2024 Klamath Dam Removal Science Collaboration Workshop

Summary Report

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Institute for Applied Sustainability, Southern Oregon University, and Resource Environmental Solutions

November 7-8, 2024

Southern Oregon University, Ashland, Oregon

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Cover photo: Slopes of the former Iron Gate reservoir bloom with thousands of seeded poppies following dam removal (photo: Chhaya Werner)

Executive Summary

The Klamath River is one of the largest salmon-producing rivers on the west coast of the United States, and the river's rich resources and surrounding watershed have sustained Indigenous people since time immemorial. The health of the Klamath Basin ecosystem is intertwined with the culture, well-being, and identity of Indigenous people who live in relation with the river and its tributaries, including members and descendants of the Yurok Tribe, Karuk Tribe, Hoopa Valley Tribe, Quartz Valley Indian Reservation, Pulikla Tribe of Yurok People, Klamath Tribes, Shasta Indian Nation, and Modoc Nation. Colonial anthropogenic impacts including agricultural development, water diversions, mining, timber harvest, road development, wetland reclamation, overfishing, and dam construction have degraded the river ecosystem and caused dramatic declines to native fish populations. The Indigenous peoples of the Klamath Basin have suffered greatly as the river's health and fisheries have declined. In an historic effort to restore ecosystem function and fisheries, four Klamath River hydroelectric dams have been removed, representing the largest dam removal in history.

While extensive biophysical data were collected from 2000-2023 documenting the "dams-in," impaired condition of the river, the future of environmental monitoring to document long-term ecosystem recovery is less certain. The unprecedented opportunity to study dam removal and river restoration at this large scale will inform future management of the Klamath Basin and river restoration broadly, making it an important case study. Effectively documenting ecosystem recovery will continue to require the collaboration of many entities involved in dam removal, and coordination is needed to integrate existing data collection efforts with new studies so that efficient study designs are implemented to assess short- and long-term effects of dam removal.

The Klamath River Renewal Corporation's (KRRC – the entity created to carry out dam removal and restoration) mission includes monitoring activities associated with the project to comply with federal, state, and local permit conditions. However, these activities are limited and designed as independent survey efforts to address specific regulatory requirements and obligations rather than to address larger-scale and more complex ecological questions. Further, monitoring requirements associated with dam removal are primarily focused within the vicinity of the hydroelectric reach or on Endangered Species Act-listed species rather than addressing watershed-scale and whole-ecosystem changes.

Support and coordination for a more general understanding of how river geomorphology, ecology, and fisheries will respond following approximately 100 years of impoundment does not exist on a broad scale. Tribal governments, federal, state, and regional government agencies, non-profits, and academic institutions are now attempting to address the significant gaps in knowledge about river response following large-scale dam removal on the Klamath River with limited resources. While there have been numerous dam removals nationally along with significant synthesis of available information, each removal is different. The Klamath Basin possesses history and characteristics that make it unique, even among several high-profile removals in the Pacific Northwest. In many cases, our understanding of the ecological effects of dam removal on the Klamath will be enhanced by current monitoring and planned future data

collection, where researchers can leverage these existing data sources to address questions related to large-scale dam removal.

Despite the unique opportunity to learn about river recovery following dam removal, formal coordination of dam removal research and monitoring is limited by several factors. The Klamath River basin, along with the dams that were removed, straddles two states, a prominent mountain range, and the jurisdiction and interest of numerous state, federal, and tribal natural resource and land management agencies. In 2020 and 2023, workshops were held to prioritize research, coordinate data collection, and foster collaboration to address pressing ecological questions around Klamath dam removal (Genzoli et al. 2021, Keel et al. 2023). This third workshop in November 2024, held during the ongoing removal of Klamath dams in 2023-2024, was intended for researchers to compare early results of drawdown and decommissioning, further coordinate to extend coverage of monitoring and research, generate a list of priorities for dam removal research, and address complex interdisciplinary questions.

This document is divided into five sections. The Introduction details the history of Klamath dam removal and the particular importance of the project to Tribal communities, as well as predictions for short- and long-term impacts. The second section summarizes reflections by two keynote speakers, Leaf Hillman and Amy Bowers Cordalis, both long-time advocates in the tribal movement for dam removal, and an update from Ren Brownell, the KRRC Public Information Officer. This is followed by a summary of a panel focusing on tribal sovereignty in research collaboration, featuring tribal researchers and community members Ron Reed, Barry McCovey, Jr., and Stephanie Quinn-Davidson. The fourth section summarizes seven intra-disciplinary sessions that described current observations, revisited the research agenda of previous workshops, and set out new directions. These sessions were focused on water quality, hydrogeology and geomorphology, fish populations and movement, fish health, aquatic food webs, terrestrial systems, and socio-ecological responses. The final section summarizes six interdisciplinary sessions centered on topics submitted by participants, charting new priorities and possibilities: water quality and fish health, downstream sediment effects, hatchery and flow management, fire interactions, connecting across space, and eco-cultural and social framings.

This workshop included the participation of approximately 150 individuals from over 30 organizations, many of whom are actively conducting research in the Klamath Basin. These proceedings will be useful for anyone seeking information on the background of Klamath dam removal, tribal leadership in dam removal science, research collaborations with tribal communities, initial observations of drawdown and decommissioning, updates to previously documented research agendas, priorities for dam removal research, research needs met and unmet in the Klamath, and current efforts toward collaboration on Klamath dam removal science.

River restoration is often carried out with limited effectiveness monitoring. The Klamath dam removals offer a unique opportunity to conduct thorough, well-coordinated monitoring and research to gain a mechanistic understanding of ecosystem recovery following dam removal. Insights gained from this monumental restoration action will help inform future management and restoration goals on the Klamath River and rivers around the world.

Acknowledgments

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Review of Proceedings: all invited speakers, planning committee members, moderators, and notetakers

This event was held in Ashland, Oregon, in the ancestral homelands of Shasta, Takelma, and Latgawa people. We quote from the Southern Oregon University land acknowledgement:

> "We want to take this moment to acknowledge that Southern Oregon University is located within the ancestral homelands of the Shasta, Takelma, and Latgawa peoples who lived here since time immemorial. These Tribes were displaced during rapid Euro-American colonization, the Gold Rush, and armed conflict between 1851 and 1856. In the 1850s, discovery of gold and settlement brought thousands of Euro-Americans to their lands, leading to warfare, epidemics, starvation, and villages being burned. In 1853 the first of several treaties were signed, confederating these Tribes and others together – who would then be referred to as the Rogue River Tribe. These treaties ceded most of their homelands to the United States, and in return they were guaranteed a permanent homeland reserved for them. At the end of the Rogue River Wars in 1856, these Tribes and many other Tribes from western Oregon were removed to the Siletz Reservation and the Grand Ronde Reservation. Today, the Confederated Tribes of Grand Ronde Community of Oregon and the Confederated Tribes of Siletz Indians are living descendants of the Takelma, Shasta, and Latgawa peoples of this area. We encourage YOU to learn about the land you reside on, and to join us in advocating for the inherent sovereignty of Indigenous people."

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1. Introduction

1.1 Meeting Purpose and Overview

On November 7-8, 2024, approximately 150 professionals from over 30 tribal governments, federal, state, and regional agencies, universities, and other organizations convened at Southern Oregon University in Ashland, Oregon, to discuss research and monitoring of the Klamath dam removals. The removal of four dams from the Klamath River is the world's largest dam removal and native fish restoration project, reconnecting salmonids and other native fishes to over 420 miles of historic anadromous fisheries habitat above the dams (Hamilton et al. 2005, Huntington 2006). In addition, the former hydroelectric reach is being restored to lotic habitat, including reaches formerly submerged beneath reservoirs and others that were dewatered or managed for daily hydro-peaking.

In response to limited formal coordination of research and monitoring related to dam removal, the Karuk and Yurok Tribes initiated the first of what was to become a series of Klamath Dam Removal Science Coordination Workshops in 2020 in Medford, Oregon. Responding to "an urgent need to identify and prioritize research questions, plan data collection that will address these pressing questions, and begin collecting data in an efficient and well-coordinated manner," the participants set out an agenda for dam removal research and monitoring, and initiated collaboration and heard lessons learned by invited speakers working on the Elwha River dam removal (Genzoli et al. 2021, p. 1). In 2023, a second workshop was held at Cal Poly Humboldt to advance collaborative efforts in the year leading up to reservoir drawdown. Noting that "support and coordination for more general understanding of how river geomorphology, ecology, and fisheries will respond following approximately 100 years of impoundment does not exist on a broad scale," Tribes, agencies, university researchers, and others refined a research agenda for dam removal (Keel et al. 2023, p. iii).

As is reported in these proceedings, entities including Tribes, state and federal agencies, academic researchers, and Resource Environmental Solutions (RES, a consultant retained by KRRC), have been collaborating on both compliance monitoring and research associated with dam removal. Many scientists have been collecting data spanning 2023, the year before drawdown, and 2024, the year of drawdown. However, many research needs remain unaddressed and the future of long-term research and monitoring on the Klamath River is uncertain. Further, some of the entities working on dam removal remain working in parallel, yet unconnected.

Klamath dam removal presents an unprecedented opportunity to learn about dam removal, disturbance ecology, restoration outcomes, and the Klamath Basin itself. However, the relatively small scale of research and monitoring resources is challenged to match the large scale of this monumental restoration project. This third workshop, held at Southern Oregon University in Ashland, Oregon, focused on building communication between existing efforts, identifying and addressing remaining gaps in research and monitoring, and building larger interdisciplinary

understandings of dam removal and river restoration. This conference advanced a dam removal research agenda by exchanging observations about the early stages of the project and proposing or highlighting research and monitoring gaps.

This document provides background on the Klamath River dam removal, summarizes presentations by tribal speakers including two keynote speakers and a panel on tribal sovereignty in research collaboration, and details current research and research needs presented in breakout sessions. This document serves as a resource to researchers interested in studying dam removal in the Klamath Basin and will be especially helpful to those who lack knowledge of the cultural, political, and historical context of Klamath River management, restoration, and monitoring. For those already involved in monitoring and research in the basin, this document provides opportunities to learn about and to connect with others with similar research interests or projects and to collaborate beyond the scope of current activities. Proceedings of the two previous workshops provide additional background (Genzoli et al. 2021, Keel et al. 2023).

1.2 Klamath Dam Removal Background

1.2.1 Tribal Connection to the Klamath River and Dam Removal

The Indigenous peoples of the Klamath Basin have lived in relationship with the Klamath River since time immemorial. Throughout history and continuing today, Indigenous people including members and descendants of the Yurok Tribe, Karuk Tribe, Hoopa Valley Tribe, Quartz Valley Indian Reservation, Pulikla Tribe of Yurok People, Klamath Tribes, Shasta Indian Nation, and Modoc Nation have depended upon the River and its tributaries for sustenance, culture, commerce, and religion. In turn, the abundant environment known today is the result of dedicated and sophisticated natural resource management by tribes over millennia (e.g., Anderson 2005, Knight et al. 2022). The Klamath River is still integral to Indigenous ways of life and the Klamath Basin ecosystem is intertwined with the well-being and identity of Indigenous people (e.g., Diver et al. 2024a). The decline of tribal fishery resources is the result of numerous legacy land and water management practices that were implemented with little regard for the health of fisheries and other cultural resources, and without consultation with the tribes of the Basin. These land and water management practices include, but are not limited to, gold mining, timber harvest, road construction, crop and livestock agriculture, water diversions, draining of wetlands, and construction of hydroelectric dams (see Diver et al. 2010, Reed 2023). The Indigenous people of the Klamath Basin have suffered greatly due to the mismanagement of the river and have borne the brunt of the negative ramifications from the destruction of the ecosystems they continue to rely upon.

Based on a traditional management perspective, tribes were the first to advocate for dam removal, and dam removal has continually been a primary objective for many tribal communities in the basin. In the early 2000s, tribes took a strategic scientific approach by acquiring and reviewing existing technical information and determined that dam removal was feasible and would have significant benefits for the Klamath River ecosystem. As more information was

synthesized, including a large amount of scientific evidence acquired by tribal monitoring and research efforts, the long-term impacts of the dams and the benefits of removal became more apparent. This work helped link dam removal to long-term survival of Klamath River anadromous fish runs in the face of climate change. Some important tasks undertaken by the tribes include: the scoping and development of NEPA documents required for the United States to determine if dam removal was in the public interest; participation in key water quality studies related to dam removal; assessing the amount and quality of fish habitat above the dams; evaluating the feasibility of fish passage options to show decommissioning as the more cost effective option; collecting and analyzing data related to fish diseases (*Ceratonova shasta*-enteronecrosis in particular) along with federal partners and universities to develop a better understanding of the link between the dams and fish disease in the Klamath; partnering with USGS and the Army Corps of Engineers to develop detailed above and below-surface topography of the Klamath River using a combination of LiDAR and side-scan sonar techniques; developing and evaluating aquatic resource mitigation measures, drawdown plans, and restoration plans; and having representatives on the Board of Directors of the Klamath River Renewal Corporation (KRRC), the entity responsible for removal of the dams. This tribal history is central to the story of Klamath dam removal, which must be told with this perspective. Moreover, primary elements of our scientific understanding of dam removal are based on tribal contributions of quantitative science woven together with existing Indigenous knowledge. In considering the current state of research on Klamath dam removal, we recognize the tribes as key leaders in the advocacy and research that has brought us to this point today and as ongoing stewards of the land.

1.2.2 Klamath River Geography, Hydrology, and Geology

The Klamath River Watershed covers over 12,000 square miles in southern Oregon and northern California, including Cascade Mountains, high desert, and coastal forests (Figure 1). The Upper Klamath Basin, lying between the Cascade Range and the Basin and Range Province, has relatively high elevation and typically receives substantial snow in winter, resulting in a snowmelt-driven hydrograph in the upper half of the watershed. The Upper Basin is relatively dry with little precipitation for the remainder of the year. As a result of the Cascades' volcanic geology, groundwater is also a major contributor to stream flows here, including several large spring complexes and wetlands with steady flows (Gannett et al. 2007). Many of the Upper Basin streams are groundwater-fed and historically provided critical habitat and cold-water refugia for salmonids (O'Keefe et al. 2022). These surface and groundwater flows enter the large, shallow, Upper Klamath Lake, which is the source of the Klamath River. The U.S. Bureau of Reclamation built dams on the Klamath River at the outflow of Upper Klamath Lake (Link River Dam) and 21 miles downstream near Keno, Oregon (Keno Dam), to store and divert water as part of the Klamath Irrigation Project. These two dams, which have fish ladders, and associated diversions were not part of the dam removals and will remain in operation. Water management in the basin is largely controlled by Link River and Keno dams, where water is stored in Upper Klamath Lake during snowmelt and then released to irrigated lands and the Klamath River in the summer and fall. Unlike most dams, Link River Dam was not built to store more water, but instead it was built as a control outlet for Upper Klamath Lake. Lake water

levels are regularly lowered below natural levels to support irrigated agriculture in the Upper Klamath Basin, with resulting impacts on water quality (Kann and Walker 2020).

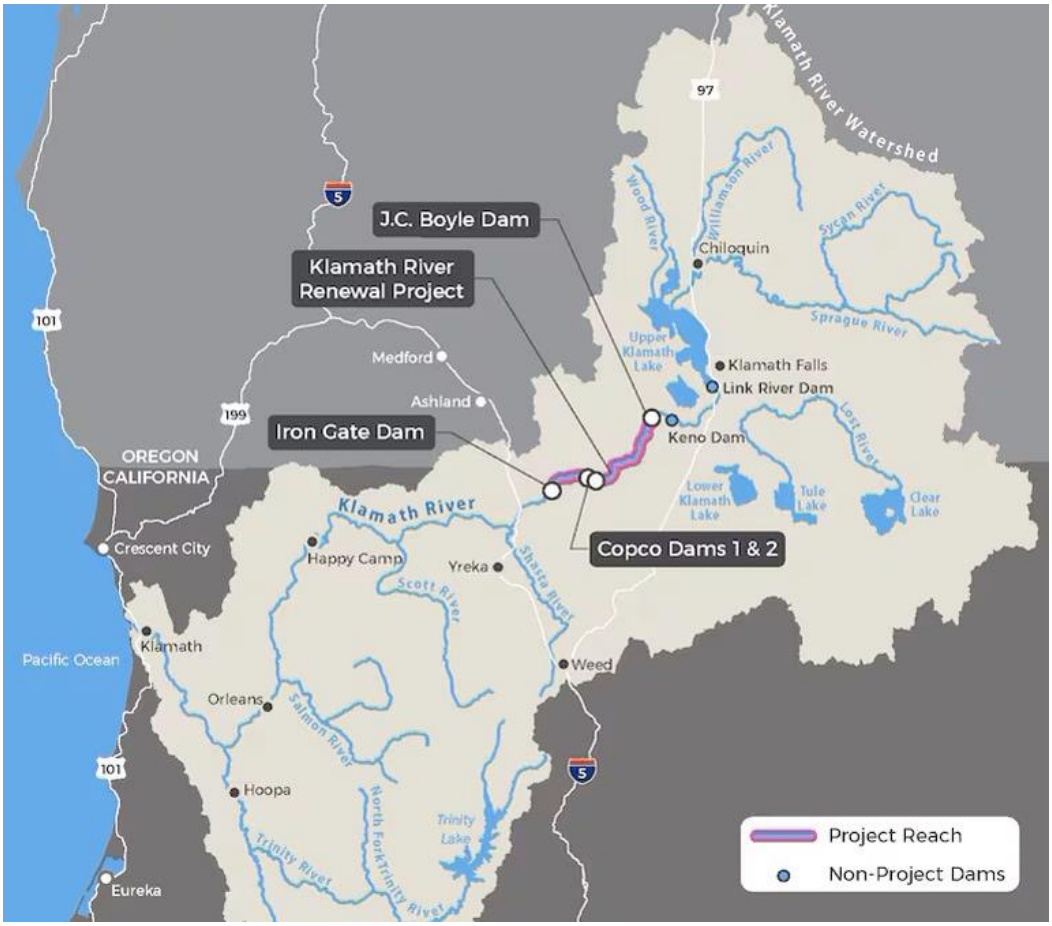

Figure 1 Map showing the hydroelectric reach and the four former Klamath River dams in that reach and the two upstream remaining dams (KRRC)

Downstream of Keno Dam, the Klamath River steepens as it cuts through the Cascade Mountains and the associated volcanic bedrock. The four former dams–J.C. Boyle, Copco 1, Copco 2, and Iron Gate–sat in this geologic transition region between the relatively low-gradient and groundwater-dominated upper basin and the higher gradient, rainfall runoff-dominated lower basin. In the approximately 30 miles between Keno and the former Iron Gate dam (referred to as the “hydroelectric reach”), several tributaries enter that are important sources of water, sediment, and habitat for anadromous fish. Among these are Spencer, Shovel, and Jenny Creeks, which have runoff-dominated hydrology, and Fall Creek, which has a large groundwater source and correspondingly steady flows and cool temperatures (O’Keefe et al. 2022).

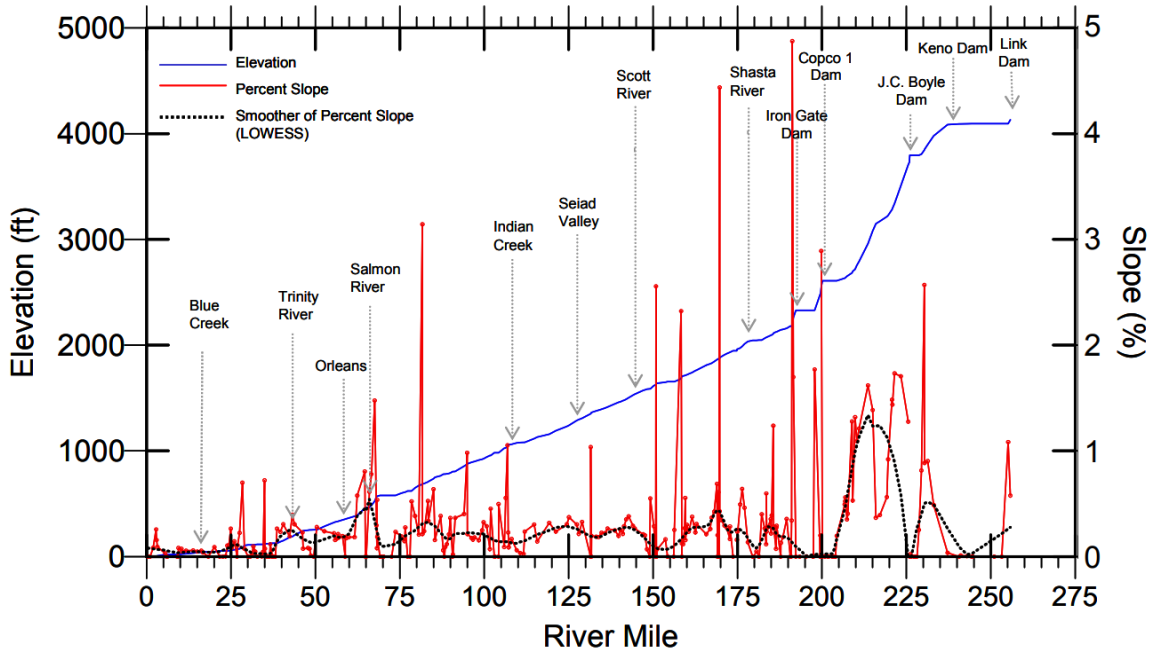

Figure 2 Elevational and riverbed slope profile of the Klamath River. Grey arrows show where tributaries enter. (Asarian et al. 2010, p. 42)

Downstream of the former Iron Gate Dam, the river enters the Klamath Mountains, where it is laterally constrained by confined valley walls and flows freely for 190 miles to its terminus with the Pacific Ocean. Major tributaries, including the Shasta River, Scott River, Indian Creek, Salmon River, Trinity River, and Blue Creek, among numerous smaller tributaries, contribute flows to the Klamath. In the winter, the flows from these tributaries are substantial (up to >10 times the contribution from the upper basin as measured at the former Iron Gate Dam). In the summer, tributary inflow is low due to a lack of precipitation and diversions for agricultural uses. As a result, the river's flow during summer is largely derived from above the former Iron Gate Dam, although the Trinity River (also regulated by large upstream dams) is a major source of water in the final 40 miles of the Klamath River (Asarian and Kann 2013).

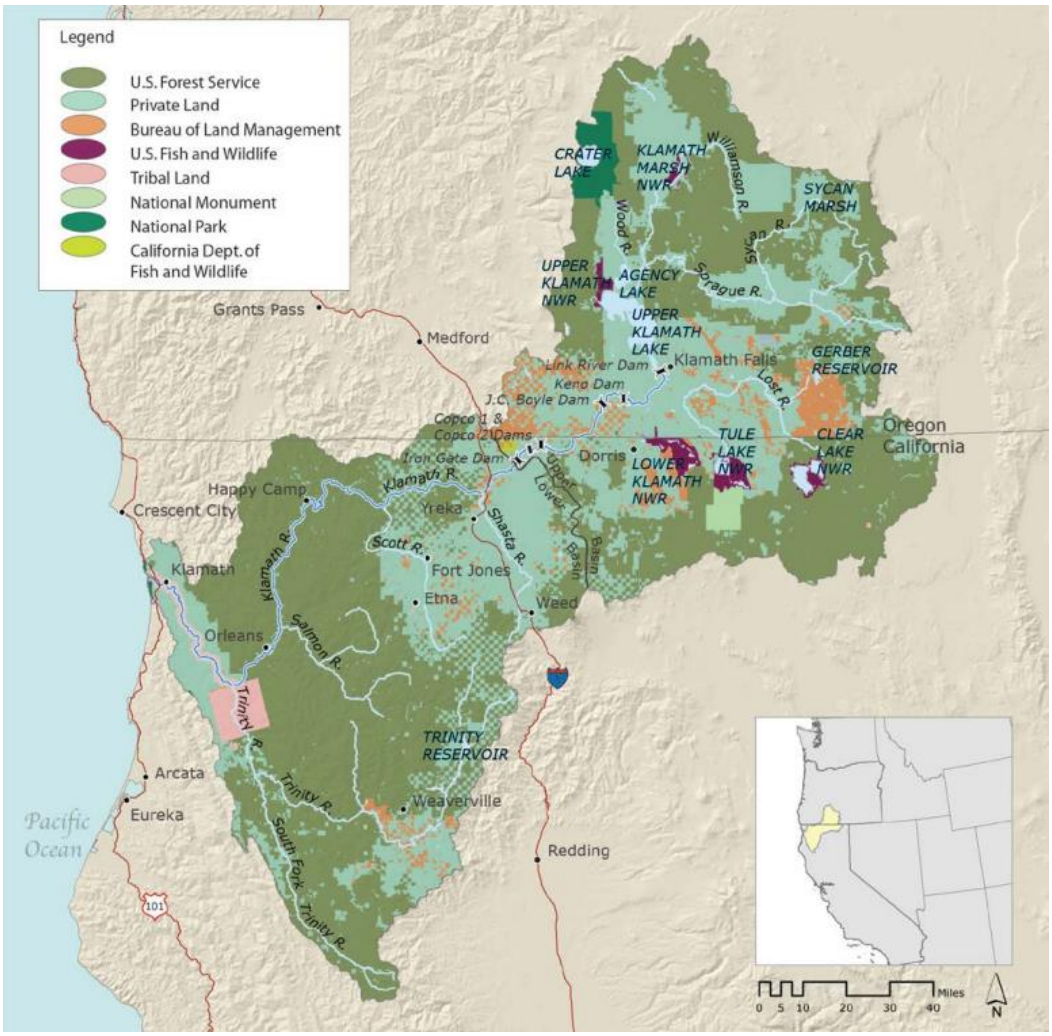

Figure 3 Klamath Basin land ownership (Stillwater Sciences et al. 2012, p. 12)

The Klamath River estuary is relatively small with a short hydraulic residence time, but with a large depositional and forested area with backwater habitats and side channels providing important low-velocity rearing habitat for fish (Patterson and Beesley 2011). The Klamath River Estuary is a lagoon-type estuary, bounded on the west by a large sand spit. The mouth of the river remains open except during periods of low river flow, and its confluence with the Pacific Ocean migrates periodically. The location of the riverine breach in the spit, through which most of the tidal exchange occurs, determines velocity and sediment dynamics in the estuary (Lowe et al. 2018).

1.2.3 Motivating Factors for Dam Removal

Poor water quality and declines in fish populations can be attributed to multiple stressors in the Klamath Basin. The construction and operation of hydroelectric dams, loss of wetlands, water diversion and nutrient enrichment associated with agriculture, mining, road building, and timber harvest have contributed to the decline in fisheries, resulting in severe hardships for tribal communities and the commercial and sport fishing industries. In addition to prominent concerns

about salmonids, many other riverine cultural resources relied upon by Indigenous peoples have also been negatively affected including lamprey eel, sturgeon, sandbar willow, regalia species, medicinal species, large game, and ceremonial sites (Diver et al. 2024b, Petersen 2006, Salter 2003, Sloan 2011). Salmonid runs that once made the Klamath River one of the iconic West Coast salmon rivers have been decimated by colonial anthropogenic activity over the past 150 years. For example, while annual Chinook returns to the Upper Basin were once estimated at 149,700-438,000, contemporary years averaged only 28,793 in the fall run and 651 in the spring run, an 80-95% decrease (CDFW 2023, PFMC 2021). In the Karuk Tribe, annual salmon consumption was once estimated at 450 lbs/person/year but has since fallen to less than 5 lbs/person/year (Norgaard 2005). Yurok fisherpeople report historically catching hundreds to thousands of lamprey per day, but less than 20 contemporarily (Larson and Belchik 1998, Petersen 2006). Commercial ocean harvests of fall run Chinook salmon fell 88% between the 1980s and 2000s (PFMC 2008).

In 2002, Tribal members and residents were devastated to see thousands of adult salmon dead along the banks of the lower Klamath River. Politically reactionary upstream water diversions for agriculture that year had culminated in poor water quality and a fish disease outbreak that resulted in an estimated 34,000-78,000 adult salmon and steelhead dying without spawning (Belchik et al. 2004, CDFG 2004). Barry McCovey, Jr. (Yurok Tribal Fisheries Department) recalled the scene: “The carnage I’ve seen over the past week and a half is so utterly grotesque that I cannot sleep at night. I close my eyes and the images of dead, rotting fish envelop me. You may have seen the photographs in newspapers or caught a glimpse on the television, but you cannot begin to imagine the smell. The smell of death and decay is impossible to escape” (McCovey 2002). The 2002 fish kill spurred tribal communities to action, expressed through the coincident dam license renewal process. Tribal representatives in the dam removal process remember early days as a struggle to be heard or recognized. One key turning point was Kari Norgaard (University of Oregon) and Ron Reed’s (Karuk Tribe) report *The Effects of Altered Diet on the Health of the Karuk People*, which traced the chain of causation between dam construction, spawning habitat loss, declining salmon runs, and increasing incidence of diet-related disease in tribal communities (Norgaard 2005). Tribal science departments conducted cutting-edge research guided by traditional ecological knowledge demonstrating the impacts of the dams.[1] The tribal campaign for dam removal lasted over two decades, and included demonstrations at shareholder meetings in Nebraska and Scotland, the annual 350 mile Salmon Run organized by youth, and unquantifiable effort from innumerable Tribal members and allies (Bring the Salmon Home n.d., Werk 2023).

Flow regimes and water quality in the Klamath River were heavily altered due to the operation of the hydroelectric dams and reservoirs, as well as diversions and discharges associated with irrigated agriculture. The continuation of large alterations in the headwaters of the Klamath River distinguish the Klamath from other large dam removals where the headwaters above other

[1] Just a few examples of this research referenced in this report are Asarian and Kann 2013, Asarian et al. 2009, 2010, Bartholomew et al. 2023, Belchik et al. 2004, Genzoli and Hall 2016, Genzoli and Kann 2017, Gillett et al. 2016, Kann and Corum 2009, Kann and Walker 2020, Kann et al. 2010, Larson and Belchik 1998, Norgaard 2005, Petersen 2006, Salter 2003, and Sloan 2011.

dams have been in a more pristine and free-flowing state, and where the affected downstream reaches have been relatively short. Due to combined impacts of continued flow alteration and nutrient enrichment from above the dams, the impacts of the dams on the Klamath River ecosystem are different from those in less-altered watersheds (Oliver et al. 2014). The benefits of dam removal go beyond opening up additional habitat for fish; they also address water quality problems and an interrupted sediment supply downstream of the dams, which are both linked to multiple stressors for fish, river ecosystem health, and human health. Many lessons from prior dam removals are transferable to the removal of the four Klamath Hydroelectric Project (KHP) dams, but differences among previous dam removals and the removal of the KHP dams are also anticipated (e.g., McCaffery et al. 2024).

1.2.4 Impacts of Dams on Water Quality and Native Fish

The effect of the KHP dams on water quality and fisheries share some commonalities with other dammed rivers, while also displaying unique impacts associated with additional stressors. Most of the recent large dam removals in the West have been at least partially motivated by concern for salmonids, where dams have blocked salmon passage and intercepted sediment, causing decreased spawning habitat downstream of the dams. Similarly, Iron Gate Dam formerly blocked fish passage, preventing salmon access to over 90% of spawning and rearing habitat for some species (Hamilton et al. 2005, Huntington 2006). Furthermore, disruption of sediment transport processes and reduced magnitude and duration of peak flows have adversely affected mainstem spawning and rearing habitats in the Klamath below the dams.

The combined effect of warm water, high organic loads, stable flows, lack of upstream sediment inputs that resulted in reduced scouring, less bed mobility, and fish crowding near Iron Gate Dam resulted in conditions enhancing the benthic annelid, *Manayunkia occidentalis*, and its myxozoan parasite, *Ceratonova shasta*, which infects juvenile salmonids and in previous years decimated native salmonid populations (Fujiwara et al. 2011, Stocking and Bartholomew 2007). Beginning in water year 2017, pulse flows were released from Upper Klamath Lake to reduce the impacts of fish disease by scouring surface sediments of the riverbed and reducing infections in juvenile fish (Bartholomew et al. 2023).

The KHP dams negatively affected water quality within the reservoir reach and in the river below the dams, extending to the Klamath River estuary nearly 190 miles below. The primary water quality concern has been the extensive proliferations of toxin-producing cyanobacteria in the reservoirs that were transported downstream throughout the Klamath River. Levels of the cyanotoxin microcystin continuously exceeded public health thresholds in the reservoirs and rivers annually in late summer, when visitors and residents rely on the river for recreation, ceremonial use, and subsistence fishing, among other beneficial uses (Genzoli and Kann 2017). Toxins posed a threat to recreation and bioaccumulated in traditional foods (Backer et al. 2010, Kann et al. 2010). These blooms were associated with high levels of nutrients entering the stagnant water of Copco 1 and Iron Gate reservoirs where plankton were able to proliferate, which would not be possible in the naturally high-gradient, high-velocity, flowing waters of the Klamath River below Keno.

Other water quality concerns associated with the KHP dams included seasonally increased or decreased downstream water temperatures, where water was cooler for longer during the spring months, thereby reducing fish growth and delaying emigration to the ocean; and water was warmer for longer in the fall, thereby compromising conditions for adult fish migration (Bartholow 2005, NAS 2004). Both of these temperature-related phenomena were due to thermal inertia within the reservoirs.

Alterations to sediment regimes and scour likely increased downstream eutrophication, nuisance growth of benthic algae, high rates of primary productivity, and concomitant impairments of dissolved oxygen and pH (Asarian and Kann 2013, Genzoli and Hall 2016, Gillett et al. 2016). As a result of these water quality issues, the Klamath River has been under a set of Total Maximum Daily Load (TMDL) allocations since 2009, with separate individual TMDLs for different riverine and reservoir segments (NCRWQCB 2010, ODEQ 2019a, 2019b).

1.3 Expectations for Klamath Dam Removal

While some short term impacts to water quality were anticipated with dam removal, the long term improvements to fisheries health and water quality are expected to greatly outweigh these potential short term impairments. During environmental review some concerns were voiced around flooding, reduced water for people and agriculture, release of toxins, and river drying, but these impacts were not predicted to occur, nor have they been observed in the first year following dam removal. The only purpose of the dams was minimal hydropower production, with capacities of 98 megawatts (MW), 20 MW, 27 MW, and 18 MW for J.C. Boyle, Copco 1, Copco 2, and Iron Gate dams, respectively (KRRC n.d.). If operating at full capacity, they could power about 70,000 homes, although actual production levels were lower (Associated Press 2022). These dams were not used for water storage or flood protection, and were expected to attenuate a 100-year flood by just 7% for only 10 hours (Reclamation 2011). Rather than reducing water availability, dam removal actually returns approximately 6,200 acre feet to the river due to reduced evaporation (Reclamation 2011).

Concerns about toxicity of reservoir sediments was extensively explored through sediment cores and risk to native aquatic or human life was judged to be minimal. While reservoir fish were unsafe to consume due to toxin bioaccumulation in reservoir waters, exporting the sediment relatively quickly prevented risk elsewhere (CDM 2011). Upper Klamath Lake will ultimately still be dam-controlled through Link and Keno dams and operated in accordance with the Biological Opinions for endangered fishes, meaning downstream flows will likely be consistent with past flow conditions.

1.3.1 Short Term Impacts

Dam removal consisted of initial deconstruction of Copco 2 in 2023, followed by the commencement of drawdown in January 2024, and deconstruction of Copco 2, J.C. Boyle, and Iron Gate dams throughout the spring, summer, and autumn of 2024. The primary water quality

management challenge of dam removal was the accumulation of 4.2 million tons (dry weight) of sediment in the reservoirs. Flushing flows during dam removal were expected to remove 36-57% of this weight during drawdown, and then return to the background sediment regime. Unlike other dams, reservoir sediments were primarily composed of fine sediment, being 84% silt and clay. This is largely due to the accumulation of decaying algal matter (USDOI and CDFG 2012).

Hydrology, sediment, and dissolved oxygen dynamics were modeled for the Secretarial Determination on dam removal (FERC 2022, Reclamation 2011, Stillwater Sciences 2008). These predictions include suspended sediment concentrations as high as 20,000 mg/L, resulting in many days of impaired dissolved oxygen concentrations (below 5 mg/L). However, drawdown was timed to minimize impacts to the ecosystem, with high success. Not only did higher flows dilute reservoir sediment, but the timing also avoided salmonid migration and human recreation. Preliminary data suggests that actual water quality impairments were far less severe than predicted (Oberholzer Dent 2025).[2]

In the short-term, rapid change has also taken place within the reservoir reach where new lotic and terrestrial ecosystems are being formed from the receding waters. Water quality conditions, flow regime, substrate changes, and sediment transport have allowed for the reclamation of important habitat in the mainstem and access to critical tributaries (O'Keefe et al. 2022). At the same time, an immense restoration operation led by the Yurok Tribe and RES has taken place in the reservoir footprint, distributing to date 100,252 pounds of seeds; 134,788 bareroot, plug, and container plantings; and 25,585 acorns (around 14 billion seeds total; D. Keel, pers. comm. 19 August 2025).

As these processes, including water quality impairment and restoration of the hydroelectric reach, were ongoing in 2024, one of the main purposes of this meeting was to accumulate knowledge of the immediate response of the river to dam removal, in addition to discussing future monitoring. The fruits of previous coordination efforts were clear in the diverse monitoring and research reported in Section 4.

1.3.2 Long Term Impacts

Dam removal is anticipated to bring a wide variety of benefits to the Klamath River ecosystem, including the humans who live in relation with the river. In this workshop, we considered future impacts centered around the domains of water quality, hydrogeology and geomorphology, fish populations and health, aquatic food webs, terrestrial systems, and socio-ecological systems.

Areas above the former Iron Gate dam contain approximately 310 miles, 78 miles, and 435 miles of habitat for Chinook, Coho, and steelhead, respectively (Hamilton et al. 2011). In addition, other species including lamprey and redband trout now similarly have access to

[2] Water Quality is publicly available from KRRC at https://www.waterboards.ca.gov/waterrights/water_issues/programs/water_quality_cert/lower_klamath_ferc14803.html and from the Karuk Tribe at https://waterquality.karuk.us/. We also refer to unpublished data from the Karuk and Yurok Tribes.

historic habitat. Restoring connectivity of the river will bring access to historic spawning and rearing habitat, and anadromous fish will also benefit from reduced crowding, additional thermal refugia, and access to more diverse thermal regimes (Hamilton et al. 2011). These conditions are expected to increase genetic diversity and reduce dependence on hatchery production, which has had a number of negative effects in the long-term including widespread disease (Naish et al. 2007, Robinson et al. 2020).

Dam removal is expected to improve water quality and fish health through multiple mechanisms. Shifting the thermograph of the river back to its natural pattern will reduce salmonid exposure to stressful conditions in both spring and fall (Bartholow 2005, NAS 2004). Before dam removal, 89% of days in July and 100% of days in August exceeded the 20 °C tolerance of migrating salmonids (Asarian and Kann 2013). In the future, dam removal is projected to decrease late summer water temperatures by 2-10 °C (Perry et al. 2011). This in turn will increase dissolved oxygen levels and support resilience to fish disease (Ray et al. 2012, Wood et al. 2006). Fish parasites including *Ceratonova shasta*, *Ichthyopthirius multifiliis,* and *Parvicapsula minibicornis* have historically had infection rates up to 99%, but are now expected to be controlled through the scouring of annelid hosts and decreasing fish crowding (Bartholomew and Foott 2010, Voss et al. 2022). More natural flow regimes and sediment transport are also expected to benefit fish health through multiple pathways (Bartholomew et al. 2023).

With the hydroelectric reach returned to lotic (flowing) habitat, this section of river is no longer producing dense blooms of planktonic harmful cyanobacteria, which exported cyanotoxins downriver at levels far above public health guidelines (Genzoli and Kann 2017, Kann and Corum 2009, Oberholzer Dent 2025). In addition, removing the reservoirs is intended to improve nutrient conditions during summer, a time when water quality has historically impaired fish migration and river health. These expected decreases in bioavailable nutrients could contribute to improvements in dissolved oxygen and pH by reducing primary productivity (Asarian and Kann 2013, Asarian et al. 2009, 2010). In the first months after dam removal, inhibition of algal growth (in large part by elevated turbidity) have already contributed to decreases in diel fluctuations in dissolved oxygen and pH, in addition to temperature improvements (Oberholzer Dent 2025).

Dams attenuate peak and low flows, which are a beneficial disturbance in lotic ecosystems,and the Klamath River is still dam-controlled upstream at Keno with water managed for agriculture. Differences in all levels of flow are expected to change less than 10% at Seiad Valley, 7% at Orleans, and 3% at Turwar (Reclamation 2011). However, the newly restored hydroelectric reach, as well as the reach between the former Iron Gate dam and the confluence of the Scott River, experienced little to no natural hydrologic variation under the dammed regime. These reaches will benefit from more dynamic flows owing to accretions from tributary flows in the reservoir reach (e.g., Jenny Creek, Spencer Creek, Shovel Creek). With these sources varying naturally, discharge is projected to rise below the former Iron Gate dam by 290-360 cfs in the highest floods, a 20-30% increase over the dams-in scenario with diminishing effects at lower flows (Reclamation 2011).

The significance of salmonid health and water quality extends beyond the river to the human communities that live with it. Tribal peoples who rely on salmon, lamprey, and other riverine cultural resources associate the ill health of the river with their community and personal health (Diver et al. in review, Salter 2003, Sloan 2011). After fighting for a better future, many believe that dam removal will bring prosperity to their communities. The possibilities that flow from a healthy river extend into riparian, upslope, and human ecologies. Figure 5 represents an accumulation of knowledge from cultural practitioners and tribal scientists linking dam removal to cultural resources significant to the Karuk Tribe (Diver et al. 2024a). Through participation in the ecosystem via intergenerational eco-cultural practices, Indigenous peoples of the Klamath Basin anticipate experiencing improvements in river health firsthand. This includes not only tribal people who live on the river but also thousands of tribal members in diaspora who continue to know the Klamath as their ancestral home (Diver et al. 2024b).

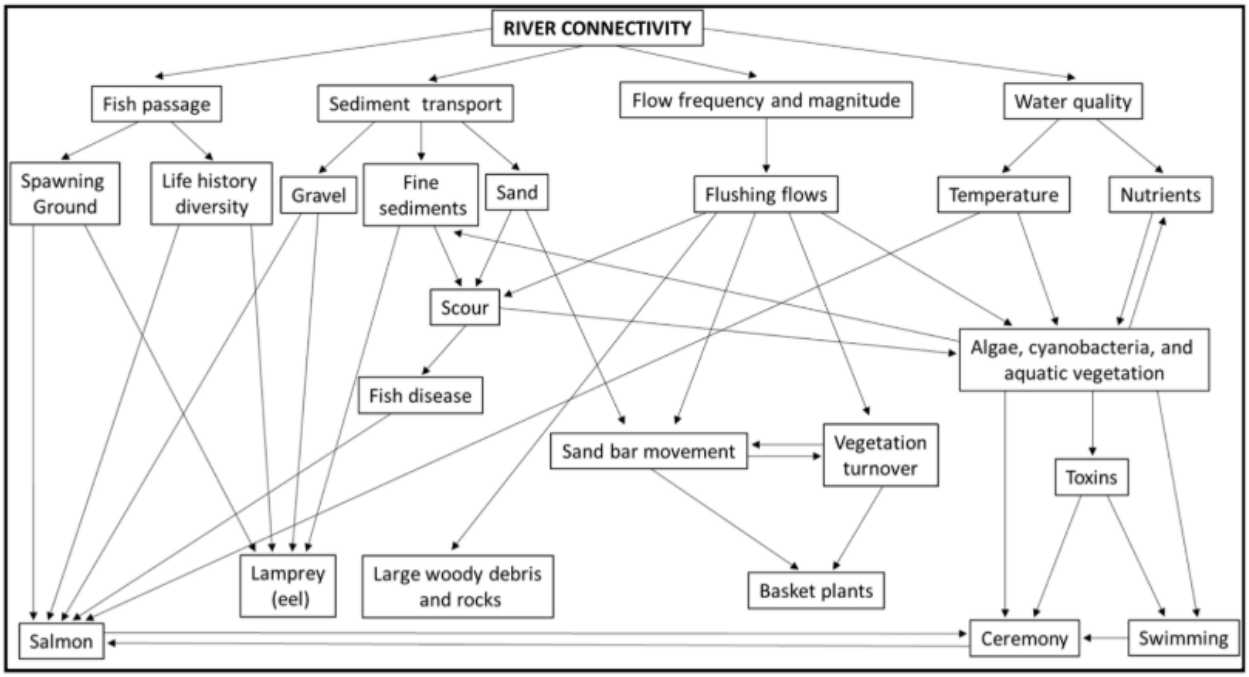

Figure 4 "Based on focus groups and interviews, this diagram shows a simplified model of selected biophysical factors associated with a free-flowing river that affect Karuk cultural resources (not comprehensive). While useful as a schematic we note that the unidirectional flow of benefits does not represent how Karuk cultural practices, such as coppicing, cultural burning, and ceremony, also shape the system." (Diver et al. 2024, p. 13)

Other interested parties that stand to benefit from Klamath dam removal include Pacific commercial fisheries, irrigators who will see increased water quantity from reduced evaporation, other residents and visitors who use the river for subsistence and sport fishing, outfitters in the recreation industry who will benefit from improved water quality, communities in Yreka and Siskiyou County that will have a functional river corridor available close to them, and the many non-Native people who benefit from Tribal services. Furthermore, improvements in the health of communities who depend on the river could lower the exorbitant social costs associated with, for example, diet-related disease (Norgaard 2005). A healthy Klamath River is capable of

supporting a healthy economy and healthy regional community, which could be a basis of connection and collaboration moving forward.

2. Keynote Speakers: Leaf Hillman, Amy Bowers Cordalis, and Ren Brownell

Leaf Hillman

Leaf Hillman is a Karuk cultural practitioner, ceremonial leader, former director of the Karuk Tribe Department of Natural Resources, and in his words, “a full-time Indian.” Mr. Hillman has been centrally involved in the movement for dam removal, describing it as a life’s passion rather than a job. He began by telling the Karuk origin story, of how the first world’s Spirit People became trees, rocks, animals, fish, insects, water, wind, fire, sun, moon, stars, and some, humans. This means that humans are related to all these things, and hold responsibility for mutual caretaking with them. Furthermore, the Spirit People enacted creation stories that were given to the people as divine instructions. Mr. Hillman described Coyote, a central figure in these stories, as a leader, but also a trickster; funny, yet mean; generous, yet stingy. In all these things, Coyote represents us humans, and the creation stories teach us how to function with each other as a society. They also explain how the world came to be and how to live with it. Reflecting on this context, Mr. Hillman explained that “anything that is good in this world came about through the collaborative actions of many.” He acknowledged that collaboration is hard, and requires not only listening to but *hearing* people with different worldviews, making new relationships, mending old ones, adapting, and practicing empathy.

Thinking back to the early days of the dam removal movement, Mr. Hillman expressed his comfort with Coyote, because he relates to Coyote’s contradictions. In those days, dam removal was not “sexy or cool.” When tribal people first began advocating, they were ostracized without allies, friends, or collaborators. He told the story of a conflict over tribal sovereignty, when federal agencies attempted to act on Karuk lands without authorization. This conflict led to early collaborations, and eventually to contracting Tribes to do the scientific work themselves. Tribes built scientific expertise and successfully developed “two-eyed seeing” methodological approaches that combine the strengths of Western science and traditional ecological knowledge. Under high scrutiny and legal pressure, Mr. Hillman explained that tribal science has to be “bulletproof” and pointed out that because of this tribal science departments have built top-tier programs with unassailable expertise. He recounted feeling like David facing Goliath, and having to “appear bigger than we actually were… But we built our movement and got the job done.” He attributes the tribes’ success to “relentless political will combined with unimpeachable science.”

Reflecting on earlier days of the movement, Mr. Hillman explained that “Those days and those people are now in us. We are the ones that have to do the hard work.” Dam removal brings a new set of issues to be addressed with tribal science; those processes need to be collaborative and acknowledge the people who are still here and always have been. With this in mind, he

concluded, “There’s no limit to what can be accomplished–so long as it doesn’t matter who gets credit.” Mr. Hillman closed by thanking scientists, and in particular tribal scientists.

Amy Bowers Cordalis

Amy Bowers Cordalis is a Yurok fisherwoman, attorney, former Yurok Tribe General Counsel, and Executive Director of Ridges to Riffles Indigenous Conservation Group. She is from a dance family from the village of Rek-Woi and grew up gill net fishing on the lower Klamath River. She began with a moment of appreciation for the work in the room and for the heartbreak that tribal elders shared about the condition of the river and the fight to reverse it. Reflecting on the immediate success of dam removal in facilitating salmonid migration above the dams, she said, “It doesn’t matter what is going on in politics. The fish will show us what to do, the river will tell us what to do, the water will tell us what to do. Because they know.” She celebrated that we are living in a moment of transformation and pointed out the responsibility of witnessing and participating in it: “You’re going to rise to the occasion. And you’re going to do the river justice.”

Ms. Bowers Cordalis emphasized the importance of holistic knowledge, not just technical training, and the leadership of tribal elders in caring for and cultivating relationships with the river. “Set down the PhD. Mother Nature is the real teacher,” she explained. Relationship to the river is what will empower researchers and practitioners. In building that relationship, she invited attendees to ask the river for permission, to observe, and to learn in a comprehensive way. She encouraged attendees to “Put it all aside and go to the river!” Ms. Bowers Cordalis also emphasized the interconnectedness of the natural world, and of the greater Klamath watershed: “Now that the dams are out, we can’t afford to treat the Basin as divided.” Reflecting on Indigenous leadership, she asserted the importance of continuing to support tribes’ leadership and pointed out how that leadership is what made Klamath dam removal happen.

Ms. Bowers Cordalis concluded by saying that our job is to show people how to live in balance and how to live better with the natural world and to uplift Indigenous communities: “We have a duty as a people who work on the Klamath to show the world that this is possible.” Ridges to Riffles then facilitated a game where attendees imagined being a salmon swimming upriver, dodging obstacles and nets, building and defending redds. We closed our eyes and imagined finally being precisely where we need to be, and having done everything we needed to do, fulfilling our tasks and providing for the next generation.

Ren Brownell

Ren Brownell is the Public Information Officer for the Klamath River Renewal Corporation and grew up on the Klamath River. She presented a summary of dam removal and restoration construction completed in recent months, from the drawdown of the dams in January-March 2024, through the demolition phase in March-September 2024, to the return of salmon in October 2024.

Ms. Brownell shared amazing photography and videography taken on the project, including featured images from Swiftwater Films, of pre- and post-dam removal comparisons (see photos

below). She discussed “the dark times” when decades of accumulated sediment was released from behind the dams into the Klamath, and the river looked muddy and black. “I couldn’t make eye contact with the river,” she said, reflecting on the emotional personal and professional impact of that time. Ms. Brownell described how her views on the sediment pulse changed on a reservoir visit with Mr. Hillman, when she asked him what he felt and he responded, “I feel cleansed.”

She concluded her presentation with an overview of the transition to clear-flowing water, aerial images of the unobstructed reservoir reaches, and pictures of Chinook salmon spawning in the Jenny Creek tributary above the previous Iron Gate location. Overall Ms. Brownell’s presentation highlighted the resilience of river, salmon, and people through the dam removal process and excitement for the transitions to come.

Figure 5 Clear water from Dillon Creek dilutes heavy sediment loads in the Klamath River during drawdown (photo: Swiftwater Films)

Figure 6 Deconstruction of Copco 1 dam in March 2024 (photo: Swiftwater Films)

Figure 7 Site of former Iron Gate dam during deconstruction (photo: Swiftwater Films)

Figure 8 Jenny Creek enters Iron Gate reservoir, filled with toxic algae, before dam removal (above). After dam removal at the same site, Jenny Creek finds a path through reservoir sediments toward its confluence with the Klamath River (below). (photo: Swiftwater Films)

3. Indigenous Sovereignty Panel: Ron Reed, Barry McCovey, Jr., and Stephanie Quinn-Davidson

A central goal of the workshop was centering tribal perspectives on research in the Klamath and furthering education about tribal sovereignty for non-tribal researchers. To this end we were honored to host a panel of tribal researchers, community members, and longtime dam removal advocates to discuss collaborative research with tribal communities. Ron Reed (Karuk Tribe) is a traditional dipnet fisherman, ceremonial leader, and co-founder of the Karuk Tribe-UC Berkeley Collaborative. Barry McCovey, Jr. (Yurok Tribe, Karuk descendant) is the Director of the Yurok Tribal Fisheries Department where he has worked for 25 years. Stephanie Quinn-Davidson (Brothertown Indian Nation) is a fisheries scientist who currently serves as Science and Policy Director for Ridges to Riffles Indigenous Conservation Group. The panel was moderated by Kenwani Kravitz (Pit River Nation, Wintu), SOU Native Nations Liaison.

What defines successful research partnerships?

- Mr. Reed offered that "what defines healthy partnership is reciprocity." Keeping in mind the many challenges faced by tribal communities, researchers need to be attentive that their collaborators actually benefit from the research process and outcomes. Communities need to be incorporated into the economic model of research, with tribal members and scientists paid to participate. "Voluntourism" should now be over.
- Ms. Quinn-Davidson shared the advice that "actionable science is a good starting point." Research must be relevant to tribal priorities and needs, concretely benefitting tribal members. Ensuring that research is relevant means taking time to build relationships with tribes, not just an email or a phone call. She explained, "Start relationships *before* you even have a research question in mind. How can you volunteer for the tribe?" Working with tribes often means different timelines and "fighting fires" along the way. "With sovereignty, there comes a different timeline from Western science."
- Mr. McCovey shared that researchers must focus on communication and collaboration *early on*, and go beyond "checking a box." Tribal partners must be involved in all of the steps of research, including report writing and publications. Collaborations often fail when researchers don't share funding and workload with tribal partners, even when tribes have the capacity to participate. He noted many successful partnerships present at the conference.

How can researchers or agencies respectfully initiate collaboration with tribes?

- Once again, Mr. McCovey emphasized the need for communication early and often. Tribal partners must be "included from A to Z." Working with tribes means allowing them to take leadership and including tribal perspectives including traditional ecological knowledge, but also extending to broader epistemology.
- Ms. Quinn-Davidson emphasized the importance of "coming with good intentions," and understanding how to account for and move on from mistakes. Acknowledging that living in a colonized system inevitably creates friction with tribal sovereignty, she said that "the

most important is to recognize and learn from it; come to the table with better intentions next time."

- Mr. Reed raised the importance of cultural integrity and not lumping tribes together. He described researchers approaching with "the wrong research questions for the wrong people." The solution, he explained, is to "do your research and know who you are talking to." Tribes alone are responsible for their "cultural integrity," and researchers must be supportive of their leadership.

What is the value of guiding documents such as memorandums of understanding (MOUs) or other frameworks for research collaboration?

- Mr. McCovey believed that MOUs are "one tool, but not the end all be all… they are only as good as the intentions of the people you're dealing with." Intentions and interpretations can change, so MOUs may have a limit to their usefulness.
- Mr. Reed has used MOUs for ceremonial grounds and cultural management areas, and noted how important those arrangements were for tribes that lack a land base.
- Ms. Quinn-Davidson advised researchers to leave it up to the tribe if they want an MOU. Not all projects need it, and MOUs may be viewed negatively due to power imbalances at play.

How have you practiced traditional frameworks for research collaboration?

- Mr. Reed spoke about the centrality of fire, "the oldest teacher." In his words, "Indigenous fire is Indigenous lifestyle… Fire on the landscape creates resources that provide life, and social conditions that make us healthy and well." Mr. Reed has been advocating for cultural fire for many years, and has partnered with researchers working on fire. He pointed out that research needs "tribal support, tribal leadership, to accomplish a spiritual sense of well-being" in the community.
- In turn, Mr. McCovey acknowledged how far discourse around fire has progressed thanks to Mr. Reed's work. He added, "These teachings from the beginning of time have a bearing on how we move forward in a successful way for ecosystem restoration. Pass it through the lens of balance and fixing the world.[3] That is our major framework that we've always followed." He said that monitoring, research, policy, and management can be tied to "a traditional framework of restoring balance."

What are appropriate ways of sharing research when data is collected by or reflects traditional worldviews (e.g., for agencies with publication mandates)?

- Mr. McCovey pointed to data sovereignty agreements that define who has access and what is released before the research begins. These agreements may need to go through tribal councils or cultural resources review and thus take time. He emphasized the importance of communication and collaboration early on, and the different data sensitivity needs of different tribal communities.

[3] This phrase is the direct translation of the Karuk name for the World Renewal Ceremony, *pikyávish*

- Mr. Reed pointed out that tribal governments are not the only arbiters of traditional knowledge, and the importance of engaging with ceremonial and family-based traditional knowledge. He emphasized the need for high standards in community based research to protect data sovereignty, and described “cross-pollinating” with researchers to ensure that both technical and traditional standards are adhered to.
- Ms. Quinn-Davidson stressed that different tribal communities have different values and cultural traditions, and that research must be designed to include tribal values and protocols. She noted that ceremonies are extremely important (i.e., appropriate behavior, accounting for time commitments).

How can collaborators respectfully learn from tribal researchers in a way that engages with traditional ecological knowledge without extracting and appropriating?

- Mr. Reed reminded researchers to develop “well thought out reciprocity measures” and to operate based on the interest of the health and well-being of the community.
- Mr. McCovey encouraged researchers to build trust and friendship, starting with “more of a conversation.”
- Ms. Quinn-Davidson highlighted the importance of having a tribal partner be co-principal investigator on a research project. In her words, “Academics need to step aside and let tribes lead the way… You are the supporting cast.”

What are best practices for when and how potential collaborators should reach out?

- Mr. McCovey answered, “Early and often.” He emphasized that tribes are busy and often pulled in many different directions. Emails may be passed over and need to be sent again.
- Ms. Quinn-Davidson advised that “If you have a project that’s a priority for the tribe, you’ll get a response… The best projects are the ones that are the ideas of tribes.” She suggested that collaborators attend tribal research presentations to better understand tribal needs.
- Mr. Reed spoke about researchers coming into community research, building their resumes, and never coming back. He said that instead collaborators need to hold trust and relational accountability with the community itself, and verify their leadership through established community pathways.

These moderated questions were followed by open audience questions.

What continues to give you hope in the day to day?

- Mr. Reed’s first answer was, “I have a beautiful family.” He spoke about working to fix the world with his family beside him, sharing the medicine; and the life-long process of replacing prejudice with love. He ended by thanking his wife, Robyn Reed.

How can tribal youth be involved?

- Mr. McCovey believed that it was deeply beneficial to include youth, and worthwhile to ask about when collaborating with tribes. Oftentimes, tribes have structures for engaging with youth that can be augmented or complemented.
- Ms. Quinn-Davidson highlighted the importance of including students in elementary and middle school, pointing out that formational experiences with learning and education take place during this time. She also encouraged researchers not to overlook tribal colleges.
- Mr. Reed spoke about exposing youth to higher education, such as through college visits. Introducing these opportunities early on can make a huge difference.

What advice could the panelists offer inter-tribal partnerships?

- Mr. Reed spoke to the ancient history of collaboration between tribes, exemplified by the fish weir system on the Klamath. He said, “There is more love in the room than you can imagine.”
- Ms. Quinn-Davidson pointed out that colonial systems pit tribes against one another, creating false scarcity and competition. She said that in this paradigm “we have winners and losers, and that is not an Indigenous value. We take care of one another, our neighbors.”

To close the panel, Mr. Reed shared his thoughts on the past two decades of the dam removal movement:

> “What is sovereignty? It is being able to practice your faith-based system, whoever you are, wherever you are. It is health and wellness. Being Indigenous is being sovereign. Creator put down the prescriptions that provide for life over time, and we follow the methodology of the creation stories… What keeps me going is making a meaningful difference. The dams are out. Prescribed fire with cultural objectives is happening. The Karuk Tribe is leading nationally in prescribed fire. We are on the right path. We’re fixing the world with modern management techniques relying on the backdrop of Indigenous knowledge. A fish is not just a fish, a fire is not just a fire. Indigenous people aren’t ordinary people.”

4. Morning Intra-Disciplinary Sessions

4.1 Water Quality

The water quality group moderator was Laurel Genzoli (University of Nevada, Reno) and the notetaker was John Harrison (Washington State University). Other participants were Eli Asarian (Riverbend Sciences), Bob Gearhardt (Cal Poly Humboldt), Wayne Hong (Southern Oregon University), Randy Turner (Klamath Basin Monitoring Program), Josh Cahill (Yurok Tribe Environmental Department), Abraham Saleeb (Yurok Tribe Environmental Department), John R. Oberholzer Dent (Karuk Tribe Department of Natural Resources), Jacob Kann (Aquatic Ecosystem Sciences), Jacob Delaney (Hoopa Valley Tribal Environmental Protection Agency), and Christine Alford (Oregon State University).

This group began by considering the components and impacts of water quality. Participants pointed to the impacts of human health, fish health, food security, cultural use, community health, and the constituents of flow regime and disturbance, temperature, biogeochemistry, and biota. This broad definition was supported by work from participants in diverse aspects of water quality work, emphasizing the centrality of water quality in both human and non-human life in the Klamath Basin.

In the past year, what did you expect to happen or not happen? What are your observations in the midst of this first year of change?

- Temperature has been affected immediately, aligning with expectations.
- More nutrients are being released below Iron Gate dam earlier in the year.
- Macrophytes were still present in summer of 2024, supporting past work suggesting that strong floods are required for their turnover (Genzoli 2022).
- Sediments are accreting in the estuary, with new islands forming, and nutrients are being consumed.
- Different water quality constituents are responding to disturbance on different time scales (e.g., temperature and turbidity).
- Microcystin was barely detected this year, also aligning with expectations.
- Turbidity has been high following dam removal, but dissolved oxygen has only dropped for brief periods of time.
- Flows have been highly regulated for the past several months (summer 2024), but flushing flows may come with winter storms.
- High-turbidity conditions from catastrophic wildfire such as the 2022 McKinney Fire prepared tribes for monitoring drawdown.

Revisiting Previous Research Topics

- Prioritization of the collection of baseline metrics
    - The Karuk and Yurok Tribes have been working to fill gaps in the nutrient sampling left after the expiration of the KHSA, as well as additional sampling

specifically during the drawdown period. Parameters include nutrients, DOC and POC, TSS and VSS, and alkalinity.
    - The Yurok Tribe led a multi-agency collaboration in 2018 to comprehensively map pre-dam removal topography LiDAR data prior to dam removal along a 260 mile corridor.
- Measuring the chemical, biological, and food web recovery within the newly exposed main stem and tributary channels. What can this newly exposed river teach us about how rivers work and about how to do effective river restoration?
    - Independent of restoration effectiveness monitoring defined for the project, RES intends to work with tribes and other collaborators to monitor DO and GPP in these reaches in order to study primary succession and stream recovery.
    - Darren Ward (Cal Poly Humboldt) has been collecting pre-drawdown data in creeks, focusing on fisheries and food webs.
    - The Karuk and Yurok Tribes are considering establishing water quantity monitoring stations in these areas.
    - The Yurok Tribe has been producing thermal and visual profiles of the river with regular over-flights.

Outstanding Questions from Previous Meetings

- A repeatable method for identifying research and monitoring gaps like a formal literature review
- Building a conceptual model linking water quality outcomes such as temperature, GPP, and pH to *C. shasta* and other diseases, to fish survival, or to fish abundance

What new priority areas have emerged? What questions is your work focused around?

- What is the role of cultural fire in the recovery of the reservoir reach? How will it be incorporated into the long-term management of this area?
- What patterns of sediment deposition and mobilization will materialize in coming years?
- How will changes in Upper Basin constituent loading affect river nutrient and ecosystem dynamics?
- How will river and tributary water quality and biogeochemistry (e.g., GHG fluxes) respond to dam removal over a timescale of years to decades?

4.2 Hydrogeology and Geomorphology

The geology and hydrogeology group moderator was Jenny Curtis (USGS) and the notetaker was Liam Schenk (USGS). Other participants were Emily van Seeters (USBOR), Seth Brenton (Hoopa Valley Tribal Fisheries Department), Tammy Church (USACE), Julian Palmisano (Yurok Tribe Environmental Department), Su Jin Lee (Oregon Institute of Technology), Hima Hassenruck-Gudipati (Southern Oregon University), Mark Thompkins (USBOR), Mike Dixon (Trinity River Restoration Program), Desiree Tullos (Oregon State University), Ken Sandusky

(Modoc Nation), DJ Bandrowski (Yurok Tribe Fisheries Department), Patrick Haluska (USGS), Sandra Bond (USGS), and Tom Skyles (Oregon Water Resources Department).

In the past year, what did you expect to happen or not happen? What are your observations in the midst of this first year of change?

- Large material (rocks) in the reach below former JC Boyle dam don't have vegetative growth after drawdown; likely "scrubbed clean" by sediment.
- Fine sediment has been deposited in the estuary.
- Fine sediment has been deposited along the margins of the Klamath River and in side channels.

Revisiting Previous Research Questions

- Sediment movement and characteristics below the hydroelectric reach
    - The Yurok Tribe will be mapping morphological changes in the river annually.

Outstanding Previous Research Questions

- The re-examination of flushing flows under different channel conditions post-dam removal (e.g., what post-dam removal flows will mobilize bed sediments and affect annelid ecology?)
- Integration of physical processes with ecological response
- Defining spatial and temporal resolution of data collection for different kinds of data (repeat measurements, time series, etc.)

What new priority areas have emerged? What questions is your work focused around?

- Bathymetric conditions within the reservoir (continuous observations will be needed) and bathymetric data for habitat and hydraulic modeling
- Will bedload flux increase? Where will bedload transport create new channel conditions?
- Will contributions from scree slopes in the canyon reach add more sediment to the mainstem channel?
- How will tributary mouths be affected by the end of hydropeaking?
- How will remobilization of sediments stored in-channel after drawdown contribute to suspended sediment and nutrient loads?
- What is the contribution of tributaries and recovered mainstem channel to downriver sediment flux?
- How can floodplain reconnection be prioritized in coming years?
- How will changes to the hydrograph affect channel stabilization?
- How will sediment deposition in the estuary affect water levels during tidal fluctuations?

4.3 Fish Population and Movement

The fish population and movement group moderator was Stephanie Quinn-Davidson (Ridges to Riffles) and the notetaker was Sam Stroich (University of Oregon). Participants in this session were not recorded due to clerical error.

In the past year, what did you expect to happen or not happen? What are your observations in the midst of this first year of change?

- Fish have returned to upriver areas in Oregon, and have been seen passing the Link River segment.
- Fish are finding large areas of spawnable habitat.

Revisiting Previous Research Questions

- How will the life histories, distributions, and abundance of different fishes change following dam removal, including coho and Chinook salmon, steelhead, Lost River and Shortnose suckers, anadromous and non-anadromous lamprey, and non-native fish?
    - PIT tag data is being collected by many collaborating entities in the basin.
    - USFWS is completing escapement surveys.
    - The Klamath Tribes are collaborating with Oregon Department of Fish and Wildlife monitoring salmonids.
    - The Klamath Tribes are also continuing to monitor endangered suckers.
    - California Department of Fish and Wildlife is operating video weirs and outmigrant traps, and completing dive surveys on the Scott and Shasta Rivers and sampling for genetic studies.
    - The Karuk Tribe is completing redd and carcass surveys between the reservoirs and Happy Camp, taking gut samples for disease, working on a sonar project with Cal Trout and the Yurok Tribe radio tagging adult salmonids, and continuing longstanding fish disease work with Oregon State University.
    - The Trinity River Restoration Program is continuing work on long-term monitoring, focusing on fish health in the lower Trinity River.
    - The USBOR is working on restoration projects with the Quartz Valley Indian Reservation, fish screens on irrigation canals in Oregon, and fish passage monitoring.

Outstanding Previous Research Questions

- How will dam removal influence anadromous and non-anadromous lamprey in the Klamath River?
- How will dam removal affect redband and bull trout in Upper Klamath Lake?

What new priority areas have emerged? What questions is your work focused around?

- How far into the Upper Basin will anadromous fish migrate?

- How will the return of the salmon impact tribal nations?
- Will spring run Chinook repopulate the Upper Basin on their own? What passage barriers exist to distinguish fall and spring run habitat in the Upper Basin?
- How do juvenile salmonids utilize restoration habitat like floodplain reconnection projects?
- How will sediment recruitment change or enhance species like lamprey?
- How will dam removal affect population genetics?
- What life histories will result from Upper Basin migration?
- What will be the timing of outmigrant juveniles from Upper Klamath Lake, and how will it relate to water temperature and water quality?
- How will suckers and salmon interact?
- What are the persistent limiting factors to fisheries recovery after dam removal (i.e., passage, disease, water diversions, climate change, degraded habitat, water quality)?
- What is the bioenergetic cost of migration above Keno?
- How will sturgeon be affected by dam removal?

4.4 Fish Health

The fish health group moderator was Sascha Hallett (Oregon State University) and the notetaker was Tommy Williams (National Marine Fisheries Service). Other participants included Torrey Tyler (USBOR), Tyler Jones (Yurok Tribe Fisheries Department), Katherine Major (Yurok Tribe Environmental Department), Barry McCovey, Jr. (Yurok Tribe Fisheries Department), and Mahala Harms (Oregon State University).

In the past year, what did you expect to happen or not happen? What are your observations in the midst of this first year of change?

- Annelid host numbers were greatly diminished during the first year of dam removal, and fish no longer crowd the areas below Iron Gate dam.

Revisiting Previous Research Questions

- How will fish disease severity and distribution change after dam removal?
    - The Karuk Tribe and Oregon State University will continue to monitor *C. shasta* downstream of the former Iron Gate dam
    - The new Biological Opinion holds a requirement for monitoring *C. shasta*, but it is unclear what form that monitoring will take.

Outstanding Previous Research Questions

- What are the persistent limiting factors to fisheries recovery after dam removal (i.e., passage, disease, water diversions, climate change, degraded habitat, water quality)?

What new priority areas have emerged? What questions is your work focused around?

- With lessons learned from years of sampling in the Lower Basin, what monitoring should be undertaken in the project reach and Upper Basin following dam removal?
- How will salmonid migration affect disease in the Upper Basin? As one participant put it, “what are they bringing to the party?” This will require sampling adult kidneys and intestines now.
- What are juveniles being exposed to in the new environment with dams out?
- How will dam removal change disease dispersion downstream?
- How will the prevalence of thiamine deficiency complex be affected with dam removal?
- How can fish disease researchers collaborate with migrant trapping researchers for collecting samples?
- How will the new distribution and abundance of fish affect the distribution and abundance of their pathogens and parasites?
- Where will fish spend time (spawning, rearing, bottlenecks) in the reconnected system?

4.5 Aquatic Food Webs

The aquatic food webs group moderator was Alison O’Dowd (Cal Poly Humboldt) and the notetaker was Dylan Keel (RES). Other participants were Rosa Cox (Cal Poly Humboldt), Oshun O’Rourke (Yurok Tribe Fisheries Department), Michelle Perruzi (Yurok Tribe Environmental Department), Charlie Cramer (USFWS), Amanda Wik (UC Berkeley), Issi Tang (Oregon State University), and Julie Alexander (Oregon State University).

In the past year, what did you expect to happen or not happen? What are your observations in the midst of this first year of change?

- Counter to predictions, cofferdam removal may have had a larger short-term impact on some parts of the ecosystem than the initial drawdown.
- Spatial accumulation of fine sediment is heterogeneous.
- Fish are exhibiting resiliency and may vary by life stage, taxa, location, and dispersal mechanisms.
- Fringe wetland establishment in the Middle Klamath is being driven by sediment accumulation.
- Proximity to tributaries and dispersal mechanisms of different taxa are predicted to drive macroinvertebrate distribution initially.
- Shifts in sediment pulses are predicted to result in long term shifts in invertebrate communities driven by flow and sediment mobilization.
- Greater turnover of macrophytes and invertebrates is expected from increased bed instability, making winter flushing flows less critical.
- Shifting temperatures (warmer in spring, cooler in summer) may lead to earlier emergence and faster growth of macroinvertebrates.

Revisiting Previous Research Questions

- Measuring the chemical, biological, and food web recovery within the reservoir.
    - Independent of restoration effectiveness monitoring defined for the project, RES intends to work with tribes and other collaborators to monitor DO and GPP in these reaches in order to study primary succession and stream recovery.
- Measuring the chemical, biological, and food web changes downriver from the reservoirs.
    - Rosa Cox and Alison O'Dowd (Cal Poly Humboldt) are surveying benthic macroinvertebrates and fish diet (via gastric lavage) of juvenile salmonids in tributaries and mainstem sites between the former Iron Gate dam and Seiad Valley.
- How does dam removal impact mussel distribution, recruitment, and survival?
    - USFWS PIT tagged thousands of mussels (and translocated many more) to study the effects of sedimentation in the reach below the former Iron Gate dam.
- Prioritization of the collection of metrics that require baseline data rather than those monitoring activities that can take place after dam removal.
    - The Karuk and Yurok Tribes collect continuous water quality and grab sample nutrient data supporting the study of metabolism and food webs below the former Iron Gate dam.

Outstanding Previous Research Questions

- A repeatable method for identifying research and monitoring gaps like a formal literature review
- Building a conceptual model linking water quality outcomes such as temperature, GPP, and pH to *C. shasta* and other diseases, to fish survival and abundance, or to invertebrate taxonomic shifts

What new priority areas have emerged? What questions is your work focused around?

- What does recovery look like for invertebrates, vegetation, and other communities? How does it compare to interannual variation?
- Will fish practice prey switching to maintain growth despite changes in macroinvertebrate abundance and composition (1-5 years)?
- What is the role of macrophytes as ecosystem engineers at the intersection of deposition, disturbance, and growth?
- What would a robust sampling design for basin-wide mussel and clam distributions look like?
- Will mercury bioaccumulate in fish or invertebrates during the dam removal period?
- How will turbidity and fine sediment provoke ecological responses in light, scour, vegetation, macroinvertebrates, and fish?

4.6 Terrestrial Systems

The terrestrial response group moderator was Barbara Clucas (Cal Poly Humboldt) and the notetaker was Sheena Sidhu (Stanford University). Other participants were Maya Ceja (Southern Oregon University), Tallulah Fattorusso (Southern Oregon University), Caitlin Boise (RES), Sarah Schaefer (Quartz Valley Indian Reservation), Sarah Rockwell (Klamath Bird Observatory), Joshua Chenoweth (Yurok Tribe Fisheries Department), Chhaya Werner (Southern Oregon University), and Karen Mager (Southern Oregon University).

In the past year, what did you expect to happen or not happen? What are your observations in the midst of this first year of change?

- 450 acres have been hand-seeded, and 126 species have been observed. Some areas had even 100% cover.
- Wetland species are prominent, and germinate from the sediment seedbank.
- The best performers included pollinator plants (chick lupine, smoothstem blazingstar, squirreltail grass, poppy, common gumweed, common yarrow, fiddleneck).
- Where seed mixes were established, more native diversity was seen. Vegetation cover was generally higher where seeded.
- Cracks from 2 cm to 1+ m disrupted species establishment in unseeded areas.
- Impacts to bats were mitigated with bat boxes.

Revisiting Previous Research Questions

- How will vegetation respond to dam removal?
    - RES is monitoring carbon sequestration and soil health including eDNA for fungal and bacterial communities.
    - Southern Oregon University is monitoring species richness, diversity, native/non-native diversity, and cover.
    - RES and collaborators are attempting to coordinate a regular vegetation workshop to coordinate research.
    - RES has also surveyed for rare plants including Detling's silverpuffs, Greene's mariposa lily, and Holzinger's orthotrichum moss, among others.
- How will wildlife respond to dam removal?
    - Cal Poly Humboldt has completed baseline monitoring of 12 bat species and is pending funding with collaborators to monitor dam removal restoration and white-nose syndrome.
    - Fences were built to prevent non-native herbivores (horses, cattle) tracking in invasive species and overconsuming small, establishing plants.
    - Klamath Bird Observatory is pursuing a grant to study bird responses in the reservoir footprints, especially in riparian zones.
    - Pulikla Tribe of Yurok People is engaged in numerous wildlife monitoring efforts on its reservation including American bullfrog, spring migration bird counts, forest carnivore camera studies, dragonflies, amphibians, mollusks, and fish.

    - RES is monitoring species of concern including western pond turtle, gray wolf, willow flycatcher, northern spotted owl, cliff swallow, osprey, great blue heron, peregrine falcon, sandhill crane, tricolored blackbird, bald eagle, golden eagle, and bats, among others.

Outstanding Previous Research Questions

- Several terrestrial species of interest remain unaccounted for currently:
    - Native herbivores (i.e., beaver, deer, elk)
    - Piscivorous aquatic mammals (i.e., otter)
    - Terrestrial mammalian carnivores (i.e., Humboldt's marten)
    - Insect responses, especially pollinators

What new priority areas have emerged? What questions is your work focused around?

- What is the role of cultural fire in succession ecology?
- What will be the pollinator response to dam removal? The response of pollinators in the first year of restoration is an indication of success.
- What will be the future of oak woodland ecology beyond the mandated five years of monitoring?
- What manipulative experiments are possible during the restoration process?

4.7 Socio-Ecological Responses

The socio-ecological responses group moderator was Sibyl Diver (Stanford University) with key facilitation provided by Kenwani Kravitz (Pit River Nation, Southern Oregon University) and the notetaker was Jamie Trammell (Southern Oregon University). Other participants were Ron Reed (Karuk Tribe), Robyn Reed (Hoopa Valley Tribe), Regina Chichizola (Save California Salmon), Dan Shelby (Oregon State University), Paul Wilson (Maqlaqs Media), Thadeus Super (Quartz Valley Indian Reservation), Wiyaka Bennett (Quartz Valley Indian Reservation), McKayla Woodie (Quartz Valley Indian Reservation), Regine Familara (Yurok Tribe Environmental Department), Thatcher L. Alvarado (Yurok Tribe Environmental Department), Lexi Karon (USACE), Erin Wheeler (Oregon State University), Rebecca Wheaton (Oregon State University), Adrienne Chenette (American Rivers), Michelle Kunst (Pulikla Tribe of Yurok People), Demetrios Davis-Boucher (Southern Oregon University), Tiana Gilliland (Shasta Indian Nation, Southern Oregon University), Kiya Jackson (MHA Nation, Southern Oregon University), Lune Wolgamott (Shawnee Tribe, Southern Oregon University).

This was the first year that social and eco-cultural research approaches were explicitly included in a dam removal coordination conference. For this reason, there are no previous research objectives to report on. However, prior to the meeting, researchers from Stanford, UC Berkeley, and the Karuk Tribe had produced a comprehensive social impact assessment of the Karuk Tribal community based on focus groups, interviews, and a survey of the tribal membership.

Their results, including a technical report and a first published article, are available at damremovalsocialimpact.com/results.

Group participants spoke to early days of dam removal, when the Altered Diet Report by Kari Norgaard and Ron Reed shifted the conversation at dam removal negotiations through demonstrating downstream impacts with research weaving Western and Indigenous knowledge systems (Norgaard 2005). This work was an early university-tribe collaboration that laid the foundations for future collaborative research.

This discussion group, which had a majority of Indigenous participants, discussed tribal community needs in the Klamath Basin and how social science researchers and others can participate in uplifting tribal science and tribal community well-being. Needs and topics discussed were:

- Education
    - A lack of scientists, specifically Indigenous scientists, to analyze data collected by tribal science departments
    - Dam removal education curriculum for tribal communities and the California school system
    - Need for Indigenous scientists as role models
    - Resources for college students who are engaging in knowledge co-production and guidance on critical questions that students should ask when engaging with tribal partnerships. How to fully represent coproductions of knowledge and do so in a responsible manner?
- Youth
    - Intertribal youth opportunities, especially with education and training
    - Activities on the river and outdoors
    - Including college students in collaborative initiatives
    - Expanding mental health support and positive mentorship opportunities though outdoor initiatives (“outside the counseling office”)
    - Gaining funds for outdoor, experiential education
    - Growing support for youth in Siskiyou County, specifically
- Health
    - Documenting positive holistic health benefits of outdoor education for youth, and incorporating this into health and education policy
    - Supporting intergenerational transfer of knowledge and cultural reclamation
    - Focusing on traditional foods
- Cultural Safety
    - Raising awareness around racial violence that persists as the background for this work
    - Ensuring safety of tribal technicians and scientists working in the field, particularly around Yreka and the Scott Valley
- Intertribal Institutions
    - Centering the importance of reconnecting tribal peoples across the basin for research, trade, and mutual support

    - Emphasizing the need to bring in smaller tribes; they may not have the capacity that larger tribes have to be engaged, but it doesn't mean that the interest and the connection isn't there
- Eco-Cultural Resource Management
    - Intergenerational transfer of knowledge and cultural reclamation
    - Management planning that is place-based, modeling and adapting based on local cultural leadership
    - Basin-wide, river-wide management strategies

Ron Reed, a long time leader in university-tribal co-production of knowledge, explained how he felt looking back on the campaign in respect to tribal community health and well-being:

> "I said, 'I hate what is happening to me, so I am going to change it.' I love who I am now, I love what I'm doing–that's dam removal. Indigenous- and community-led. I've gained so much from my allies, and now it allows me to look at my children and see them learning. And not just them–we are collectively recreating harmony and balance."

5. Afternoon Inter-Disciplinary Sessions

5.1 Water Quality and Fish Health

Guiding Question: How do sediment movement and water quality outcomes link to fish health and survival?

The moderator for this session was Summer Burdick (USGS) and the notetaker was not recorded. Other participants were Eric Reiland (US BOR), Issi Tang (Oregon State University), Julie Alexander (Oregon State University), Russ Perry (USGS), Rosa Cox (Oregon State University), Eric Peterson (Trinity River Restoration Program), Sandra Bond (California Water Science Center), Mark Tompkins, and Hima Hassenruck-Gudipati (Southern Oregon University).

This session focused on distilling a key list of priority emerging and cross-cutting questions. Participants framed a number of complex interactions involving sediment impacts of all parts of the anadromous life cycle. These questions included:

- How will fish disease be impacted under the new system with respect to connectivity, adult carcass distribution, and impacts to annelid hosts?
- What will be the magnitude of future flows beneath the reservoirs given new accretions in the reservoir reach?
- What is the interplay between fine and coarse sediment inputs?
- How will sediment mobilization be monitored in the long-term?
- Are dissolved oxygen sags expected for future sediment mobilization events?
- How will turbidity affect fish movement and survival, and what will the spatial and temporal extent of these impacts be with respect to:
    - Foraging efficiency
    - Predation
    - Egg survival
    - Redd construction
    - Growth rates
- How will sediment movement impact available habitat quality, and how can this be monitored (e.g., sonar)?
- How can dangers from extensive irrigation ditch networks in the former hydroelectric reach be monitored or mitigated?
- How to assess successful spawning under high turbidity drawdown conditions?
- How will lamprey recruitment be impacted by fine sediment inputs?

These questions involve researchers working in a variety of disciplines in a variety of contexts. Innovative methodologies and linkages between fields are needed to effectively assess these questions. As always, funding and teamwork will be required to address them.

5.2 Downstream Sediment Effects

Guiding Question: What are the impacts of sediment movement downstream of the dams, including shifts from lentic to lotic, estuary changes, and coastal marine impacts?

The moderator for this group was Dylan Keel (RES) and the notetaker was Alison O'Dowd (Cal Poly Humboldt). Other participants were Michelle Kunst (Pulikla Tribe of Yurok People), Michelle Perusi (Yurok Tribe Environmental Department), Dan Shelby (Oregon State University), Kristine Alford (Oregon State University), Jenny Curtis (USGS), Josh Cahill (Yurok

This group assembled a list of emerging and cross-cutting sub-questions for this topic concerning the river channel, estuary, and coastal environment. Questions for the river included:

- How well is the sediment being tracked? Efforts to this end include LiDAR scans before and after, side scan sonar plus multibeam sonar, turbidity and suspended sediment concentration rating curves, and core samples from the estuary. Most of the change has been within the wetted channel.
- A terrain model that combines bathymetry and terrestrial LiDAR is needed for the area from the former Iron Gate dam to the crossing of I-5 near Hornbrook. This picture is made more complicated by sediments deposited by McKinney Fire debris flows interacting with sediments from dam removal. There are multiple water quality sondes operated by tribes on the main stem but they are still many miles apart.
- Measurements of inputs, outputs, and storage are needed to make a sediment budget.
- What will be the future distribution of sandy beaches and fine sediment deposition on banks? Although the reservoir sediments contained only ~10% sand, there are also now available sources from tributaries such as Cottonwood Creek. The McKinney Fire also produced sandy material from decomposed granite. The Karuk Tribe and USGS are collaborating on a large-scale sandbar willow habitat project.
- What is the duration and persistence of newly formed fringe wetlands along the margins of the Klamath River post-drawdown?
- Bedload is not currently being measured, a notable data gap, although reservoir sediments were dominated by fine material.
- What is the particulate carbon and nutrient flux associated with reservoir sediments? The Karuk and Yurok Tribes are collecting high-resolution nutrient data to study this question.
- Sediment flux in large tributaries like the Shasta, Scott, Salmon, and Trinity Rivers is not currently being measured.

Questions for the estuary and coastal environment included:

- What is the impact to the local community from sediment deposition in the estuary? How long will it persist and will fish movement, water quality, or flood risk be affected?
- What additional heavy sediment deposition is possible in the future given large riverbed deposits of sediment stored below the former Iron Gate dam?

- What are seasonal patterns of deposition given lower transport capacity at low flows in summer and fall, and then remobilization by high winter flows?
- How do silt and fine sediment interact with sand? High energy environments will settle out sand, but not silt, and the estuary is currently very coarse, composed of exposed cobble, sand, and gravel.
- Will the timing of lagoon closure (typically 1-2 weeks per year now) change? The location of the mouth has also shifted from the north end to the south end of the beach.
- What will be the impacts on mussel communities? The Pulikla Tribe of Yurok People is monitoring water quality via mussels.
- Will the future reductions in freshwater harmful algal blooms (HABs) upriver have impacts on the diet of filter-feeding bivalves such as mussels?

Many of these questions reflect concern for the long-term fate of sediment and when and how it may impact the estuarine and coastal environments. The complications presented by the McKinney Fire debris flows are difficult to parse, and one recommendation was sediment fingerprinting to determine sediment source. As has been noted previously, the McKinney Fire debris flows prepared tribes and agencies for responding to high sediment loads and initiated collaborations leading up to dam removal.

5.3 Hatchery and Flow Management

Guiding Question: What management options are now available under the new river/hatchery operations and what research or monitoring is needed to help guide those?

The moderator for this group was Sascha Hallett (Oregon State University) and the notetaker was Desiree Tullos (Oregon State University). Other participants were Ray Beamesderfer (Pacific States Marine Fisheries Commission), Torrey Tyler (USBOR), Jordan Ortega (Klamath Tribes), Nell Scott (Trout Unlimited), Toz Soto (Karuk Tribe Department of Natural Resouces), Amy Fingerle (UC Berkeley), Tommy Williams (NMFS Southwest Fisheries Science Center), and Alex Corum (Karuk Tribe Department of Natural Resources).

Discussion in this group centered around two topics, the future of hatcheries on the Klamath River and of flow management in accordance with Biological Opinions. Following dam removal, the Iron Gate hatchery was moved upriver to Fall Creek, and is set to continue operations for eight years as currently planned, and possibly longer. The goal of the hatchery is to meet tribal trust fishery commitments for Chinook and Coho salmon, not necessarily to re-establish populations. US Bureau of Reclamation will pursue volitional reintroduction and passage at Keno and Link River dams. Ultimately, the goal is to have self-sustaining, natural populations. In the Elwha River, it took 2-3 generations for Chinook numbers to start to rebound.

Current hatcheries in the Klamath Basin now include:

- Trinity River Hatchery - spring and fall run Chinook salmon, Coho salmon, and steelhead trout

- Fall Creek Hatchery - fall Chinook, Coho
- Klamath Fish Hatchery (Crooked Creek) - spring run Chinook
- Klamath Falls Hatchery - suckers

Volitional passage brings an array of new management decisions to make, including timing of releases and where to release water, brood stock sources, and monitoring methods. Key questions include:

- What are we managing for? This may include priorities like ocean fisheries, in-river fisheries, ESA-listed species, etc.
- What is changing? The previous system was heavily managed for Chinook, and included more hatchery fish than there will be moving forward. Timing was specifically managed around fish disease risk, which is changing as fish are no longer trapped in the highly infectious zone below Iron Gate Dam.
- What is needed? Programs are moving away from coded wire tags, a shift in the monitoring paradigm. New programs, such as genetic assessments currently used for coho that may be applied to Chinook in the Upper Basin, may need to be expanded. Additionally, transitioning from a hatchery-dependent system to a non-hatchery dependent system will require new harvest rules.

Fundamentally, the new Biological Opinion does not change water storage and release for the foreseeable future (next five years). Flows at Keno will be managed to preserve the prior patterns of flow at the former Iron Gate dam. Flows will thus largely look the same as the previous decade. However, accretions from springs and streams in the reservoir reach will no longer accumulate in the reservoirs, and will add some variability in flow and temperature to reaches of the river in and below the former reservoirs. The new planning model is using RiverWare, which is based on National Resources Conservation Service forecasts of water storage. Management decisions are based on the results of models on March 01 and April 01. The next five years will be used to monitor and “bridge” the biological opinions for the start of the next consultation.

Other water quantity changes are simultaneously taking place in the basin. Wetland restoration efforts in the Upper Basin will increase water storage, including 35,000 ac-ft as part of the Barnes and Agency Lake reconnection. Passage at Keno is being evaluated, raising questions as to what could improve fish mortality there and in Lake Ewauna.

Central questions of flow management with respect to fisheries include:

- What are the effects of flow releases on thermal refugia and springs? Does it “flush” them out or does it increase thermal diversity?
- What are disease risk dynamics with changing migration paths of adults and juveniles?

5.4 Fire Interactions

Guiding Question: What is the relationship between post dam removal recovery and fire – including sediment flows, hydrology shifts, invasive species management, and eco-cultural revitalization?

The moderator for this session was Joshua Chenoweth (Yurok Tribe) and the notetaker was Kim Deniz (Salmon River Restoration Council). Participants were not recorded for this session due to clerical error.

In thinking about how to approach this question, participants reflected on the interrelated concepts of *diversity, resilience*, and *richness* in relationship to fire. In the interest of all three, fire is something that must be built into the monitoring plan for post dam removal recovery. This includes the much-needed benefits of fire, like water temperature cooling from smoke deliberately used by tribes for fisheries management, and also the dangers of high severity fire in the extreme drought environment, as was seen with the McKinney Fire in 2022 (Curtis et al. 2025, David et al. 2018). More, smaller, and more frequent fires beneficially cool river temperatures and improve the health of the entire landscape in myriad ways, but large catastrophic fires can cause disastrous debris flows.

Including fire in post dam removal recovery plans faces many challenges. It requires overcoming disciplinary boundaries, fighting fear of fire, gaining support for prescribed burns, navigating red tape, and including land owner priorities and perspectives. Key questions with respect to these challenges include:

- Data is needed to show what is missing and prove that fire is necessary. Where can this foundation be laid, as in a conceptual review paper?
- Temperature data is more common, but fish movement and survival data is harder to collect. How can existing knowledge of temperature and fish movement be paired?
- Some ecological knowledge is not citable in academic literature. How do we uplift and validate stories and place-based knowledge?
- To be blunt, who’s going to pay for it?

Participants felt that fire has been overlooked in dam removal restoration, despite extensive investments in reservoir and riparian areas. They also reminded that upslope burning is a necessary component of river health. They agreed that restoration is not completed upon removal of the dams, but when fire is put back on the landscape. Since the former reservoir lands are the homelands and soon to be title of the Shasta Indian Nation, these discussions must uplift their interests and follow their leadership.

5.5 Connecting across Space

Guiding Question: What is required to build research networks from the Upper to the Lower Basin, and from the tributaries to the mainstem?

The moderator for this group was Sarah Schaefer (Quartz Valley Indian Reservation) and the notetaker was Randy Turner (Klamath Basin Monitoring Program). Other participants were Monica Diaz (Pacific States Marine Fisheries Commission) and Angelina Cook (California Sportfishing Protection Alliance).

Several efforts at accumulating basin-wide or larger-scale data exist, including the federal Water Quality Portal database and the KBMP monitoring location metadata map which directs researchers to relevant sources. KBMP has successfully maintained coordination and connection between the many entities engaged in Klamath water quality, but does not complete monitoring or restoration itself. Other datasets exist within individual organizations, such as the Pacific States Marine Fisheries Commission's decades of wire tag data. However, agency regulations and tribal data sovereignty make mass accumulation of data problematic (see Carroll et al. 2019 and Reyes-Garcia et al. 2022 for an introductory discussion of Indigenous data sovereignty). Greater understanding of tribal data sovereignty and appropriate collaboration with tribes is needed in the realm of data management.

Furthermore, many sources become defunct when agencies change direction or individual employees move on, making the maintenance of data sources more difficult. Academics working in the basin are often not aware of existing efforts or agency or tribal datasets. Many of the researchers working with data are disconnected from people on the ground doing the field work to make it happen. While the immense scale of research in the Klamath Basin makes tackling these questions difficult, we note an exceptional spirit of collaboration given the political tensions of dam removal. The continued steps towards collaborative projects, sharing data and knowledge, and advocating for existing or new networks may be critical to advancing scientific insights and better managing species and ecosystem recovery in the Klamath Basin.

5.6 Eco-Cultural and Social Framings

Guiding Question: How do eco-cultural and social science framings shape our understandings of fisheries, food webs, and terrestrial restoration responses?

The moderator for this session was John R. Oberholzer Dent (Karuk Tribe Department of Natural Resources) and the notetaker was Rebecca Wheaton (Oregon State University). Other participants were Sibyl Diver (Stanford University), Laurel Genzoli (UN Reno), Nate Berne, Amanda Wik (UC Berkeley), Ken Sandusky (Modoc Nation), Katherine Major (Yurok Tribe Environmental Department), Julian Palmisano (Yurok Tribe Environmental Department), Regine Familara (Yurok Tribe Environmental Department), Abraham Saleeb (Yurok Tribe Environmental Department), and Thadeus Super (Quartz Valley Indian Reservation).

While a majority of participants in this session were not social scientists by training, all brought a unique perspective to the issues addressed. Conversation ranged from repatriation of ancestral remains to youth education, with a wide distribution of social issues intersecting with the

environmental systems impacted by dam removal. Some of these human-environment themes included:

- Social network studies and political ecology approaches to understand the transfer of funds and resources occurring through dam removal and subsequent restoration
- Communities in the Lost River subbasin, especially the Modoc people, who have been terribly affected by the draining of Tule Lake and Lower Klamath Lake and surrounding wetlands
- Operating under colonial frameworks that pit tribal nations against one another by reinforcing a false sense of scarcity
- The spiritually transformative nature of dam removal, and the renewal of associated ceremonies that is associated with ecological and social changes
- The linguistic understanding of spring and fall run Chinook as distinct among Native peoples, and the struggle to save spring run Chinook as a distinct being
- Changes over time in the paradigm of environmental decision making in the Klamath Basin
- The power of inter-tribal exchange and the building of tribal unity through dam removal and eco-cultural restoration
- The power of storytelling in capturing the public imagination
- Traditional tattooing and the significance of human-environment relationships represented therein
- Creation stories and their connection to place-based science

The group also engaged in an enlightening discussion about methodology, particularly tensions between quantitative and qualitative methodologies. Ultimately, researchers with different disciplinary training agreed that new understandings are possible when integrating information from multiple sources, and that different questions require different approaches. Starting from place was acknowledged to be particularly important. One example of mixed-methods research that engages Indigenous communities and environmental knowledge is the recent collaboration between Stanford, UC Berkeley, and the Karuk Tribe on a baseline social impact assessment of dam removal on the Karuk community using both survey and focus group methodologies (damremovalsocialimpact.com).

The group also discussed challenges to bringing eco-cultural and social science framings to bear under the current situation. Some of these challenges included:

- Dismissal of qualitative data by quantitative scientists
- The dominant fisheries management paradigm which relies on hatcheries
- Shifting restoration frameworks to move toward nature-based solutions
- Working from Indigenous epistemologies and ontologies, including Indigenous science
- Leveraging funding for eco-cultural and social science research
- Producing generalizable knowledge from community-based case studies
- Appropriately citing biophysical science within social research

Participants discussed the siloing of knowledge in Western research systems and the problems this brings to interdisciplinary work. Biophysical scientists and social scientists present came to

the agreement that social science can be one way of understanding the ecology of the river, and biophysical science can be one way of understanding the ecology of humanity. Participants discussed the heuristic of centering Indigenous well-being and working to “fix the world” as paramount to this work.

6. Field Trip to Reservoir Sites

To bring the conversation into the field and give participants the opportunity to listen to and learn from the river, the indoor workshop day was followed by field visits to the previous Iron Gate dam site, the Jenny Creek tributary and confluence, the previous JC Boyle dam site, and the Spencer Creek tributary and confluence. At the previous Iron Gate dam site, Ren Brownell shared information about the structure of the dam and process of demolition, including an on-location photo so participants could compare the changes. The group also traveled to the dam overlook view point to see the river flowing freely through the previous dam location.

Figure 9 Ren Brownell showing a photo of Iron Gate dam while looking upriver at the former dam site (photo: Laurel Genzoli)

Figure 10 Klamath River free-flowing through the former Iron Gate dam location, from the dam overlook viewpoint (photo: Chhaya Werner)

Figure 11 Field trip participants observe Iron Gate reservoir from the dam overlook viewpoint (photo: Chhaya Werner)

The absolute highlight was seeing dozens of Chinook salmon spawning in Jenny Creek, a key tributary upstream of the removed Iron Gate dam. Dave Coffman (RES) oriented participants to the Jenny Creek tributary, explaining RES's ongoing channel restoration work in the area. As the group walked along the creek from Copco Road to its confluence with the Klamath River, folks shared their observations, expertise, and questions. Fisheries biologists pointed out female salmon with tails worn white from building and defending their redds and explained the structure of different monitoring stations. Others brought up how the channel structure and sediment changes would likely impact water quality and geomorphology. Plant ecologists observed the naturally establishing willows, which could provide future shading and nutrient inputs to the water. And overhead flew the Yurok Tribe's Condor One aerial mapping plane.

Figure 12 Small-group discussion on the field trip at the Jenny Creek tributary location (photo: Chhaya Werner)

Figure 13 Two Chinook salmon in the Jenny Creek tributary, with worn tails indicative of females defending redds. The banks of the tributary have abundantly sprouting willow stems. (photo: Chhaya Werner)

A subset of participants also drove up to the former JC Boyle dam site, where Ren Brownell discussed the dam removal and restoration process there, differences among the dams, and the uncovered Moonshine Falls. When folks expressed disappointment at not seeing salmon at this site, Ken Sandusky led an impromptu additional trip to the Spencer Creek site and its confluence with the Klamath River within the former JC Boyle reservoir footprint. There participants observed Chinook salmon spawning upstream of all three former dam sites, returning to these waters for the first time in over 100 years.

Figure 14 Moonshine Falls at the site of the former JC Boyle dam (photo: Chhaya Werner)

Figure 15 Field trip participants observe salmon swimming up Spencer Creek (photo: Chhaya Werner)

Figure 16 Chinook salmon swimming upstream in the Spencer Creek tributary, above all three former dam sites. The mark in front of the dorsal fin is indicative of a lamprey attachment site. (photo: Chhaya Werner)

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