

The Porter Creek Streamflow Augmentation System was designed to satisfy two ecological objectives: (1) increasing connectivity during the period of smolt outmigration, and (2) improving rearing habitat during summer low-flow conditions.

Nearby landowners, E & J Gallo staff, and fisheries agencies have noted that Porter Creek predictably becomes disconnected from the Russian River at its mouth in the late spring/early summer. With spring flow releases, surface flows in Porter Creek can be reconnected to the Russian River, thereby extending the window of time that smolts can outmigrate from the system. Oversummer water releases in the summer and early fall not only increase wetted habitat availability in the stream channel, but also reduce the negative effects of instream dissolved oxygen (DO) impairment, which generally exhibit a downward trend over the summer season, nearing or even dropping below fish impairment levels (Coho Partnership 2019).

Increasing streamflow in the dry season is expected to have many ecological benefits. However, modification of a natural (though impacted) system through water releases could also cause unintentional negative impacts, such as disrupting non-salmonid species and/or causing salmonids to occupy habitats that become dewatered when flow augmentation is stopped. For this project, we took all measures possible to avoid potential negative impacts (e.g., maintaining minimal releases following higher augmentation levels to avoid stranding, ramping flow release rates, monitoring water quality, etc.). We also determined that near complete stream drying would be more harmful to the fish populations than the potential negative effects of augmentation.

In addition to increasing the probability of over-summer survival and spring outmigration in juvenile salmonids, we assumed that flow augmentation in Porter Creek would have positive impacts on aquatic macroinvertebrate communities, amphibians, non-salmonid fishes, and other aquatic and riparian flora and fauna. Improving stream conditions for non-salmonid species may have an additional positive benefit to salmonid recovery by increasing macroinvertebrate food supply, and, in turn, increasing growth opportunity for juvenile salmon. Studies show that larger smolts have higher survival rates in ocean environments (Bennett et al. 2015, Hayes et al. 2008).

Site History

E & J Gallo Winery, established in 1933, is recognized as the largest winery in the United States. From the early days of the business, the co-founders established a commitment to the environment and the family-owned winery believes in the importance of preserving and enhancing the land for future generations to enjoy. Over the last decade, E & J Gallo has demonstrated that commitment by collaborating with multiple resource agencies to improve stream conditions for the benefit of salmon populations in Porter Creek.

Beginning in 2010, E & J Gallo participated with the Russian River Coho Salmon Captive Broodstock Program (Broodstock Program) – a collaborative partnership that works together to build a self-sustaining coho population within the Russian River watershed – to allow for the release and monitoring of coho salmon on the MacMurray Ranch property's reach of Porter Creek. E & J Gallo coordinated water releases from a water storage pond on the property to ensure adequate streamflow was present in Porter Creek for the survival of coho released from the Broodstock Program.

In 2011, SRCD began working with E & J Gallo Winery by removing a fish passage barrier on a portion of Porter Creek that lies within the MacMurray Ranch property. This project was a success and SRCD continued to work with the winery in 2014 to enhance the habitat of Porter Creek by installing large woody debris structures at a total of 11 sites along the portions of Porter Creek that are under E & J Gallo ownership. In response to the severe drought conditions in May 2014, California Department of Fish and Wildlife (CDFW) and National Oceanic and Atmospheric Administration (NOAA) Fisheries announced a Voluntary Drought Initiative designed to protect imperiled populations of salmon and steelhead from negative effects resulting from drought conditions. Priority watersheds were chosen to concentrate efforts where the risk of drought-related effects to Federal Endangered Species Act (ESA) and California Endangered Species Act (CESA) species were the greatest. Porter Creek was chosen as a priority watershed, expanding opportunities and available resources for streamflow enhancement work in this area.

To address the potential impacts of low-water drought conditions on salmonids, E & J Gallo entered into a Voluntary Drought Agreement with CDFW and NOAA in 2014. In this agreement, E & J Gallo agreed to release water from the existing off-stream reservoir, through a temporary piping system, into Porter Creek for the purpose of supplementing natural streamflow to benefit anadromous fishes (under the guidance of agencies) during the critically low flow conditions.

During April of 2015, the mouth of Porter creek became dry during the coho salmon smolt out-migration season (March through June), creating a blockage in the migration corridor and trapping coho smolts in pools where they would likely perish. When this occurred, E & J Gallo Winery expressed their willingness to release water, again, from the nearby reservoir into Porter Creek. This time, to reconnect Porter Creek to the Russian River and allow trapped smolts to access the river and ocean. California Sea Grant (CSG) placed temporary fish tracking equipment near the mouth of Porter Creek and was able to determine that two pulsed flow releases provided passage for fish and estimated that over 200 smolts were able to leave that otherwise would have remained trapped in Porter Creek. This initial evidence of success was promising; however, there was still uncertainty about whether this approach would be feasible in future years. E & J Gallo was willing to conduct spring flow releases each year, but with a limited water supply for both spring and summer releases, they needed guidance as to when and how much water to release. Further evaluation was needed to determine the timing, magnitude, and duration of flow augmentation that would have the highest probability of allowing coho smolt passage when flows become too low. Furthermore, problems with the temporary flow-release system made it clear that additional investment would be needed to continue streamflow enhancement activities in the long-term.

To address knowledge gaps and infrastructure limitations, Sonoma RCD applied for a California Wildlife Conservation Board Proposition 1, Streamflow Enhancement grant for the Porter Creek Streamflow Enhancement Project on the E & J Gallo MacMurray Ranch property. Trout Unlimited (TU) and CSG were included as project partners to conduct streamflow and fish monitoring, respectively. Funded in December of 2016, construction of the flow augmentation system began in March of 2017 and was completed in October of 2017. A second Streamflow Enhancement Program grant was awarded to UC Berkeley in 2019, which supported additional monitoring and study on Porter Creek through 2022.

CSG monitored coho smolt migration timing, with TU conducting streamflow monitoring and wetted habitat surveys in Porter Creek from February 2017 through October 2019. The data collected though this monitoring effort was used to develop this Streamflow Enhancement Plan for Porter Creek, with the goal of maximizing the benefits of streamflow enhancement for fish while considering the constraints of water available for release. In 2019 and 2020, CSG and UC Berkeley completed a study on the effectiveness of streamflow augmentation to support outmigration of coho salmon smolts and over summering coho and steelhead trout. This study included monitoring the movement of tagged salmon and steelhead, as well as recapturing fish to estimate survival and growth and comparing the response of fish populations to changes in habitat connectivity, water depth and velocity, water quality, and invertebrate drift.

Project Partners

Sonoma Resource Conservation District (SRCD), established in 1946, is one of 97 RCDs in California and remains a leader in promoting stewardship of natural resources in Sonoma County. Resource Conservation Districts are local partners in conservation working tirelessly with rural, agricultural, and urban partners to support healthy ecosystems, habitat, and biodiversity, and ensure sustainable, high-quality water supplies for both people and wildlife. All work performed is voluntary, at the will of the landowner with specific property concerns and goals addressed.

Working closely with project partners in the Russian River basin, CSG's Russian River Salmon and Steelhead Monitoring Program has been conducting widespread monitoring and research to support salmonid recovery for over a decade. CSG science-based information supports the Broodstock Program, statewide Coastal Monitoring Program, Russian River Coho Water Resources Partnership as well as providing summer habitat assessments, habitat enhancement monitoring, and studying the relationship between streamflow and fish survival.

TU's conservation hydrology team conducts streamflow monitoring throughout coastal systems to determine ecological responses to even the smallest streamflow changes in addition to the impacts of human water use on streamflow conditions. TU works with an extensive network of project partners within the Russian River basin to support salmonid recovery efforts by providing accurate low-flow streamflow data. Recent hydrologic studies have identified effects of water releases, drought, and direct diversions on streamflow conditions.

Starting in 2017 a research group from the University of California at Berkeley, led by Dr Ted Grantham began collaborating with CSG on research in Porter Creek. Dr Grantham is a cooperative extension specialist and adjunct professor in the Department of Environmental Science, Policy, and Management at the University of California, Berkeley. The Grantham lab studies environmental water needs and strategies for incorporating ecological principles in water management. Dr. Gabriel Rossi completed a portion of his PhD dissertation on the ecological effects of the Porter Creek flow augmentation system (Rossi 2020, Chapter 2, Rossi et al. *in review* 2023). A large group of graduate and undergraduate researcher assistants also participated in this research project including Brian Kastl, Shelley Pneh, Weston Slaughter, Keane Flynn, Gunnar Reith, Sam Larkin, and Shannon Mckillop-Herr.

Streamflow Augmentation System

The storage pond at the E & J Gallo MacMurray Ranch has a capacity of approximately 250-acre feet (Figure 2) and is located upslope of Porter Creek approximately 2.7 km upstream from the mouth (Figure 1). The pond is filled by rainfall and under water right from a diversion well along the Russian River for vineyard irrigation during the dry season. The flow augmentation system utilizes the storage pond and existing vineyard irrigation system to collect and convey water from the pond to a pump house, where it flows down to the creek. Water is released to two release points in the creek via two buried pipes (Figure 3). Water releases are controlled by a valve and meter system that utilizes programmable technology (Figure 4) with remote access, a photo-voltaic array (Figure 5), and battery storage. The maximum potential flow release rate for the system is approximately 400 cubic feet per second.

The water release control system was designed by Weeks Drilling and Pump Co. and CORE Utilities to allow precise control of the water releases, including a mechanism for a slow shutdown of high-volume releases for smolt outmigration. In 2023, Sonoma RCD worked with Gallo staff and the farm management company HotSpot Ag to update the controller system. HotSpot Ag installed and programmed new and updated capabilities for the controller to allow for a better user experience with superior capabilities for long term operation and maintenance. The system is designed to allow flexibility in the rate of valve closure to accommodate modifications of water released for streamflow augmentation at any given time.

The water released from the reservoir flows via gravity through an existing watermain (Figure 6). The upper water release pipe constructed of 3-inch high-density polyethylene (HDPE) pipe runs in a northwest direction down a drainage to Porter Creek (Figure 7). The terrain is relatively steep oak woodland and required trenching using a combination of a small walk-behind trencher and hand-crews from Conservation Corps North Bay (CCNB). The pipeline crosses two small drainages via seasonal above-ground pipeline sections that can be removed in winter to prevent damage from high flows in the drainages and replaced in the summer.

The lower water release pipe, constructed of six-inch HDPE pipe, is tied into the same point of connection as the upper pipe and runs downhill adjacent to an access road in a southwest direction, before turning northwest to drain into Porter Creek (Figure 7). Except for a short section along the access road, the lower pipeline had easier access and was constructed using conventional trenching equipment such as excavators and backhoes. The lower water release pipe also has a removable section at the point of release that can be removed during winter months (Figure 6). This eliminated the need to disturb the streambank with pipeline installation and prevents damage to the release system in high winter flows. Each pipe was installed with a tracer wire to locate the pipes and prevent damage to the pipes if future construction work will occur in the area.

Figure 2. Existing approximate 250-acre foot storage pond on the E & J Gallo MacMurray Ranch property.

Figure 3. Installation of six-inch (pictured left) and three-inch (pictured right) HDPE pipe to carry water from the storage pond to the Porter Creek release points.

Figure 4. Valve and meter system (pictured left) and the system controller (pictured right) for the Porter Creek flow augmentation system.

Figure 5. Pictured left, existing pumphouse located below the storage pond that was used for housing system control infrastructure with the constructed photo-voltaic array that provides power to the controller and valve actuator in the background (also pictured right).

Figure 6. Water releases from the E & J Gallo MacMurray Ranch storage pond into Porter Creek. Pictured left, removable section of aluminum pipe at the upper release site. Pictured right (top and bottom), removable section of aluminum pipe at the lower release site.

Figure 7. Schematic of approximate locations of pipe and water release points to Porter Creek from the storage pond.

II. STREAMFLOW AND SALMONID MONITORING GOALS AND METHODS

Monitoring studies at Porter Creek were designed to help inform the long-term operation and management of the streamflow augmentation system by evaluating the effects of flow releases on passage of coho smolts outmigrating in the spring and in-stream habitat for juvenile coho salmon during the summer dry season. Specific objectives were to:

1. Characterize rainfall, streamflow, and wetted habitat conditions in different water year types
2. Document smolt emigration timing in relation to streamflow
3. Determine how spring flow augmentation affects the connectivity of Porter Creek to the mainstem of the Russian River, allowing smolts to access to the ocean
4. Determine how flow augmentation in the summer dry season affects streamflow, wetted habitat, water quality, invertebrate drift, and fish movement, growth, and survival

Figure 8. Map of Porter Creek showing flow release sites, streamflow gage locations, monitoring sites, trail camera configuration location, and stocking and snorkel survey reaches.

Rainfall, streamflow, and wetted habitat monitoring methods

Rainfall Data

The rainfall data used in this report was collected by the National Oceanic and Atmospheric Administration (NOAA), at the nearby Healdsburg, CA at NCDC Station (# 3875). Total annual rainfall, total monthly rainfall, median average annual rainfall, and median average monthly rainfall were calculated based on daily recorded values in inches and were used to contextualize precipitation patterns over the study period.

Streamflow Data

Streamflow data used in this report was collected by Trout Unlimited at 6 sites within the Porter Creek watershed (Figure 8). The most downstream measurement site (Po01, Porter Creek below fish antenna) is just upstream of the confluence of Porter Creek with the Russian River. This site is slightly downstream of a PIT tag antenna (fish tracking device) operated by CSG. Monitoring this site is important because the downstream reach is usually the first to disconnect as streamflow recedes in the spring; depending on the timing of disconnection, this may trigger the need to initiate spring flow releases so that smolts can successfully outmigrate. Monthly flow measurements were conducted at this site, and a rating curve and hydrograph was developed using stage data from the next upstream site (Po02, Porter Creek above fish antenna) which has a datalogger continuously recording stage (water level) and temperature. The next upstream sites, (Po03, Porter Creek at weir, and Po04, Porter Creek below second release) also have continuous data loggers recording stream water level and temperature, and streamflow measurements were conducted here to create rating curves and hydrographs. Po05, Porter Creek between releases, which was named so because of a second future upstream release, is upstream of the release. This site does not have a datalogger, but monthly flow measurements were conducted at this site. Po06 is the Upper Porter Creek gage site and was installed in summer 2020. Po06 has a continuous data logger recording stream water level and temperature, and streamflow measurements were conducted here to create rating curves and hydrographs. In addition to flow measurements, monthly site visits also included wet/dry mapping to create wetted habitat maps of the stream from the confluence to the crossing of the creek with Westside Road (described in more detail in the next section).

Water temperature

Water temperature data used in this report was collected by Trout Unlimited at the 4 gage sites within the Porter Creek watershed (Figure 8). Water temperature was collected at 15-minute intervals throughout the study period.

Wet-dry mapping

Beginning in 2017, a series of wet-dry mapping surveys were conducted each year on Porter Creek from the confluence with the Russian River upstream to the flow augmentation point or as far as 5.01 km. Surveys were conducted before, during, and after flow augmentations. During each survey, the spatial extent of "wet" (flowing stream), "intermittent" (dry riffles, but wet pools), and "dry" (dry riffles and pools) channel was mapped using a mobile ArcCollector application with a handheld GPS unit (BadElf, 2.5m stationary accuracy). A full description of protocol for wet-dry mapping surveys is available online (CA Sea Grant 2019). Results were made available via a web-based mapping wetted habitat dashboard in ArcGIS online.

Smolt outmigration monitoring methods

Each fall between 2016 and 2020, the Broodstock Program released approximately 4,500 to 6,000 juvenile coho salmon into Porter Creek as part of the coho salmon recovery effort in the Russian River watershed (Table 1). A proportion of these juveniles were implanted with passive integrated transponder (PIT) tags, uniquely coded electronic tags that can be detected at stream locations using PIT tag detection systems (antennas and transceivers). These Broodstock Program releases served as a study population for tracking smolt movement in relation to streamflow.

Table 1. Number of juvenile coho salmon released into Porter Creek during the fall season.

Year	Total number released	Number (proportion) PIT-tagged
2016	6,096	913 (0.15)
2017	6,062	1,728 (0.29)
2018	5,073	1,009 (0.20)
2019	4,532	680 (0.15)
2020	6,095	920 (0.15)

PIT Tag Detection System

To evaluate the ability of juvenile coho salmon to migrate out of Porter Creek as smolts at different stream flows during the spring, we installed a PIT tag detection system near the mouth of Porter Creek and operated it from March 9, 2017 through June 30, 2021. The PIT tag detection system consisted of a Biomark multiplexing transceiver placed in a waterproof box on the streambank (Figure 9) and was powered using AC power with a DC conversion system. A 300-foot cable led from the transceiver to four fifteen by two-and-a-half foot antennas, housed in four-inch PVC, that were placed flat on top of the streambed and secured with duckbill anchors. The antennas were placed in a paired, channel-spanning arrangement (two upstream and two downstream) (Figure 9) so that detection efficiency could be estimated, and the movement direction of individuals could be determined. When a PIT-tagged fish swam over an antenna, the individual tag number, date, and time was logged. This allowed us to document the number and timing of coho smolts migrating out of Porter Creek and relate this data to stream flow levels and flow augmentation timing. During the study period, antennas were checked every two weeks and data was downloaded, transferred to Excel, error checked and uploaded to a SQL database. More frequent checks were made during storm events. The detection system was powered off each summer when the site became dry (typically between July and November).

Camera

In the spring of 2019, CSG installed a Spypoint Link-Evo cellular trail camera 0.08 river km upstream from the mouth of Porter Creek (Figure 8) to document the date and time of disconnection from the Russian River. The camera location was chosen based on observations of previous disconnections. Camera settings were placed at 15-minute photo intervals at an image size of 12MP, including timestamps. Images were in color during the day and infrared by night. Photos were stored on a SanDisk 32GB micro-SD card but could also be viewed in real-time through an online portal provided by Spypoint. When Porter Creek was thought to be nearing disconnection in early June, site visits were done to validate that the monitored riffle was the first point of disconnection along the creek.

Figure 9. PIT transceiver (left) and antenna array (right) located near the mouth of Porter Creek.

Snorkel Surveys

Snorkeling surveys were conducted on an as-needed basis in the spring when we needed to determine whether migrating smolts were trapped in pools between the confluence with the Russian River and the bridge crossing at Westside Road (Figure 8). For each survey, a diver snorkeled each pool from a downstream to upstream direction and recorded the number of coho salmon, steelhead, and Chinook salmon observed.

Methods for assessing flow release effects on outmigration

When disconnection occurred during the coho smolt outmigration window (March 1 - June 30), and smolts were observed trapped in pools upstream of the point of disconnection, the team assessed whether a spring flow augmentation was warranted. Considerations included the number of trapped smolts, weather conditions, extent of drying, river level, and the quantity of water available for a release. To evaluate the success of spring flow releases, we evaluated whether the stream reconnected by viewing camera images, visiting the site, and viewing streamflow data. To determine whether the flow release resulted in increased fish passage, we summarized PIT tag detection data in relation to flow release timing.

Spring Streamflow Releases

2017: No spring augmentation was conducted in 2017. Few smolts remained in Porter Creek at the time of disconnection, therefore no spring flow release was initiated. Flows rapidly decreased in early June 2017 prompting the oversummer release on June 8, 2017 (Figure 10). The release ended June 30, 2017. Two more releases were initiated due to increased stream drying and disconnection on July 21, 2017 (through August 24, 2017) and August 27, 2017 (through the end of September). Data logs are not available throughout the end of September, presumably because the control and augmentation system were not complete and received modifications through the completion of implementation in October 2017.

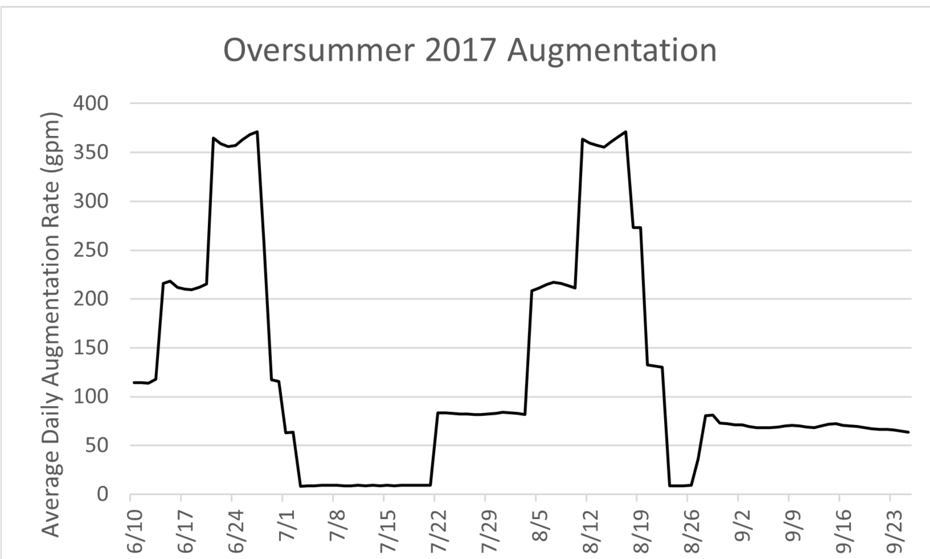

Figure 10. Average daily gallons per minute (gpm) of water released during the oversummer 2017 flow augmentations of 6/8/2017 – 6/30/2017, 7/21/2017 – 8/24/2017, and 8/2/2017 – end-September 2017 (data not available through exact end date).

2018: The spring 2018 flow release was initiated on May 7, 2018 (Figure 11) due to the disconnection of Porter Creek in early-May. The release ended May 14, 2018 when disconnection of Porter Creek remained despite maximum flow release. An oversummer water release was initiated on June 30, 2018 (Figure 12) after flow connectivity receded and zero flow was recorded at one gage. The release ended November 30, 2018.

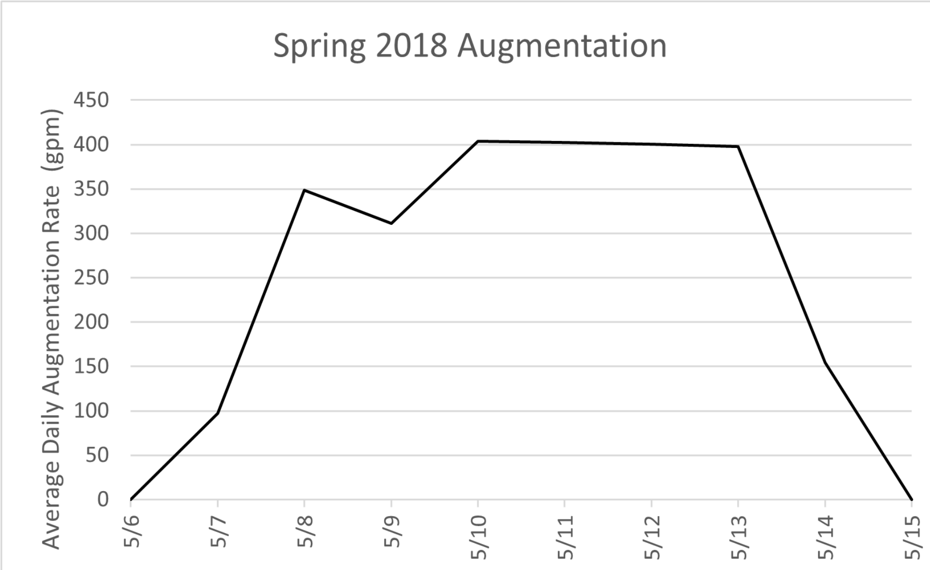

Figure 11. Average daily gallons per minute (gpm) of water released during the spring 2018 flow augmentation 5/7/2018 – 5/14/2018.

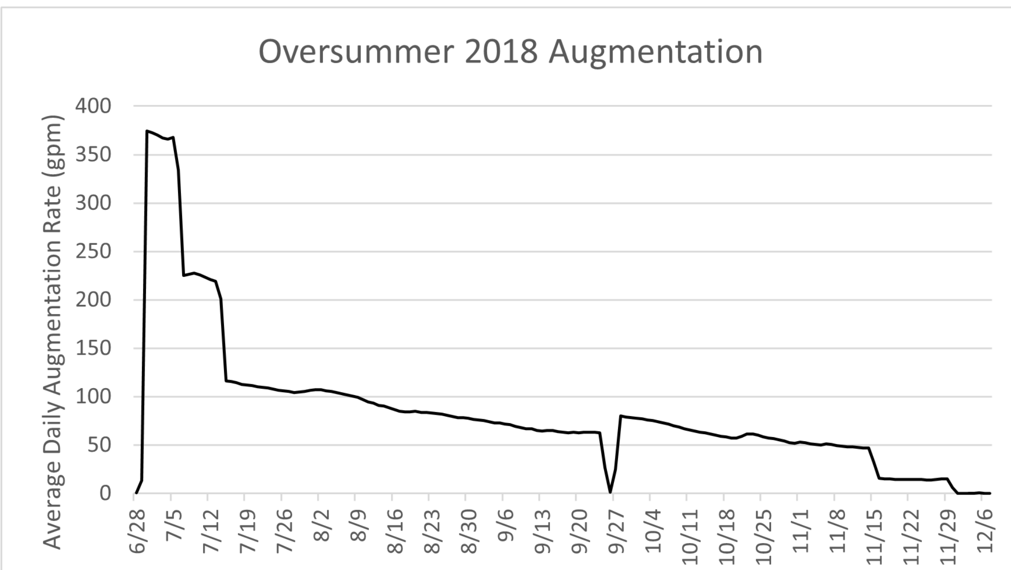

Figure 12. Average daily gallons per minute (gpm) of water released during the oversummer 2018 flow augmentation 6/30/2018 – 11/30/2018.

2019: No spring flow release was conducted as the mouth of Porter Creek remained connected due to a mid-May storm. The oversummer release was initiated on July 12, 2019 (Figure 13) when one of the gage sites dried out. The release ended on December 1, 2019.

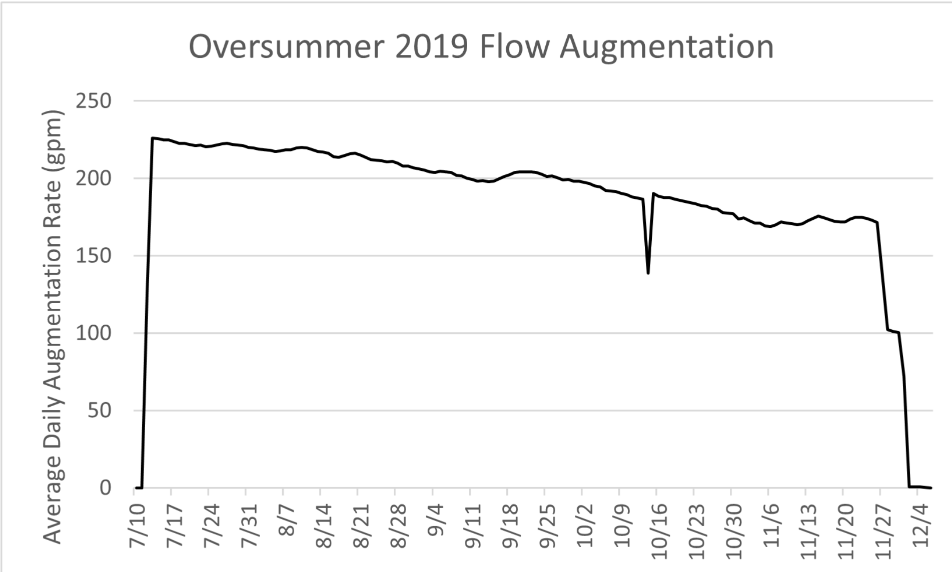

Figure 13. Average daily gallons per minute (gpm) of water released during the oversummer 2019 flow augmentation 7/12/2019 – 12/1/2019.

2020: The spring 2020 flow release was initiated on April 15, 2020 (Figure 14). The release ended April 24, 2020. An oversummer flow release was initiated on June 26, 2020 (Figure15) and ended on August 20, 2020.

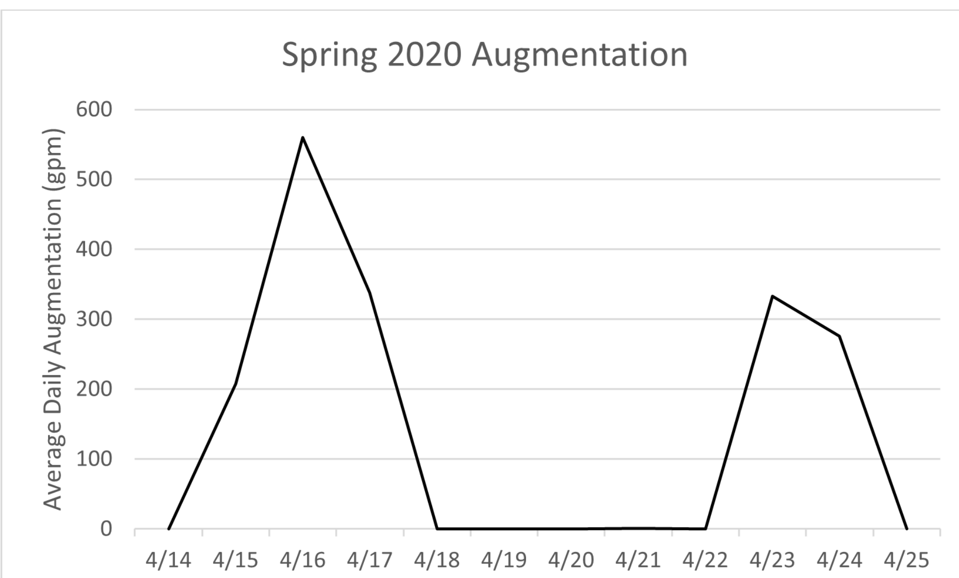

Figure 14. Average daily gallons per minute (gpm) of water released during the spring 2020 flow augmentation 4/15/2020 - 4/24/2020.

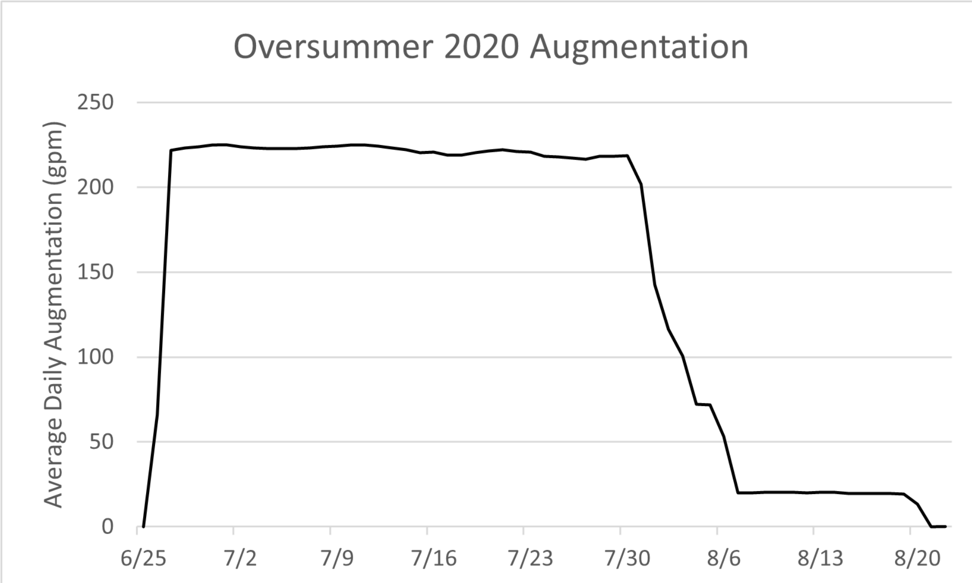

Figure 15. Average daily gallons per minute (gpm) of water released during the oversummer 2020 flow augmentation 6/26/2020 – 8/20/2020.

Methods for assessing stream augmentation effects dry season rearing habitat

In addition to monitoring smolt outmigration, we also conducted a two-year study to evaluate the effect of augmentation on over-summering juvenile steelhead and coho salmon. The study included both the unusually wet summer of 2019 and the dry summer of 2020. The purpose of this study was to determine whether augmentation could significantly improve conditions (habitat and water quality) for over-summering salmonids, whether those effects translated to increased survival, and under what ambient streamflow conditions augmentation is warranted. The results of the over-summering, together with the smolt outmigration study inform the "Long-term water release protocol and recommendations" (Section V).

Four study reaches were selected on Porter Creek – two in a control reach (upstream of augmentation between river kilometer [rkm] 3.7 and rkm 4.65) and two in an impact reach (downstream of augmentation between rkm 1.0 to 1.65; Figures 1). Each study reach contained four riffle-pool habitat units which served as replicates resulting in eight "control" units and eight "impact" units (Figure 16). The riffle-pool unit is a ubiquitous geomorphic feature in alluvial streams with slopes between 0.5% and 2% (Leopold and Wolman 1957) and provides a discrete habitat unit for evaluating juvenile salmonid rearing and foraging during the low-flow period (Rossi et al. 2021). Study site selection was constrained by landowner access and channel confinement in the upper reaches of Porter Creek and was, therefore, not random. We selected reaches with similar slope and geomorphic characteristics that supported foraging salmonids and we prioritized sites with simple hydraulic controls so that we could develop robust rating curves at the downstream riffle crest.

<u>Streamflow Augmentation</u>

We tested the same level of flow augmentation during a wet summer (2019) and a dry summer (2020). Experimental augmentations were timed to occur just prior to riffle-pool disconnection in Porter Creek. In 2019, a large May freshet extended surface connectivity until mid-July in the control reach. We tested an augmentation treatment of 13.9 L/s starting on July 12 and continuing through October. This treatment (13.9 L/s) was repeated during the much drier summer of 2020 starting on June 25 and ending on August 6 (Figure 3). Streamflow was gaged at three locations below augmentation (rkm 2.75, 1.05 and 0.25) and one location upstream (rkm 4) (Figure 1).

Wetted Habitat Mapping

The spatial extent of “wet” (flowing stream), “intermittent” (dry riffles, but wet pools), and “dry” (dry riffles and pools) channel was mapped immediately prior to and after one month after augmentation. Surveys began at the confluence with the Russian River and continued upstream 5.01 km to the top of our control reach (Figure 1). Data were entered using the mobile ArcCollector application with a handheld GPS unit (BadElf, 2.5m stationary accuracy). A full description of protocol for the wetted habitat surveys is available online (CA Sea Grant 2019). Summary statistics describing the proportion “wet,” “intermittent,” and “dry,” channel from rkm 0 to rkm 5.01 were computed for each surveyed interval and related to augmentation level and ambient streamflow.

Hydraulic Habitat Measurements

HOBO U20 water level loggers were deployed in all pools within each study reach to measure continuous changes in pool depth. Water level loggers were mounted to rebar and installed near the pool maximum depth (Figure 16). Depth was measured where the thalweg bisects the downstream riffle crest of each pool, a point known as the ‘riffle crest thalweg’ (RCT) (Rossi et al. 2021). Riffle crest thalweg depth serves as an indicator of fish passage and has been shown to be correlated with dissolved oxygen concentrations (Rossi et al. 2021). The elevation of the RCT was surveyed relative to the elevation of the water level logger, to allow for a conversion between continuous pool stage and continuous RCT depth. Velocity was measured along the thalweg of the pool from the upstream point where water entered the pool at one-meter increments. These velocity profiles served as a proxy for the changing length of feeding zones in pools below riffles due to augmentation.

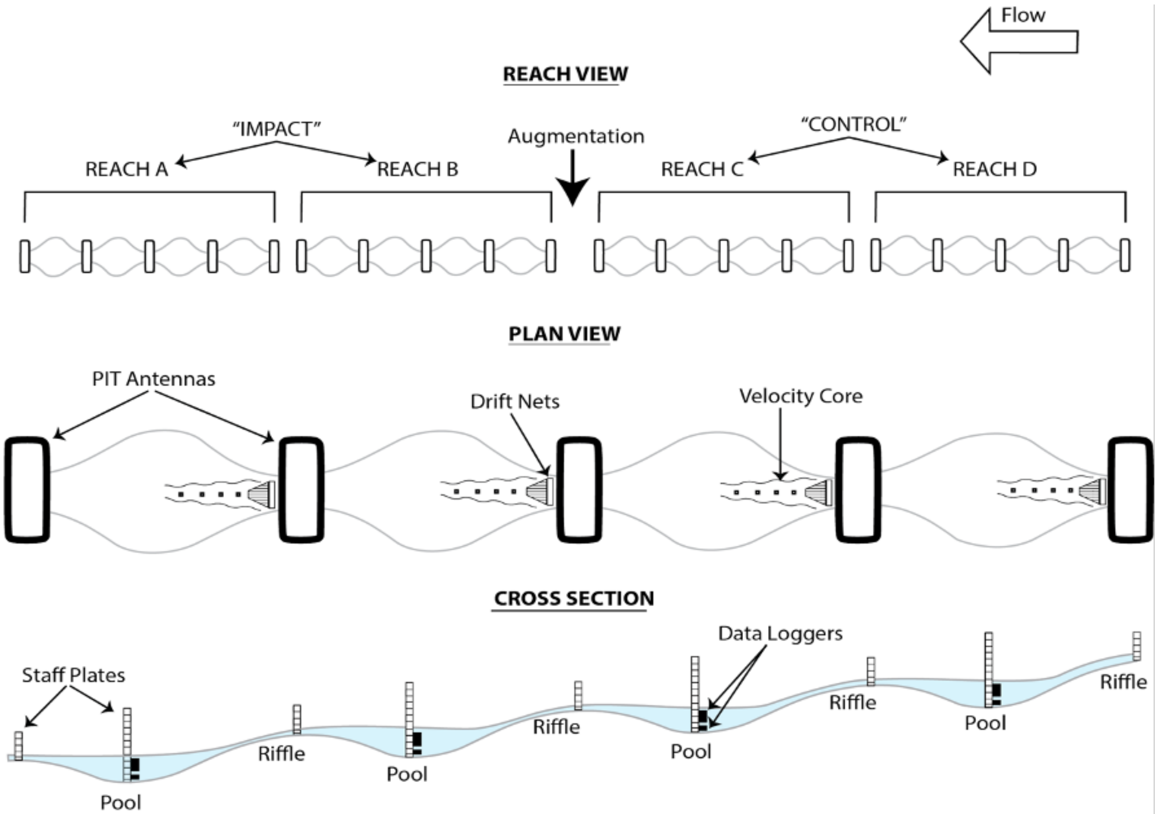

Figure 16. Schematic of the Porter Creek study design showing two "control" and two "impact" study reaches separated by the point of augmentation (top), as well as a plan view (middle) and cross-section view (bottom) of a study reach. Each study reach contained four consecutive riffle-pool units, bounded by a PIT antenna and containing a staff plate, HOBO U26 DO logger and HOBO U20 water logger in the pool, and a staff plate on the downstream riffle crest. The BMI drift net and pool velocity measurement locations are also shown.

Water Quality Monitoring

Dissolved oxygen and stream temperature were measured using continuous HOBO U26 data loggers in each pool (Figure 16). The dissolved oxygen loggers were calibrated prior to deployment, and the output data was corrected using HOBOware Pro's Dissolved Oxygen Assistant software. Calibration measurements were taken three times during the study period using a handheld YSI Pro20 in each pool.

Invertebrate Sampling

To estimate the effect of streamflow augmentation on the stream invertebrate assemblage, and associated prey abundance for salmonids, we sampled invertebrate drift entering each pool. Invertebrate drift was sampled for two hours (+/- 10 minutes) two weeks before and two weeks after augmentation in both years (Figure 17). Sampling took place between 16:00 and 19:00. Drift was collected in nets with a 50 cm x 20 cm mouth aperture and 500-µm mesh. The drift net was installed just below the water surface at the head of each pool (Figure 16). Cross-stream position of the net was adjusted on each occasion to capture the region of highest velocity at each sampled streamflow. All invertebrate samples were preserved in 100% ethanol in the field, and in the lab, identified to the closest taxonomic value and measured to the nearest 0.5mm with a dissecting scope (Merritt (Merritt et al. 2008). Each invertebrate was measured to the nearest 0.5 mm under a dissecting scope and biomass (mg dry mass) was estimated from published length to dry mass relationships (Benke et al. 1999; Sabo et al. 2002). Since our statistical analysis was intended to evaluate the effect of invertebrate availability as a food resource for fish, we removed large (>10mm) taxa which made up less than 0.5% of the total drift.

Study Population

Salmonid movement, growth, and survival were evaluated using a population of passive integrated transponder (PIT) tagged fish. As an initial marking event, fish were captured from each study reach using backpack electrofishing during sampling events on June 24th and 25th, 2019, and June 1st and 2nd, 2020. Untagged fish larger then 60 mm were fitted with 12 mm FDX PIT tags [TG1] [OM2] by creating a small (1mm) incision in the body cavity on the ventral side and inserting the tag (Table 1). In addition to electrofishing, tagged juvenile Coho Salmon raised at the Don Clausen Fish Hatchery at Warm Springs Dam were stocked in reaches A and C (Figure 1) during both 2019 and 2020. Approximately 250 Coho Salmon were stocked into each of the two reaches on June 27th, 2019 (mean of 65 fish/pool) and June 8th, 2020 (mean of 62 fish/pool) (Table 2).

Table 2. Counts of salmonids that were PIT tagged in Porter Creek (left) or tagged individuals released into Porter Creek from Don Clausen Fish Hatchery (right) in 2019 and 2020. Hatchery coho salmon were released only into reaches A and C (Figures 1).

Species	2019			2020		
	Wild	Hatchery	Total	Wild	Hatchery	Total
Steelhead	186	0	186	174	0	174
Coho Salmon	5	517	522	166	497	663

Salmonid Movement

Movement of all PIT-tagged fish was monitored using stationary PIT antenna arrays mounted over riffles between each study pool. Antennas were mounted 30 cm above the water surface on cinder blocks to allow fish to swim freely while maintaining proximity to the antennas for detection. The PIT antennas were connected to power sources and a data logger located on the adjacent terrace. To estimate the effect of augmentation on salmonid movement between pools and riffles, we computed the total number of detections at each antenna per day (in the control and impact reaches), and also the number of detections per unique tag per day so that a single mobile fish wouldn't bias the results.

Salmonid Growth

Fish growth was estimated by measuring the fork length (mm) of recaptured individuals and comparing those measurements to fork length at the time of tagging. Growth intervals were 52 days in 2019 and 57 days 2020 (Figure 17). These intervals include time before and after augmentation started but more than half the duration of the growth intervals (33 days in 2019 and 34 days in 2020) occurred after augmentation. Growth was computed as change in length (mm/day). We differentiated fish smaller then 80 mm as "young-of-year" (YOY) from larger "parr" (>80 mm), but restricted our statistical analysis to YOY because too few parr were captured. No smolts were observed during our summer sampling.

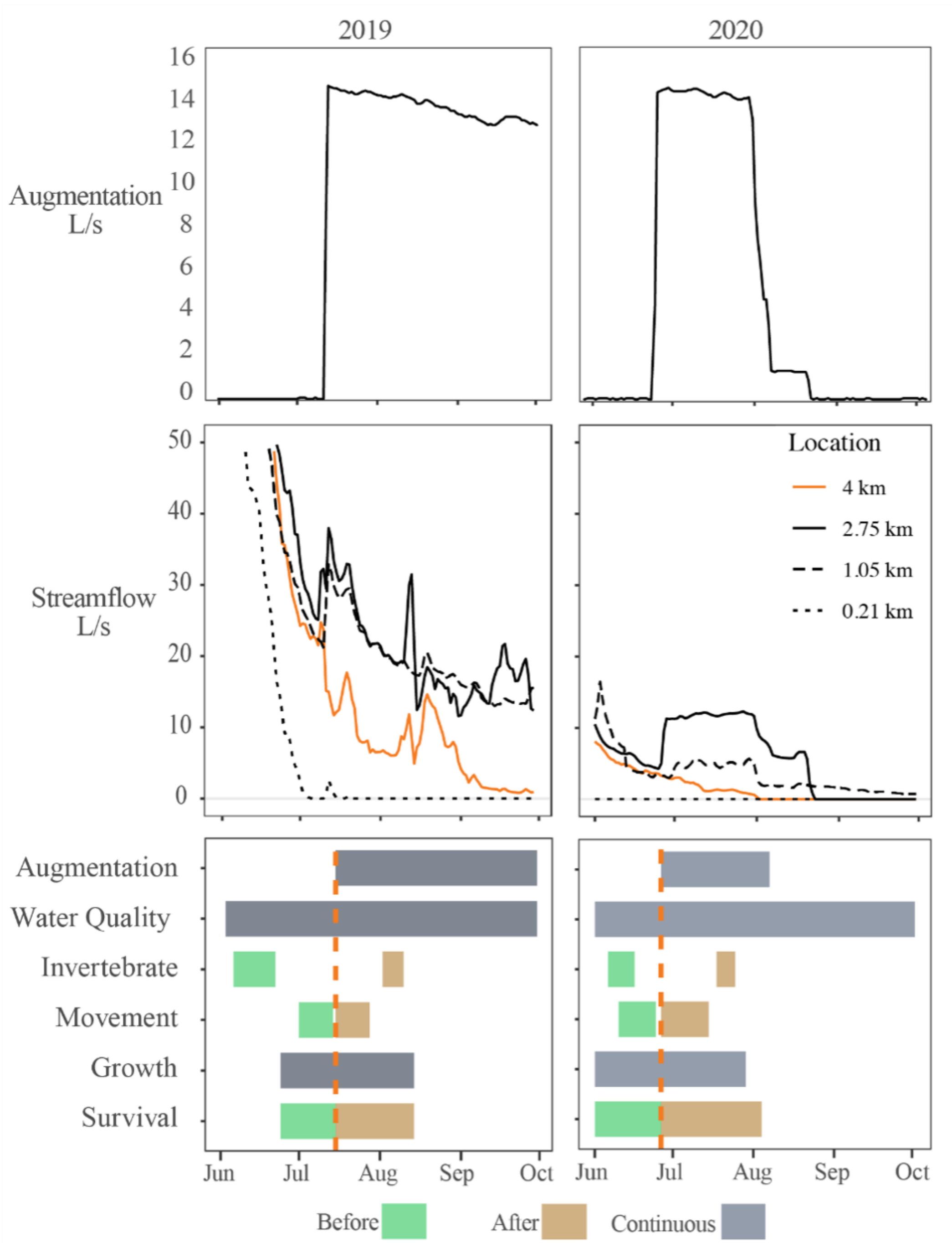

Figure 17. Top row: streamflow augmentation schedule during 2019 (left) and 2020 (right). Middle row: ambient streamflow above the augmentation (orange, 4 km), at the augmentation (black solid, 2.75km) and downstream (dashed lines) in 2019 (left) and 2020 (right). Bottom row: the timing of augmentation relative to data collection for parameters measured in this study in 2019 (left) and 2020 (right).

Salmonid Survival

To estimate reach-specific survival before and after augmentation, we used an individual-based capture-mark-recapture approach that consisted of an initial marking event and two subsequent primary recapture occasions each year, one before the onset of augmentation and one following a period of augmentation. The initial electrofishing surveys in which fish were tagged and dates in which tagged hatchery population were released served as initial capture and marking events (Table 2). Each of the two recapture occasions consisted of two consecutive days of PIT tag “wanding” in which biologists waded the full extent of each reach, detecting as many fish as possible using a portable PIT tag detection system, or “wand”. This sampling approach allowed estimation of survival probability using the robust design model as implemented in Obedzinski et al. (2018).

Statistical Analysis

Wetted habitat data was compared with descriptive statistics as percent of wet, intermittent, and dry channel in the control and treatment reach during 2019 and 2020 (Table 3, Group A). For most other variables, we used multiple before–after-control-impact timeseries (mBACIPs, Table 3, Groups B) or categorical (mBACI, Table 3, Groups C) statistical analysis (Keough and Mapstone 1997, Wauchope et al. 2020). This follows our study design which included multiple sites (riffle-pool units) in the control (not augmented) and impact (augmented) reaches, and sampling occurring before and after treatment (augmentation).

In the mBACI experiments, the interaction of “Time” (before or after augmentation) and “Location” (control or impact reaches) was considered significant when change occurred for the impact reach but not the control reach (e.g., Popescu et al., 2012; Smokorowski and Randal 2017). For time series data (Table 3, Group B) we constructed mBACI time series analysis following methods of Wauchope et al. (2020), equation 1:

EQ 1. Variable ~ Time + BA + CI + (BA*CI) + (BA* Time) + (CI* Time) + (BA*CI* Time),

where Time is a daily timestep centered on the day of augmentation; BA is a categorical variable of either “before” or “after”; and CI is a categorical variable of either “control” or “impact.”

For categorical mBACI data (Table 3, Group C) we used the same model except without the “Time” variable. Site (riffle-pool unit) was added as a random effect in all models. For both timeseries and categorical data (Table 3, Groups B and C) we used linear mixed effect models with the LMER command in R version 3.5.1. To determine an augmentation effect, we used the interaction BA*CI as the predictor variable (Table 3, Group C); to determine a trend effect we used the interaction Time*BA*CI (Table 3, Group C), Wauchope et al. (2020).

We could not evaluate the effect of augmentation on juvenile salmonid growth using a BACI design due to insufficient sampling intervals. Reach-scale differences on growth were therefore described using a control impact (CI) analysis with ANOVA and discussed qualitatively (Table 3, Group D). For survival analysis (Table 3, Group E), we developed robust design capture-mark-recapture models using the PIT tag wand data as described by Obedzinski et al. (2018) and used model evaluation to determine whether survival probability differed between control and impact reaches before and after augmentation. For each species, we constructed models in Program MARK (White and Burnham 1997) that allowed survival to vary by treatment (control or impact), time (before and after augmentation), and year (2019 or 2020). We also included a null model that held survival constant across treatment and year. In all models, detection probability was allowed to vary by reach and survey. Akaike's Information Criterion corrected for small sample size (AICc) was used to evaluate model support, and models were considered to show similar support if they were within 0-2 AICc units and/or carried >10% of total model weight (Burnham and Anderson 2002). For the models with highest support, we then estimated the effect size using methods described in Cooch and White (2019).

Table 3. Statistical design used to evaluate each response variable in the flow augmentation experiment.

Group	Variable	Type	Analysis
A	Wetted Habitat	Categorical (manual measurement)	Summary Statistics
B	Water Temperature	Continuous logger or antenna detections	mBACIPs linear mixed effects model. Variable ~ treatment* reach*time + (1|site + (1|date)
	Dissolved Oxygen		
	RCT Depth		
	Fish movement		
C	Pool Velocity Pool Depth BMI Drift	Categorical (manual measurement)	mBACI linear mixed effects model. Variable ~ treatment* reach + (1|site)
D	Fish Growth	Categorical (capture mark recapture)	Control vs Impact ANOVA
E	Fish Survival (by species)	Categorical (capture mark recapture)	MARK analysis.* 1. Null 2. Treatment 3. Year 4. Treatment and Year

*Models were run separately for each species (coho or steelhead).

III. STREAMFLOW AND SALMONID MONITORING RESULTS

Rainfall, stream flow, and wetted habitat monitoring results

Rainfall Analysis

Rainfall patterns influence seasonal streamflow patterns. Here we analyze local rainfall data for context of study years. Rainfall data was recorded over an 80-year period in nearby Healdsburg, CA at NCDC Station # 3875 (Healdsburg station, hereafter), along with the median annual rainfall of 37.5 inches (Figure 18). These long-term records indicate that rainfall can be variable from one year to the next. Notably, 2021 was the driest year on record. Over the 80-year period 1941 to 2022, annual rainfall has varied from as low as 15.8 inches (2021) to as much as 83.3 inches (1983), with extended periods of low and of high rainfall throughout the historical record. The drought of 2012-2015 represents one of three periods of below-average rainfall for four or more consecutive years: the others were 1989-1992 and 2018–2022.

Figure 19 shows the average monthly rainfall throughout the year at this station. These data show that 90 percent of the average annual rainfall occurs during the wet half of the year November through April; less than 2 percent of the average annual rainfall occurs from June through September. While the total amount of rainfall may be variable from one year to the next, the seasonality of precipitation is consistent among all years. Figure 20 shows the average annual rainfall vs the long-term average for all 6 years of gaging in Porter Creek. 5 out of the 6 years of this study (2017 to 2022) were characterized as below average, with above average conditions in WY2017 (48.2 inches), well below-average rainfall in WY2018 (22.3 inches), near average rainfall in WY2019 (34.9 inches), well below-average rainfall in WY2020 (19.9 inches), severe drought conditions WY2021 (15.8 inches) and below average rainfall in WY2022 (30.4 inches).

The timing and amount of precipitation has a significant effect on summer streamflow. Figure 21 shows the monthly rainfall recorded during each month of the study period (2017 to 2022). Rainfall can be variable from month to month, as was the case during the years of the study period, but still follows the general pattern of wet winter months and dry summer months. Studies have shown that rainfall that occurs later in the wet season (March-June) can have the effect of prolonging summer flows. Figure 21 shows that in WY2020, rainfall was above average in December and May, but below average in all other months. In WY2021, rainfall was below average in all months.

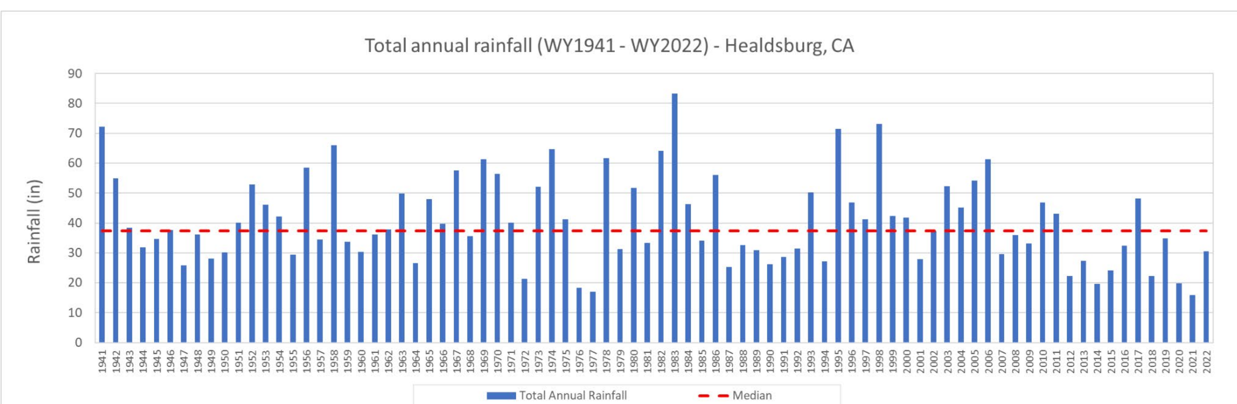

Figure 18. Total and median annual precipitation in Healdsburg, CA (1941-2022) from NCDC station 3875.

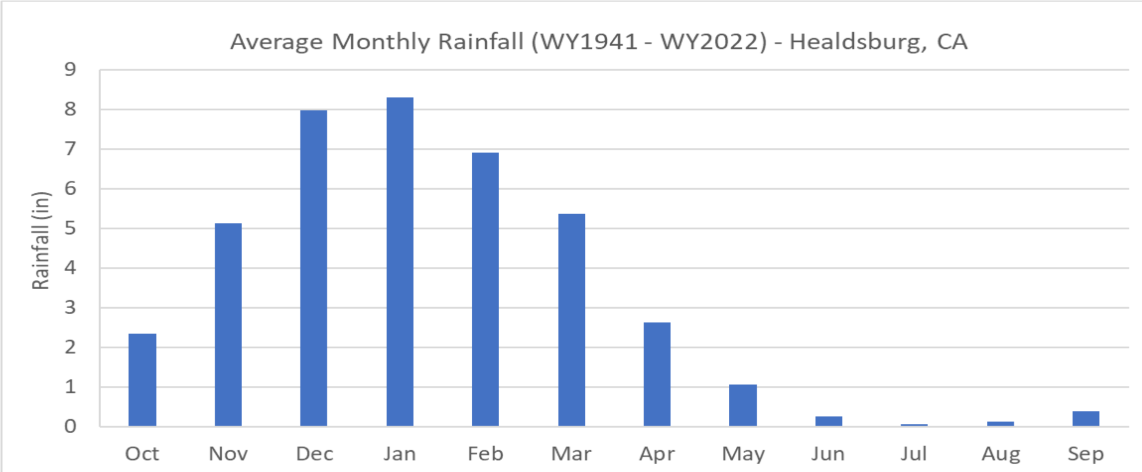

Figure 19. Average monthly precipitation (1941-2022) recorded in Healdsburg, CA from NCDC station #3875.

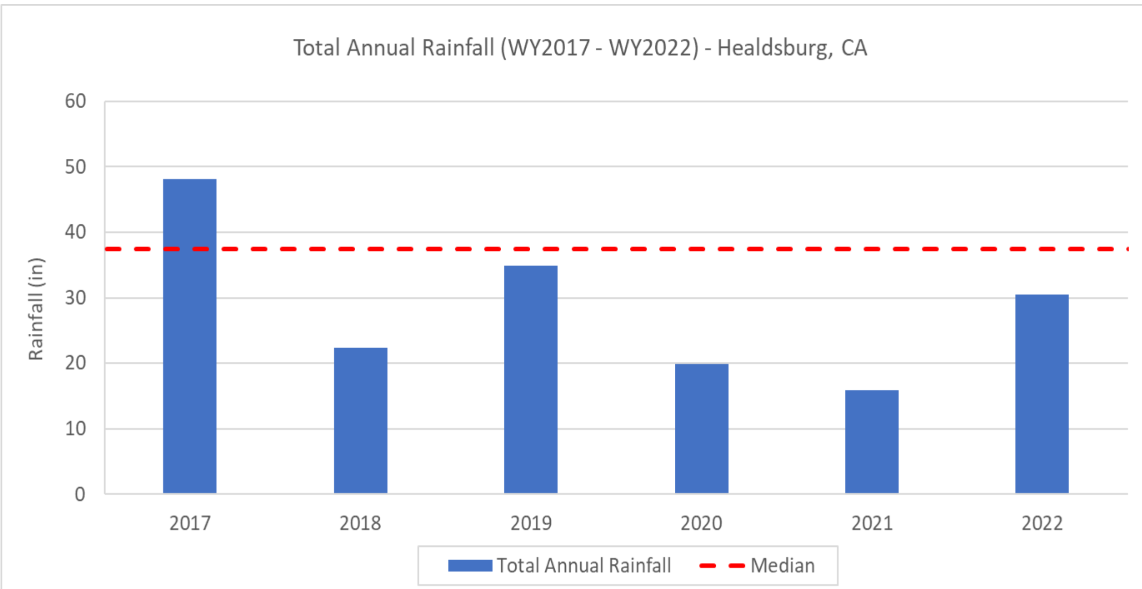

Figure 20. Total and average annual precipitation, WY2017-WY2021, recorded in Healdsburg, CA from NCDC station 3875.

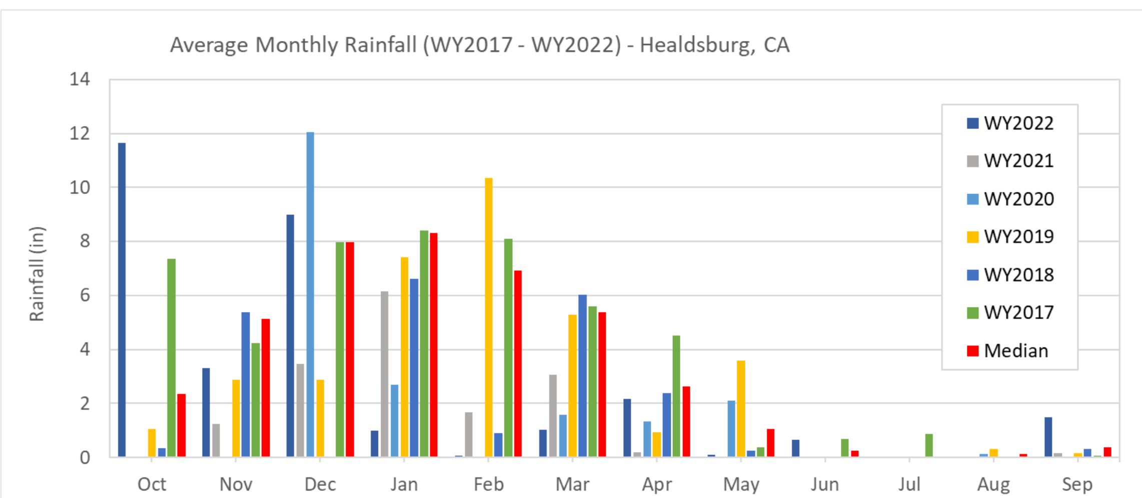

Figure 21. Total monthly precipitation, WY2020-WY2022, recorded in Healdsburg, CA from NCDC station #3875.

Streamflow Analysis

Summary of WY2017 Streamflow

Gages were installed in the spring of WY2017, and stage data were collected from the date of installation (May 26, 2017) throughout the dry season. Flows were at their highest point in the record at the time of the installation, then receded slowly through the early part of the record, then drop rapidly until early June (Figure 22). On June 8, 2017 flow was released into the channel at the upstream end of the study reach. The June 8 spike in flow at the gages corresponded with the beginning of this release. Streamflow fluctuations corresponded to the magnitude of the release, and then began to drop more quickly in late June, as the flow release was gradually shut off. Throughout the record, flows were considerably lower at the furthest downstream site (Po01) than the sites further upstream, suggesting that the downstream reach of stream was a losing reach from late May onward. In late June, streamflow began to drop more rapidly. The lower site went dry on June 30, 2017 when the flow release was shut off, and remained dry throughout the rest of the summer, despite a second release which began in mid-July. The response to this release was seen in the upstream gages starting on July 21; flows rose and fell with the magnitude of the release through late September. Porter Creek above the fish antenna (Po02) went dry on August 24, the day after the release was shut off for a short time and did not recover when more flow was released again on August 27.

WY2017 was a relatively wet year, with above average rainfall received, following five years of historic drought. The data collected at our gage sites in WY2017 reveal that the most distal reach of Porter Creek (Po01), below the fish antenna, was a losing reach at the beginning of data collection for the study, in late May 2017. This lower reach responded to the first augmentation release in mid- to late June but became intermittent soon after the release decreased and was eventually shut off and did not respond to the second release later in the summer. While it was actively flowing, the flow release kept the pools in the reach above the fish antenna connected. These pools then disconnected after the shutoff. Pools in the upper reaches remained connected through October 2017.

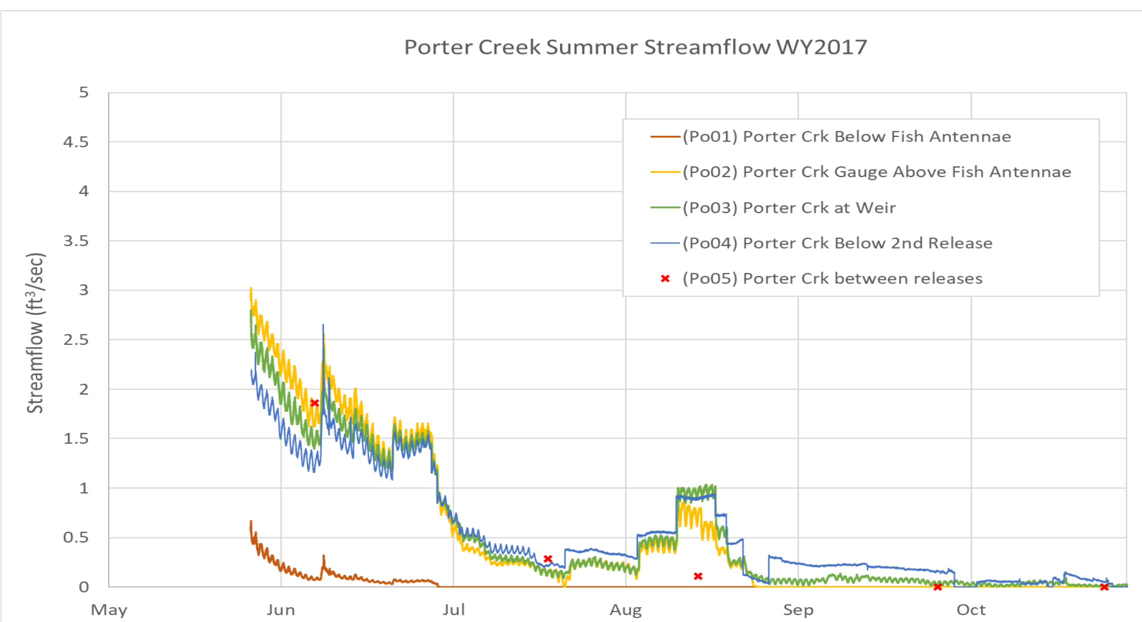

Figure 22. Streamflow at Po01-Po05, WY2017.

Summary of WY2018 Streamflow

WY2018 was a dry year. Flows began to rise following the first rain events of the season in mid-November (Figure 23). December 2017 and February 2018 were relatively dry, but flow spikes were observed corresponding to storms in January, March, and April. The highest flows of the season occurred on March 22, 2018 at the following rates, 561 ft^3/sec at Po01, 591 ft^3/sec at Po02, 400 ft^3/sec at Po03, and 251 ft^3/sec at Po04. Peak flows and flow records above 75 ft^3/sec were estimated based on rating curve extension that included peak flow values scaled from the USGS Austin Creek gage (USGS gage 11467200, Austin Creek near Cazadero CA).

Streamflow in the drier months of the year (March - October) at all sites is shown in Figure 24. After the last larger storm of the season in early April, flow at all sites began to recede, dropping quickly in early May. A release of water began on May 7, 2018 to keep the mouth of the creek connected to the Russian River and allow for smolt outmigration. Flows at all sites increased by about 1 ft^3/sec during the release. When the release was stopped in mid-May, site Po01 continued to dry at a similar rate, eventually drying on May 19, 2018. The sites further upstream continued their recession, though more slowly than Po01. The next upstream site, (Po02) Porter Creek above the Fish Antenna, dropped to zero flow briefly in late June, before the next release was initiated on June 30, 2018. Flows at all sites increased by about 1 ft^3/sec initially following the release. When the release volume was decreased periodically over the following weeks, Po02 disconnected again on July 15, 2018, but the further upstream sites remained connected due to continued water release throughout the dry season. Above the release, streamflow at (Po05) Porter Creek between releases was dry from the mid-August measurement onward through the dry season, showing that the release was effective in keeping portions of the channel wetted and connected through the dry season in a year that was comparably as dry as the peak of the 2012-2016 drought.

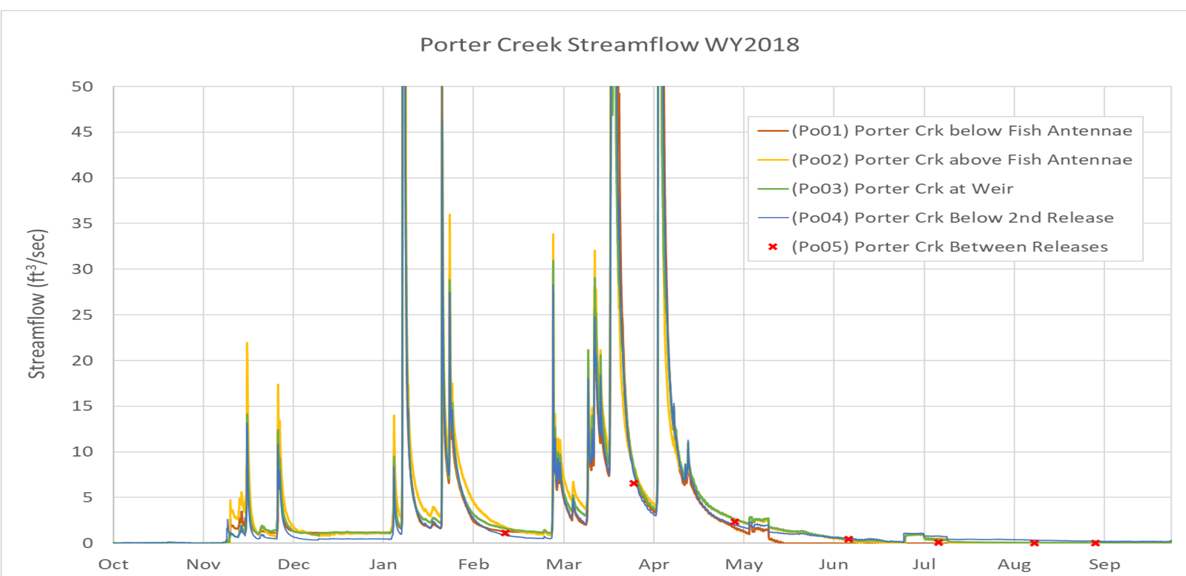

Figure 23. Streamflow at Po01-Po05, WY2018 (scale limited to 50 ft^3/sec to show detail of low streamflow).

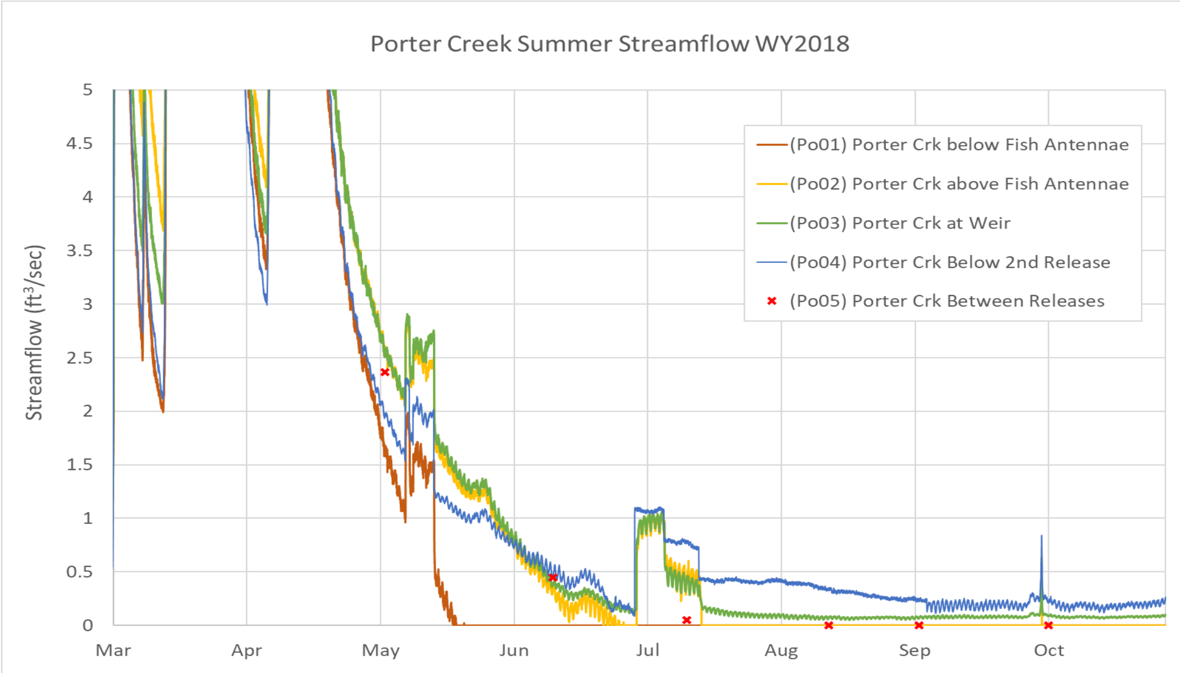

Figure 24. Summer streamflow at Po01-Po05, WY2018.

Summary of WY2019 Streamflow

WY2019 was another relatively dry year, however the area experienced a large rain event in May, which boosted summer streamflow conditions significantly (Figure 25). Flows in WY2018 began to rise in late November and early December, following the first storms of the season, and continued to rise and fall due to numerous storms through April. The highest flows of the season occurred on February 27, 2019. Streamflow data was not assigned above 500 ft^3/sec at sites Po01 and Po02 due to uncertainty caused by the influence of back water from the Russian River. Po03 and Po04 peak flows were 1,824 ft^3/sec and 1,601 ft^3/sec, respectively. Peak flows and flow records above 75 ft^3/sec were estimated based on rating curve extension that included peak flow values scaled from the USGS Austin Creek gage (USGS gage 11467200, Austin Creek near Cazadero CA). A notable storm also occurred in mid-May, causing flows to rise again after the spring recession had begun in April.

Streamflow at all sites in the spring through fall (March - October) is shown in Figure 26. This year was the wettest dry season streamflow conditions year of the study due to the high rainfall in May 2019. As a result, the effect of the releases is less visible in the hydrographs. The release was initiated on July 12, 2019, days after site Po01 had dried out, and remained steady at 0.5 ft^3/sec until late September, when it was decreased to 0.22 ft^3/sec through November. The downstream sites, Po01 and Po02, were dry or intermittent at times during the summer, and show an increase in flow in mid-September, perhaps due to the first small rain events of the year, decreasing evapotranspiration and the continuation of water releases. The two sites closer to the release, Po03 and Po04, were connected throughout the dry season.

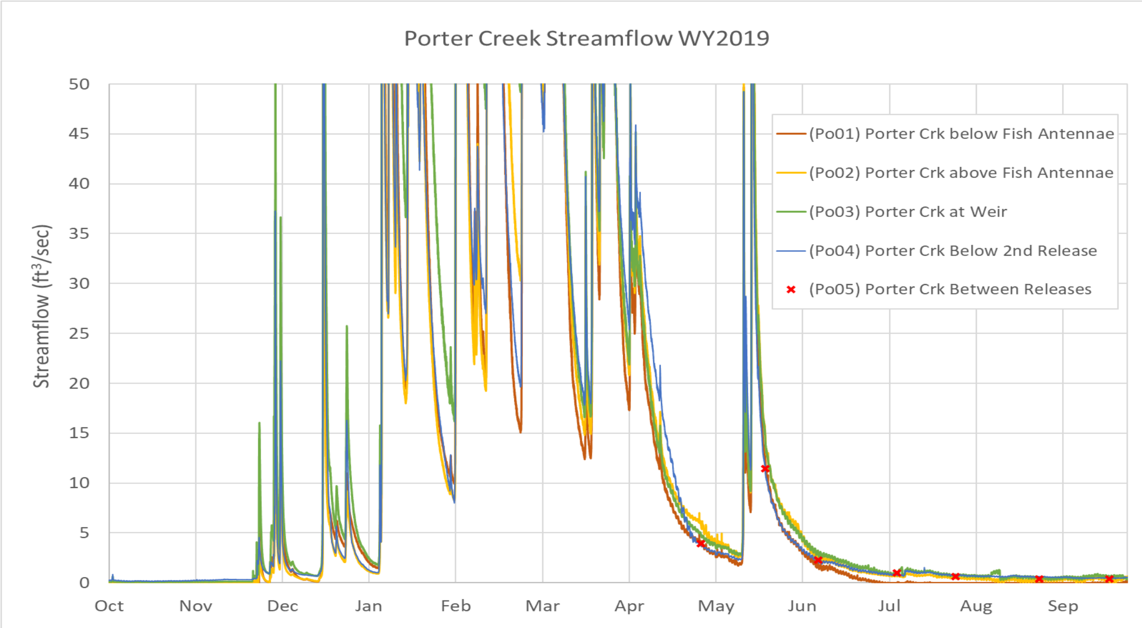

Figure 25. Streamflow at Po01-Po05, WY2019 (hydrograph scale limited to 50 ft^3/sec to show detail of low streamflow).

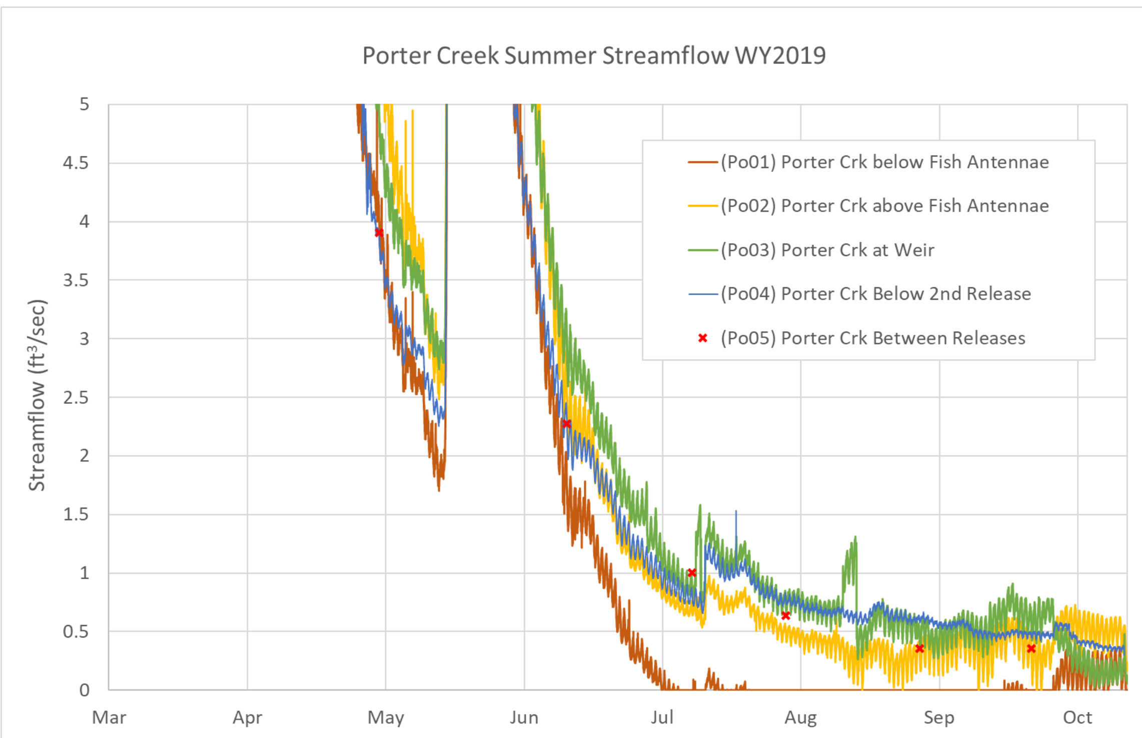

Figure 26. Summer streamflow at Po01-Po05, WY2019.

Summary of WY2020 Streamflow

WY2020 was another dry year. Flow at the sites began to rise in late November and early December, following the first larger rain storms of the season (Figure 27). The largest storms of the season were on December 1, 2020 December 7, 2020. Flows rose and fell with storms from mid-December through January, however a dry February caused flows to recede early, with only small storms in March, April and May punctuating the recession. As seen in previous years of gaging, the furthest downstream site, Po01 (Porter Creek below the Fish Antenna), is in a losing reach and is notably drier than sites further upstream throughout the period of record.

Figure 28 is a plot of streamflow at the sites from March through October 2020. Po01 became intermittent in early March of 2020, flowing only during spring storms. The disconnection at this site prompted the organization of spring flow releases, from April 16-17 and again on April 24. The first release caused a flow increase at the Po01 site, from 0 ft^3/sec to approximately 0.2 ft^3/sec. Following this release the site was dry for the remainder of the summer.

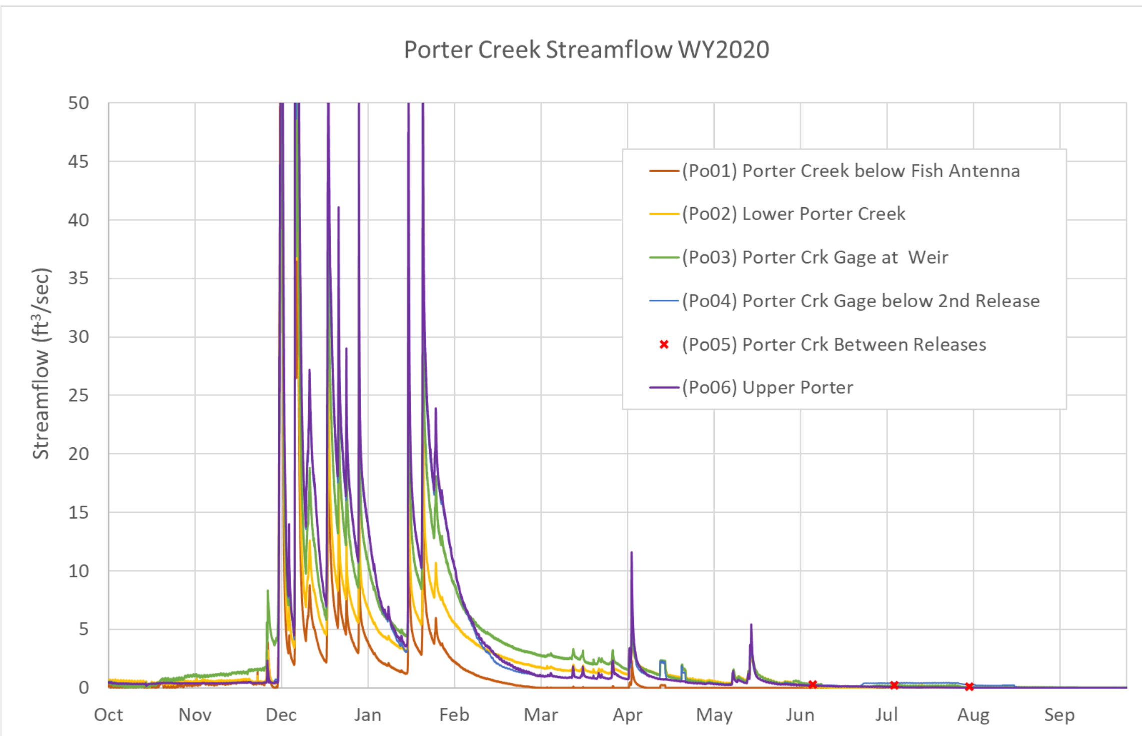

Figure 27. Streamflow at Po01-Po06, WY2020.

Further upstream, winter baseflows and spring storms kept the channel at Po02, Po03, Po04 and Po06 connected from early March through early summer. The highest flows in early March were recorded at Po03 (Porter Creek at the Weir), at about 3 ft^3/sec, followed by Po02 (Lower Porter) at 1.8 ft^3/sec. The further upstream sites, Po04 (Porter Creek below 2nd Release) and Po06 (Upper Porter) had flow of approximately 1.2 ft^3/sec at this time. Flows at these sites rose and fell with spring storms, and those below the releases (Po02, Po03, and Po04) rose by about 0.7 to 1.5 ft^3/sec in response to the April releases. A larger storm in mid-May caused flow to rise, then flows quickly receded in June. Lower Porter (Po02) dried out on June 19, 2020. Flows at the remaining wetted sites were at about 0.15 ft^3/sec when flow releases were turned on June 26, 2020. Flows just below the release (Po04) responded immediately, rising to 0.4 ft^3/sec. Flows at the weir (Po03) and Lower Porter (Po02) saw the effects of the release on July 1, with flows rising between 0.1 and 0.2 ft^3/sec. Po02 became intermittent in mid-July despite the release, and Po04 dried out when the release was shut off mid-August. Po06, just upstream, had dried in early August. Po03 remained at a low base flow before reaching intermittency in late October.

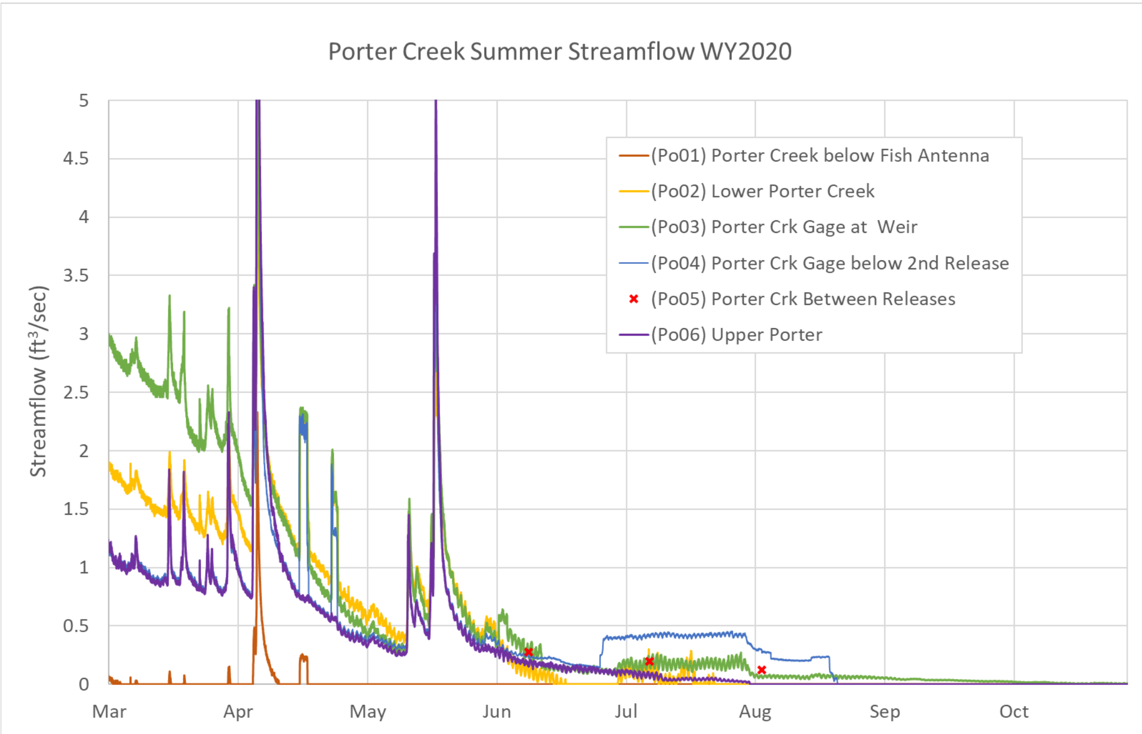

Figure 28. Summer streamflow at Po01-Po05, WY2020.

Summary of WY2021 Streamflow

WY2021 was a severely dry year, the driest rainfall year on record at the Healdsburg Rain Station. Flow at the sites did not begin to rise until late December and early January, following the first larger rainstorms of the season (Figure 29). The largest storms of the season were on January 4, 2021, January 27, 2021 and March 18, 2021, with little precipitation between these events. As seen in previous years of gaging, the furthest downstream site, Po01 (Porter Creek below the Fish Antenna), is in a losing reach and is notably drier than sites further upstream throughout the period of record.

Figure 30 is a plot of streamflow at the sites from March through September 2021. In early March, flow at all sites was very low, with flow at about 0.1 ft^3/sec, and flows upstream at about 0.5 to 0.7 ft^3/sec. Late spring base flow was the lowest in 2021 out of the 6-year gaging period. Flows rose in mid-March due to a spring storm, then quickly receded. A short duration, high magnitude flow release took place from March 17 through March 21. The release rate was about 1.25 ft^3/sec at its peak. Because this release was concurrent with a rain event, it is not seen as a separate peak in the hydrographs. Flow at Po01 disconnected on April 20, 2021, and rose briefly again on April 26, 2021, due to a small storm. Following this rain, the site remained dry for the rest of the summer. The next gage upstream, Po02 (Lower Porter), disconnected on May 8, 2021. The remaining upstream sites disconnected in early- to mid-June. Flow was released on June 30, 2021, which raised flow at the Po04 site (Porter Creek below the 2nd release) briefly to 0.09 ft^3/sec; flow slowly decreased and became intermittent in late July. Flow at sites further downstream did not increase in response to the release.

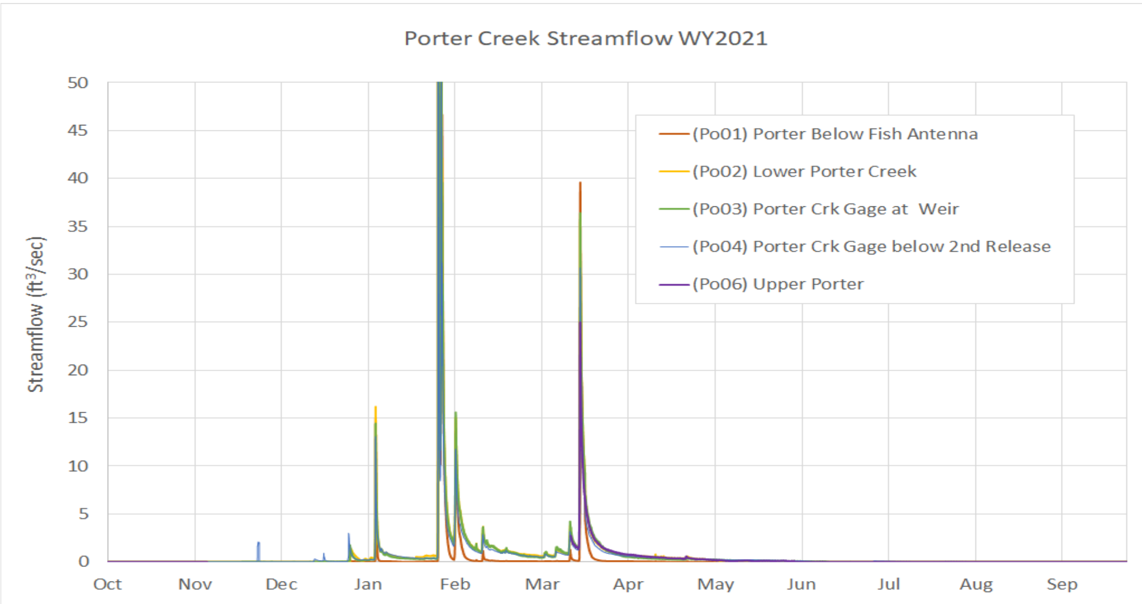

Figure 29. Streamflow at Po01-Po06, WY2021.

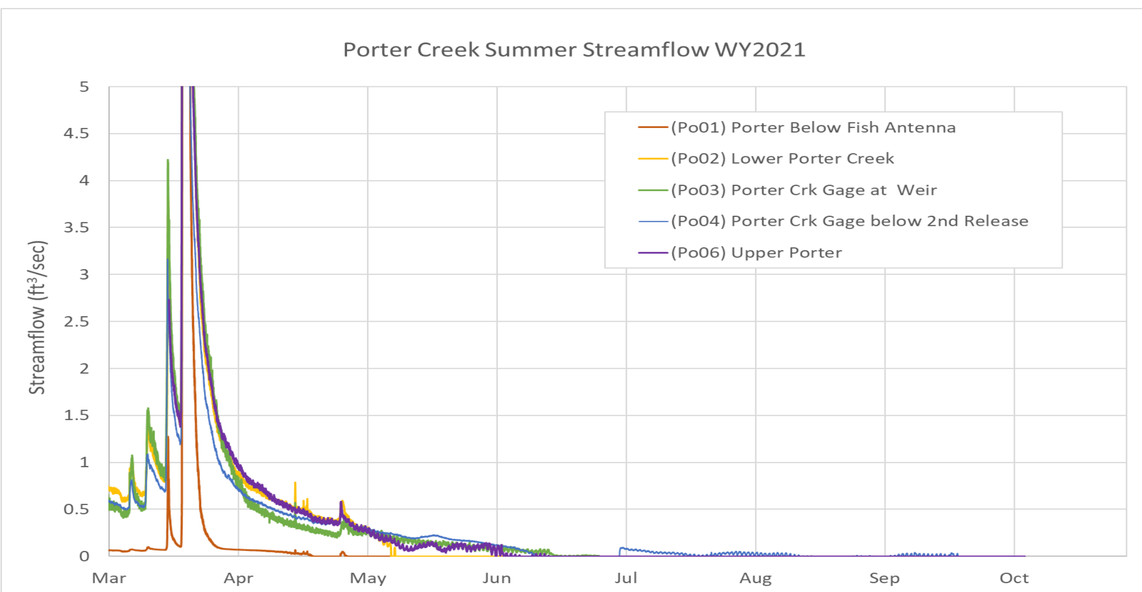

Figure 30. Summer streamflow at Po01-Po06, WY2021.

Summary of WY2022 Streamflow

WY2022 was another dry year. Flow at the sites began to rise in late October, following the first large rain storm of the season (Figure 31). The largest storm of the season was on October 24, 2021. Flows rose and fell with storms from late-October through January, however a dry February caused flows to recede early, with only small storms in March, April and May punctuating the recession. As recorded in previous years of gaging, the furthest downstream site, Po01 (Porter Creek below the Fish Antenna), is in a losing reach and was notably drier than sites further upstream, TU was unable to collect enough streamflow measurements at Po01 in WY2022 to develop an accurate rating curve, thus data from Po01 is not shown in the hydrographs for WY2022.

Figure 32 is a plot of streamflow at the sites from March through October 2020. Winter baseflows and spring storms kept most gage sites (except for Po03) connected from early March through mid-June. Lower Porter (Po02) dried out on June 21, 2020. Po03 experienced periods of intermittent flow in April, May, and June before remaining disconnected for the rest of the dry season. Further upstream, winter baseflows and spring storms kept the channel at Po04 and Po06 connected from early March through late-July. Flows just below the release (Po04) responded immediately, rising from zero to 0.4 ft^3/sec. The gage sites farther downstream did not show a response to the flow release in late August.

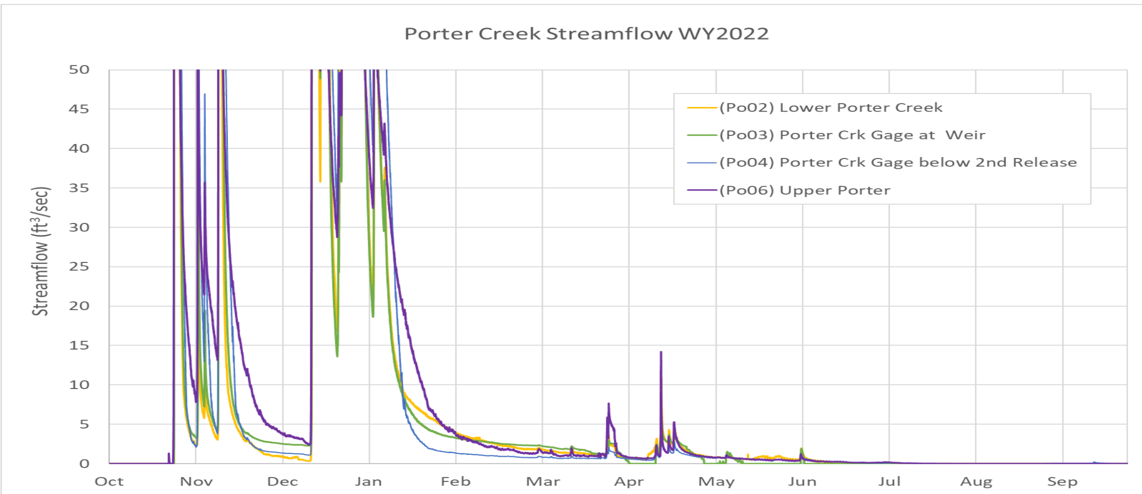

Figure 31. Streamflow at Po01-Po06, WY2022.

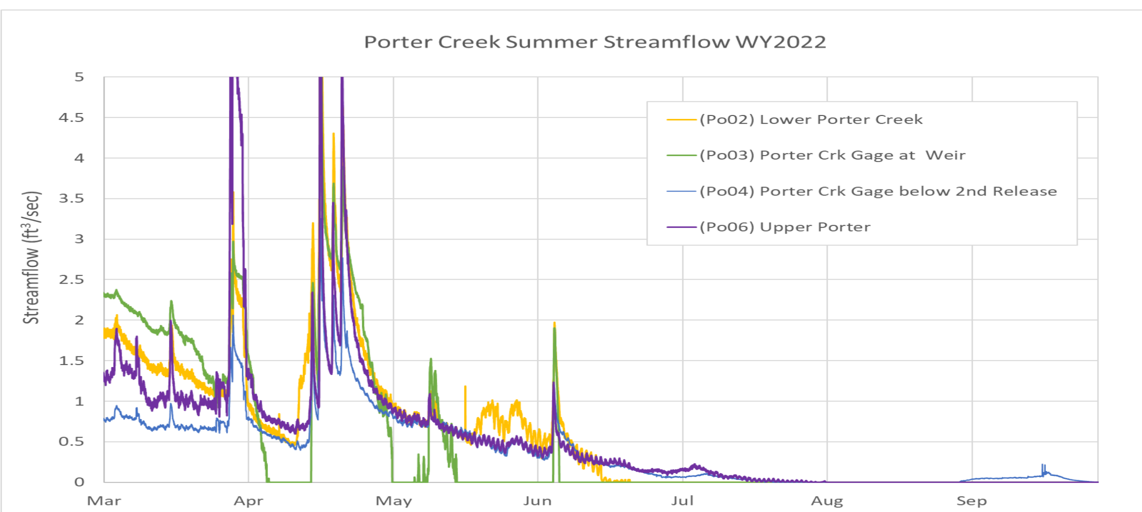

Figure 32. Summer streamflow at Po01-Po06, WY2022.

Water Temperature

Instream water temperature was recorded at gages Po02, Po03, and Po04. Water temperature of the water released from the flow augmentation system was recorded on the control system with augmentation data. Figures below depict the average daily water temperature from each gage and the control system, named "release." Stream gage Po04 is located directly at the lower release pipe, while Po03 and Po02 are located further downstream, respectively.

2017: Water temperature data from the augmentation system is not available from the 2017 logs. Presumably, this is due to complications in recording temperature in addition to the control and augmentation system not being complete and receiving modifications through the completion of implementation in October 2017 (Figure 33).

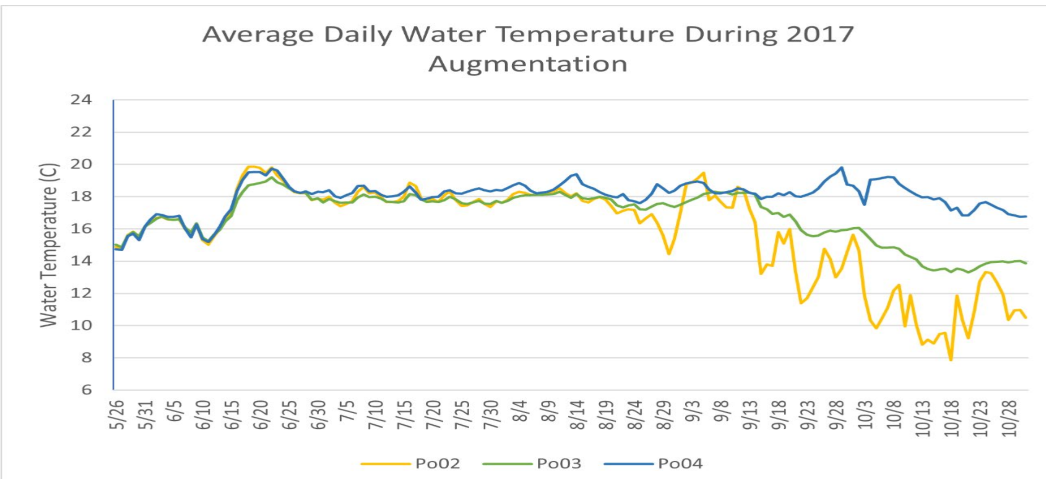

Figure 33. Average daily water temperature during 2017 augmentation, 6/8/2017 – 6/30/2017, 7/21/2017 – 8/24/2017, and 8/2/2017 – end-September 2017.

2018: Spring augmentation occurred May 7, 2018 through May 14, 2018. Oversummer augmentation occurred June 30, 2018 through November 30, 2018. During the spring augmentation, there was no effect on instream water temperature (Figure 34). During mid-summer throughout the oversummer augmentation, instream water temperatures do increase, but only at the point of augmentation (po04). Temperature increases disappear less than one kilometer downstream, where no temperature increase was seen (confirmed by UC water quality instrument placed between Po04 and Po03 gages). Currently, it is very difficult to decipher if the temperature increase was due to high temperatures of water released during augmentation, or the very low instream flow. Overall, even though an increase in instream water temperature was documented, we do not believe that any effects of augmentation were significantly negative as the water rapidly cooled.

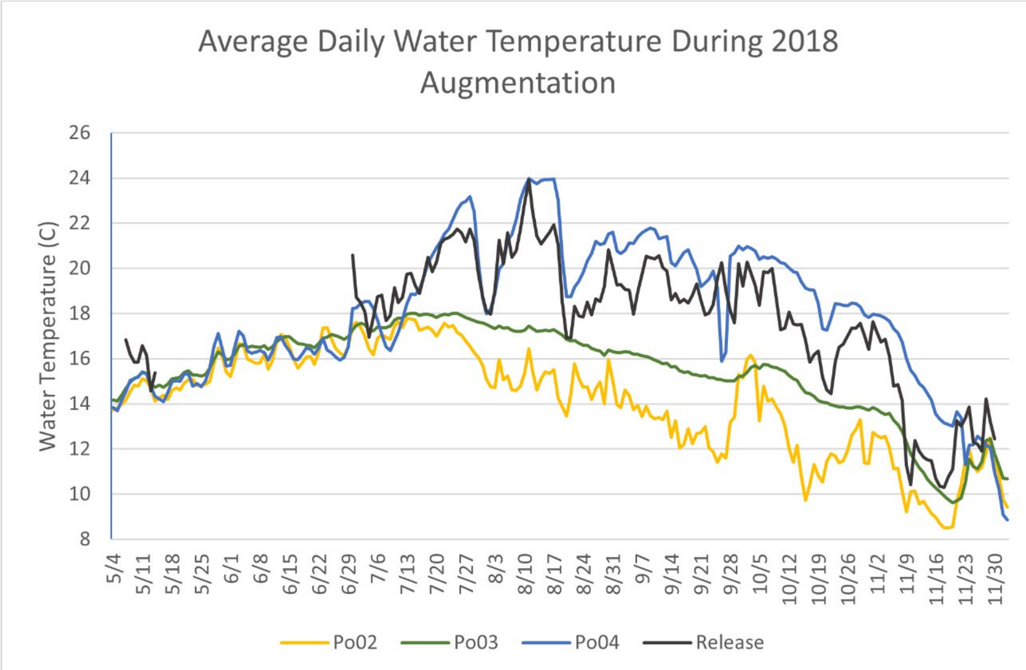

Figure 34. Average daily water temperature during 2018 augmentation, 5/7/2018 - 5/14/2018 and 6/30/2018 - 11/30/2018.

2019: Oversummer augmentation occurred July 12, 2019 through December 1, 2019. Throughout August and September, water temperature of the released water spikes (Figure 35). Although this temperature is not ideal, we see that there is a negligible effect on instream water temperature even at the direct point of augmentation (Po04).

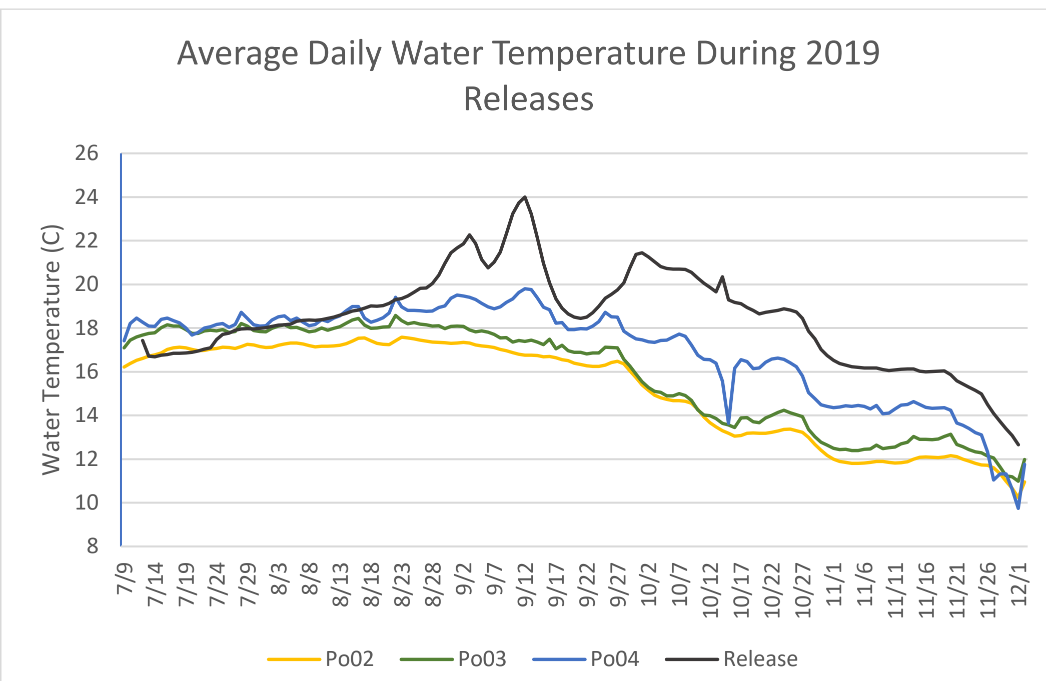

Figure 35. Average daily water temperature during 2019 augmentation, 7/12/2019 - 12/1/2019.

2020: Spring augmentation occurred April 15, 2020 through April 24, 2020. Oversummer augmentation occurred June 26, 2020 through August 20, 2020. Although the release temperature data from April 26, 2020 through June 20, 2020 is very elevated, this was not problematic to the release nor harmful as water was not released during this time (Figure 36).

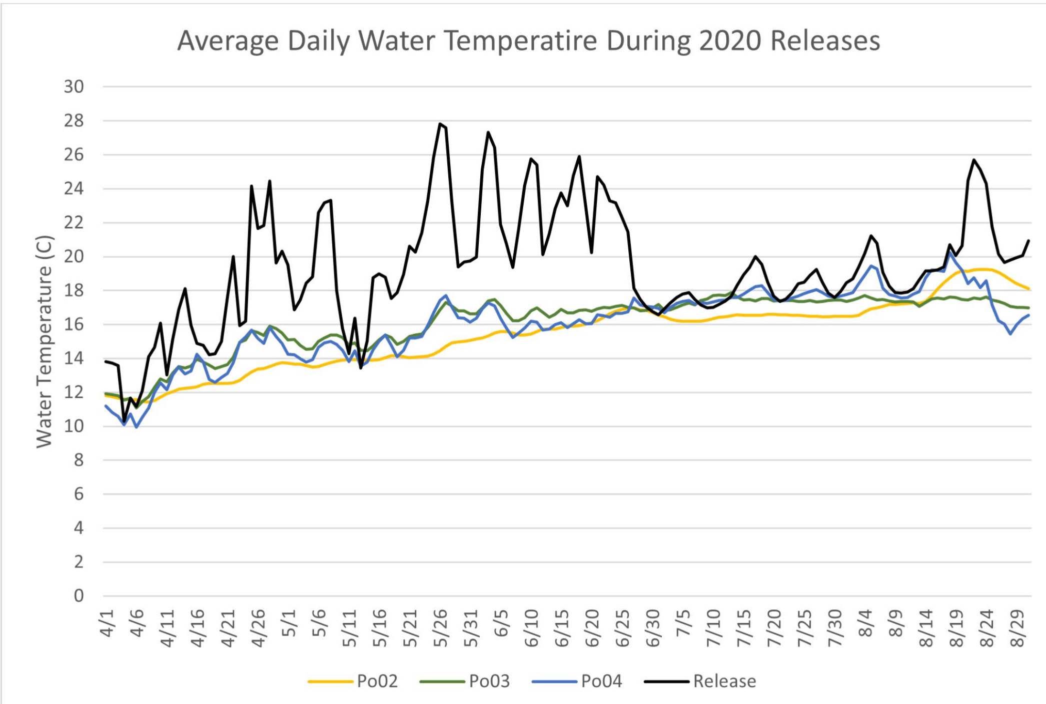

Figure 36. Average daily water temperature during 2020. Note that augmentation releases only occurred between 4/15/2020 - 4/24/2020 and 6/26/2020 - 8/20/2020.

Smolt outmigration monitoring results

<u>Operation of PIT tag detection system</u>

The PIT detection system was first installed on March 8-9, 2017. A subsequent large storm event shifted the antennas such that additional work was necessary to reposition them after flows had subsided. Continuous operation of the antennas began on March 29 and continued through June 30, 2021. On two occasions during the study period, antenna operation was interrupted. The first interruption occurred from May 12, 2017 through May 25, 2017 and was caused by equipment failure which powered off the transceiver for nearly two weeks until the compromised part could be replaced. The second interruption occurred on February 13, 2019 when a huge flood event damaged some of the equipment (Figure 37). Replacement parts were ordered, and a new transceiver was reinstalled on March 4, 2019 and ran continuously for the remainder of the study period to detect movement of coho and steelhead marked with PIT tags (Figure 38).

The PIT antenna array was located approximately 100m upstream of the point of first disconnection, therefore it was possible to detect fish on the antenna array after Porter Creek disconnected from the Russian River. Any fish detected on the array following disconnection were considered fish that were trapped in Porter Creek.

Figure 37. Westside Road during flood event and subsequent damage to PIT tag transceiver.

Figure 38. Coho salmon being implanted with a PIT tag.

<u>Coho migration timing</u>

Timing of juvenile coho emigration from Porter Creek varied among the five study years (Figure 39 - Figure 43). In 2017, the peak of detections occurred in late-April/early-May; however, we did not operate the antennas until late March, so it is likely that coho emigrated prior to antenna installation. In 2018, we observed three pulses, with the largest occurring in early-May. In 2019, the largest pulse of fish occurred in mid-March, with a smaller pulse occurring in mid-April/early-May. In 2020, migration peaked in May and in 2021, it peaked in March.

Disconnection from the Russian River during coho salmon smolt emigration

Over the three years surveyed, the date that Porter Creek disconnected from the Russian River ranged from early May to mid-June (Table 4). The flow level at each gage site that disconnection occurred varied among years, with the level of variation decreasing the further upstream the gage was located. For example, at Po01, the flow level at disconnection ranged from 0.41 ft^3/s in 2017 to 1.52 ft^3/s in 2018, whereas at the uppermost gage (Po04), the range in flow was 1.83 ft^3/s in 2019 to 1.99 ft^3/s in 2017.

Table 4. Date of Porter Creek disconnection from the Russian River in relation to streamflow at four Trout Unlimited gage sites.

			Mean daily streamflow (ft^3/s)			
Year	**Method of determining disconnection date**	**Disconnection date**	**Po01**	**Po02**	**Po03**	**Po04**
2017	field observation	5/27 - 5/28*	0.41	2.70	2.40	1.99
2018	field observation	5/3 - 5/4*	1.52	2.47	2.48	1.90
2019	camera image	6/18	1.14	1.86	2.27	1.83
2020	camera image	3/16	0.00	1.55	2.63	0.96
2021	camera image	3/23	0.37	2.44	2.78	1.98

* Unsure which of the two dates disconnection occurred so used average flow over this 48-hour period.

2017: Porter Creek disconnected from the mouth of the Russian River at a riffle approximately 100m downstream of the antennas between May 27 and May 28. Based on our antenna detections, the last date that individuals passed over the antennas when the mouth of Porter Creek was still connected to the Russian River was on May 11 (Figure 39). It is possible that additional fish passed over the antennas between May 11 and May 25; however, due to equipment failure, we did not collect antenna data during that time. Following disconnection of Porter Creek from the Russian River, we conducted two snorkel surveys from the mouth of Porter upstream to the Westside Road Bridge to determine whether coho smolts were trapped in pools and unable to access the Russian River. On June 1, we observed five coho salmon smolts and on June 22, we observed one (Table 3). The small number of smolts observed suggested that the majority of coho smolts migrated out of Porter Creek prior to disconnection from the river. Because there were so few smolts remaining in Porter Creek at the time of disconnection, E & J Gallo did not conduct a spring flow augmentation in 2017.

2018: Porter Creek disconnected from the mainstem of the Russian River between May 3 and May 4. PIT antenna detections at this time indicated that smolts were still attempting to emigrate from Porter Creek into the Russian River (Figure 40). Project partners were notified and a flow release of 385 gpm was initiated on May 7 at 18:00. On May 8 at 14:00, we observed that Porter Creek was reconnected to the Russian River. To determine whether it would be possible to keep Porter Creek connected at lower flows (to conserve water), the augmentation was reduced to 230 gpm on May 8 at 17:00. The following day Porter had disconnected again so the augmentation was increased back to the maximum of 390 gpm on May 9 at 11:00. Porter Creek was observed connected on May 10 and remained connected until May 13, when it disconnected for the rest of the smolt migration period. On May 11, we conducted a snorkeling survey and observed 32 coho salmon smolts in the lowest pools above the disconnection point (Table 5). During a follow-up survey on June 6 (after final disconnection), we counted a total of six coho smolts.

Table 5. Juvenile salmonid snorkel counts in Porter Creek from the mouth to Westside Road bridge.

Year	Date	Coho smolts	Coho YOY	Steelhead YOY/parr	Chinook smolts
2017	6/1/2017	5	3	209	0
	6/22/2017	1	5	461	0
2018	5/11/2018	32	10	27	3
	6/6/2018	6	198	167	0
2019	5/13/2019	3	0	525	22

2019: Streamflow remained high throughout the smolt migration period due to a storm in mid-May, so no flow releases were initiated. The camera allowed us to identify the date and hour of disconnection as June 18 at 16:00 (Figure 44).

2020: The camera images in 2020 indicated that Porter Creek was disconnected from the Russian River on March 1, the typical onset of the smolt outmigration period. On three occasions in March, it briefly reconnected with rain events, though we are unsure if flows were sufficient to allow fish passage (Figure 42). A more significant rain event during the first week of April reconnected the creek between April 4 and April 10, followed by another closure. In mid-April, following an uptick in PIT tag detections at the antennas and observations of smolts holding in pools upstream of the confluence, the group decided to initiate a flow release to coincide with a forecast for rain. The augmentation began on April 15 and was terminated on April 17, averaging approximately 370 gpm, and peaking at 560 gpm. Camera images confirmed that the creek reconnected during this period. A second, similar flow augmentation occurred on April 23 through April 24 which also briefly reconnected the stream. On May 1, the camera was moved to the upper reaches of Porter Creek for the summer rearing study. We presume that Porter remained disconnected for the remainder of the smolt outmigration period except for a storm event between May 17 and 19.

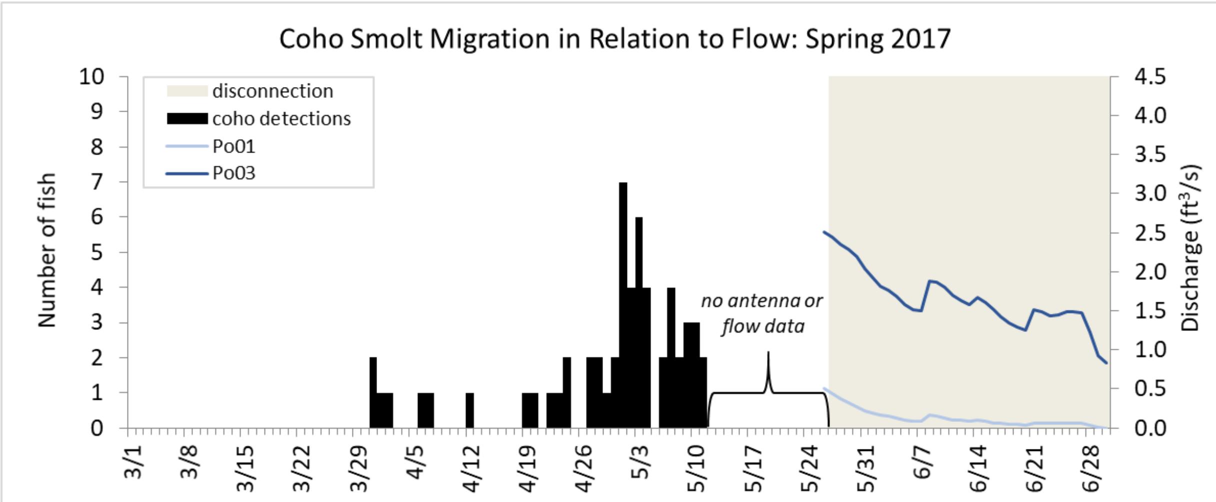

Figure 39. Unique coho salmon smolts detected on Porter Creek PIT antenna array in relation to streamflow and disconnection from the Russian River, May 1 – June 30, 2017.

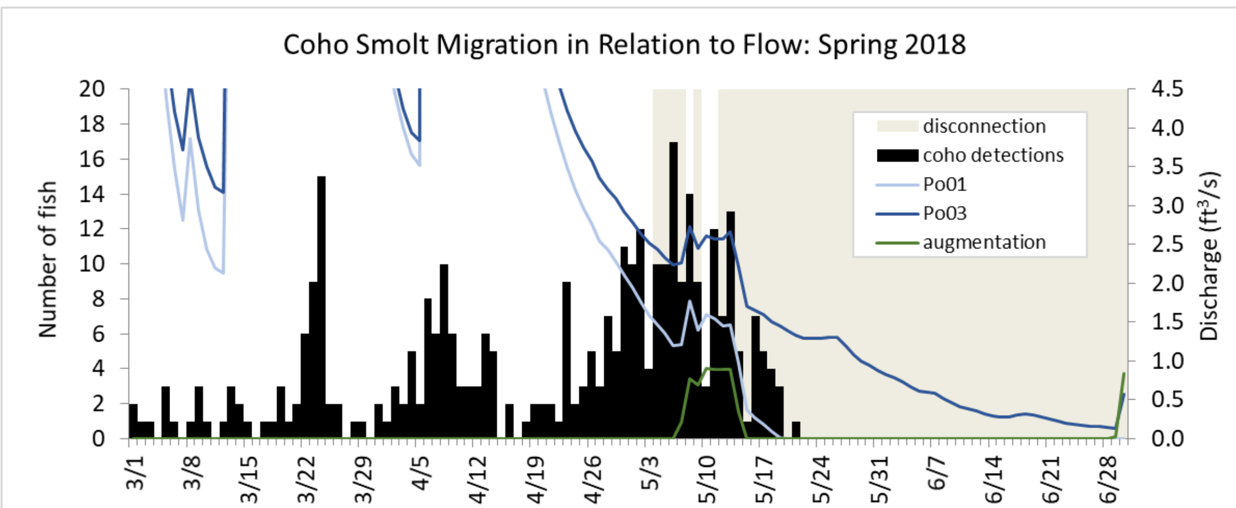

Figure 40. Unique coho salmon smolts detected on Porter Creek PIT antenna array in relation to streamflow, augmentation and disconnection from the Russian River, May 1 – June 30, 2018.

2021: As in 2020, disconnection was documented in early March on the camera images. A flow augmentation was initiated on March 18 (Figure 43) and continued through March 20, averaging 375 gpm during this timeframe and peaking at 560 gpm. The timing coincided with a rain event and reconnected the stream during the augmentation period.

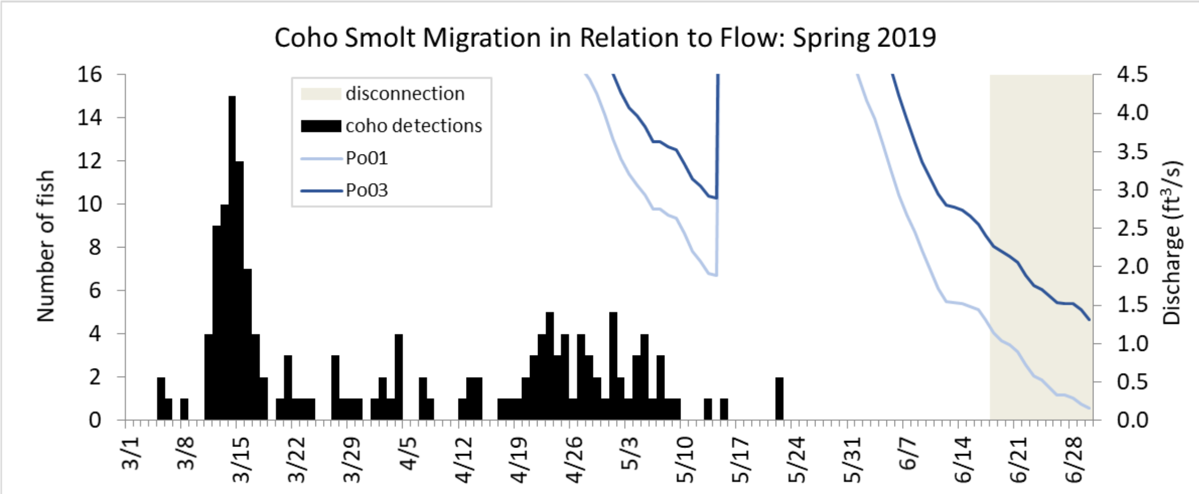

Figure 41. Coho smolts detected in relation to streamflow and disconnection from the Russian River, May 1 – June 30, 2019.

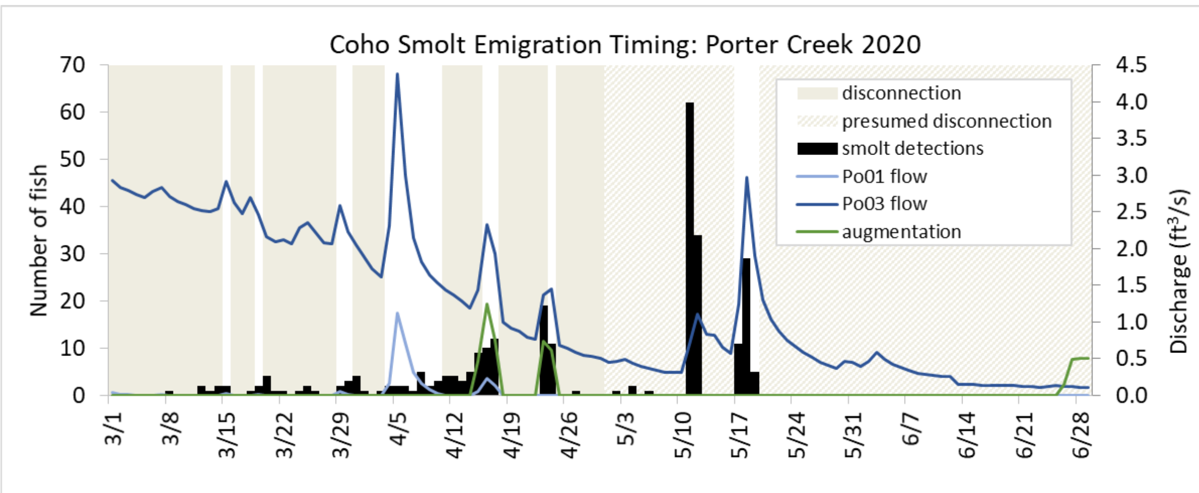

Figure 42. Coho smolts detected in relation to streamflow and disconnection from the Russian River, May 1 – June 30, 2020.

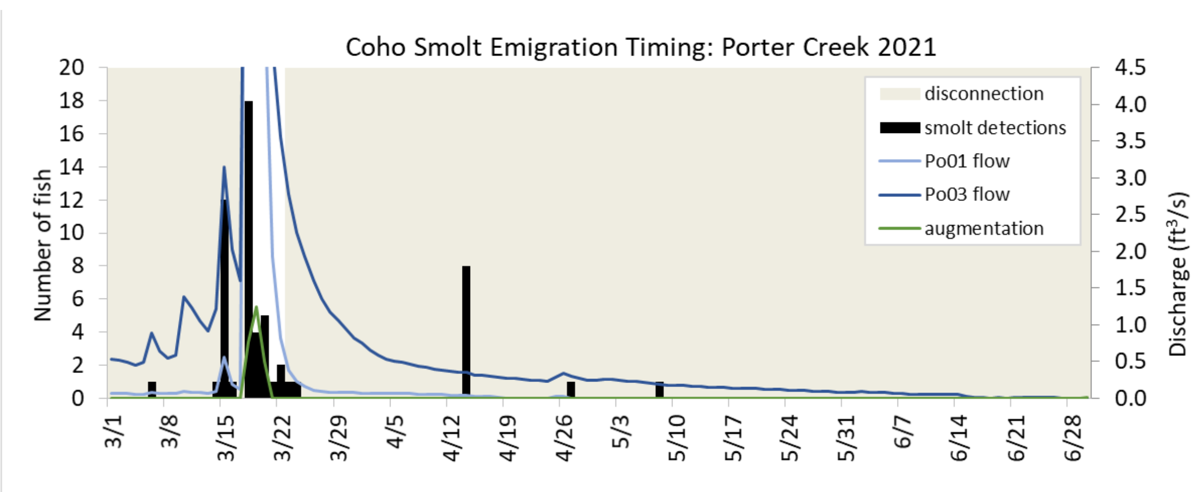

Figure 43. Coho salmon smolts detected in relation to streamflow and disconnection from the Russian River, May 1 – June 30, 2021.

Figure 44. Spypoint camera images showing disconnection timing of Porter Creek from the Russian River on 6/18/19.

Figure 45. Spypoint camera images showing stream conditions in lower Porter Creek immediately before and during a flow augmentation that began on 3/18/21.

Streamflow augmentation effects on smolt emigration

To estimate the number of coho salmon smolts that benefited from flow augmentation, we summed the number of unique PIT tag detections on the antenna array during the augmentation as well as during disconnection up to 12 days prior to the augmentation (Table 6, Figure 46 - Figure 48). We then expanded the number of PIT-tagged fish by the tagging proportions at the hatchery to estimate the total number of fish that benefitted. To estimate the proportion of the smolt run that benefitted, we divided the number of unique detections of fish thought to benefit by the total unique detections between March 1 and June 30 each year. The estimated number of coho smolts that benefited from the flow augmentations ranged from 278 to 372 which represented between 25% and 78% of the total number of fish emigrating each year (Table 6).

Table 6. Estimated number and proportion of coho salmon smolts thought to benefit from flow augmentations.

Year	PIT-tagged individuals	Expanded total fish (based on tagging rates)	Percentage of smolt run
2018	84	295	25%
2020	77	372	27%
2021	42	278	78%

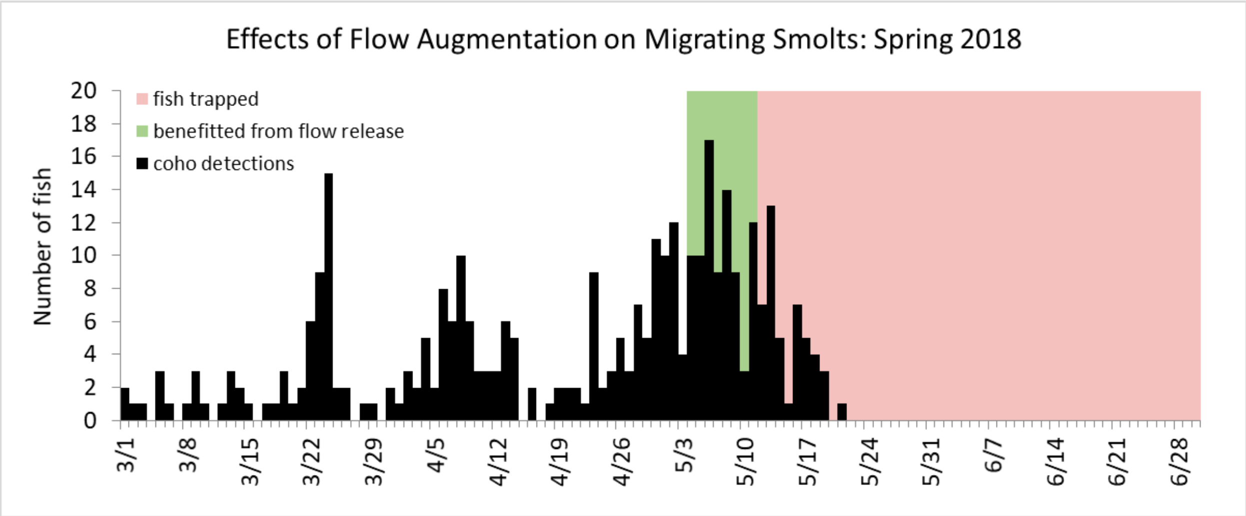

Figure 46. Detection of coho salmon smolts between March 1 and June 30, 2018 in Porter Creek. Green shading indicates the time during which migrating fish may have benefitted from the flow augmentation and red shading indicates the time during which coho smolts were trapped.

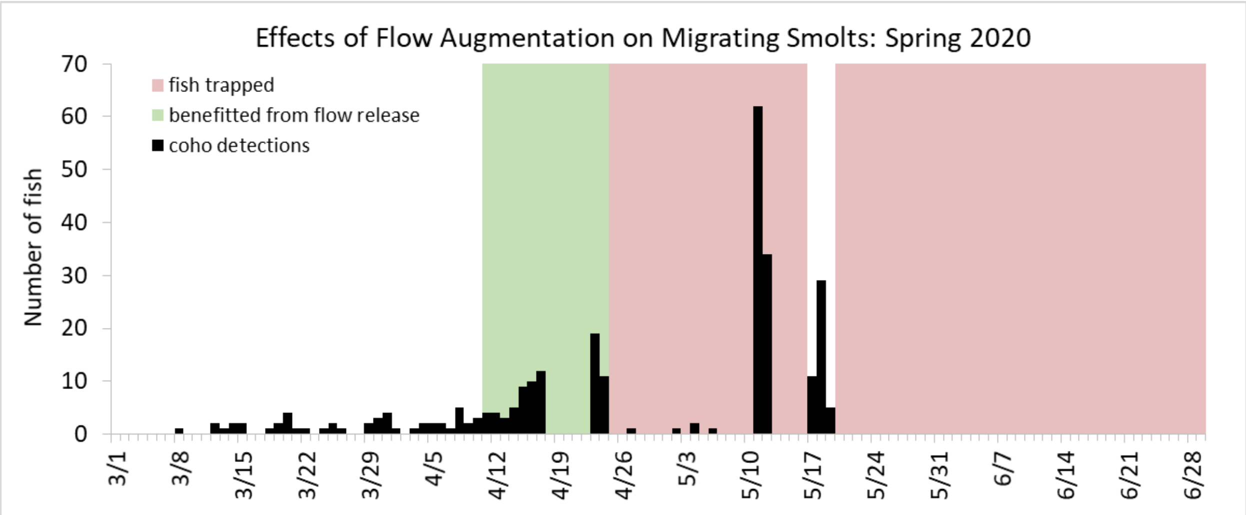

Figure 47. Detection of coho salmon smolts between March 1 and June 30, 2020 in Porter Creek. Green shading indicates the time during which migrating fish may have benefitted from the flow augmentation and red shading indicates the time during which coho smolts were trapped.

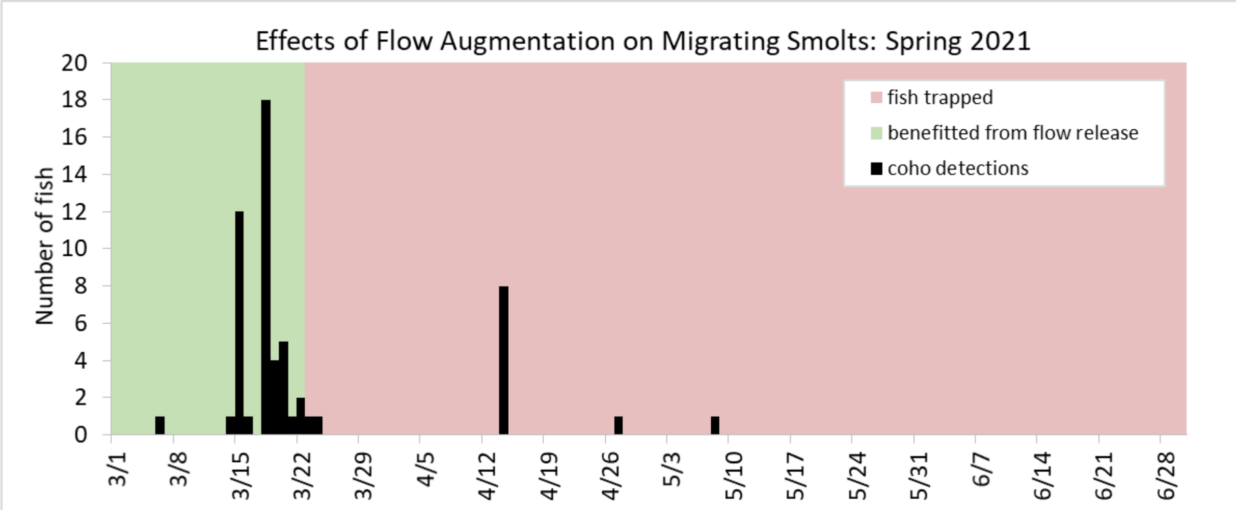

Figure 48. Detection of coho salmon smolts between March 1 and June 30, 2021 in Porter Creek. Green shading indicates the time during which migrating fish may have benefitted from the flow augmentation and red shading indicates the time during which coho smolts were trapped.

Streamflow augmentation effects on juvenile rearing habitat

In both the wet (2019) and dry (2020) summer we tested an augmentation of 13.9 L/s (220 gpm). Augmentation was initiated just prior to pool-riffle disconnection in both years. We evaluated the effects of this augmentation level on habitat connectivity, water quality, invertebrate drift, and juvenile salmonid movement, growth, and survival. We found that differences in ambient streamflow between the two years mediated the physical and ecological effects of augmentation. In the dry year, flow augmentation significantly improved dissolved oxygen and habitat connectivity at sites > 1.5 km downstream from the point of augmentation but had a marginal warming effect on stream temperature. During the wet year, both dissolved oxygen and water temperature effects were negligible. In both years augmentation had a small but positive effect on invertebrate drift. Inter-pool movement of juvenile steelhead (*Oncorhynchus mykiss*) and stocked Coho Salmon (*O. kisutch*) increased due to augmentation during the dry summer. Perhaps the most consequential finding of this study was the significant increase in over-summering survival due to augmentation for both juvenile coho salmon (+24%) and steelhead (+20%) in 2020 and for juvenile coho (+11%) in 2019. Previous work on salmonid over-summering mortality in Russian River tributaries indicated that days of disconnectivity (intermittent flow) and low dissolved oxygen had strong negative correlations with Coho over-summer survival (Obedzinski et al. 2018), whereas pool volume and water temperature were weakly correlated with survival. Our study suggests that augmentation, particularly in drier years, has the strongest effect on those variables most associated with salmonid survival (i.e., wetted channel extent and dissolved oxygen).

<u>Wetted Habitat</u>

The effects of augmentation on wetted habitat and surface flow varied between years but also expressed consistent spatial patterns. Stream drying occurred in low-gradient reaches, characterized by alluvial gravel deposits and wide bar-riffle morphology, especially downstream of rkm 0.5 and between rkm 4.0 and 1.75 in the drier summer of 2020 (Figure 49). These reaches were previously identified as particularly susceptible to drying (California Sea Grant Wetted Habitat Dashboard). In 2019, after a May freshet, Porter Creek maintained surface connectivity throughout the summer except in the lowest reaches closest to the confluence with the Russian River. By early October, 30% of the control reach was dry or intermittent, whereas only 12 percent of the impact reach was dry or intermittent. Augmentation had a much larger effect on wetted habitat during the dry summer of 2020. Prior to augmentation (June 24, 2020), 92% the control reach was still wetted whereas only 56% of the impact reach was wet. One month after augmentation (July 30, 2020), the control reach experienced significant drying, with wetted habitat decreasing from 92% to 50%; whereas wetted habitat in the impact reach increased from 56% to 90% (Figure 49).

Water Quality

Augmentation significantly increased dissolved oxygen in the impact sites during both years; although the effect size was much larger during the dry summer of 2020 (2.26 mg/L) than the wet summer of 2019 (0.23 mg/L) and the trend (mg/L/day) was only significant in 2020 (Table 3). During the wet summer (2019), augmentation had a small cooling effect on daily average water temperature (-0.41 C) and a negligible (but statistically significant) effect on the trend (+0.043 C/day). During the dry summer, augmentation increased water temperature (+1.34 C), although water temperature stayed within suitable ranges for rearing salmonids. There was no effect on the trend. Figure 50 illustrates the effect of augmentation on water temperature, dissolved oxygen, and riffle crest depth at a single site in impact reach B.

Hydraulic Habitat

During the wet summer of 2019, augmentation had no effect on pool velocity, and caused a small, but statistically significant increase on riffle crest depth (+0.23 cm mean and +0.02 cm/day trend) and pool depths (+0.26 cm mean) (Table 3). During the dry summer of 2020 augmentation had a much larger effect on riffle and pool depths leading to an effect size of 3.4 cm increase in RCT depth (and +0.155 cm/day trend) and 4.4 cm increase in pool depth. Pool velocity also increased significantly (6.2 cm/s) due to augmentation in the dry summer (Table 7).

Stream Invertebrates

Although drifting invertebrates were near annual minimums by mid-summer in Porter Creek (Rossi et al. 2022), drift rate in the impact reaches increased relative to the control reaches after augmentation in both 2019 and 2020 (Figure 51). However, the increase in invertebrate flux was only significant in 2020 (Table 3). Following augmentation in 2020, drifting invertebrate flux increased in the impact reach by 3.3 mg/hr relative to the control site (Table 7). The biomass flux of drifting invertebrates (mg/hr) was 66% to 85% higher in impact sites after augmentation than before. The increases in drifting invertebrates were largely due to increases in Chironomidae midges and Baetidae mayflies which are vulnerable to predation by juvenile salmonids. Smaller increases in other vulnerable taxa, including all other Diptera and Lepidosomatidae caddisflies, were also observed after augmentation.

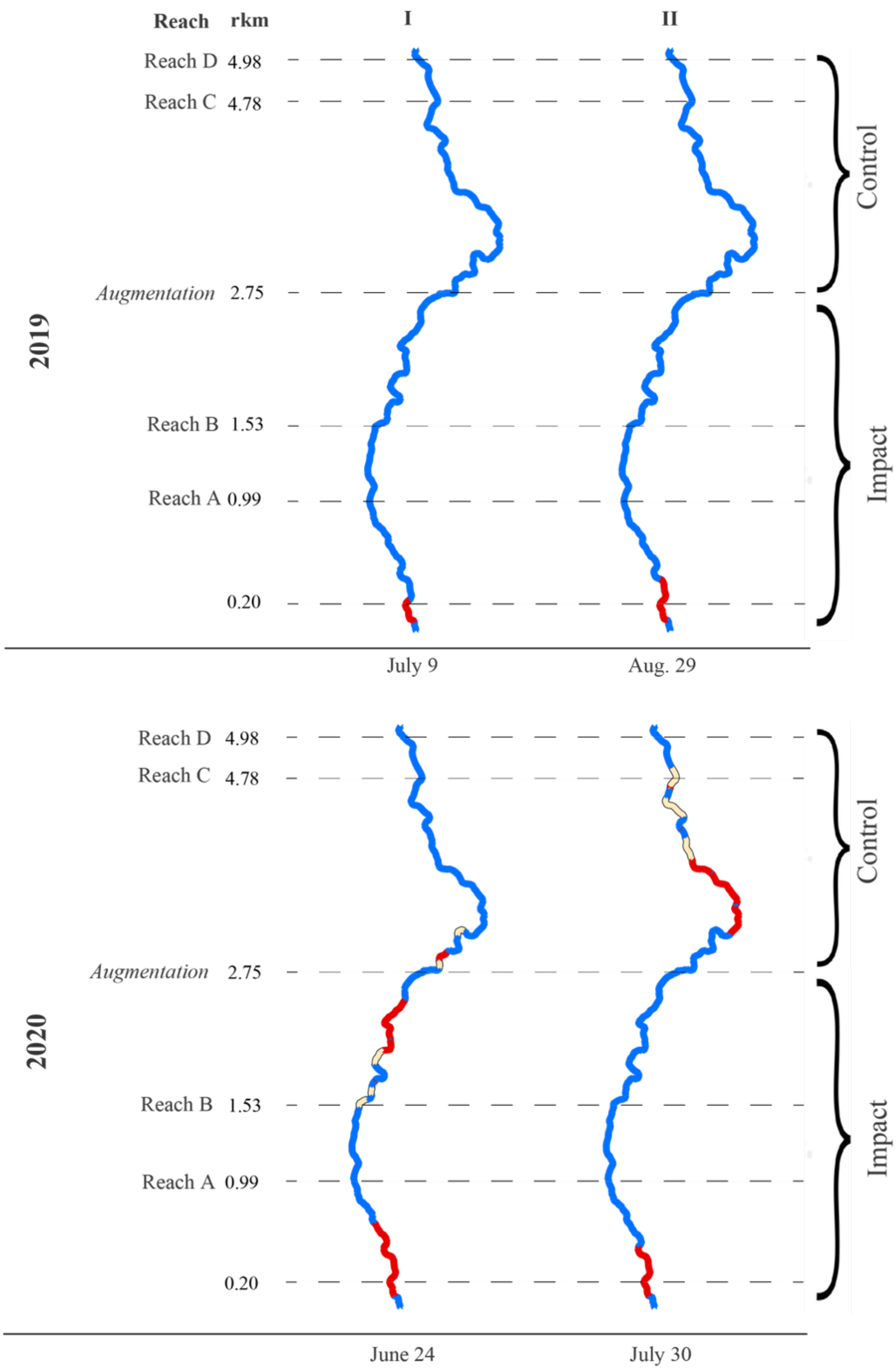

Figure 49. Wetted habitat maps showing flowing (blue) intermittent (yellow) and dry (red) channel immediately before (I) and following one month (II) of a 13.9 L/s augmentation; in 2019 (top) and (2020) bottom; at sites upstream of the augmentation (2.75 rkm) and downstream. The start (downstream end) of each study reach is shown with a dashed line.

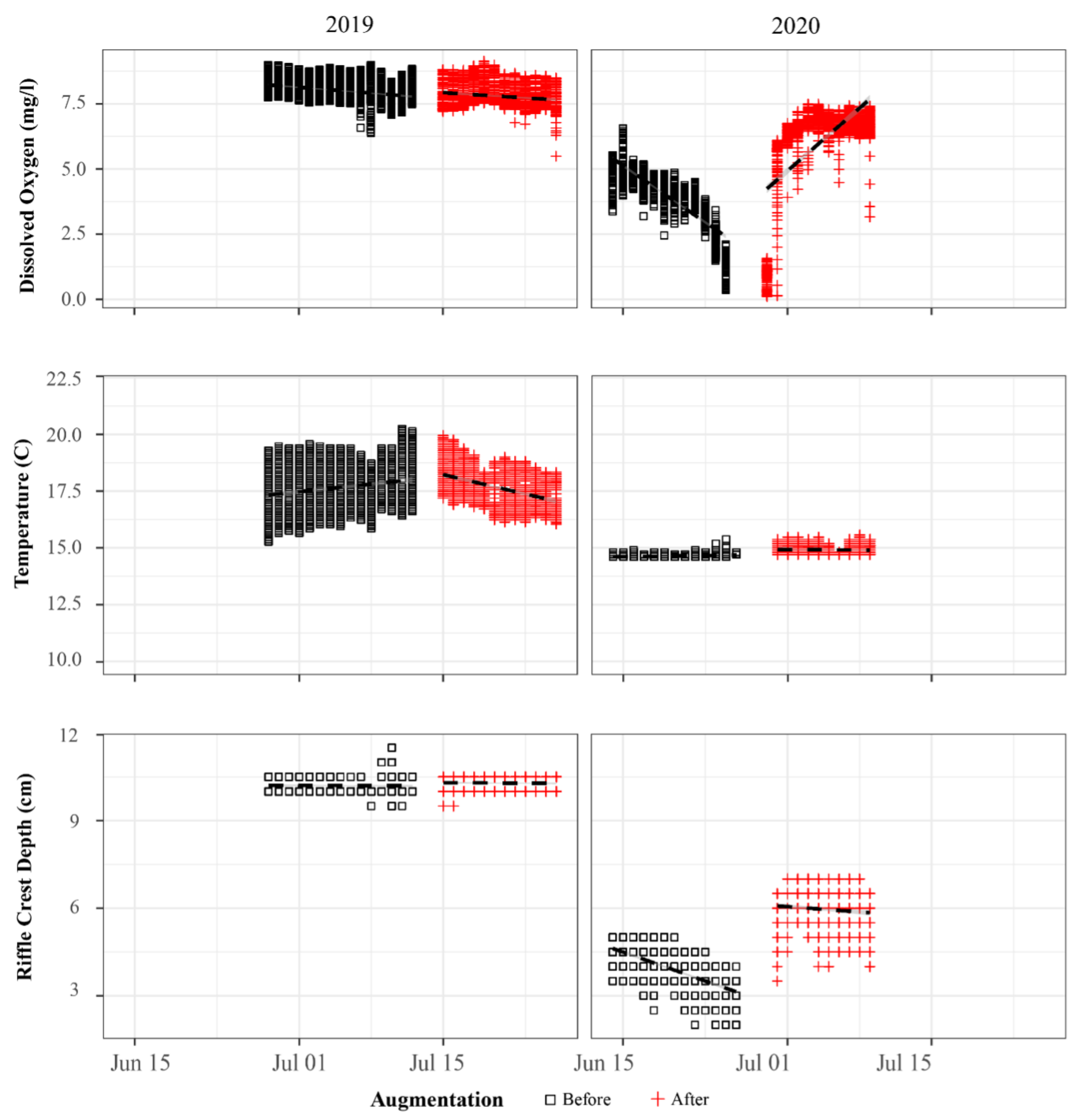

Figure 50. Dissolved oxygen (top), water temperature (middle), and riffle crest depth (bottom), shown for a representative impact site in reach B (Figure 2) to illustrate the before (blue) and after (yellow) periods in both 2019 (left) and 2020 (right).

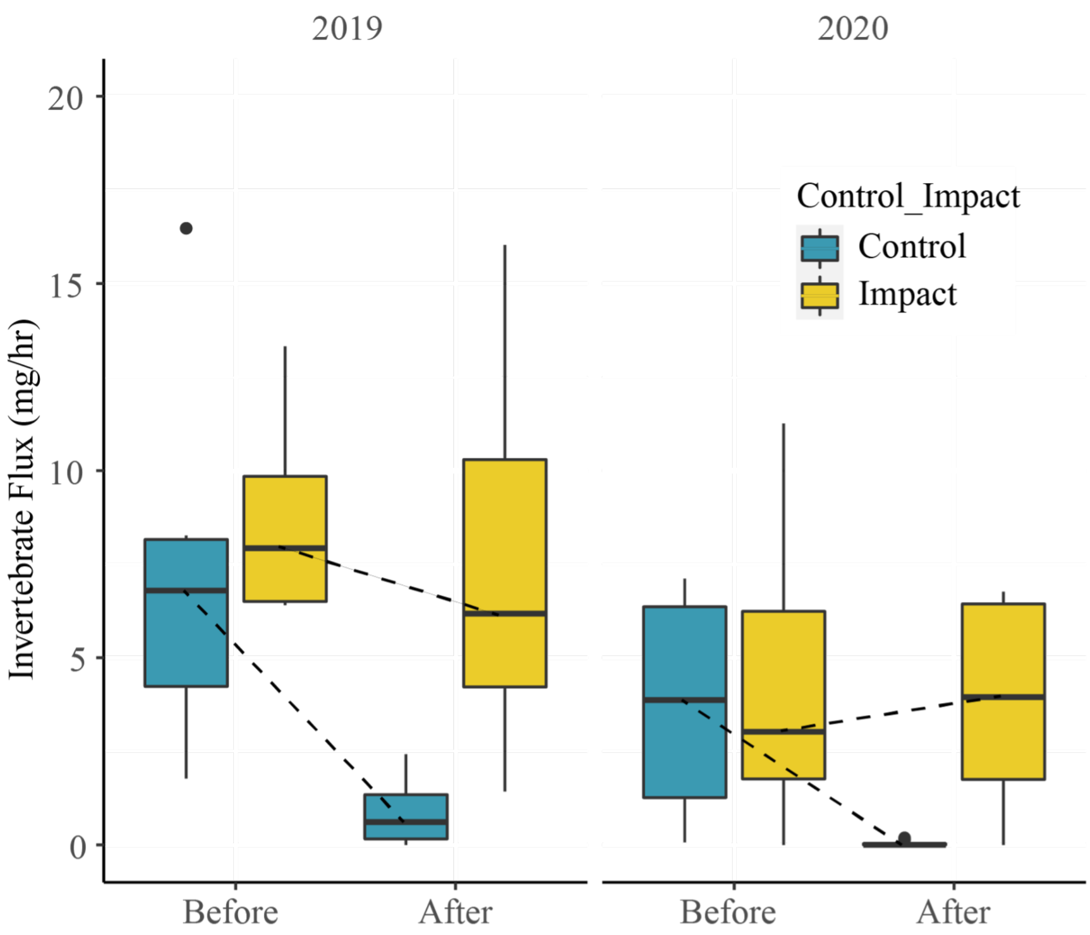

Figure 51. Mid-summer benthic invertebrate drift (mg/hr) before and after the onset of flow augmentation in Porter Creek during the control (blue) and treatment (yellow) reaches during in a wet year (2019) and a dry year (2020).

Table 7. Results from mixed modeling for BACI (comparison of means) and BACIPs (comparison of trends) effects from augmentation in 2019 and 2020.

Year	Variable (units)	Fixed Effect	Estimate	Std. Error	*p-value*	Sig.
2019	Dissolved Oxygen (mg/L)	BACI (means)	0.232	0.036	**0.000**	***
		BACIPS (trends, day)	0.004	0.005	0.468	
	Water Temperature (C)	BACI (means)	-0.413	0.049	**0.000**	***
		BACIPS (trends, day)	0.043	0.006	**0.000**	***
	Riffle Crest Depth (cm)	BACI (means)	0.228	0.077	**0.003**	**
		BACIPS (trends, day)	0.020	0.011	**0.073**	*
	Pool Depth (cm)	BACI (means)	0.266	0.099	**0.008**	**
	Pool Vel. (cm/s)	BACI (means)	-2.112	4.073	0.612	
	BMI Drift (mg/hr)	BACI (means)	3.253	2.669	0.243	
	O. mykiss move (#/tag/day)	BACI (means)	3.0957	2.9663	0.297	
		BACIPS (trends, day)	0.7104	0.3861	**0.066**	*
	O. kisutch move (#/tag/day)	BACI (means)	1.293	2.232	0.563	
		BACIPS (trends, day)	0.873	0.278	**0.002**	**
	O. mykiss growth (mm/day)	ANOVA (reach means)	0.071	0.014	**0.000**	***
	O. kisutch growth (mm/day)	ANOVA (reach means)	-0.011	0.009	0.224	
2020	Dissolved Oxygen (mg/L)	BACI (means)	2.264	0.302	**0.000**	***
		BACIPS (trends, day)	0.151	0.034	**0.000**	***
	Water Temperature (C)	BACI (means)	1.344	0.192	**0.000**	***
		BACIPS (trends, day)	-0.016	0.021	0.457	
	Riffle Crest Depth (cm)	BACI (means)	3.410	0.225	**0.000**	***
		BACIPS (trends, day)	0.155	0.029	**0.000**	***
	Pool Depth (cm)	BACI (means)	4.410	0.362	**0.000**	***
	Pool Vel. (cm/s)	BACI (means)	6.293	1.670	**0.002**	**
	BMI Drift (mg/hr)	BACI (means)	3.300	1.539	**0.050**	*
	O. mykiss move (#/tag/day)	BACI (means)	4.178	2.058	**0.043**	*
		BACIPS (trends, day)	0.372	0.278	0.181	
	O. kisutch move (#/tag/day)	BACI (means)	2.067	0.730	**0.005**	**
		BACIPS (trends, day)	-0.094	0.112	0.401	
	O. mykiss growth (mm/day)	ANOVA (reach means)	0.015	0.027	0.578	
	O. kisutch growth (mm/day)	ANOVA (reach means)	0.009	0.011	.394	

Salmonid Movement

In the wet summer of 2019, augmentation had no significant effect on total detections per tag of salmonids at riffle antennas, but the rate of detections per tag per day (trend) showed a significant increase after augmentation for both steelhead (0.71 detections/tag/day) and coho salmon (0.87 detections/tag/day) (Table 7). During the dry summer of 2020 augmentation significantly increased the total detections per tag of juvenile steelhead (by 4.2 detections per tag) and coho salmon (2.1 detections per tag) but had no significant effect on trend for either species (Table 7).

Salmonid Growth

The effect of augmentation on salmonid growth cannot be assessed using BACI design methods since we did not have two growth intervals (before and after) in each reach (control and impact). During both years the growth interval spanned the “before” and “after” augmentation periods with at least 30 days of growth after augmentation. However, an ANOVA analysis at the reach scale indicated a significant effect on growth for young-of-year steelhead during the wet summer of 2019 when steelhead in the impact reach grew 0.071mm/day more than those in the control reach (Table 3). No effect on coho growth was observed and no effect on steelhead growth in the dry year.

Salmonid Survival

In the wet summer of 2019, the probability of survival for Coho Salmon increased in the impact reach during the interval that the flow augmentation occurred (Figure 52). While the probability of survival for steelhead declined in both the control and impact reaches in 2019, the decline was significant only in the control reach. In 2020, the dry year, we observed a decline in survival probability from the pre-augmentation interval to the post-augmentation interval in all reaches; however, for both species the magnitude of the decline was greater in the control reaches. For juvenile Coho Salmon, the effect of rearing in the augmentation reach was an increase in survival probability of 0.11 in 2019 (wet year) and 0.24 in 2020 (dry year) (Figure 53). For steelhead, there was no significant effect of rearing in the augmentation reach in 2019, and in 2020, it increased survival probability by 0.20.

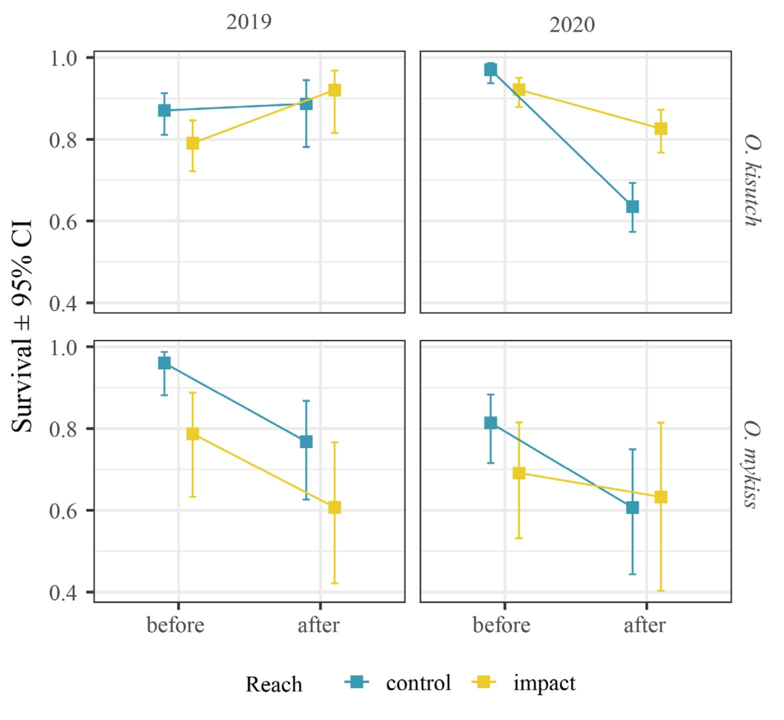

Figure 52. Probability of juvenile salmonid summer survival before and after the onset of flow augmentation in Porter Creek in a wet year (2019) and a dry year (2020). Change in probability from control reaches is shown as the blue line, and for impact reaches in the yellow line.

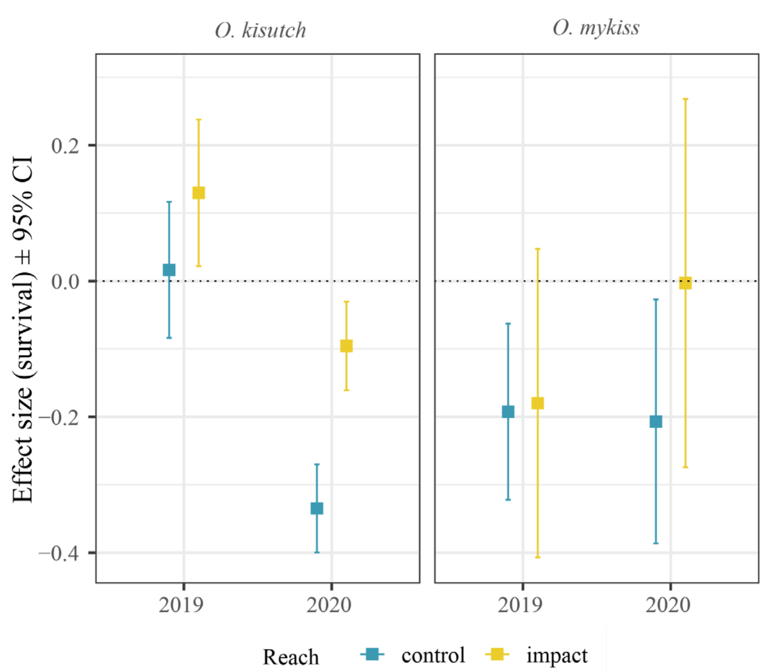

Figure 53. Effect size of juvenile salmonid survival before and after flow augmentation in control and impact reaches in a wet year (2019) and dry year (2020).

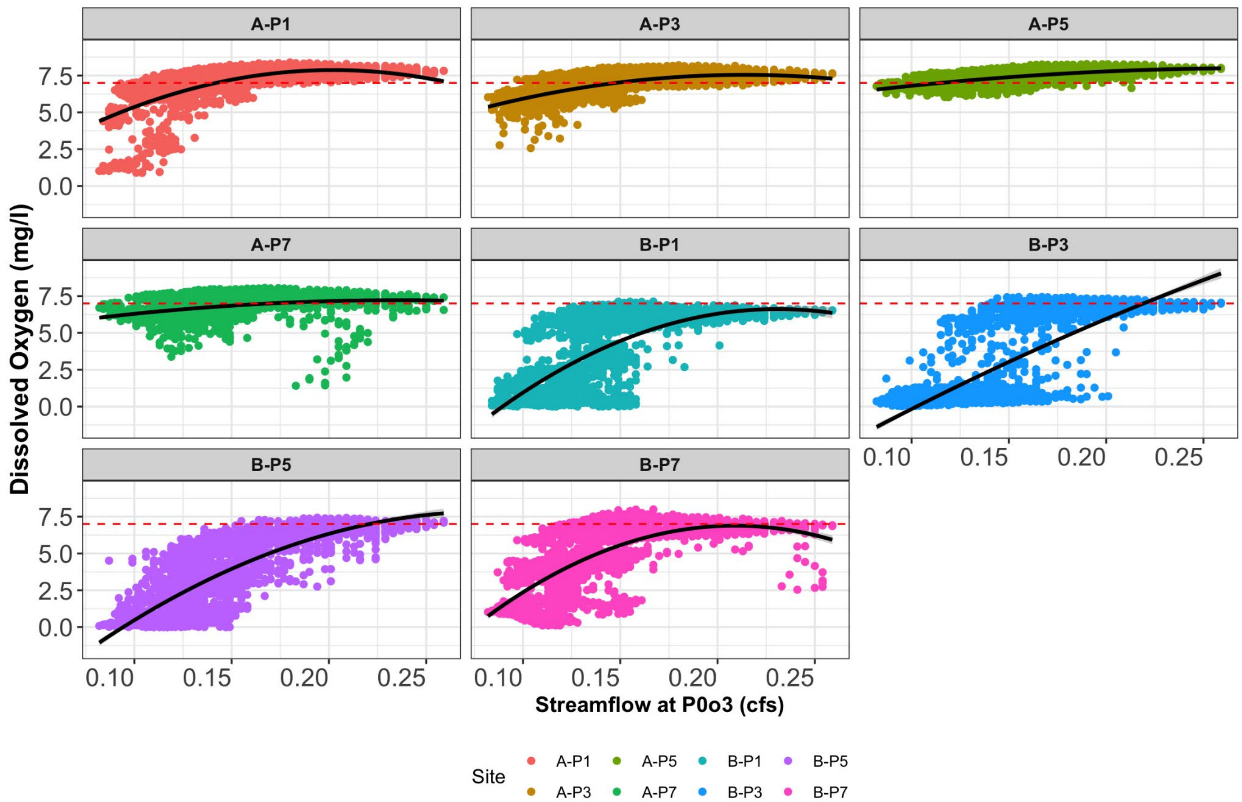

Figure 54. Relationship between dissolved oxygen (8 sites, 15-minute data) and streamflow at TU gage Po03, during the dry summer of 2020. Exponential trend lines were added in R. Dissolved oxygen fell below 7 mg/L at streamflows ranging from 0.225 to 0.1 in 2020. Conservatively, we estimate that initiating augmentation at flows of 0.3 cfs on gage Po03 will have the greatest effect at sustaining suitable dissolved oxygen in dry years. However, in extreme dry years (e.g., 2021) this effect may only extend to 1 or 2 pools.

V. LONG-TERM WATER RELEASE PROTOCOL AND RECOMMENDATIONS

Water Release for Spring Smolt Outmigration

Augmentation volume and timing to support spring smolt outmigration will depend on date, water year type, Porter Creek flow, and wetted habitat conditions between March 15 and May 30th each year. Although Porter Creek may become disconnected from the Russian River during dry winters prior to March 15, Coho Salmon migration timing suggests that augmentation prior to mid-March will have a limited benefit for out migrating smolts. The proposed spring augmentation decision process is shown in Figure 58 and described here. The "Operator" is here defined as the person evaluating stream data and making augmentation decisions.

Water Year Determination

Each year in early-March, a water year determination will be made by the Operator based on the California Nevada River Forecast Center using the "% of normal precipitation" value for the Santa Rosa Airport (https://www.cnrfc.noaa.gov/ol.php?product=PNS&zoom=10&lat=38.408&lng=-122.816). Values above 80% of normal by the end of March will be considered Wet and values below 80% of normal will be considered "Dry/Normal." Values below 20% of Normal will be considered "Critically Dry." Augmentation will occur in Wet and Dry years but not in Critically Dry years. Gallo will determine the augmentation volume allotted for "Wet" and "Dry/Normal" years. Here we describe the augmentation based on 130 ac/ft available during "Wet" years and 40 ac/ft available during "Dry/Normal" years.

Streamflow and Camera Installation

After March 15th the Operator will check Gauge P0o3 at the Concrete Weir (rKm 1.0, Figure 8), once each day. As soon as flows drop to 5 cfs on this gage, three SpyPoint cellular trail cameras will be installed in lower Porter Creek (Figure 56 and 58) to monitor wetted habitat conditions. The Operator will maintain a SpyPoint account to view the images from the cellular cameras. Camera #1 is installed on the ridge between Porter Creek and the Russian River, approximately 40 meters upstream of the Russian River (Figure 56). Camera #2 is installed on a right bank terrace approximately 100 meters upstream of the Russian River (Figure 56). Camera #3 is installed on a right bank tree, approximately 180 meters upstream of the Russian River and just upstream of the Sea Grant PIT tag antenna locations (Figure 56). Each camera will be trained on the channel perpendicular to flow from the camera location. Cameras 1 and 2 are installed on monumented 4X4 posts (Fig 57).

Camera Operation and Augmentation

After the cameras are installed, images will be checked daily to determine if augmentation is warranted (Figure 58). Images will be transmitted via cellular signal and viewed using the SpyPoint App. The two conditions that warrant augmentation are if: (A) Camera #3 and either Camera #1 or Camera #2 are wet; or (B) Camera #3 is wet and more than 0.5 inches of rain are forecast (Figure 56). If either of these two conditions is met, the Operator will turn the augmentation on immediately as follows: release 450 gpm for 2 days (using both augmentation release points to achieve this flow rate). If Porter Creek is not connected to the Russian River after 2 days, then augmentation releases will be stopped. If Porter Creek is connected after 2 days, the Operator should continue augmenting at 450 gpm for 3 more days (for a total of 5 days) (Figure 58). This process is repeated until a set percentage of the total available augmentation volume is exhausted. For a wet year, this represents 15% of the seasonal augmentation flow volume and, for a dry tear, 50 % of the season augmentation flow volume. For example, if during a wet year a 130 ac-ft allotment is available, augmentation releases to support spring smolt outmigration should generally not exceed 19.5 ac-ft (corresponding to approximately 10 days of augmentation at 450 gpm). The same volume (19.5 ac-ft) can also be prescribed during a dry year, but this will constitute a larger portion (~50%) of the 4 ac-ft allotment for dry years (Figure 58).

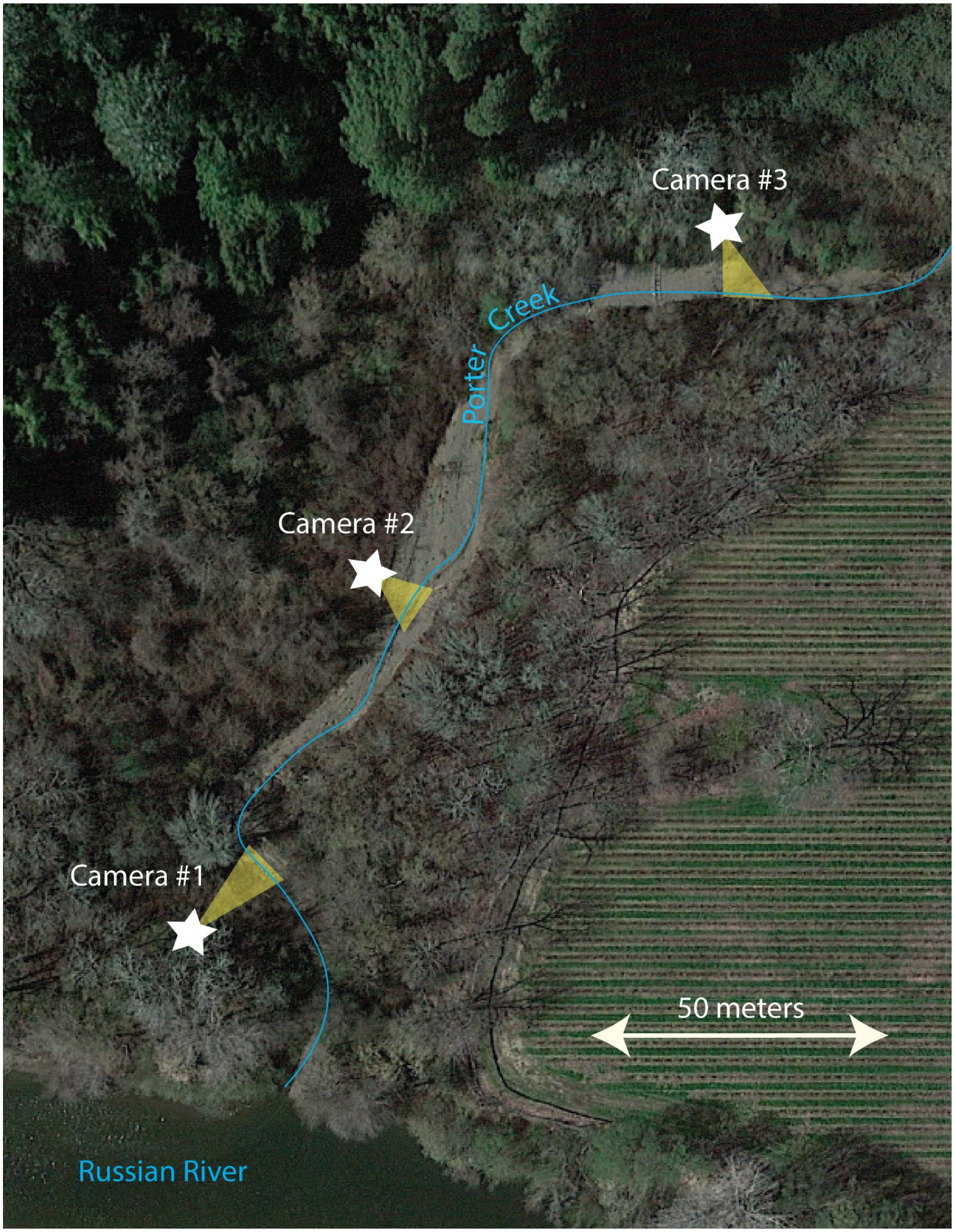

Figure 56. Location schematic for Porter Creek trail cameras to be used in augmentation decision tree process. Three cameras are placed in the lower 200 meters of Porter Creek.

Figure 57. Spypoint Cellular Camera installed at location #2 (Figure 56).

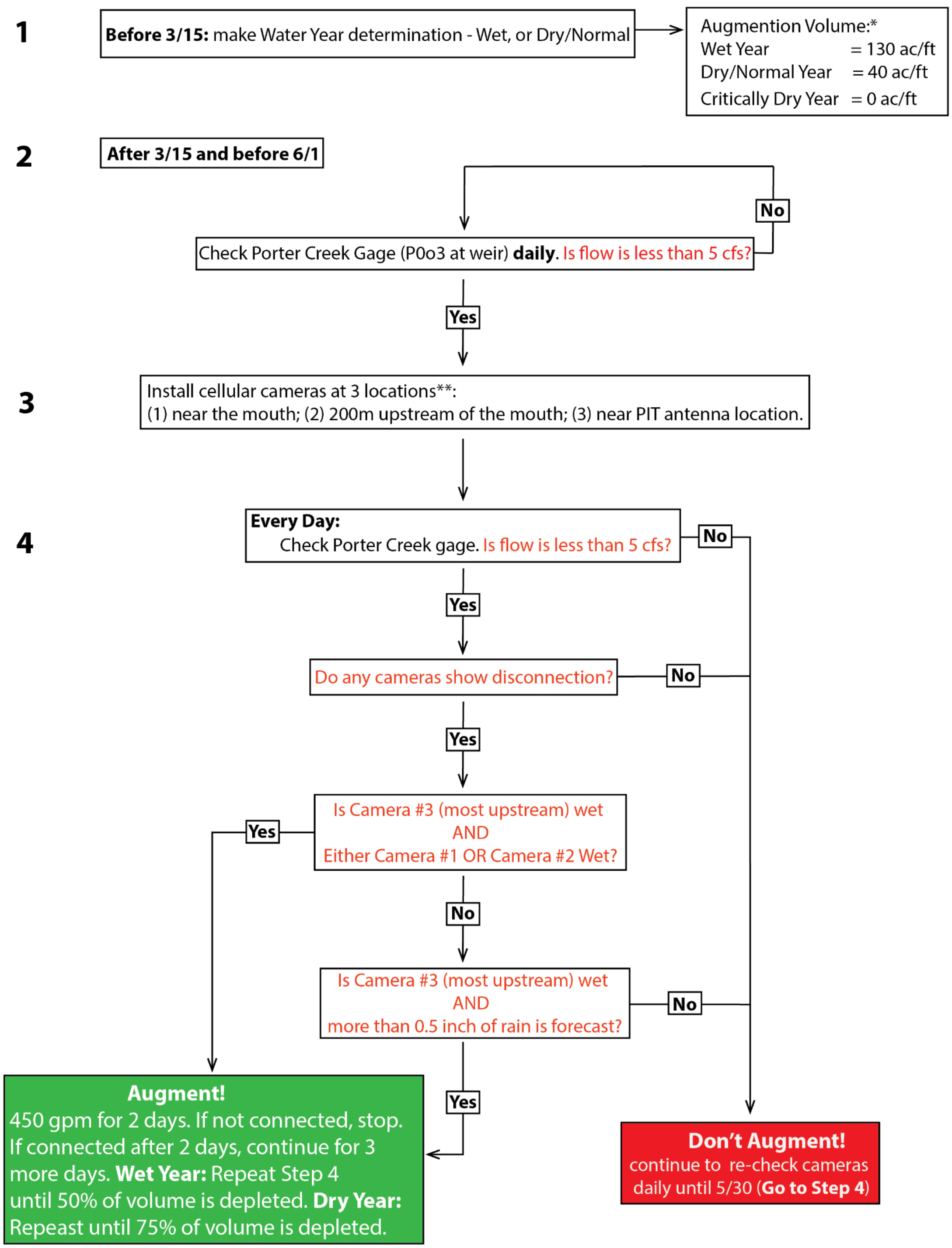

Figure 58. Decision tree for augmentation during spring smolt outmigration (April 1 to May 30). For over-summer rearing augmentation see Figure 59. * Augmentation volumes may vary. **See camera schematic, Figure 56.

Water Release for Over-summering Juvenile Salmonids

Augmentation volume and timing to support rearing habitat for juvenile salmonids in the dry season will depend on date, water year type, and Porter Creek streamflow between 6/1 and 10/31 each year (Figure 59). The primary goal of augmentation in the dry season is to maintain suitable habitat within water quality thresholds (specifically dissolved oxygen) during wet and dry/normal years. The proposed summer augmentation decision process is shown in Figure 59 and described here. The "Operator" is here defined as the person evaluating stream data and making augmentation decisions.

<u>Water Year Determination</u>

As in spring, each year in mid-late May, a summer water year determination will be made by the Operator based on the California Nevada River Forecast Center using the "% of normal precipitation" value for the Santa Rosa Airport. Values above 80% of normal by the end of March will be considered Wet and values below 80% of normal will be considered "Dry/Normal." Values below 20% of Normal will be considered "Critically Dry." As with smolt outmigration, augmentation will occur in Wet and Dry years but not in Critically Dry years.
https://www.cnrfc.noaa.gov/ol.php?product=PNS&zoom=10&lat=38.408&lng=-122.816

<u>Streamflow and Augmentation</u>

After June 1st the Operator will check Gauge P0o3 at the Concrete Weir (rKm 1.0, Figure 8), once each day. In wet years, augmentation (200gpm) should commence if flows drop below 0.3 cfs at Gauge P0o3 and continue until the end of October. This is based on a conservative threshold for maintaining dissolved oxygen levels greater than 7 mg/l (Figure 54) through the reach between the point of augmentation and West Side Rd. During dry/normal years augmentation (20gpm) will commence if flows drop below 0.5 cfs at Gauge P0o3. This is based on a goal of maintaining dissolved oxygen levels in pools adjacent to the augmentation site.

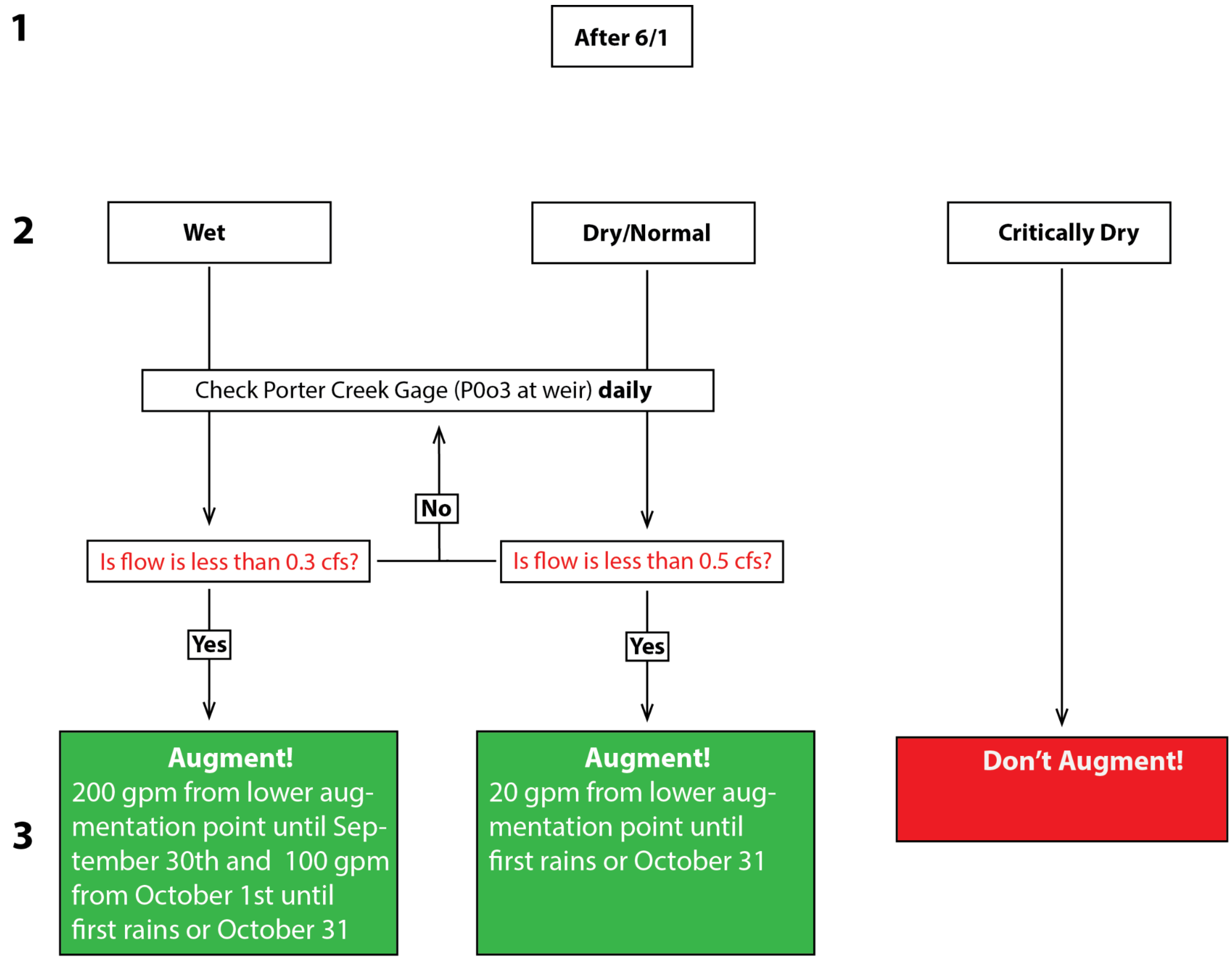

Figure 59. Decision tree for augmentation during dry season (June 1 until October 31). Augmentation volumes may vary – if more water is available for augmentation, we recommend increasing rates up to 250 gpm through October to have a beneficial effect for over-summering juvenile salmonids.

Ongoing Recommendations

We recommend that representatives from E & J Gallo regularly communicate with regulatory agencies (such as CDFW and NOAA) to ensure that the recommendations within this Streamflow Enhancement Plan remain suitable for the current year's conditions and follow best practices for restoring salmonid populations in Porter Creek. This plan was written with the intent to inform annual water releases for the betterment of habitat conditions for juvenile salmonids, but we realize due to environmental conditions beyond our control, there may be instances where these recommendations should not be followed.

<u>Flow Release Best Management Practices</u>

Flow releases should not be abruptly turned off. The system is designed to slowly decrease flow each time an augmentation period is ended. Check control panel settings and monitor release to validate. Consult with regulatory agencies for specific thresholds relating to water quality of released water, special requirements for the given water year (drought, etc.), and ramp down rates for ending water releases.

Years with No Streamflow Impairment

In very wet years, flow augmentation is not expected to influence salmonid habitat. If streamflow conditions are adequate to facilitate outmigration and maintain suitable rearing habitat throughout the dry season, there is no need to release water from the storage pond.

Fish Rescues

Even when flow release schedules and recommendations are followed, there may be instances when fish remain stranded due to low streamflow conditions. If this situation is observed, please notify CDFW to inform of the potential need for a fish rescue.

Operation and Maintenance of System

Please refer to the *Operations and Maintenance Plan for the Porter Creek Streamflow Enhancement Water Release and Control System (May 2023)* for additional specifications regarding the flow augmentation system design, maintenance, and operations. Maintenance and appropriate operation of the water release system are the responsibility of E & J Gallo as outlined in the Landowner Implementation Agreement held by Sonoma RCD. If additional questions arise, please consult with Sonoma RCD staff.

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