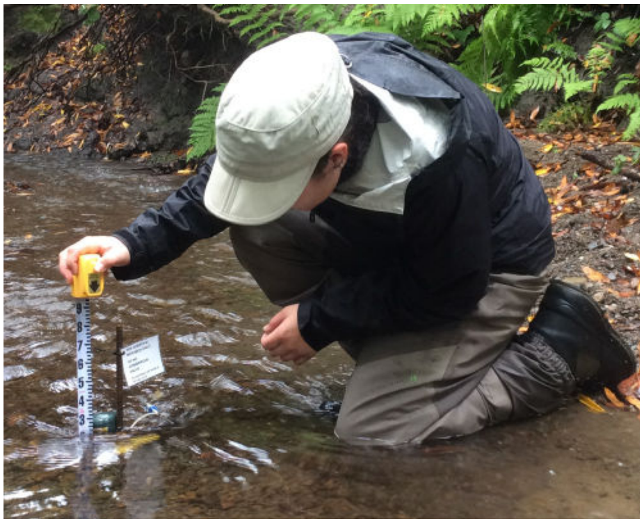
The Russian River Coho Water Resources Partnership

Lessons learned for streamflow enhancement in California | January 2022



GOLD RIDGE RESOURCE CONSERVATION DISTRICT

Sea Grant California

TROUT UNLIMITED

WATER INSTITUTE OCCIDENTAL ARTS & ECOLOGY CENTER

SONOMA RESOURCE CONSERVATION DISTRICT

I. Introduction

The purpose of this report is to summarize the lessons learned by the Russian River Coho Water Resources Partnership (Partnership) and its many partners through more than a decade of work on streamflow restoration in the Russian River watershed (Sonoma County, California). Our goals are to describe the reasons we think the Partnership has been successful in a way that allows our experiences to be transferable, and to provide our perspective on conditions that will facilitate future instream flow enhancement on the California coast.

The report is a companion to a second publication, *The Russian River Coho Water Resources Partnership: Dedicated to improving water reliability for fish and people* (2022), which summarizes the Partnership's specific activities and accomplishments.

Our intent is to provide information that will be useful to other organizations that are involved in (or are considering) coordinated efforts to address streamflow impairment in other watersheds using similar approaches. We hope that the information will also support resource managers — including funders and regulatory agencies — who are critical to the development, planning, implementation, and monitoring of streamflow improvement projects as part of a larger salmonid recovery strategy.

II. Partnership background

The need: Impacts of insufficient streamflow on coho salmon

Coho salmon in the Russian River watershed typically spend the first half of their three-year life cycle in tributary streams where they rely on sufficient levels of flowing water to access spawning habitat during the winter, support incubation of eggs and alevins in redds, rear in pool habitat throughout the summer dry season, and migrate out to the ocean in the spring as smolts. Insufficient flows during any one of these seasons can severely impact one or more life stages and prevent a cohort of fish from completing its life cycle.

One of the most pronounced bottlenecks in this life cycle occurs during the summer dry season, when juveniles are rearing in pools. California Sea Grant has documented extensive intermittency and stream drying in coho-bearing streams, especially during drought years (Moidu et al. 2021). For example, only about 40% of the rearing habitat in 14 sampled coho streams in the lower Russian River watershed remained wet and connected through the summer of 2015 (California Sea Grant 2016). Intensive studies of juvenile coho survival in relation to flow-related variables in focus tributaries revealed that survival probability was highly dependent on flow conditions (Obedzinski et al. 2018, Vander Vorste et al. 2020).

Another significant impact of low streamflow in the Russian River watershed occurs in spring when coho smolts are attempting to migrate out of the tributaries and through the mainstem of the river on their way to the ocean. Without sufficient flow during the migration window between March and June, the downstream-most alluvial reaches of many coho streams become dry, and smolts become trapped and perish. If such disconnections occur before or during the peak of the smolt migration, the impacts on a cohort can be devastating. In recent years, low streamflow has even had significant detrimental impacts on Russian River salmonids during the winter months, delaying migratory access for adults returning to spawn, reducing the stream habitat available to fish during their spawning window, and in some cases causing redds to dry and adult fish to become stranded (California Sea Grant 2021).

While low-flow coho survival bottlenecks were long suspected in Russian River tributaries, at the time the Partnership was formed there were no comprehensive efforts to document the impacts of flow impairment on salmonids and their habitat or to improve streamflow in priority streams. This was likely due to the daunting nature of such a complex and long-term task. The Partnership formed to address this gap in coho recovery efforts.

Russian River Coho Water Resources Partnership approach

With support from the National Fish and Wildlife Foundation (NFWF) and Sonoma Water, the Partnership — comprised of California Sea Grant, the Center for Ecosystem Management and Restoration, Gold Ridge Resource Conservation District, Occidental Arts and Ecology Center's WATER Institute, Sonoma Resource Conservation District, and Trout Unlimited — formed in 2009. The Partnership's goal is to improve streamflow for coho salmon and water supply reliability for water users in five priority Russian River tributaries: Mark West Creek, Grape Creek, Mill Creek, Dutch Bill Creek, and Green Valley Creek.

The Partnership developed a non-regulatory approach to streamflow restoration with the following elements:

Integration. The program relies on close communication between a multidisciplinary team of partner agencies and organizations with clearly defined roles. The Partnership's body of work includes:

- Public outreach
- Project development, design, permitting, fundraising, and implementation
- Streamflow, fish, and habitat monitoring to support project prioritization, evaluate project effectiveness, and contribute to a better understanding of flow-related habitat needs and limitations
- Professional support for agencies and other organizations working on streamflow enhancement efforts

Multi-year vision. The Partnership began with a long-term vision to create a diversified portfolio of projects in various phases of development and to use a watershed-scale approach to monitoring and project implementation (as opposed to more piecemeal, one-off projects). The Partnership's vision acknowledges the landscape-scale processes that have changed over time, the holistic restoration needed to fully recover watersheds, and the regulatory and permitting drivers that influence both water user incentives for action and the timeline and feasibility of restoration work.

Partnerships. The Partnership relies on relationships with private landowners and water users with the goal of meeting their water supply, reliability, and infrastructure needs in tandem with streamflow enhancement and fisheries recovery goals. Relationships with other professionals (e.g., practitioners, designers, engineers, construction professionals, lawyers, scientists, researchers, resource managers, regulatory agency staff, journalists, educators, etc.) have been critical because the magnitude and nature of the work require community-scale and cross-disciplinary collaboration.

Communication. From the outset, the Partnership committed to share what we learned, both in terms of our process and our data. We serve as a hub for documenting on-the-ground conditions and communicating with regulators, practitioners, and landowners making decisions regarding funding, the allocation of limited resources, water management, and drought actions. As such, we have filled a critical knowledge gap, providing information on flow, fish and habitat status, trends, and real-time conditions. In addition to data, we have been able to provide information on land management practices and social and economic considerations to guide and facilitate outreach efforts to landowners in these flow-limited tributaries. The need for this information has been especially pronounced during drought years.

Outcomes. Since 2009, the Partnership has implemented over 30 streamflow enhancement projects and has another 30 projects in planning and design phases. The projects include water conservation measures, conjunctive use, water storage and forbearance projects, diversion timing shifts, flow augmentation, and upland projects that reduce runoff and increase groundwater recharge. The Partnership has also conducted extensive fish and flow monitoring efforts. We have operated over 30 streamflow gages used to generate critical hydrologic data and have documented salmonid distribution, abundance, survival, and habitat conditions across the lower Russian River tributaries. Key scientific studies and models have come out of the monitoring and data analysis, including the publication of four Streamflow Improvement Plans (SIPs) and custom interactive web tools that provide access to real-time biological and environmental data.

III. Key lessons learned

The Partnership has learned a great deal about conducting flow enhancement work in the last decade. The following summarizes our key lessons learned.

Local, trusted partners are essential. Organizations involved in implementation must be based in and have support in the watersheds where they operate. This is especially critical to understanding fish and habitat usage and in garnering the trust necessary to develop projects. Colleagues in other western states joke that ten years after implementing a small habitat project with a landowner, one can cross their fingers and hope to talk with them about their water rights. We can point to many examples of this foundational work occurring in the Russian River watershed. The Partnership's work has demonstrated that non-regulatory organizations can play an important role in reaching out to water users, opening doors, and building trust within communities.

A science-based effort is key. Any flow restoration effort must include organizations that are doing the necessary monitoring and data analysis to support the effort, answer questions, and provide input and advice during each step of project and program development.

Streamflow data are foundational. Data on streamflow are limited-to-non-existent in most areas and in most recovery plans and therefore must be developed to understand local issues and effects on salmonids. This requires investment in monitoring, gage network design, close coordination, negotiation with landowners, and time. The data provide a scientific foundation upon which to base decisions and can inform metrics used to set expectations, develop projects, and support funding proposals. Long-term datasets are incredibly compelling and reveal important insights about a watershed's conditions and characteristics. They are especially powerful when coupled with data on biological response (the ability to understand how flow conditions and changes to flow conditions impact fish).

Flexible funding is essential. Flexible funding has been critical to the Partnership's success. This allowed the Partnership to set priorities and adjust the allocation between monitoring and project work as appropriate, and as we gained more knowledge. It allowed for the development of a project pipeline, providing seed funding and cost share for project implementation, which was then funded by more highly restricted sources with longer proposal-to-award timelines. It enabled us to be nimble and adapt to the opportunities and challenges presented by events like drought and wildfire. Finally, it allowed us to provide support for agencies — which filled a critical need especially during emergency situations — and for organizations working on flow efforts in other coastal watersheds.

Honesty and authenticity advance restoration practice. We knew the work would be challenging, and the Partners agreed to be brutally honest about many things: (a) the risks, failures, and the limitations of certain project types (e.g., flow releases); (b) what we did not know, which — in the world of flow restoration — can be a lot; and (c) expectations about what we could accomplish with funders and partners, which manifested both as not overselling our accomplishments and not overpromising what we could deliver. This was accompanied by a commitment to share what we have learned with others through scientific publications, presentations and tours, landowner-to-landowner communication, and cross-pollination through communication, professional conferences, and platforms like the California Environmental Water Network.

Coastal flow work requires addressing the cumulative effects of multiple diversions. When the Partnership began assessing water demands in tributaries to the lower Russian River, it became clear that it would not be possible to remediate streamflow impairment by addressing a handful of large water diversions because, in general, those diversions simply do not exist. Water management is decentralized and dispersed, consisting of direct diversions among a patchwork of streamside wells. The collective effect of these numerous small withdrawals on the stream ecosystem was essentially resulting in "death by a thousand straws." We needed a way to evaluate the cumulative effects of many small water diversions scattered throughout the drainage network. We also needed to successfully recruit numerous landowners to complete small-scale water conservation, storage, and alternative sourcing projects, each at a cost. To respond to these needs, we:

- Developed a spatially explicit model to evaluate the cumulative impacts of surface water rights and evaluate whether water is available for further appropriation (as defined in state policies). This work was described in a peer-reviewed article published in *Applied Geography* (Deitch et al. 2016).
- Set out to better understand and characterize the social and environmental constraints and opportunities for streamflow restoration in the Mediterranean climate of coastal California. This work was included in a peer-reviewed article, published in the journal *Water* (Deitch and Dolman 2017), which began to lay the framework for prioritizing projects and understanding whether they could be expected to yield intended benefits.

Given that this situation exemplifies the circumstances of the vast majority of coho salmon-bearing streams in our state, the ability to evaluate, prioritize, and address decentralized and dispersed water use is likely key to future instream flow work.

Returning small amounts of flow to coastal streams can benefit salmonids. As we developed our approach, two critical questions stood out to the Partnership: First, was the substantial investment of time and resources worth it given the potential improvements to streamflow, especially if it was impossible to address every "straw"? Second, could the relatively small amounts of streamflow gained possibly tip the scales in favor of salmon survival? In search of answers, the Partnership conducted a seven-year study to correlate flow and other environmental variables with juvenile coho survival using an innovative approach that incorporated PIT-tag technology. Outcomes highlighted a significant negative relationship between fish survival and pool connectivity and provided evidence that reducing the number of days that pools are disconnected by surface flow in a given summer was a critical step in increasing the probability of fish survival. Monitoring data indicated that streamflow of just hundredths to tenths of a cubic foot per second is sufficient for sustaining pool connection and limiting salmon mortality in tributaries to the lower Russian River. In other words, we learned that returning even what could be considered a minute volume of flow to these streams could have a large positive impact on juvenile salmon survival. This information helped highlight the considerable value of small-scale flow restoration projects in intermittent streams that provide refuge for imperiled rearing juvenile salmonids throughout coastal California. We summarized our findings in two peer-reviewed articles (Obedzinski et al. 2018, Vander Vorste et al. 2020).

Streamflow impairment is present and impacts fish every year, not just in extreme drought years. At the time the Partnership formed, there was a general assumption that flow impairment was impacting salmonids primarily in drought years. Following twelve years of monitoring that encompassed both wet and dry years, it is clear that low streamflow is impacting fish every dry season. The spatial and temporal extent of those impacts increases with intensification of drought, but for salmon populations to recover, flow protections are needed during every dry season, regardless of whether a given year is classified as a drought year.

The spatial extent of flow impairment is much broader than the five Partnership focus streams. While the Partnership's efforts have focused on the five streams initially identified as flow impaired and critical for coho recovery, monitoring over the last decade indicates that flow impairment is occurring at a much broader spatial scale throughout the watershed. Nearly all coho streams within the Russian River watershed experience flow impairment on an annual basis and will require increases in dry season streamflow to adequately support coho populations.

Define appropriate metrics. From the inception of the Partnership, determining metrics for evaluating progress posed a challenge. With an ultimate goal of increasing coho salmon population size in the Russian River watershed, monitoring the number of adults returning to the watershed each year was a tempting metric. However, this was inappropriate because many factors aside from summer streamflow have a strong influence on the number of returning adults (e.g., number of hatchery fish released, ocean conditions, estuary closures, etc.). Recognizing this early on, we worked with NFWF science staff to develop metrics that were more closely linked with improving streamflow, such as oversummer survival of stream-rearing juvenile coho.

Our initial monitoring strategy for project evaluation was to use a before after control impact treatment (BACI) design using oversummer survival as a response variable. This quickly proved to be too costly and long-term in nature given the scope of the funding, so we adapted our approach. Instead, we conducted focused research designed to identify relationships between juvenile coho survival and flow-related variables. The results of this work highlighted a strong relationship between survival and days of streamflow disconnection, with the probability of survival decreasing the longer that pools were disconnected (Obedzinski et al. 2018). We then focused on identifying the streamflow levels at which pools become disconnected (connectivity thresholds) in priority reaches within each stream and used those values as minimum targets for flow improvement. Instead of directly measuring the survival benefits of specific projects — which would be tremendously expensive and time-consuming — we use survival functions developed from our research to interpret the survival benefits of increasing flow to levels that maintain pool connectivity for longer periods of time. This approach is described in a working document that we produced with the NFWF science team: *Coho Partnership Proposed Metrics* (Russian River Coho Water Resources Partnership 2016).

Consider the bigger picture when evaluating projects. Project evaluation is challenging because streamflow is so low in coastal California streams during the summer season that it is difficult to accurately measure. As such, the benefits of individual projects are difficult to quantify because they may fall within the range of measurement error. Compounding that with a high level of natural variability in annual flow due to dynamic precipitation and climate patterns, it can be nearly impossible to directly attribute a change in flow to a particular flow enhancement project. To address this, we estimated the collective benefits of multiple projects along a stream corridor in both time and space. For an illustration, see the *Dutch Bill Creek Streamflow Improvement Plan* (Russian River Coho Water Resources Partnership 2017). In some cases, a single project may not be enough to achieve flow levels at or above connectivity thresholds in an average water year, but when placed in the context of all projects planned for a particular stream, the value of the work is made apparent.

Watershed-scale solutions are needed to repair hydrologic function. The Partnership's work leads us to believe that reducing or eliminating dry season water extraction, both directly from streams and indirectly via alluvial wells, may not be sufficient by itself to maintain suitable flows for juvenile coho to thrive over the long-term. There are numerous other factors beyond water diversion that contribute to watershed health and hydrologic function. Because of landscape-scale changes to land use and cover, many of the upland areas of our coastal watersheds no longer act like sponges, collecting precipitation during the rainy season and sinking it into the ground, then slowly releasing it to streams through groundwater flow, seeps, and springs in the dry season. With the development of roads, buildings, and other less- or impervious surfaces, runoff has less opportunity to infiltrate and flows to streams at a higher rate, leading to lower rates of groundwater recharge, as well as erosion and channel incision. Restoring the hydrologic function of our watersheds is possible using low impact development techniques, proper stormwater management, and improved roadway design to mimic more natural drainage patterns. Instead of the classic collect and convey model of stormwater management, we need to slow it, spread it, sink it, and store it!

Other practices such as improved forestry and grassland management may also enhance streamflow. For example, properly thinning and managing forested land, by removing small trees and dense underbrush, not only improves fire resiliency, but also results in less evapotranspiration from the shallow water table, leaving more water in the ground and ultimately instream (O'Connor Environmental, Inc. 2020). Addressing other impairments to streams, such as temperature and loss of habitat (e.g., by adding large wood, reducing channel incision, reconnecting streams to their floodplains, and reintroducing missing keystone species such as beaver) will improve instream conditions for salmonids and may result in increased alluvial water storage. These and other landscape-scale efforts must be coupled with strategies to address the impacts of surface and groundwater diversions if we are to sufficiently improve flow and habitat in the long-term for salmonids (and the myriad of other species that depend on our stream ecosystems), particularly in the face of increasing climate volatility and water scarcity in our region.

The work takes time. In the last twelve years, the Partnership has met the initial goals set out by NFWF, and we have learned from our experience with multiple droughts, extreme wildfires, and the plight of coho salmon, that our work is nowhere near complete. The relationships that are key to successful projects take time to develop, often spanning many years from initial communication to implementation (i.e., they do not follow typical one-to-three-year grant cycles). It also takes time to realize the cumulative benefit of multiple projects across watersheds. Climate change is a severe and present threat to our collective work. Working to undo the impacts of centuries of human development and land

and water management practices is not something that can be accomplished in one decade; it requires a long-view approach.

IV. Facilitating future instream flow work in coastal California

Below are several recommendations for facilitating more successful streamflow enhancement work in California coastal streams.

Identify restoration priorities and link them to funding. It is critically important that funding be targeted to broad-scale restoration priorities. The more that agencies can proactively identify and fund their priorities, the better. Doing so allows practitioners to develop better projects, engage and maintain engagement with landowners, and develop a pipeline of projects.

Create additional sources of long-term, flexible programmatic funding. Sources of programmatic, flexible funding are required to effectively do this work, but are also extremely limited. As we have learned, more general funds (not earmarked for a specific task or line item) can comprise a small percentage of the total cost of a project or program, but are often the most important because they are critical to developing a pipeline of projects, shortening implementation timelines, and allowing for nimble, creative responses to test approaches (like flow releases) and react to emergencies (like drought and fire). Public funders should consider and explore funding models that treat restoration practitioners more as partners (as distinguished from contractors) and invest in their capacity to do the work required.

Increase agency leadership, discretion, and partnership in restoration project permitting. Most permitting processes were designed to regulate rather than to restore, and, as a result, restoration projects are often treated with a similar level of skepticism and scrutiny as development projects. Policy, permitting, and regulatory changes — including and beyond those identified as part of the California Natural Resources Agency's Cutting Green Tape Initiative (see California Landscape Stewardship Network 2020) — are needed to enable restoration to occur at a faster pace, commensurate with the urgency of salmon decline. Agencies should be prepared to employ a greater use of discretion when permitting beneficial projects. Where severe backlogs exist, we should think creatively about how to prioritize and expedite restoration projects (e.g., the Wildlife Conservation Board partially funds a staff position focused on water right permitting for state-funded streamflow enhancement projects). We need more agency involvement in on-the-ground project development, plus more integrated agency teams that take ownership for project success, help anticipate permitting challenges, and aid in project implementation — as partners and collaborators. Programmatic permits linked to restoration work and/or grant solicitations further streamline project implementation.

Use the "stick" when appropriate. Restoration practitioners are necessarily limited to collaborative and cooperative work. There are times and places when enhanced and targeted enforcement is appropriate, particularly when restoration investment is being undermined by activity that will only change if it is regulated. Agency leadership and collaboration with local governments may be key. In addition, it is important that enforcement of existing regulatory and permit requirements be fair and strategic. There is a fear among water users and landowners, that often manifests as a disincentive for participation, that those who come forward to engage in cooperative action will be the only targets for agency scrutiny (the "no good deed goes unpunished" effect).

Provide support for long-term monitoring. It is essential that long-term quantitative monitoring accompany project planning and implementation efforts. Ideally, monitoring should include documentation of hydrological, biological, and environmental conditions. Pre-project monitoring helps to identify limiting factors, develop project objectives, and prioritize restoration actions and sites. It also provides the baseline data required for accurately determining the effect of restoration actions. Teasing apart the cumulative impacts of small-scale streamflow enhancement projects, or even larger-scale infiltration projects, from the natural variability of environmental conditions is tremendously complex. Longer, more robust post-project datasets are needed to understand hydrological and biological responses amid trends over time. Long-term datasets also provide valuable information about how streamflow and salmonids are responding to changing climatic conditions and weather-related events like wildfire and drought, which may influence restoration priorities. They also help us to predict and prepare for future drought. An absence of funding for long-term monitoring efforts has resulted in a piecemeal approach to continuous operation of flow gages and biological data collection. This has left holes in long-term datasets and is a much less efficient way of providing the monitoring support required. Funding that supports ongoing monitoring efforts independent from discrete projects is needed for successful implementation of streamflow improvement strategies.

Plan for future drought and climate change. Since the Partnership began, the region has experienced two historic droughts – the first from 2012-2016 and the second beginning in 2020 and growing more extreme through the present. During that time, we observed increasing impacts on surface and groundwater resulting from antecedent drought conditions. Studies of tree ring data indicate that we are in a megadrought and a warming climate is playing a key role (Williams et al. 2020). As climate forecasts indicate that more frequent and intense drought conditions are likely to be the new normal, is it important that resource managers and restoration professionals adapt our perspective and methodologies. The Partnership's observations have led us to the following recommendations for planning for drought and climate change:

<u>Link flow restoration and wildfire management efforts</u>. Often with prolonged drought come increases in extreme wildfire. Three of the Partnership's priority watersheds — Mark West Creek, Mill Creek, and Grape Creek — experienced significant, stand-replacing wildfires: the Tubbs Fire in 2017, and the Walbridge and Glass fires in 2020. Our understanding of the short-and long-term impacts to water quantity and quality remains incomplete, as many effects are still unfolding. The Partnership documented increased streamflow immediately post-fire in watersheds that experienced extensive and intense burning, but the long-term effects on streamflow from successional forest regrowth, sedimentation, and other fire-related changes remain unclear. With wildfire events likely to be a common part of our future in this region due to climate change, we must be proactive about linking pre- and post-fire land management and planning efforts with drought planning.

<u>Identify and protect drought refugia</u>. The Partnership evaluated flow and habitat data for three Russian River streams to determine the impact of the 2012-2016 drought on streamflow and habitat (Deitch et al. 2018). Outcomes from that study and another collaboration with the University of California, Berkeley (Vander Vorste et al. 2019) suggest that many of the pools that sustain salmon during non-drought years transition to ecological traps during drought years, while some pools in the study streams serve as refuges even under extreme drought conditions. It is imperative that we identify and protect such drought refugia to increase resilience for rearing fish during future drought episodes.

<u>Adapt monitoring and recovery actions to meet changing patterns</u>. The impacts of the drought are extending beyond the summer into all seasons, leading to changes in fish and available habitat

distribution. For example, in drought winters, fish are often limited to spawning in the lowest reaches of accessible streams, placing their offspring in areas that generally become intermittent or dry during the summer months (as opposed to higher, perennial reaches across numerous stream systems). If this trend continues, we may need to shift priorities to restoring summer streamflow and juvenile rearing habitat in areas previously thought to serve primarily as migratory corridors to higher-quality upstream habitat. We have also observed increases in flow-related passage barriers for outmigrating smolts during the spring months. Climate-driven changes such as these should lead to careful consideration of long-standing restoration priorities in light of evolving needs.

Decouple state and federal support for streamflow improvement from drought declarations. When the state declared a "drought emergency" near the end of the 2012-2016 drought, the Governor's Order made additional permitting tools and other resources for flow enhancement projects available, and resource agencies began a Voluntary Drought Initiative (VDI) program that increased regulatory certainty and agency support for these projects. These efforts were discontinued when the drought declaration ended, and only resumed years later when a second drought emergency was declared. Because increases in streamflow are needed to support fish in all years and project development is a slow and continuous process, intensive, proactive, and continuous agency support for flow enhancement projects and other drought efforts, including dedicated staffing, are needed to make effective headway.

Plan for drought in non-drought years. Agency planning is needed to anticipate future dry years, articulate the thresholds for both voluntary and potential regulatory actions, identify the actions needed in advance so landowners and water users can plan and adapt, establish strategies for communication and collaboration with on-the-ground partners, and facilitate the development, approval, and implementation of projects that address drought and climate change on the timelines that match their urgency.

References

California Landscape Stewardship Network. 2020. Cutting Green Tape: Regulatory Efficiencies for a Resilient Environment.

California Sea Grant. 2016. UC coho salmon and steelhead monitoring report: Summer-fall 2015. University of California Cooperative Extension, University of California, Santa Rosa, CA.

California Sea Grant. 2021. Russian River Coho Salmon and Steelhead Monitoring Report: Winter 2020/21. Windsor, CA.

Deitch, Matthew J., Dolman, Brock. 2017. Restoring Summer Base Flow under a Decentralized Water Management Regime Constraints, Opportunities, and Outcomes in Mediterranean-Climate California. Water, 9:1, 29.

Deitch, Matthew J., van Docto, Mia, Feirer, Shane T. 2016. A spatially explicit framework for assessing the effects of weather and water rights on streamflow. Applied Geography, 67, 14-26.

Deitch, Matthew J., van Docto, Mia, Obedzinski, Mariska, Pierce, Sarah Nossaman, Bartshire, Andrew. 2018. Impact of multi-annual drought on streamflow and habitat in coastal California salmonid streams. Hydrological Sciences Journal, 63:8, 1219-1235.

Moidu, Hana, Obedzinski, Mariska, Carlson, Stephanie M., Grantham, Theodore E. 2021. Spatial Patterns and Sensitivity of Intermittent Stream Drying to Climate Variability. Water Resources Research, 57:11.

Obedzinski, Mariska, Pierce, Sarah Nossaman, Horton, Gregg E., Deitch, Matthew J. 2018. Effects of Flow-Related Variables on Oversummer Survival of Juvenile Coho Salmon in Intermittent Streams. Transactions of the American Fisheries Society, 147:3, 588-605.

O'Connor Environmental, Inc. 2020. Integrated Surface and Groundwater Modeling and Flow Availability Analysis for Restoration Prioritization Planning, Upper Mark West Watershed, Sonoma County, CA.

Russian River Coho Water Resources Partnership. 2016. Coho Partnership Proposed Metrics (draft).

Russian River Coho Water Resources Partnership. 2017. Dutch Bill Creek Streamflow Improvement Plan.

Russian River Coho Water Resources Partnership. 2022. The Russian River Coho Water Resources Partnership: Dedicated to improving water reliability for fish and people.

Vander Vorste, Ross, Obedzinski, Mariska, Pierce, Sarah Nossaman, Carlson, Stephanie M., Grantham, Theodore E. 2019. Refuges and ecological traps: Extreme drought threatens persistence of an endangered fish in intermittent streams. Global Change Biology, 2020:26, 3834-3845.

Williams, Alton P., Cook, Edward R., Smerdon, Jason E., Cook, Benjamin I., Abatzoglou, John T., Bolles, Kasey, Baek, Seung H., Badger, Andrew M., Livneh, Ben. 2020. Large contribution from anthropogenic warming to an emerging North American megadrought. Science, 368:6488, 314-318.