2023 Klamath Dam Removal Science Collaboration Workshop

Summary Report

Hosted by the Yurok and Karuk Tribes, Resighini Rancheria, and Quartz Valley Indian Reservation

Sponsorship provided by: Cal Poly Humboldt College of Natural Resources & Sciences and Resource Environmental Solutions (RES)

January 10th & 11th, 2023

Cal Poly Humboldt, Arcata, CA

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Executive Summary

(updated from Genzoli & others (2021))

Historically, the Klamath River was the third largest salmon-producing river on the West Coast of the continental United States. The river's rich resources and surrounding watershed have sustained native people since time immemorial. The health of the Klamath Basin ecosystem is intertwined with the well-being and identity of native people throughout the watershed, including the Yurok and Karuk people. Agricultural development, water diversions, resource extraction, over-fishing, and dams have degraded the river ecosystem and caused dramatic declines to native fish populations. The Indigenous people of the Klamath Basin have suffered greatly as the river's health and fisheries have declined. In a historic effort to restore ecosystem function and fisheries, four Klamath River hydroelectric dams are being removed , representing the largest dam removal in US history.

Despite the unprecedented scope of the Klamath Dam Removal, formal coordination of dam removal research and monitoring has been limited. The Klamath River Basin, along with the dams slated for removal, straddles two states, a prominent mountain range, and the jurisdiction and interest of numerous state, federal, and tribal natural resource and land management agencies. One dam (Copco 2) was removed in 2023 and the other three dams (J.C. Boyle, Copco 1 and Iron Gate) are slated for removal in 2024 (at the time of this publication), but there remains an urgent need to prioritize research, and collect data in an efficient, well-coordinated, and collaborative manor to address the pressing ecological questions around dam removal.

Despite a relatively robust network of monitoring programs on the Klamath River, much existing monitoring was not designed to assess the results of dam removal on aquatic resources. Data from existing programs can be used to describe the condition of the river with dams in place and inform predictions following dam removal, however additional coordination is needed to integrate existing data collection efforts with new studies, so efficient study designs are implemented to assess the short and long-term effects of dam removal upon the Klamath River ecosystem.

Similarly, the Klamath River Renewal Corporation's (KRRC – the entity whose sole mission is to remove the Klamath River Dams to restore a free-flowing river) dam removal effort includes monitoring activities associated with dam removal 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 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, including several high-profile removals in the Pacific Northwest, along with significant synthesis of available information, each removal is different, and the Klamath Basin has some particularly unique aspects. 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.

To increase collaboration and coordination, the Yurok and Karuk Tribes initiated a process in the winter of 2020 to coordinate dam removal science and monitoring focused on fisheries, water quality, and physical processes, . In February 2020, a workshop was held in Medford, Oregon to discuss monitoring and research of the planned dam removals. At that workshop, invited speakers involved in research and monitoring of other large dam removals shared their experiences assessing the effects of dam removal, and participants identified and documented research priorities for Klamath River dam removal. Following that meeting, Genzoli & others (2021) produced a document to summarize the events held therein, and to document the historical background leading up to the Klamath dam removals. Spurred by the momentum of the Medford workshop, the Yurok and Karuk Tribes, the Resighini Rancheria, and the Quartz Valley Indian Reservation hosted a follow-up workshop coordinated by a pluralistic group of workshop organizers, on January 10^{th} & 11^{th}, 2023 at the campus of California State Polytechnic University, Humboldt in Arcata, CA. At this two-day workshop, invited speakers involved with research, monitoring, and restoration on the Klamath River and other large dam removals presented updates on monitoring and dam removal and lessons learned from past efforts. Additionally, a panel of Tribal natural resource managers and researchers presented on traditional ecological knowledge and the value of incorporating it into research and management decisions. A large portion of this document is dedicated to summarizing these presentations as well as the outcome of the breakout groups. Breakout groups on day 1 were organized by topic: 1) Geomorphology and Hydrology; 2) Water Quality, Food Webs, and Ecology; 3) Fisheries and Fish disease; 4) Vegetation; and 5) Wildlife. On day 2 breakout groups were organized by geography: 1) Lower Basin (Weitchpec to Estuary); 2) Mid-Klamath (Iron gate to Weitchpec); 3) Reservoir Reach (Link River to Iron Gate Dam); 4) Upper Klamath Lake and above; 5) Tributaries to the mainstem Klamath River; and 6) Basin-Wide. Each breakout group created lists of current projects, gaps in research and monitoring, top research and monitoring priorities, and opportunities for collaboration to conduct needed research and monitoring related to Klamath dam removal. The remainder of this document is dedicated to summarizing existing monitoring efforts and providing additional resources for researchers, managers, and the public to access information about the state of Klamath dam removal and dam removal research.

River restoration is often carried out with limited effectiveness monitoring. The Klamath River 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.

How to use this document to find Klamath Dam Removal resources

The purpose of this document is to summarize the proceedings of the 2023 workshop held at the campus of California State Polytechnic University, Humboldt, the relevant historical background that preceded dam removal, and to organize a list of resources and monitoring/research activities associated with Klamath dam removal. To use this document to find resources and information related to dam removal research, review the Klamath River Fisheries, Water Quality, and Dam Removal Resources located in SI-1 and the list of Current monitoring activities in the Klamath Basin Relevant to Dam Removal located in SI-3. For additional information regarding resources and monitoring actions, utilize the SI-2 to locate contacts of natural resource practitioners engaged in the project of interest from the relevant Tribe, state or federal agency, research institution, or private partner. References and additional resources are arranged as footnotes throughout the document text. At the time of publication, these resources represent the most contemporary information on Klamath Dam Removal research and monitoring activities. Going forward, the co-editors of this document recommend engagement and collaboration with experts and practitioners identified herein to access current information.

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1 Introduction

(updated from Genzoli & others (2021))

1.1 Meeting Purpose and Overview

On January 10th and 11th, 2023, approximately 200 natural resource professionals, researchers, community members, and students from over 70 Tribal governments, federal, state, and regional agencies, universities, private companies, and other aquatic resource-focused organizations, met to discuss monitoring and research associated with the removal of hydroelectric dams from the Klamath River. The removal of the four dams will be an unprecedented restoration effort, representing the world's largest dam removal and river restoration effort to date, which will reconnect salmon and other native fish to historic habitat while also improving water quality and physical processes within the river. The removal of these dams and their associated reservoirs will open up over 420 miles[1,2] of historic anadromous fisheries habitat above the dams, restore a dewatered and hydro-peaked river channel to a free-flowing river, and improve water quality and habitat condition in the 190 miles of river below the dams. Expected improvements to fisheries and ecosystem function will benefit local communities, including members of the Indigenous Tribes who have relied on a healthy Klamath River for millennia.

Despite the unprecedented scope of the Klamath dam removal, formal coordination around planning basin-wide, hypothesis-driven research outside of the hydroelectric reach has been limited. The Klamath River Basin and the dams to be removed straddle two states, a prominent mountain range, and the jurisdiction and interest of numerous state, federal, and tribal natural resource and land management agencies. Uncertainty surrounding the timing of dam removal, paired with limited financial resources for monitoring the effects of the dam removal had resulted in minimal formal coordination regarding dam removal monitoring on the Klamath River. With dam removal already in progress (2024 as of the time this publication), there is an urgent need to prioritize research and monitoring goals, plan additional data collection that will address outstanding questions identified herein, continue existing data collection in an efficient and well-coordinated manor, and utilize momentum from the 2023 workshop to coordinate additional research.

Monitoring ecosystem response associated with dam removal on the Klamath River is a monumental opportunity that will inform future management and restoration on the Klamath River and rivers around the world. River restoration is often carried out with limited effectiveness monitoring. This limited monitoring, often of short duration and limited scope, may not capture the long-term results of restoration, or ignore the specific mechanisms associated with restoration, which change the ecosystem. Conducting thorough, well-coordinated research and monitoring of dam removal will lead to mechanistic understanding of ecosystem recovery. Documenting ecosystem response to dam removal will help inform future restoration and water management of the Klamath River and can provide useful information to inform restoration in other rivers. Considering the long and winding path that large dam removals often take, monitoring ecosystem recovery should be part of the restoration efforts and

[1] Huntington, C.W. 2004. Klamath River flows within the J.C. Boyle Bypass and below the J.C. Boyle Powerhouse. Clearwater BioStudies, Canby, Oregon.

[2] Huntington, C.W. 2006. Estimates of anadromous fish runs above the site of Iron Gate Dam. Clearwater BioStudies, Inc., Canby, Oregon

should start as soon as possible to establish baseline conditions from which to compare the effects of this monumental restoration of the Klamath River.

Moreover, the continued communication of efforts in support of the goals outlined herein is similarly essential to retaining the knowledge gained from such an undertaking. This document builds upon the work of Genzoli and others[3] in documenting the efforts of the scientific community in working towards more collaborative solutions to monitoring and researching Klamath River dam removal impacts.

1.2 Klamath Dam Removal Background and Karuk and Yurok Tribal Importance

1.2.1 Yurok and Karuk Tribal Connection to the Klamath River and Dam Removal

The Indigenous people of the Klamath River Basin have relied upon the river's resources since time immemorial. Throughout history and continuing today, the Yurok and Karuk Tribes, among others, have depended upon the Klamath River for sustenance, culture, commerce, and religion. The Klamath River is integral to the indigenous way of life and the health of the Klamath Basin ecosystem is intertwined with the well-being and identity of Yurok and Karuk people. This section focuses on the Yurok and Karuk Tribes' connection to the Klamath River, while acknowledging its importance to other tribes too.

The Klamath River has always been the cornerstone of Yurok culture. The importance of the river to the Yurok Tribe was not formally recognized by the federal government, however, until it demarcated the boundaries of the Yurok Reservation in 1855. The reservation was designed to extend one mile out from each side of the lower 44 miles of the Klamath River, making the river the central feature of the Tribe's homeland. The importance of the Klamath River to the Yurok People was also noted by the Ninth Circuit Court of Appeals who opined that the salmon fishery of the Yurok Tribe is "not much less necessary to the existence of the Indians than the atmosphere they breathed." The same court also confirmed that the executive orders that resulted in the creation of the Yurok Reservation also vested the Yurok Tribe with federally reserved fishing rights.

The Karuk Tribe is a historic tribe, and Karuk People today live in their ancestral homelands along the middle parts of the Klamath River. Since time immemorial, the Karuk people continue to practice their cultural traditions including fishing, gathering, hunting, basketmaking and ceremonies. Even though the Tribe has had a government-to-government relationship with the US federal government since 1851, the Tribe's treaties were not ratified by congress, so the Karuk Tribe has no formal reservation. Therefore, the Karuk Tribe manages cultural and natural resources within and upstream of Karuk Aboriginal Territory and on Tribal trust parcels of land. The Karuk Tribe is the second-largest tribe in California, with over 3,700 enrolled members.

In light of the importance of the river to Yurok and Karuk Tribes, one of the highest tribal priorities is to protect the resources of the river and to restore the anadromous fish runs of the Klamath Basin. By restoring anadromous fish runs, the Tribes will strengthen and re-establish traditional connections to the Klamath River and maintain subsistence, cultural, commercial, and religious uses. Historically, the river was filled with abundant populations of salmon, steelhead, Eulachon, lamprey, and Green

[3] Genzoli, L., Bandrowski, D.J., Fricke, S., McCovey, B., Hillemeier, D., Belchik, M., and Soto, T., Eds. 2021. Klamath Dam Removal Science Coordination Workshop Summary Report. Workshop Proceedings, Medford, Oregon, February 12-13, 2020. Yurok Tribe Fisheries Department. 65 p. https://www.klamathwaterquality.com/documents/DamRemovalScienceCoordinationWorkshop.pdf

Sturgeon. Today, Klamath River fish populations are a small fraction of their historic abundance. The decline of the Tribal fishery resources is the result of numerous legacy land and water management practices that were implemented with little regard to the health of the fishery and with minimal input from the tribes of the basin. These land and water management practices include, but are not limited to, gold mining, timber harvest, road construction, cattle grazing, water diversions, and construction of hydroelectric dams. The Indigenous people of the Klamath Basin have suffered greatly due to the management of the river and have borne the brunt of the negative ramifications from the destruction of the ecosystem they continue to rely upon.

Since the Yurok constitution was adopted in 1993, a high priority for the Yurok Council has been to develop the infrastructure necessary to responsibly conserve, manage, and restore the fishery resource of the Tribe. This strategy involves the integration of the best available science with existing tribal knowledge. The Tribe has made great strides toward this goal, especially given the relatively short time since the government has been formally organized, with the development of a Fisheries Department, Watershed Restoration Department, Environmental Program, and Wildlife Department. These departments employ dozens of professionals and technicians to protect, restore and responsibly manage the Tribe's resources. However, the stressors affecting the fishery resource and Klamath River ecosystem are numerous, and much work is needed to reverse ecosystem degradation and the associated downward trend facing fish populations.

The Karuk Tribe's constitution was adopted in 1985 and the Karuk Department of Natural Resources was established in 1989. The mission of the Karuk Department of Natural Resources is to protect, enhance and restore the cultural/natural resources and ecological processes upon which Karuk people depend. Natural Resources staff ensure that the integrity of natural ecosystem processes and traditional values are incorporated into resource management strategies. The Karuk Department of Natural Resources actively leads, coordinates, and manages monitoring, research, and restoration related to tribal trust resources within and beyond Karuk Aboriginal Territory.

A key element of the Tribal strategy to restore the Klamath River is dam removal. The Indigenous people of the Klamath Basin have always known and experienced the detrimental effects of the Klamath River dams; thus, dam removal has continually been a primary objective. In the early 2000's, the 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 to the Klamath River ecosystem. As more information was developed, 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 even 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; analyzing data related to fish diseases (*Ceratanova shasta* in particular) along with federal partners and universities to develop a better understanding of the link between the dams and fish disease on 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; specific drawdown plans; restoration plans; and having Yurok and

Karuk representatives on the Board of Directors of the Klamath River Renewal Corporation (KRRC), the entity responsible for removal of the dams.

Throughout this process, the Tribes have worked to blend science with existing tribal knowledge to take a more holistic and landscape-oriented approach to dam removal. Tribal work continues, as they and other practitioners strive to develop short and long-term plans for dam removal itself and fisheries management in a post dam removal world.

1.2.2 Unique Aspects of the Klamath River and the Dam Removals

Taken together, Link, Keno, J.C. Boyle, Copco 1, Copco 2, and Iron Gate dams form the Klamath Hydroelectric Project, which were previously owned and operated by PacifiCorp. Under the terms of the Modified (2016) Klamath Hydroelectric Settlement Agreement, the two uppermost dams, Link and Keno, would be transferred to the U.S. Bureau of Reclamation, while licenses for the remaining four lower dams were transferred to the non-profit Klamath River Renewal Corporation and subsequently surrendered for the purposes of removing the dams. The reach between Keno and Iron Gate Dam is commonly referred to as the "Hydroelectric Reach."

Dam removal in the Klamath Basin is different from many recent removals in the American West due to the position of the dams in the watershed, the low gradient headwaters, and the extensive modifications from agriculture above the Hydroelectric Reach. As a result of the basin's geology, additional hydrologic modifications, and flow management that is specified under the Klamath Project Biological Opinions[4] the hydrologic response to the removal of the four Klamath Hydroelectric Project (KHP) dams is not expected to mirror other dam removals. Nevertheless, the restored fish habitat and expected improvements in water quality are large compared to that achieved in the other dam removals, making removal of the KHP dams a compelling restoration objective.

Many lessons from prior dam removals are transferable to the removal of the four KHP dams, but differences among previous dam removals and the removal of Klamath River dams are also anticipated. Among these factors are the geological and hydrological settings and the effects the dams have had on water quality and native fish. The removal of four hydroelectric dams from the Klamath River will result

[4]United States Fish & Wildlife Service, & National Marine Fisheries Service. 2013. Biological Opinions on the Effects of Proposed Klamath Project Operations from May 31, 2013, through March 31, 2023, on Five Federally Listed Threatened and Endangered Species. https://www.usbr.gov/mp/kbao/programs/docs/klamath-project-biological-opinion.pdf

National Marine Fisheries Service. 2019. Endangered Species Act Section 7(a)(2) Biological Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for Klamath Project Operations from April 1, 2019 through March 31, 2024. https://www.fisheries.noaa.gov/resource/document/2019-klamath-project-biological-opinion

United States Fish & Wildlife Service. 2020. Biological Opinion on the Effects of the Proposed Interim Klamath Project Operations Plan, effective April 1, 2020, through September 30, 2022, on the Lost River Sucker and the Shortnose Sucker. https://www.usbr.gov/mp/kbao/docs/20200410-klamathproject-interimplanbo-final-wcover.pdf

United States Fish & Wildlife Service. 2023. Biological Opinion on the Effects of the Proposed Interim Klamath Project Operations Plan, effective January 13, 2023, through September 30, 2023, on the Lost River Sucker and the Shortnose Sucker.https://www.usbr.gov/mp/kbao/docs/20230113-final-2023-klamathproject-biologicalopinion-fwswcover-signed.pdf in: 1) relatively small changes to the flow regime; 2) the release of mostly fine sediment from the reservoirs due the geological and water quality context of these dams; 3) large improvements in water quality associated with the elimination of the reservoirs, including the return to a thermal regime more similar to what fish evolved with; and 4) improvements to native fish populations in response to increased habitat connectivity and expected decreases in fish disease. These factors will influence the ways in which monitoring, and research of dam removal will be carried out.

1.2.3 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[5]. Many of the upper basin streams are groundwater-fed and historically provided critical habitat and cold-water refugia for salmonids[5,6]. 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 operates 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 and associated diversions are not part of the planned 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. Keno Dam is used to maintain water levels high enough for agricultural diversion and pumping in the Lake Ewauna to Keno reach, and receives irrigation return flows from the Klamath Irrigation Project.

Downstream of Keno Dam, the Klamath River steepens as it cuts through the Cascade Mountains and the associated volcanic bedrock. The four dams slated for removal, J.C. Boyle, Copco 1, Copco 2(already removed), and Iron Gate sit in this geologic transition region between the relatively low gradient and groundwater-dominated upper basin and the higher gradient, rainfall-runoff dominated lower basin (Figure 2)[7]. In the approximately 30 miles of the Hydroelectric Reach, several tributaries enter that are important sources of water, sediment, and habitat for anadromous fish. Among these tributaries are

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[5] Gannett, M.W., Lite Jr., K.E., La Marche, J.L., Fisher, B.J., and Polette, D.J., 2007. Ground-Water Hydrology of the Upper Klamath Basin, Oregon and California: U. S. Geological Survey Scientific Investigations Report, 84 p., https://pubs.usgs.gov/sir/2007/5050/

[6] Hamilton, J.B., Curtis, G.L., Snedaker, S.M. and White, D.K., 2005. Distribution of anadromous fishes in the upper Klamath River watershed prior to hydropower dams—a synthesis of the historical evidence. Fisheries, 30(4), pp.10-20.

[7] Asarian, E., Kann, J., and Walker, W.W., 2010. Klamath River Nutrient Loading and Retention Dynamics in Free-Flowing Reaches, 2005-2008. Final Report to the Yurok Tribe Environmental Program, 59 p. + appendices

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. Fall Creek also has a natural waterfall a short distance upstream of its mouth that is a fish migration barrier.

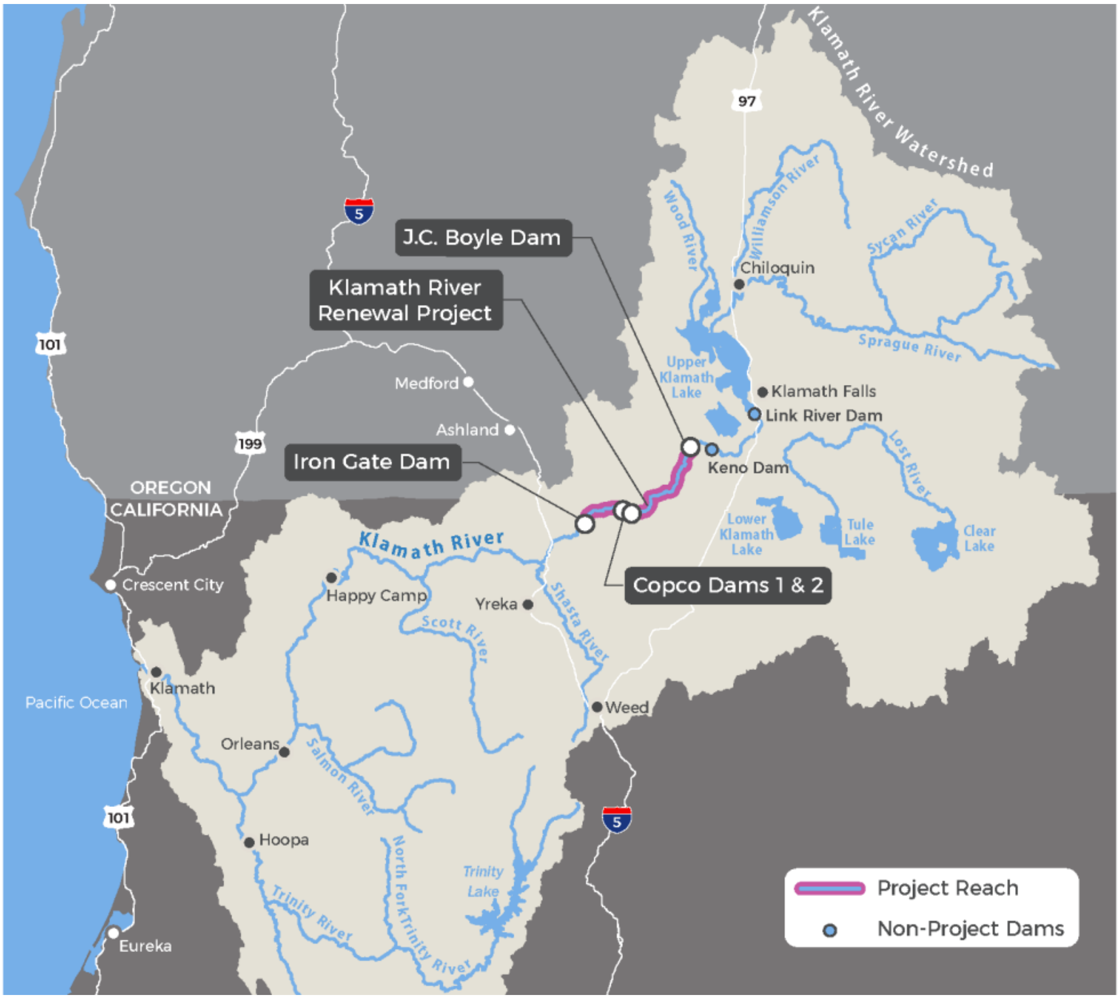

Figure 1: Map showing the Klamath River Basin. From www.klamathrenewal.org.

Downstream of Iron Gate Dam, the river enters the Siskiyou Mountains, where it is laterally constrained by confined valley walls and flows freely for over 190 river 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 Iron Gate Dam). In the summer, tributary inflow is low due to low precipitation and diversions for agricultural uses. As a result, the river's flow during summer is largely derived from above Iron Gate Dam, although the Trinity River is a major source of water in the final 40 river miles of the Klamath River (the Trinity River is regulated by large upstream dams).

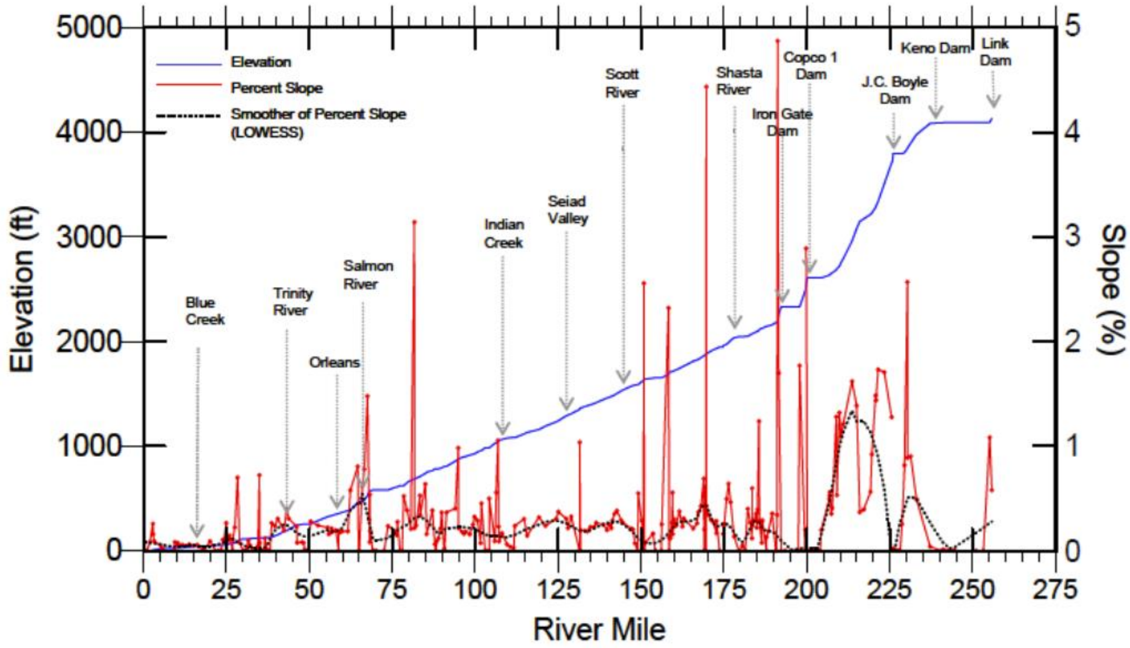

Figure 2: Elevational and river-bed slope profile of the Klamath River. Grey arrows show where tributaries enter (Asarian and others (2010)[6].

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 with important low velocity rearing habitat for fish. The estuary has a lagoon bounded on the west by a large sandy spit, with an opening to the ocean that can migrate periodically and, on occasion, can become temporarily closed off. The location of the riverine breach in the spit, through which most of the tidal exchange occurs, has a significant effect on velocity and sediment dynamics in the estuary. Marine water intrusion extends approximately 6 miles upstream, to above the Highway 101 bridge.

1.2.4 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 Indigenous communities and the commercial and sports fishing industries.

Flow regimes and water quality in the Klamath River are 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 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 in the Klamath Basin from above the Hydroelectric Reach, the impacts of the dams on the Klamath River ecosystem are different than those in less-altered watersheds. The potential benefits of dam removal not only go beyond opening up additional habitat for fish, but they also address water quality problems and an interrupted sediment supply downstream of the dams; both are linked to multiple stressors for fish.

1.2.4.1 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 blocks fish passage, preventing salmon access to over 420 miles[1,2] of habitat, including spawning and rearing habitat and cold-water refugia. 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.

The combined effect of warm water, high organic and nutrient loads, stable flows, lack of upstream sediment inputs that result in reduced scouring and less bed mobility, and fish crowding near Iron Gate Dam has resulted in conditions enhancing the myxozoan parasite, *Ceratonova shasta*, that infects juvenile salmonids and that in recent years has decimated native coho and fall Chinook populations[8,9]. Since water year 2017, managing the Klamath River to minimize the effects of fish disease has included releases of pulse flows from Upper Klamath Lake to scour surface sediments of the riverbed and reduce infection rates in juvenile fish.

The hydroelectric dams negatively affect water quality within the reservoir reach and in the river below the dams, extending to the Klamath River Estuary. One major water quality concern has been the extensive proliferations of toxin-producing cyanobacteria in the reservoirs that are transported downstream throughout the Klamath River[10]. Levels of microcystin toxin have continuously exceeded public health thresholds in the reservoirs and rivers annually in late summer, where visitors and basin residents rely on the river for recreation, ceremonial use, and subsistence fishing, among others. These blooms are associated with high levels of nutrients entering the stagnant water of Copco 1 and Iron Gate reservoirs where plankton are 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 include seasonally increased or decreased downstream water temperatures, where water is cooler for longer during the spring months, thereby reducing fish growth and delaying emigration to the ocean, and water is warmer for longer in the fall, thereby compromising conditions for adult fish migration. Both of these temperature related phenomena are due to thermal inertia within the reservoirs. Alterations to sediment regimes and scour likely increase downstream eutrophication, with nuisance growth of benthic algae, high rates of primary productivity, and concomitant impairments

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[8] Stocking, R.W., and Bartholomew, J.L., 2007, Distribution and Habitat Characteristics of Manayunkia speciosa and Infection Prevalence With The Parasite Ceratomyxa shasta in The Klamath River, Oregon–California: Journal of Parasitology, v. 93, no. 1, p. 78-88, doi: 10.1645/ge-939r.1, http://www.journalofparasitology.org/doi/abs/10.1645/GE-939R.1

[9] Fujiwara, M., Mohr, M.S., Greenberg, A., Foott, J.S., and Bartholomew, J.L., 2011, Effects of Ceratomyxosis on Population Dynamics of Klamath Fall-Run Chinook Salmon: Transactions of the American Fisheries Society, v. 140, no. 5, p. 1380- 1391, doi: 10.1080/00028487.2011.621811, https://doi.org/10.1080/00028487.2011.621811

[10] Genzoli, L and J. Kann. 2017. Toxigenic Cyanobacterial Trends in the Middle Klamath River, 2005-2016. Prepared by Aquatic Ecosystem Sciences LLC for the Karuk Tribe Department of Natural Resources. 50 p. + appendices.

of dissolved oxygen and pH[11,12]. 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 the different riverine and reservoir segments.

Water quality factors associated with the dams and their removal have resulted in regulatory oversight and permitting of Klamath dam removal through the water quality agencies in Oregon (Oregon Department of Environmental Quality) and California (State Water Control Board), via Section 401 of the Clean Water Act. Each agency must issue certifications that the dam removal project will ultimately meet the states' water quality requirements, with associated mitigation and/or monitoring[13,14]. Correspondingly, there is likely to be more emphasis on water quality, along with the fisheries, geomorphic, and sediment transport components typical with permitting for dam removals[11,12].

1.2.5 Lessons Learned from Previous Dam Removals

Scientific studies and monitoring of large (Elwha, Glines Canyon, Marmot, Condit, and the Penobscot) and smaller dam removals have led to notable scientific advances, many of which were synthesized by a recent Powell Center working group[15]. Their primary findings were: 1) Rivers are resilient and physical responses to dam removal can be relatively rapid, on the timescale of months to years rather than decades. Much of the sediment stored within the former reservoir can be eroded and transported within weeks to months of dam breaching, and phased removals extend river recovery time. 2) Rivers typically trend toward their pre-dam physical state following removal, although dam size, river size, reservoir size and shape, and sediment volume and grain size all exert first order controls on the responses to dam removal. And 3) Migratory fish have responded quickly to restored river connectivity; however, local environment, habitat, and population conditions affect the trajectory of physical and ecological responses. The growing body of knowledge has guided removal and monitoring strategies that can help avoid negative outcomes but cannot fully predict fine-scale changes that drive many ecological processes. Quantifying species and ecosystem responses through modeling lag even further behind. The findings by the Powell Center working group support conclusions that removal of Klamath River dams will be a successful restoration strategy, yet there are enough specific factors unique to Klamath (e.g. modified upper basin hydrology and land use, large proportion of fines in reservoir

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[11] Gillett, N.D., Pan, Y., Eli Asarian, J., and Kann, J., 2016, Spatial and temporal variability of river periphyton below a hypereutrophic lake and a series of dams: Science of The Total Environment, v. 541, p. 1382-1392, doi: http://dx.doi.org/10.1016/j.scitotenv.2015.10.048

[12] Genzoli, L., and Hall, R.O., 2016, Shifts in Klamath River metabolism following a reservoir cyanobacterial bloom. Freshwater Science, v. 35, p. 795–809. https://doi.org/10.1086/687752

[13] Stine, Chris. 2018. Evaluation and Findings Report Section 401 Water Quality Certification for the Removal of the Lower Klamath Project (FERC Project Number 14803). State of Oregon Department of Environmental Quality. September 2018. https://www.oregon.gov/deq/FilterDocs/ferc14803report.pdf

[14] STATE OF CALIFORNIA, STATE WATER RESOURCES CONTROL BOARD. 2020. Final Water Quality Certification for Lower Klamath Project License Surrender. April 2020. https://www.waterboards.ca.gov/waterrights/water_issues/programs/water_quality_cert/docs/401_cert/lkp_wqc.pdf

[15] The Powell Center is a USGS-sponsored Center for collaborative analysis and synthesis. The Dam Removal Working group, which included about 20 experts from agencies, academia, and NGOs, was formed in 2014 and produced numerous papers and products. See the following website for a list: https://www.usgs.gov/centers/powell-ctr/science/dam-removal-synthesisecological-and-physical-responses?qt-science_center_objects=0#qt-science_center_objects.

sediments, and the dams' effects on downstream water quality) that application of results from other dam removals requires adaptation and verification.

While the Powell Center working group was able to derive important insights from the dam removal studies conducted to date, it remains challenging to gain a comprehensive understanding of fluvial and ecosystem responses to dam removal. These challenges arise from basin-specific issues, differences in dam removal and study objectives and protocols among rivers, limited coordination among disciplines, and limited systematic monitoring and research both before and after dam removal. Most dam-removal studies have been short-lived, opportunistic, and have not covered a full range of scientific disciplines. Studies that truly integrate the biological and physical responses are rare. Moreover, very few dam removals have occurred in rivers where flows remain altered even after dam removal and where large volumes of fine-grained sediment have been released. Only one dam removal that was studied involved more than one dam in a river corridor being removed at a time. The simultaneous removal of four dams on the Klamath River provides a unique opportunity to fill these critical information gaps.

1.2.6 Benefits of Coordinated Klamath River Dam Removal Studies

Although much scientific information has been prepared to inform a general decision regarding Klamath River dam removal, detailed studies of the Klamath Ecosystem before, during, and after dam removal are vital to assess ecosystem response and restoration progress. These studies would:

1. Support adaptive management and inform real-time adjustments to minimize or mitigate effects to important human, ecological, and cultural resources in the Klamath River basin, including vast federal and tribal trust resources for six federally recognized Indian tribes in the basin (Karuk Tribe, Yurok Tribe, Hoopa Tribe, Resighini Rancheria, Quartz Valley Indian Reservation, and Klamath Tribes).
2. Improve our general understanding and ability to model and predict ecosystem and riverine responses following large dam removals, which ultimately helps resource managers and dam owners properly assess and plan for future dam removals.
3. Expand our specific understanding of how removal of reservoirs dominated by fine-grained cohesive bottom sediments (silts and clays) spatially and temporally impacts a river, an estuary, near-shore ocean environment, and their biota. Recent large dam removals in the western U.S. (e.g., Elwha, Mills, Marmot, and Condit dams) primarily included reservoirs with sediments dominated by larger-sized material.
4. Assess the response of rivers to removal of multiple large dams that are over 190 miles upstream from an estuary, a rarity in prior removals. There is potential for select Klamath River reaches to be negatively impacted by dam removal in the short term (<2 years) even while expectations are for long-term benefits. There would be a unique opportunity to understand how multiple dams in a series interact to control channel morphology as well as how their removal will affect landscape structure, hydro-geomorphic function, and ecosystem connectivity.

1.2.7 Expected Effects of Dam Removal in the Klamath River Basin

In the Klamath River Basin, the responses of different resources following dam removal are expected to follow trajectories similar to that described by Foley and others[15], (Figure 3). As a river restoration measure, dam removal is expected to be a long-term benefit for fish, especially anadromous salmonids, through a combination of opening up over 400 miles of habitat upstream of the dams and improving water quality and habitat conditions downstream of the Hydroelectric Project. Under existing conditions, there is no fish passage at Iron Gate, Copco 1, or Copco 2 dams, and their removal would ultimately provide volitional passage through the hydroelectric reach. Newly restored habitat will include free-flowing mainstem reaches currently inundated by reservoirs, smaller tributaries entering the mainstem along the Hydroelectric Reach, and ultimately the upper Klamath Basin above Keno Dam.

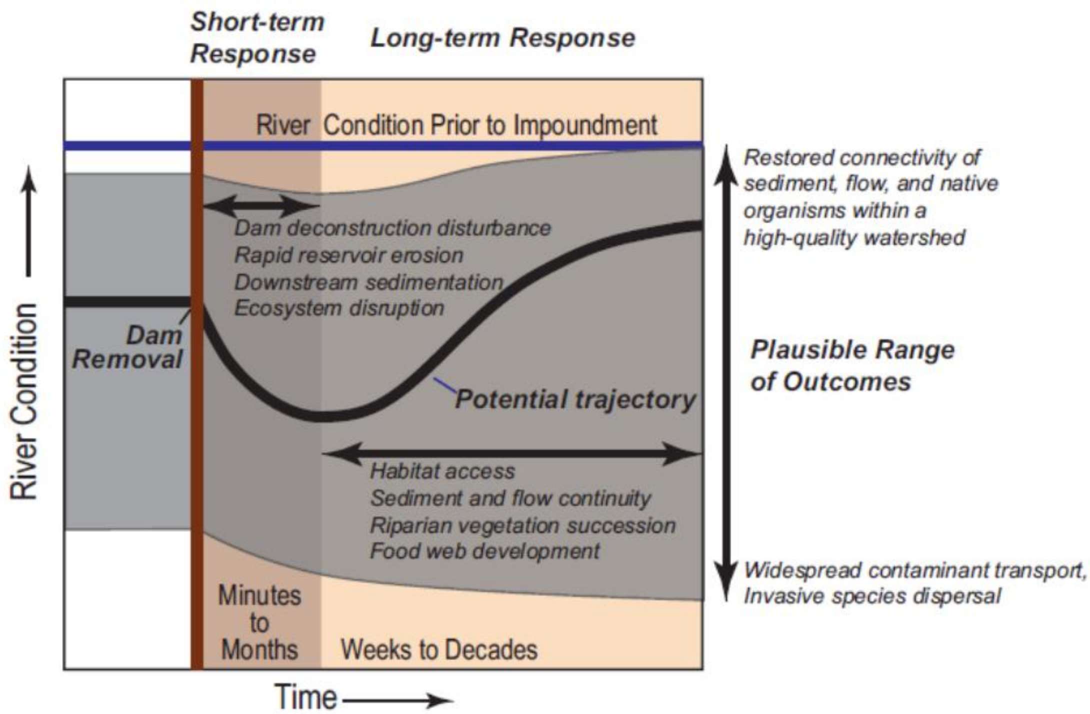

Figure 3: Conceptual river response to dam removal. Prior to dam removal, physical and ecological river condition is likely altered to some degree from pre-impoundment conditions by changed flow, sediment regime and aquatic connectivity. Dam removal will typically result in short-term disturbance, but the system will approach a new steady state dictated by overall watershed conditions. The indicated potential trajectory is just one of many possible outcomes within the gray shaded area depending on the original effects of the dam and reservoirs, their sizes, removal strategy, and regional environmental conditions. Source: Foley and others[16].

[16] Foley, M.M., Bellmore, J.R., O'Connor, J.E., Duda, J.J., East, A.E., Grant, G.E., Anderson, C.W., Bountry, J.A., Collins, M.J., Connolly, P.J., Craig, L.S., Evans, J.E., Greene, S.L., Magilligan, F.J., Magirl, C.S., Major, J.J., Pess, G.R., Randle, T.J., Shafroth, P.B., Torgersen, C.E., Tullos, D., and Wilcox, A.C., 2017, Dam removal: Listening in: Water Resources Research, v. 53, no. 7, p. 5229- 5246, doi: 10.1002/2017WR020457, http://dx.doi.org/10.1002/2017WR020457

Hydrology and water quality in the Klamath River upstream of J. C. Boyle Reservoir will be minimally affected by dam removal. Although marine derived nutrients from an influx of salmonids recolonizing habitats upstream of Iron Gate Dam may have local impacts to food webs and primary productivity in tributaries, changes to flows or other management changes affecting upstream water quality will take place under policy discussions independent of the current dam removal process. Hydrologically, the implication is that, unlike dam removals such as the Elwha, Condit, Marmot, and Carmel River dams, there will not be a substantially different hydrologic regime in the river downstream of the removed dams that might otherwise be able to rework channels or transport large amounts of sediment. This is because management at Upper Klamath Lake and Keno Dam will continue to regulate downstream flow, with changes to the downstream hydrology associated with dam removal dictated by inputs from tributaries within the project reach (whose flows tend not to be substantial compared to the flows in the Klamath River at this point in the watershed).

Over the long-term (Figure 3), dam removal is expected to benefit the Klamath River and its biota in the following critical ways[17]:

- Reopen access to over 420 miles of habitat for anadromous salmonids.
- Improve water temperatures in the existing hydroelectric reach and downstream to near the Scott River confluence, such that water temperatures are closer to natural thermal regime.
- Eliminate cyanobacterial blooms in the reservoirs and river downstream, including associated algal toxins that currently threaten human and possibly ecological health.
- Reduce the severity of juvenile fish disease from *C. shasta* via dispersion of fish into new habitats, reductions in detrital food sources for the intermediate host (the annelid worm *Manayunkia occidentalis*), changes in water temperatures, and resumption of sediment scouring processes with inputs from the tributaries between Iron Gate and Keno dams.
- Improve dissolved oxygen and pH conditions that are currently impaired due in part to reservoir algae blooms.
- Eliminate the seasonal release of nutrients and detrital material from the reservoirs into the river downstream of the dams, which contributes to increased eutrophication from nuisance growth of benthic algae (periphyton) and macrophytes. (Note that elevated nutrient concentrations from the upper basin would continue to be released through Keno Dam, such that nuisance periphyton and macrophyte could still persist although likely with changed longitudinal and seasonal patterns and community compositions).

However, as described by Foley and others[15] (Figure 3), short-term negative effects can be expected in the Klamath River. These include increased suspended sediment, nutrient, and carbon concentrations and an oxygen demand from resuspended reservoir sediment that reduces water column dissolved oxygen to levels potentially harmful to aquatic biota. Suspended sediment

[17] U.S. Department of Interior, U.S. Department of Commerce, and National Marine Fisheries Service, 2012, Klamath Dam Removal Overview Report for the Secretary of the Interior -- An Assessment of Science and Technical Information, 399 p., http://klamathrestoration.gov/

concentrations from dam removal were modeled by U.S. Bureau Of Reclamation[18] during the Secretarial Determination. Among their findings and others were that:

- Most reservoir sediment will be flushed downstream, through the Klamath River Estuary, and into the marine near shore environment off the coast of California.
- The period of active erosion and evolution of reservoir sediment would be about two years, beyond which direct effects of reservoir sediment would be more difficult to detect.
- The amounts and timing of sediment erosion and transport are highly dependent on the dam removal scenarios and the hydrology of the year of removal.
- The largest negative impacts will be in the reach immediately below Iron Gate Dam, to approximately the I-5 bridge. In this reach, reservoir sediment deposition of approximately 0.3–1.7 feet is possible.
- Suspended sediment concentrations (SSC) could peak near or above 10,000 mg/L near Iron Gate Dam and would attenuate downstream, with relatively high concentrations lasting through the spring.
- Some negative physical effects on fish are predicted from the high suspended sediment concentrations, depending on the species, but large fish kills are not expected. Timing of the dam removal was planned to minimize these effects including reduced presence of sensitive species and life stages and higher stream flows that would limit reservoir sediment evacuation to as short of a time period as possible[19,16].
- Resuspension of reservoir sediment will introduce an oxygen demand that could reduce water column dissolved oxygen concentrations to 4 mg/L or less, from Iron Gate Dam to below the Shasta River, depending on hydrology and the final dam removal scenario. This oxygen demand would abate in proportion to evolution of reservoir sediment[16].
- Deposition in pools is expected to happen throughout the river but would mostly be temporary (less than two years). Deposition on bars may occur, depending on the hydrology.
- There is little opportunity for channel migration resulting from sediment deposition or erosion, due to the highly constrained valley as the river cuts through the Siskiyou Mountains. Some bar formation is possible, especially in the Iron Gate reach, but in most cases would be temporary.
- Downstream tributaries contribute substantial water and sediment during the winter. The amount of reservoir sediment expected to erode with dam removal is equivalent to the annual sediment load of the Trinity River alone. Therefore, effects on the lower river, especially below the Trinity, are expected to be reduced and during some periods, might be hard to distinguish from other sources.
- The Klamath River Estuary may experience some deposition, including in the South Slough. Duration and effect magnitude will depend on hydrology in the following winters, including inputs from the Trinity, and on the location of the lagoon breach/mouth at the spit.

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[18] U.S. Bureau Of Reclamation, 2011, Hydrology, Hydraulics and Sediment Transport Studies for the Secretary's Determination on Klamath River Dam Removal and Basin Restoration: Prepared for Mid-Pacific Region, US Bureau of Reclamation, Technical Service Center, Technical Report No. SRH-2011-02

[19] Stillwater Sciences, 2009, Effects of sediment release following dam removal on the aquatic biota of the Klamath River: Prepared for California Coastal Conservancy Final Technical Report, 85 p.

Within the Hydroelectric Reach, the physical, chemical, and biotic changes are expected to be the most dramatic, consistent with the findings of Bellmore and others[20]. Among the changes will be a significant conversion from the reservoir areas back to riverine habitat, which fundamentally affects all aspects of local hydrology, geomorphology, sediment, and solute transport, and both aquatic and terrestrial ecology. A particularly unique aspect of dam removals in the Klamath River is the four-dam sequence, all of which would be removed together within a relatively short period. A key factor in how these changes affect the river, including the downstream reaches and especially in the short term, will be the specific dam removal scenario, including the timing and resulting hydrology. A specific set of scenarios were explored during the Secretarial Determination[16]and on behalf of the co-licensees of the Lower Klamath Project, final plans have been released by KRRC to implement the license surrender order[21]. These Management Plans, approved by FERC, incorporate requirements from Oregon's section 401 water quality certification, California's 401 water quality certification, National Marine Fisheries Service's incidental take statement, the U.S. Fish and Wildlife Services incidental take statement and Eagle Take Permit, the Interim Hydropower Operations Plan, and other interim management, monitoring, and decommissioning plans, resulting in a series of final management plans, including: The Aquatic Resources Management Plan, the Construction Management Plan, the Erosion and Sediment Control Plan, the Hatcheries Management and Operations Plan, the Health and Safety Plan, the Interim Hydropower Operations Plan, the Reservoir Area Management Plan, the Reservoir Drawdown and Diversion Plan, the Recreation Plan, the Recreation Facilities Plan, the Sediment Deposit Remediation Plan, the Terrestrial and Wildlife Management Plans (1 & 2), the Waste Disposal and Hazardous Materials Management Plan, the Water Quality Monitoring and Management Plan, and the Water Supply Management Plan. [22]

1.3 Research and Monitoring on the Klamath River

1.3.1 Past and Current Monitoring

Compared to many rivers, the Klamath has a relatively robust network of monitoring programs, whose data can help describe the condition of the river with dams in place and inform predictions following dam removal. Reasons for existing monitoring of fisheries and water quality in the Klamath River include the key role that Tribal governments have taken in the monitoring and management of the river, harvest sharing mandates between tribal and non-Tribal fisheries, as well as poor water quality and fisheries declines that have triggered more monitoring. The poor condition of water quality and fisheries in the Klamath River has led state and federal agencies to increase their monitoring and restoration efforts to fulfill expectations associated with the clean water act and the endangered species act, as well as state

[20] Bellmore, J.R., Pess, G.R., Duda, J.J., O'Connor, J.E., East, A.E., Foley, M.M., Wilcox, A.C., Major, J.J., Shafroth, P.B., Morley, S.A., Magirl, C.S., Anderson, C.W., Evans, J.E., Torgersen, C.E., and Craig, L.S., 2019, Conceptualizing Ecological Responses to Dam Removal: If You Remove It, What's to Come?: BioScience, v. 69, no. 1, p. 26-39, doi: 10.1093/biosci/biy152, https://doi.org/10.1093/biosci/biy152

[21] *Order Modifying and Approving Surrender of License and Removal of Project Facilities*, 181 FERC. 61,122 (November 17, 2022).

[22] Klamath River Renewal Corporation (KRRC). (2022). Monitoring and Management Plans. Retrieved from FERC eLibrary, Accession Number 20221205-5047. https://elibrary.ferc.gov/eLibrary/filelist?accession_num=20221205-5047

standards. Additionally, federal agencies have tribal trust obligations which require them to ensure protection of tribal trust resources, including harvestable populations of fish.

A mix of long-term monitoring and special studies has informed current knowledge describing the ecological and physical state of the Klamath River. For example, Tribal Natural Resource Departments, as well as federal agencies, have been conducting regular monitoring of water quality and fisheries in the Klamath River for over a decade (see supplemental materials for a partial list of monitoring activities; SI-3). Special studies have been conducted to address questions about specific water quality impacts and seeking to identify mechanisms driving water quality impairments and fisheries declines. Reports presenting monitoring data and the results of special studies can be found on selected websites of agencies and organizations involved in monitoring and coordinating monitoring throughout the Klamath Basin (see supplemental materials for a list of websites with links to monitoring and research reports and manuscripts, SI-1).

1.3.2 *Planned Monitoring to Comply with Government Approvals for Dam Removal*

Updated from text contributed by Daniel Chase of Resource Environmental Solutions (2020)[3]

As part of the Lower Klamath Project (LKP), a number of biological and ecologically focused surveys and monitoring efforts associated with dam removal activities will occur. The purpose of the monitoring is to comply with federal, state, and local permit conditions (collectively Government Approvals). The LKP Government Approvals include, Federal Energy Regulatory Commission requirements, Clean Water Act sections 404 and 401, state and federal Endangered Species Acts, National Environmental Policy Act, California Environmental Quality Act requirements, and other requirements that are accounted for in the creation of the final Management Plans[22]. The approach, frequency, and duration of monitoring actions are intended to meet Government Approval requirements. Monitoring activities are also intended to inform restoration and maintenance actions associated with dam removal and support the process-based and adaptively managed restoration approach. An overview of these activities was presented by Resource Environmental Solutions, LLC (RES) during the workshop by Daniel Chase, and they are summarized below section 2.2.4.1.

The LKP fits within a broader framework of surveys, monitoring, and research taking place within the Klamath River Watershed. Dedicated stakeholders across non-profit organizations, academic institutions, resource agencies, and tribal governments will engage in actions to document and study the changes that stem from dam removal and river restoration. The participation and collaboration presented at the technical workshop in 2020 and again at the 2023 workshop represents a testament to the strong scientific network already at practice in the basin. While LKP monitoring and survey actions are focused on compliance with government regulatory approvals, RES recognizes the importance coordination and data sharing will play in advancing the science of dam removal and large-scale river restoration.

1.3.3 The Need for Additional Research and Monitoring

Despite existing monitoring programs and dam removal monitoring requirements, there is an unmet need to conduct research and monitoring that will improve management of the Klamath River and bring insight into globally relevant river restoration. Most current monitoring has not been designed to specifically address questions about how dam removal will affect the Klamath River, while monitoring requirements associated with the dam removal are primarily focused in the Hydroelectric Reach, with less monitoring of water quality and sediment dynamics downstream of the dams. Support and coordination for more general understanding of how river geomorphology, ecology, and fisheries will recover following over 100 years of impoundment is still needed and has been incrementally organizing since the January 2020 workshop. Tribal governments, other government agencies, non-profits, and academic institutions are attempting to address the significant gap in knowledge about river recovery following large-scale dam removal on the Klamath River with limited resources. Dedicated funding for both scientific studies and coordinating these research efforts will lead to the creation of knowledge that will inform management of the Klamath River and future river restoration efforts on other rivers. A monumental opportunity exists to learn from the recovery of a river following the largest planned dam removal in history.

2 Workshop Components

Since formal initiation of dam removal science and monitoring coordination efforts in the winter of 2020, the community of tribal, agency, private, non-profit, and academic natural resources practitioners and educators engaged on the Klamath River has grown. In January of 2023, the Yurok and Karuk Tribes, the Resighini Rancheria, and the Quartz Valley Indian Reservation hosted a two-day workshop which was attended by over 200 experts, researchers, students, community members, and technical staff (SI-2) engaged in research and monitoring along the Klamath River and its tributaries. The January workshop was preceded by preliminary participant surveys and was specifically organized to supplement the findings of the February 2020 workshop. At the two-day workshop, invited speakers involved in research and monitoring of the Klamath River dam removal, other major dam removals, as well as experts in the use and understanding of Traditional Ecological Knowledge (TEK) shared their experiences, data, and project updates. Formal breakout groups were held on both days to identify current projects, gaps in research and monitoring, and opportunities for collaboration and conducting needed studies related to Klamath River dam removal. These breakout groups were organized by topic (day one) and by location/sub-basin (day two). The components of pre-workshop activities and details of the two-day workshop are outlined below.

2.1 Coordination Leading up to the 2023 Workshop

February 2020 Klamath River Dam Removal Science Coordination Workshop: To address a lack of dam removal science coordination, the Yurok and Karuk Tribes initiated a process in the winter of 2020 to coordinate dam removal science and monitoring focused on fisheries, water quality, and physical processes. On February 12th and 13th, 2020, approximately 60 natural resource professionals from over 20 Tribes, agencies, and organizations met to discuss monitoring and research of the planned dam removals. At the two-day workshop, invited speakers involved in research and monitoring of other large dam removals shared their experiences assessing the effects of dam removal. Formal breakout groups were formed at the workshop to develop and document research priorities for the Klamath River dam removal. These groups were divided by discipline, with experts from each discipline contributing their perspectives of which monitoring efforts and studies were most needed to document changes to the Klamath River following dam removal. The four breakout groups included 1) Geomorphology and hydrology; 2) Water quality and lower trophic-level ecology; 3) Fisheries; and 4) Riparian, wildlife, and upland ecology. Each breakout group created a list of research questions followed by observations and monitoring needs that would help address each question.

The 2020 Klamath Dam Removal Science Coordination Summary Report: In February 2021, the comprehensive summary of the 2020 workshop and findings, compiled by Laurel Genzoli & others was completed. This document[3], available online, serves the important function of providing background information on Klamath dam removal and the importance of the restoration action to the Tribes of the Klamath Basin, summarizing the state of research and monitoring on the Klamath River, archiving and interpreting the workshop events, discussions, and agreed upon Klamath dam removal related research and monitoring priorities identified in the workshop, and organizing resources, contacts, and other information of importance to the research community and the public. Additionally, the document serves as the outline for and has provided the majority of the background information included in subsequent workshop summaries: specifically for this document.

Pre-2023 workshop surveys, planning group, and sponsorship: The January 2023 workshop was organized and planned by a workshop planning group who consisted of: Mike Belchick (Yurok Tribe), Laurel Genzoli (University of Montana), Randy Turner (Klamath Basin Monitoring Program), Desiree Tullos (Oregon State University), Chauncey Anderson (USGS), Bonnie Bennett (Quartz Valley Indian Reservation), Jenny Curtis (USGS), Tommy Williams (NOAA) Bob Pagliuco (NOAA), Toz Soto (Karuk Tribe), Hans Voight (Resighini Rancheria), Grant Johnson (Karuk Tribe), Justin Alvarez (Hoopa Valley Tribe), Liam Schenk (USGS), Alison O'Dowd (CPH), Daniel Lipe (CPH), Darren Ward (CPH), Gwen Santos (RES), and Daniel Chase (RES). This planning group arranged all workshop components as well as for sponsorship of the event provided by CPH, College of Natural Resources & Sciences and Resource Environmental Solutions. Prior to the January 2023 Klamath River dam removal science coordination workshop, participants completed a survey, in which the following information was submitted: name, email contact, affiliation, position/title, area of monitoring/research in the Klamath Basin, active/past monitoring or research in the Klamath Basin, primary location of their work in the Klamath Basin, and approximate timeline of their project work. Results of the monitoring activities reported in the survey have been added to the results from 2020 in the appendix (SI-3). The primary location of work submitted served as a guide for organizing location-based breakout groups on day two of the 2023 workshop.

2.2 January 2023 Workshop Components

2.2.1 Welcome, Purpose, and Workshop Organization

The two-day workshop began with presentations on the importance, purpose, significance, and goals of the Klamath River dam removal and the 2023 Klamath Dam Removal Science Collaboration Workshop.

- Meeting participants were welcomed by a Wiyot Tribal opening by Chairperson Ted Hernandez. Chairperson Hernandez acknowledged the immensity of work and collaboration accomplished to reach the current state of Klamath dam removal and thanked those involved for their tireless work. He shared a traditional Wiyot story about a young person, who removed a dam in a neighboring village to bring the salmon back to their people, to illustrate a point that each generation of Tribal people must continue to show leadership in protecting natural resources. He emphasized the significance of dam removal and restoration to the Wiyot people, other

Tribal peoples, and the whole community of Northern California and Southern Oregon and welcomed the workshop to Wiyot Tribal Land (CPH).

- Meeting participants were also welcomed to the CPH Campus by Dr. Alison O'Dowd of the Environmental Science & Management department at Cal Poly Humboldt, who specifically thanked the Yurok and Karuk Tribes, the Resighini Rancheria, and the Quartz Valley Indian Reservation for hosting the workshop, the workshop planning group, and the workshop sponsors. Eric Riggs, Dean of the CPH College of Natural Resources & Sciences, spoke to the value of conducting restoration actions at a "natural scale" and commended the essential collaborative process required to coordinate efforts across the Klamath Basin.
- Tommy Williams with the NOAA Fisheries Southwest Fisheries Science Center presented the overview and purpose of the workshop, the desired outcomes, and the immediate and long-term goals and products. He emphasized that providing opportunities for collaboration through research and monitoring as the primary goal of the workshop, with additional goals including:

    - Providing a foundation for researchers to develop collaborative and integrated research projects
    - Providing a venue for researchers to meet practitioners from different disciplines working throughout the basin
    - Providing researchers with information on how to incorporate TEK into their projects
    - Providing researchers with conceptual models from other dam removals to inform research in the Klamath Basin
    - Providing researchers with the latest plans, milestones, and dates for dam removal
    - Sharing information about logistical issues for working within the Project Reach
    - Sharing previously identified research and monitoring needs

    Williams went on to share that the planning group had identified the immediate and long-term outcomes of the workshop should ideally include:

    - The development of key questions about both initial and long-term abiotic and biotic changes following dam removal
    - The catalyst of both descriptive and hypothesis driven projects and opportunities
    - The cultivation of collaboration across the Klamath Basin and disciplines
    - Identification of immediate data, information, and samples needed prior to dam removal activities
    - Informing researchers of processes, limitations, logistics, equipment needs, etc. to work in the "construction area"
    - The establishment of longer-term monitoring and research activities to understand the response of physical, biological, and ecological processes following dam removal
    - The development of long-term collaborative research across the Basin and disciplines
    - The further development of understanding of large-scale restoration actions to help inform future efforts

    Williams also shared the intention of compiling a workshop summary document as had been done for the 2020 workshop[3] and gave an overview of the workshop agenda added in the appendix (SI-4).

2.2.2 Klamath River Dam Removal Status and Context

Following the presentations on the importance, purpose, significance, and goals of the Klamath River dam removal and the 2023 Klamath Dam Removal Science Collaboration Workshop, an update on dam removal progress was provided by Mike Belchik (Yurok Tribe) and presentations on incorporating TEK into research and monitoring were given by Barry McCovey (Director of the Yurok Tribal Fisheries Department), Charley Reed (Hoopa, Yurok, Karuk Ceremonial Practitioner Educational Director for Save California Salmon), Shahnie Rich (Klamath Tribes Ambodat Department), and Keith Parker (Yurok Tribe Senior Fisheries Biologist). The presenters subsequently lead a discussion on the topic.

2.2.2.1 Mike Belchik - Senior Water Policy Analyst, Yurok Tribe

Presented an update on Klamath River dam removal. First, he recapped the last two decades on the process in which a collaborative partnership of Tribes, Federal, and State agencies navigated the FERC relicensing process. Belchik reaffirmed the importance of the scientific community in gathering the information to reach a common understanding of the science needed to progress with negotiations, agreement, and dam removal. He reminded the audience that the first agreement was reached in 2010 which required congressional legislation to bypass the FERC process, and upon which the legislature failed to act. Then in 2016 the agreement was reformulated which this time included the formation of a non-profit company that would take on responsibility of the Klamath dams and include the FERC relicensing process. Despite the License Surrender and Decommissioning Applications being promptly submitted following the agreement, FERC did not respond to the applications until 2020. In 2022, FERC conducted a final Environmental Impact Statement (EIS) and engaged in the evaluation of the License Surrender and Decommissioning Applications. On November 17^{th}, 2022 the EIS was announced as complete and the applications approved, on November 30^{th} PacifiCorp signed over ownership of the dams to the KRRC, and between that time and the January 2023 workshop, the Army Corps of Engineers 404 permit was finalized, the Clean Water Act Section 401 permit was issued, and KRRC had issued a limited notice to proceed with dam removal activities. He then summarized the upcoming work in the spring including upgrading roads and bridges, assemble construction staging areas and camps, move the water line that supplies the city of Yreka, CA with water, move the Iron Gate Hatchery facilities to the new site located on Fall Creek, preparing the tunnels at Iron Gate dam and Copco 1 dam to handle high flows, and finally the removal of the Copco 2 dam among other many other tasks.

Belchik went on to show gratitude for and acknowledge the contributions of Tribal activists who traveled around the country and the world, and whose endurance and commitment was essential in moving the project forward. He also thanked the practitioners and researchers who had worked on the Elwha River dam removal for aiding in navigating the process and for providing an example of a successful project on this scale. Recounting the many years and contributions from many people as dam removal moved towards implementation, Belchik acknowledged Ronnie Pierce (Karuk Tribe) who had encouraged the community to conceptualize dam removal, as well as the tribal leaders, and the TEK that had influenced the movement towards Klamath Dam removal. He then introduced the panelists, Barry McCovey, Charley Reed, Shahnie Rich, and Keith Parker.

2.2.2.2 Barry McCovey - Director of the Yurok Tribal Fisheries Department

McCovey began by defining TEK: *"Traditional ecological knowledge is the cumulative body of knowledge, practice, and belief, evolving by adaptive process, and handed down from generations by cultural transmission, about the relationships of living beings, including humans, with one another and the environment. It is cumulative, dynamic, place-based, it builds on experience, and adapts to change.*[23]*"*
McCovey explained that at the forefront of TEK is the emphasis of the connectedness between humans and the rest of nature, that it acknowledges that humans have co-evolved with salmon, suckers, lamprey, green sturgeon, and other species and that organisms have relied on one another to evolve to their current state. He went on to say that TEK recognizes that there is a carrying capacity to an ecosystem, and that when restoration projects or any other projects are planned, it is important to remember that ecosystems are limited.
He highlighted differences between TEK and western science, sharing that: 1)TEK is typically passed down in an oral tradition, while western science largely relies on a written tradition, 2) that TEK tends to focus on a holistic approach, while western science can be reductionist at times, 3) TEK is observational and experienced, while much of a western scientist's background is typically taught to them, that 4) TEK is based on cumulative and collective experience, while the cumulative knowledge of western science can be obscured by the theoretical or can appear as doctrine. He identified the key difference that the data which informs western science is often collected and analyzed by experts, while TEK is typically collected and analyzed by the community who lives among the resources it studies, with datasets that can span millennia as opposed to the shorter span of time that western research typically covers. Lastly, he contrasted that TEK is generally applied to daily living, while western science may have less clear goals.
McCovey emphasized the importance of incorporating TEK with western science and proposed that TEK is valuable to western science for the following reasons:

1. Including the people who subsist from the lands and waters upon which management decisions are being made in those decisions and research is valuable because they are the people who will end up benefitting from, or facing the consequences of, management actions. Their vested interest and knowledge of the system will support the success of the project.
2. TEK can enhance the knowledge used for decision making around species and habitats, provide longitudinal knowledge, and can be especially beneficial for informing management decisions related to long-term phenomena like global climate change.
3. Utilization of TEK in research and management builds relationships with Indigenous people around environmental topics of common interest. By creating relationships between Indigenous and non-Indigenous researchers both groups can benefit when communication is collaborative.

McCovey shared that a well-known example of TEK that has recently been acknowledged by western science is the recognition of importance of thermal refugia to migrating salmonids within the Klamath Basin. He stated that although there are many specific examples of how TEK is applied by the Yurok Tribe, there is a general application as well, consisting of a process by which restoration or development actions are evaluated to ensure that they fit within the

[23] Z. Molnár, D. Babai. Inviting ecologists to delve deeper into traditional ecological knowledge
Trends Ecol. Evol., 36 (2021), pp. 679-690

ethical, practical, and cultural guidelines that TEK has informed since time immemorial. He closed by adding that Tribal inclusion, which does not necessarily include TEK, is important and is the first step to building trusting and collaborative relationships between Tribal people and organizations that do not have a history of working with them.

2.2.2.3 Charley Reed - Hoopa, Yurok, Karuk Ceremonial Practitioner Educational Director for Save California Salmon

Reed spoke about his personal experiences growing up in the Klamath Basin, and the added resiliency that TEK had given to his life. He noted that in remote, Northwestern California where damage to the electrical grid is common and services are often far away, that TEK had increased the self-sufficiency of him and his family. Reed highlighted the importance of listening to community elders and the added benefit that multigenerational aspects of TEK bring to large projects. He recounted highlights from his research in graduate school, studying the differences between spring and fall run Chinook salmon, including his findings on the etymology of Karuk language words for various salmon run-types and how the Karuk names communicated more information than the English names, often holding connotations of time of year, religious ceremonial context, and other relationships. Reed went on to caution that sometimes western science and TEK are incompatible due to philosophical differences but encouraged Indigenous and non-Indigenous researchers to innovate collaboration where possible.

2.2.2.4 Shahnie Rich - Klamath Tribes *Ambodat* Department

Rich recounted personal experience on the Treaty Lands of the Klamath Tribes, interactions with Tribal Elders, and an academic background to present methods in which TEK can be incorporated in western science. She began by sharing an excerpt[24] to illustrate the advanced systems of natural resource management implemented by the Klamath and Modoc Peoples :

"…cultivation practices involved a variety of species within diverse habitats. The level of management also clearly operated at multiple scales, from large land-clearing fires to the burning or selective harvest of individual plants. While many of these practices are found in the repertoire of tribes nearby, in the Plateau, California and Northwest Coast regions, some – such as the management of yellow pond lily – appear to represent novel applications of broader plant management strategies. Together, these practices suggest considerable experimentation by the ancestors of today's Klamath and Modoc, facilitated by the fecundity of particular environments in their territories and the particular antiquity of Klamath and Modoc occupation that is suggested by the archaeological record[25]. These plant cultivation practices are nested within a larger management system that was employed to mediate both plant and animal worlds. For example, some interviewees have discussed conservation ethics and practices relating to duck egg gathering. While there appears to be variability between different families' protocols, the fundamental elements of restricting harvests to ensure future yields are shared by all. For example, one family reports, ''We'd pick up duck eggs. And you always had to leave a minimum of eight eggs in a nest. So, if you found a nest with nine eggs,

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[24] Deur, D. "A Caretaker Responsibility": Revisiting Klamath and Modoc Traditions of Plant Community Management. Journal of Ethnobiology. 2009. 29(2), 296-322.

[25] Cressman, Luther S. 1956. Klamath Prehistory: The prehistory of the culture of the Klamath Lake area, Oregon. Proceedings of the American Philosophical Society 46(4):375–513

you got one; if you found one with 12 you got four…and you weren't allowed to touch [the ones you left].'' In this practice, the Klamath used special willow loops to pick up eggs so that they would not leave a human smell and scuttle the nest. As a result of these practices, interviewees suggest the duck populations were always robust, ensuring the continued vitality of the duck egg harvest: ''we got several dozen eggs every time we went out.'' First fish ceremonies and other traditions related to fish and wildlife procurement also are suggestive of intentional enhancement of subsistence animal resources[26]."

Rich highlighted that these large-scale management practices were implemented by the Peoples of the Upper Klamath Basin to maintain sustainable harvest of plants and animals. Rich continued to share her experiences with TEK being incorporated into western science research on projects implemented on her homeland. She recounted how through one study which tracked the movements of reintroduced juvenile Chinook salmon in the Upper Klamath Basin, Klamath Tribal members were able to inform where best to place the acoustic receivers to detect the tagged fish, and how in other fish movement studies in which she was a part of, natural indicators such as air temperatures, river flows, and other wildlife movements were used to plan the timeline of fisheries surveys. Rich also served an essential role in sharing Tribal perspectives with other researchers and their students who have worked in the Upper Klamath Basin and informing restoration efforts such as where to construct beaver dam analogues (BDAs) and what riparian species to construct them of. She went on to explain that the Klamath Tribes actively use TEK as guidance in determining management actions and planning, including noting the locations of historic spawning grounds, historic species compositions, and function, process, and morphology of aquatic habitats, and providing specific guidance on the desired qualities of restored habitat. Rich concluded the theme of the importance of utilizing natural indicators in understanding ecosystems by saying:

"*When we see all the eagles come up the rivers and perch on the trees along the banks we know that our fish are moving up to spawn; we know when the mountains and higher elevations start to get a good amount of snow that the elk are moving down to the Lowlands; or when we feel the first cold fall breeze that our deer are starting to move around; we understand what our wildlife's diets are, and that they move around to consume different vegetation at different times of the year; all on which plays a role in both our management and our daily lives."*

2.2.2.5 Keith Parker - Senior Fisheries Biologist, Yurok Tribe

Parker was the final presenter in the TEK speaker series. Parker reiterated the importance of TEK to his and other Tribal communities, by reminding the audience that while place-based knowledge has taken millennia in some cases to form, it still is actively evolving and being used to overcome modern food scarcity issues. He shared that the closest grocery store to

[26] Deur, Douglas. 2004. Traditional Cultural Properties and Sensitive Resource Study, Klamath Tribes: Klamath River Project FERC Relicensing Documentation. The Klamath Tribes, Chiloquin.

the lower Yurok Reservation is 25 miles away on Hwy 101 which is routinely closed for repairs, so his community still relies on the river for food despite declining fish abundance.

Parker highlighted some additional differences between TEK and western ecological knowledge that centered around the perspective that humans are either apart from nature or an essential part of it. He gave the example that with western ecological knowledge the natural world could either be something to exploit (resources) or something to protect and remove people from (wilderness). Whereas TEK is a different perspective, where living resources and Indigenous culture are singular, with humanity completely intertwined with nature, along with a responsibility to care for the land and water.

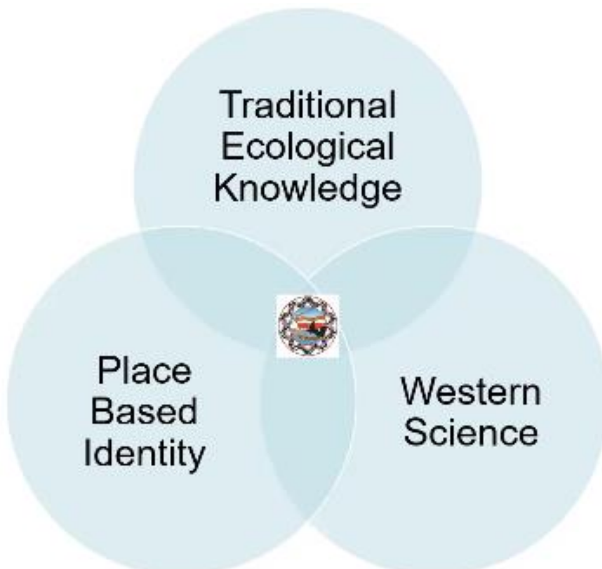

Figure 4: presented by Keith Parker, shows conceptual overlaps between traditional ecological knowledge, place-based identity of Tribal peoples, and western science. Parker included the seal of the Yurok Tribe at the center to show that the Yurok Tribe uses all three philosophies to manage their resources and conduct research.

As a Tribal scientist, Parker was able to give several examples of how his work directly incorporates both TEK and western science and where the overlaps exist between TEK, western science, and place-based identity (Figure 4). Starting with his graduate research at Cal Poly Humboldt (formerly Humboldt State University)[27], he recounted how TEK informed his question and hypothesis testing. Knowing that ocean- and river-maturing Pacific lamprey inhabited the Klamath River, Parker investigated the association of genetic variation between the ecotypes that were known by TEK and other research. He incorporated TEK into his methods as well by using traditional Yurok fishing techniques to capture hundreds of Pacific lamprey at the mouth of the Klamath River, that were then analyzed with molecular and statistical approaches. Parker's findings did not only

[27] Parker, Keith & Hess, Jon & Narum, Shawn & Kinziger, Andrew. (2019). Evidence for the genetic basis and epistatic interactions underlying ocean- and river-maturing ecotypes of Pacific Lamprey (*Entosphenus tridentatus*) returning to the Klamath River, California. Molecular Ecology. 28. 10.1111/mec.15136.

identify the genetic basis of maturation ecotypes and resolve the Klamath River Pacific Lamprey as a single genetic stock, but it reaffirmed TEK pertaining to life-history diversity of the species, applied traditional Yurok names to the ecotypes in the scientific literature, and communicated the value of Pacific lamprey ecotypes in a format more commonly accepted by western science.

2.2.2.6 Traditional Ecological Knowledge (TEK) Panel and Discussion

Following presentations from the panel, the workshop participants asked questions and the panelists took turns answering.

Question 1: Can the panel share any guidance to professors and educators on how to incorporate TEK into a curriculum?

Answer 1: Build relationships with Tribal people in an authentic way first. Do not tokenize Tribal people and consider a form of reciprocity. Don't engage only when you need input but build a continuous relationship. (Reed)

Answer 2: Look to existing programs like Cal Poly Humboldt's Klamath Connection place-based learning community for first year students. Also, get students into the field where they can develop their own connections with people and resources. (Parker)

Answer 3: Orally inherited TEK can be denied credibility in an academic setting without citations. Avoid excluding this information because it isn't written down and trust students. (Rich)

Answer 4: Communicate early and often with Tribal people and be respectful of people's time.

Question 2: What can western scientists avoid when trying to incorporate TEK into their research?

Answer 1: Be aware. Outside researchers can come across as patronizing to Tribal people. Focus on open and authentic communication and engage as equals. (Reed)

Answer 2: Tribes work at their own pace. Be patient and respectful of different timeframes. (McCovey)

After the brief discussion, the panelists volunteered to be available for the remainder of the workshop to field individual questions from the other workshop participants.

2.2.3 *How Rivers Respond to Dam Removal*

2.2.3.1 George Pess – Watershed Program Manager, NOAA Fisheries & Jeffrey Duda - Research Ecologist USGS: Dam removal response, conceptual models, and real examples

Pess presented on four primary questions: How do ecosystems respond to dam removal? How do these models and examples apply to the Klamath dam removal? What do we know about the temporal component? What are the most important elements to good collaborative research for large-scale dam removal? He also shared information from the Elwha River dam removal around key pieces of data and recommendations for collaborative processes.

To answer the first question, Pess began by discussing research on the issue[28] which identified the processes affecting biological responses to dam removal, identified the spatial extent of dam removal impacts, and illustrated that although responses can be complex, they also can be predicted. The research highlighted that ecological responses to dam removal are generally governed by a common set of physical and biological linkages and feedback loops. These linkages are also dynamic and create nonlinear ecological response trajectories. Here, Pess presented the example that relative abundance of fish, invertebrates, and periphyton may decline rapidly following dam removal, increase exponentially in an early recovery period, and then are expected to stabilize as the ecosystem recovers. These responses can be predicted if the strength of the linkages and subsequent feedback are known but must be viewed within the spatial context of the dominant processes which vary above the former reservoirs, within the former reservoirs, and below the former reservoirs. While these conceptual models are highly informative for designing studies and monitoring, they can also be applied to quantitative models such dynamic food web models[29].

Pess addressed the temporal component by presenting another conceptual model that suggests that site-level changes like turbidity and suspended sediment concentration tend to happen on the scale of hours or days; reach-level changes like streambed particle size, juvenile fish density, or species composition tend to happen on the scale of months or years; and watershed-level changes such as salmon population abundance, vegetation communities, wood recruitment, and channel types can respond on the scale of decades (Figure 5). On the Elwha, this model was mostly accurate in that the biological change took longer while the physical changes happened more rapidly. Pess went on to caution that although the temporal scale of responses to dam removal is variable, the public will expect answers to a variety of questions before some of the responses have had time to be enacted, and that managing expectations is extremely important especially because of uncontrollable factors such as hydrologic anomalies or poor ocean conditions or overharvest which can affect salmon populations.

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[28] Bellmore, J.R., Pess, G.R., Duda, J.J., O'Connor, J.E., East, A.E., Foley, M.M., Wilcox, A.C., Major, J.J., Shafroth, P.B., Morley, S.A., Magirl, C.S., Anderson, C.W., Evans, J.E., Torgersen, C.E., and Craig, L.S., (2019). Conceptualizing Ecological Responses to Dam Removal: If You Remove It, What's to Come?: BioScience, v. 69, no. 1, p. 26-39, doi: 10.1093/biosci/biy152, https://doi.org/10.1093/biosci/biy152

[29] Bellmore, J.R., Benjamin, J.R., Newsom, M., Bountry, J.A. and Dombroski, D. (2017), Incorporating food web dynamics into ecological restoration: a modeling approach for river ecosystems. Ecol Appl, 27: 814-832. https://doi.org/10.1002/eap.1486

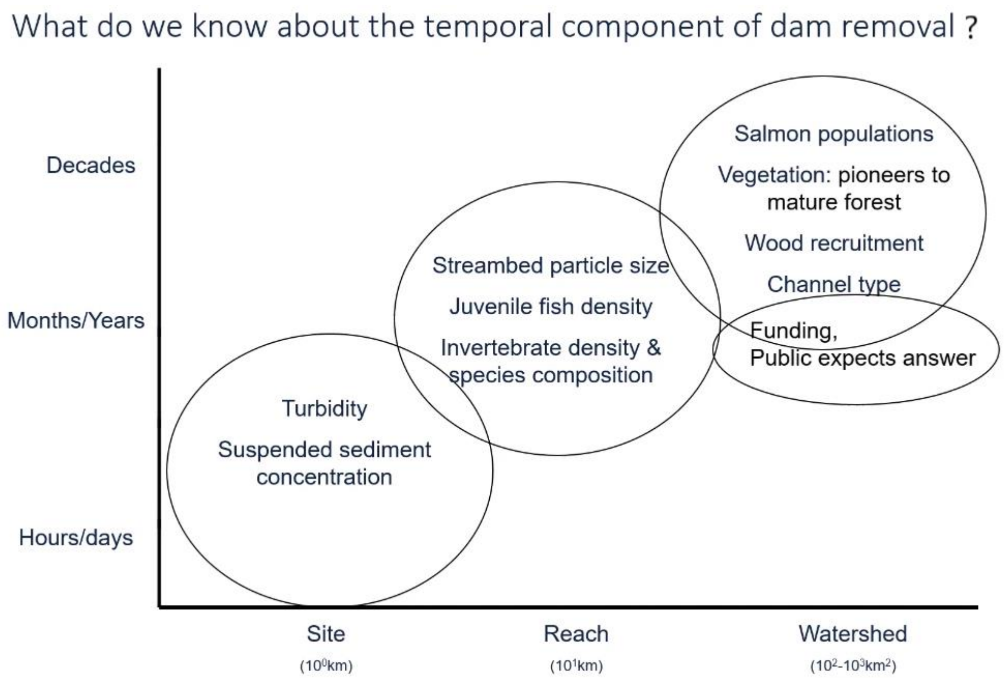

Figure 5: Conceptual model showing how different physical and biological responses to dam removal could vary in time (y-axis) and space (x-axis).

At this point, Jefferey Duda presented on the utility of using environmental DNA (eDNA) to evaluate the return of eleven anadromous and adfluvial fishes to the reaches of the Elwha River to which they were previously excluded, following dam removal[30]. Duda emphasized how fish life history is an important factor when considering the anticipated timeline of reestablishment following restoration action and explained how chum salmon (*Oncorhynchus keta*) return to the Elwha River to spawn during periods that suspended sediment tends to be high, and therefore have been the slowest species to recover.

Pess followed up with a narrative about contextualizing fisheries data and the importance of accounting for distribution and life history diversity when analyzing the effects of dam removal. He showed that although most species were found to be spawning above the former dam sites on the Elwha River, Chinook salmon rarely made it above Glines Canyon dam site, even after removing a rockfall barrier that temporarily blocked their migration. Pess suggested that the spring-run Chinook salmon, might be absent from or in low abundance among the lower basin fish and that more generations would have to return to ascertain if that ecotype would reoccupy the upper Elwha River. Pess gave another example, of coho salmon returns in the Elwha River, by presenting juvenile coho salmon emigration data from two streams. He showed how in the warmer, lower-gradient stream more coho were out-migrating as smolts, whereas in the colder, higher-gradient stream more coho were out-migrating as fry and rearing in the lower river. This life history diversity has increased abundance in coho returns in the Elwha River. Pess went on emphasize the importance of baseline data in interpreting change over time and presented data on migratory bull trout (*Salvelinus confluentus*) in the Elwha River, showing that bull trout were utilizing more of the watershed and had improved condition factor compared to the pre-

[30] Duda, J. J., Hoy, M. S., Chase, D. M., Pess, G. R., Brenkman, S. J., McHenry, M. M., & Ostberg, C. O. (2021). Environmental DNA is an effective tool to track recolonizing migratory fish following large-scale dam removal. Environmental DNA, 3(1), 121–141. https://doi.org/10.1002/edn3.134

dam-removal fish[31]. Pess also presented on the return of summer steelhead[32]. Summer steelhead have returned to the upper Elwha River and are another example of how connectivity allows for a greater expression of life-history variation and can lead to increased abundance[33].

Pess closed by communicating a key suggestions on project management:

1. The project is going to be larger than imagined, so communicate and collaborate as much as possible.
2. There will be funding shortfalls but keep monitoring and focusing on essential time series data.
3. Champions are needed and leadership is organic.
4. Definitions of success are needed, so control the narrative around success.
5. Surprises will happen, so be flexible.
6. Failures are inevitable, so adjust and adapt.

And on adaptive monitoring:

1. Collect a variety of metrics for documenting change and collect before data.
2. Quantify background variability and noise in datasets to increase signal sensitivity.
3. Required monitoring can change, be flexible.
4. Database management is critical for timely sharing of data.
5. Timely results are needed for some management issues. Plan for enough people to collect, process, analyze and write up data. Annual reports are a good idea.

And on coordination:

1. Build collaborative networks to foster multidisciplinary studies, expand questions, and efficiently use funding.
2. Host research symposia, attend conferences, coordinate a communication strategy with the media, and continue to give in-person tours of the project.

2.2.4 Klamath Basin Monitoring Overview

Tommy Williams with the NOAA Fisheries Southwest Fisheries Science Center introduced the session and speakers to give an overview of existing monitoring and research currently occurring within the Klamath River Basin. The intention of the session was to both update the research community on ongoing work in the basin and inform them about the differences between mandated monitoring activities and compliance related activities.

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[31] Brenkman, S.J., Peters, R.J., Tabor, R.A., Geffre, J.J. and Sutton, K.T. (2019). Rapid recolonization and life history responses of Bull Trout following dam removal in Washington's Elwha River. North American Journal of Fisheries Management, 39(3), pp.560-573. https://doi.org/10.1002/nafm.10291

[32] Fraik AK, McMillan JR, Liermann M, Bennett T, McHenry ML, McKinney GJ, Wells AH, Winans G, Kelley JL, Pess GR, et al. (2021).The Impacts of Dam Construction and Removal on the Genetics of Recovering Steelhead (*Oncorhynchus mykiss*) Populations across the Elwha River Watershed. *Genes*. 12(1):89. https://doi.org/10.3390/genes12010089

[33] Duda, J.J., C.E. Torgersen, S.J. Brenkman, R.J. Peters, K.T. Sutton, H.A. Connor, P. Kennedy, S.C. Corbett, E.Z. Welty, A. Geffre, J. Geffre, P. Crain, D. Shreffler, J.R. McMillan, M. McHenry, G.R. Pess. (2021). Reconnecting the Elwha River: Spatial patterns of fish response to dam removal. Frontiers in Ecology and Evolution 9:e765488. https://doi.org/10.3389/fevo.2021.765488

2.2.4.1 Lower Klamath Project Restoration Monitoring, Daniel Chase - Western Region Director of Fisheries, Aquatics & Design – RES

Chase presented on the compliance monitoring for the Lower Klamath Project (Klamath River Renewal Project) as outlined in the Lower Klamath Project Management Plans[22]. He began by introducing Resource Environmental Solutions (RES) as the largest ecological restoration provider in the country, including approximately 1,000 employees over 40 operating hubs. RES serves as the restoration contractor (as opposed to the dam removal contractor). RES supports the project's regulatory process, will implement biological conservation measures, conduct long-term monitoring and maintenance to meet performance criteria and provide a performance guarantee. RES is involved in project design, permitting, development of success criteria and performance measures, Overseeing and implementation of restoration construction, and conducting restoration monitoring and maintenance.

Chase highlighted the importance of the cultural significance of the Lower Klamath Project and noted that RES has been prioritizing working closely with Tribal partners including the Yurok Tribe, the Hoopa Valley Tribe, the Karuk Tribe, the Shasta Indian Nation, and the Klamath Tribes who have been involved in dam removal since the Lower Klamath Project first began construction in 1918.

He continued to review the project goals, principal of which is to "Achieve dam removal, a free-flowing condition on the Klamath River, and volitional fish passage" and to do so by the deconstruction of four hydroelectric facilities on the Klamath River: J.C. Boyle Dam, Copco No. 1 Dam, Copco No. 2 Dam, and Iron Gate Dam, none of which are operated for flood control or the delivery of agricultural/drinking water.

Chase went on to summarize the upcoming scheduled periods of dam removal: Pre-drawdown, consists of a 1-year period during which dam removal and restoration preparation actions as well as pre-drawdown construction will occur, Restoration & Construction, consists of reservoir drawdown, dam removal, and restoration construction for two years, and Monitoring and Maintenance, which will consist of required maintenance and monitoring actions, will continue for at least five years, and will end only once performance criteria are met. Primary restoration objectives include: a free-flowing river resulting in volitional fish passage, stabilization of remaining sediments from the former reservoirs through supplemental sediment evacuation and sediment stabilization through revegetation, and habitat enhancement through large wood placement, and improved habitat complexity within and along tributary channels. As the reservoirs are drawn down, sediment evacuation activities will occur, and revegetation activities through seed dispersal and direct planting will occur. Channels will be reconstructed at the former dam sites and volitional fish passage monitoring will occur throughout the former dam and reservoir footprints.

Revegetation work will occur from 2024-2025 and monitoring will occur from 2026 onwards. Co-led by Joshua Chenoweth, Senior Riparian Ecologist with the Yurok Tribe, RES will establish permanent reference plots, conduct invasive exotic vegetation (IEV) treatment, monitor reference plots, establish treatment & control plots for annual monitoring, and report on findings. Additional revegetation data to be collected will include landform, species richness, tree & shrub density, vegetation cover, exotic vegetation relative frequency, and photo documentation.

Water quality monitoring will occur from 2022 to 2025 and onward. RES maintains nine water quality monitoring stations, three of which are new additions. In coordination with the Karuk Tribe, the Yurok Tribe, the Klamath Tribes, and USGS, RES will provide for continuous water quality monitoring, water quality and sediment grab sampling and laboratory analysis, quantification of suspended sediment load, and reporting. Data collection will include approximately 15 water quality parameters, locations, and photo documentation.

Volitional fish passage and anadromous fish monitoring will occur post-drawdown. For volitional fish passage, planned work includes tributary confluences and restored channel monitoring, ground and drone based surveys, and reporting. Data collection will include documentation of fish presence, survey dimensions, photo documentation, and spatial reference. Beginning in 2024, 49 river miles will be surveyed (22 miles within former reservoir footprints), with the objective of documenting residual reservoir sediments and identifying anthropogenic debris that could be obstructing fish passage. Anadromous fish presence monitoring will begin post-drawdown and limited to California. The intention of the monitoring is to inform volitional fish passage within the former reservoirs, within key tributaries, and in the Klamath River between Copco Lake and the CA/OR Stateline. Planned work will include spawning-ground surveys, coordination with agencies and tribes engaged in life-cycle monitoring, and reporting. Data collection will include species and life stage data, location, distribution, and surveyed areas.

Aerial monitoring will occur during drawdown and post-drawdown. In addition to aiding in volitional fish passage monitoring, aerial monitoring will be one component of hydrologic, vegetation, and other biological monitoring. A ground-based photo point monitoring design will be established across the project area as well and will include begin pre-drawdown and continue through post-drawdown. Data collection will include establishment of fixed photo point locations, imagery, and reporting. Data will be shared either in reports or made publicly available via the Klamath River Renewal Project Data Management Platform[34].

Additional Fisheries actions undertaken by RES, outlined in the Aquatic Resource Management Plan, occurring in 2023 and 2024, include a reservoir sucker relocation action, an overwintering juvenile coho salmon relocation occurring prior to dam removal (focusing on the 60 miles of river between Iron Gate Dam and Happy Camp, CA), a coho spawning survey in the five mile reach below Iron Gate Dam and construction and drawdown related fish relocation actions. The sucker relocation effort will occur in April and May 2023 and will

[34] KRRP Data Management Platform and data request form links: Website: https://klamath-data-management-platform-klamath.hub.arcgis.com/ Form: https://survey123.arcgis.com/share/bb4bf51cf5d841e39ef155b9633ea751?portalUrl=https://Klamath.maps.arcgis.com Contact: KlamathInfo@res.us

include the movement of suckers (*C'waam* and *Koptu* or *Deltistes luxatus* and *Chasmistes brevirostris*) entrained in the Lower Klamath Project reservoirs, and movement of the fish offsite to locations overseen by the USF&WS and the Klamath Tribes. Moved suckers will receive PIT tags and tissue will be collected for a genetic library and species assignment. The overwintering juvenile coho salmon relocation effort will occur pre-drawdown in November or December 2023, will include salvage and relocation of juvenile coho salmon to off-channel sites that have previously been identified as suitable by Karuk Tribal Fisheries, to mitigate exposure to the anticipated high suspended sediment likely to occur during reservoir drawdown. The juvenile salmon relocation effort will occur during drawdown (anticipated March through July) and will include salvage and relocation of salmonids if temperature/suspended sediment thresholds are reached. Data collection will include size, number, location, and species of fish moved, as well as reporting on the environmental triggers that support the need for relocation. Salmon and steelhead spawning habitat monitoring will be implemented in 2024, and potentially 2025, in the post-drawdown phase in order to assess quantity of spawning habitat. Reporting will include spawning gravel patch size, substrate composition, tributary discharge, survey length, and locations. Spawning habitat monitoring is being completed to evaluate if the temporary impacts to salmonid spawning habitat caused by the reservoir drawdown is being offset by the long-term benefits of the project.

2.2.4.2 Klamath Basin Fishery Monitoring Overview, Crystal Robinson – Senior Environmental Scientist – Klamath Watershed Program, CDF&W

Robinson delivered a summary of the extent and purpose of fisheries monitoring in the Klamath River Basin downstream of Iron Gate Dam. Robinson showed the locations of the juvenile salmonid trapping which includes fyke-netting and rotary screw-trapping and is completed by Tribes and agencies including USF&WS, the Karuk Tribe, the Yurok Tribe, CDF&W, and others. The main purpose of the majority of the fisheries monitoring is to forecast population abundance for the management of fisheries.

Coho life history projects were also highlighted in the talk and include studies on habitat utilization. These are mostly collaborative projects and rely on the expanding PIT tagging and antenna network in the Klamath River Basin. Adult steelhead abundance data is collected by the USFS, Salmon River Restoration Council, and CDF&W on the Scott River. The Salmon River Restoration Council hosts a collaborative effort to count spring Chinook in the Salmon River. Three shared databases are where the majority of fisheries data are stored and shared, including the Megatable (1978 – present), the Coastal Monitoring Program Database (1978 – present), and the Klamath Basin Fisheries Collaboration Database which includes PIT tagging data from 2009 to the present.

Upcoming monitoring efforts lead by CDF&W for post dam removal includes four phases: fish presence, establishment, abundance/productivity, and spatial structure; a draft plan has been created. The plan focuses on working with collaborators, utilizing existing methodologies, and exploring other viable monitoring approaches.

Robinson noted that the Klamath Basin Integrated Fisheries Restoration and Monitoring Plan (IFRMP) is available and includes a monitoring summary table in chapter 7. https://ifrmp.net/

Additionally, ODF&W has published their Plan for the Reintroduction of Anadromous Fishes and the Implementation Plan for the Reintroduction of Anadromous Fishes into the Oregon Portion of the Upper Klamath Basin available on their Klamath Anadromous Fisheries Reintroduction program website: https://www.dfw.state.or.us/fish/CRP/klamath_reintroduction_plan.asp .

2.2.4.3 Summary of Sediment and Geomorphic Monitoring Pre-Dam Removal, Liam Schenk – Science Advisor – USGS

Schenk gave a presentation on sediment and geomorphic monitoring and results of the monitoring completed at the time of the workshop. This work included information on reservoir sediment, mainstem sediment flux, and river geomorphology. Data presented regarding reservoir sediments included that the sediments entrained behind the dams are approximately 13 million cubic yards, that it is 85% fine-grained sediment, and that 35-65% of the material is expected to erode. Data presented regarding mainstem sediment flux included that hydrology will be a key factor in sediment flux, peak suspended sediment concentrations of 10,000-20,000 mg/L are expected below Iron Gate Dam, suspend sediment concentrations are expected to attenuate downstream, and suspended sediment concentrations may take two or more years to return to baseline. Data presented regarding geomorphology included that the river corridor is dominated by coarse-grained material, the channel is incised, narrow, and often constrained by rock outcrops, significant sediment deposition is expected downstream to Cottonwood Creek (13 km downstream), and that textural changes are expected downstream to the Estuary (>300 km downstream).

Next, Schenk outlined the monitoring that will be completed by RES, Karuk Tribe, Yurok Tribe, and USGS. Suspended sediment monitoring will include measurements of turbidity, suspended-sediment concentration, and suspended-sediment flux estimates using surrogate regression models. Geomorphic monitoring will include characterizing grain size in deposited sediment from Iron Gate Dam to the Estuary. Schenk shared the methods used to track fine sediment through the river corridor, including sediment flux metrics (turbidity and suspended sediment concentration), sediment fingerprinting (to differentiate reservoir sediments from other sources), morphological changes (topobathymetric LiDAR, side-scan sonar, and UAS), and textural changes in bed sediments (with digital elevation models for surface roughness and orthomosaic imaging for digital grain size estimation).

A pre-dam removal suspended sediment load evaluation will be conducted before dam removal to characterize pre-dam removal suspended sediment flux from water year 2019-2023. Sediment fingerprinting, trace metals, and using diatoms as a tracer will all serve to quantify and trace reservoir sediments.

USGS has funded much of the morphological change research to date in the Klamath as part of the Integrated Water Availability Assessment (IWAA) program. This work has included using remote-sensing methods including LiDAR, sonar, UAS imagery, and underwater imagery to develop a geospatial framework to assess the physical response to dam removal. This includes repeat monitoring sites, and an assessment of baseline geomorphic conditions.

2.2.4.4 Water Quality and Ecosystem Process in the Klamath Basin: Monitoring and understanding to inform predictions of river response to dam removal, Laurel Genzoli – PhD Candidate – University of Montana

Genzoli presented on monitoring and analysis informing the current understanding of how dam removal will influence ecosystem response and water quality. Genzoli focused on expected changes downstream of and within the reservoir reach. Major changes are expected in the reservoir reach as the environment adjusts from a lentic to a lotic system. The restoration of a more natural sediment regime and riverine connectivity will alter the movements of water, sediment, and other materials through the system which are expected to be the drivers of ecological change.

Genzoli then summarized the extent of water quality monitoring throughout the Klamath Basin that has been summarized by KBMP[35], the monitoring done by the Tribes, as well as additional monitoring efforts within the reservoir reach that have been led by PacifiCorp, NOAA, Cal Poly Humboldt, BLM, ODEQ, the RES, UC Davis, and USGS.
Transitioning to what is currently known about Klamath River water quality, Genzoli highlighted that dams, nutrient inputs, and flow alterations degrade water quality on the Klamath, many water quality parameters currently exceed management thresholds, and that Harmful Algal Blooms (HABs) both are the cause and consequence of water quality concerns in the Klamath Basin. Overall, HABs that cause microcystin are expected to be mostly eliminated within and below the reservoir reach because the reservoirs were the main source of the blooms. The natural springs along the reach are expected to provide cold water refugia for native fish. Additionally, dam removal is expected to cool late summer and fall temperatures in the reaches between Keno and about to the Scott River Confluence, providing a benefit for migrating fall-run salmon[36]. Nitrogen and phosphorus concentrations are high in the Klamath River Basin, and dam removal is expected to increase nutrient concentrations in the river because the reservoirs are currently acting as nutrient sinks. Genzoli explained how the Klamath River is among the most productive rivers measured and as a result, large daily fluctuations of dissolved oxygen and pH occur. Changes to these fluctuations following dam removal will be difficult to predict, because algae and plant growth are also affected by scour, light, and nutrients.

Rooted aquatic plant cover is expected to decrease due to increased scour from more natural sediment regimes, but expected effects on filamentous algae remain unclear. Invertebrate data collection is underway, with active collection by the Yurok Tribe and UC Davis from 2020 to the present, a subset of the 16 sites is sampled four times per year. Additionally, Cal Poly Humboldt, the Karuk Tribe, and UC Davis are conducting a five-year study (2022-2026) with sites on the mainstem and tributaries to examine invertebrate and fish diet response to dam removal. The invertebrate *Manayunkia occidentalis*, the host for the parasite *Ceratonova shasta*, is also being studied extensively by researchers at OSU. Genzoli concluded by sharing that the long-term water quality and ecosystem monitoring in the Klamath Basin provides a useful baseline to compare ecosystem changes following dam removal, that recent monitoring and special studies can fill gaps in monitoring and address management questions, and that there are opportunities to integrate monitoring data into hypothesis-driven research in the Klamath River.

[35] https://kbmp.net/maps-and-data/monitoring-locations
[36] Perry, R.W., Risley, J.C., Brewer, S.J., Jones, E.C., and Rondorf, D.W., 2011, Simulating daily water temperatures of the Klamath River under dam removal and climate change scenarios: U.S. Geological Survey Open-File Report 2011- 1243, 78 p.

2.2.4.5 Examples of Tribal Wildlife Research and Monitoring Projects in the Mid and Lower Klamath River Basin, Hans Voight –Director of the Natural Resources Department– Resighini Rancheria

Voight presented an overview of Tribal research and monitoring projects related to wildlife species in the Klamath Basin. He began by discussing the Karuk Department of Natural Resources Wildlife Program which works throughout Karuk Aboriginal Territory and highlighted the following programs:

1. *sahpihnîich* (Beaver) Restoration and Recovery: beaver presence/absence and habitat condition along Klamath river mainstem from Iron Gate dam to Aikens Creek.
2. *íshyuux* (Elk) Ecology and Management initiative: research on population dynamics, movement/migration, and habitat uses of elk in Karuk lands
3. *makaamkuuk* (upslope large mammals) project: research, monitoring and management of deer, elk, bear, and cougar in Karuk Territory
4. *asáxvuh* (Western pond turtle) presence/absence and habitat monitoring
5. *tatkunuhpíithvar* (Pacific fisher) and *yupipthárish* (Humboldt marten) research and monitoring
6. *timshúkriih* (bats) acoustic recorders
7. *Kaschiip* (porcupine) presence/absence
8. Biodiversity monitoring and stewardship for Karuk Aboriginal Lands

Next, Voight listed some noteworthy wildlife research and monitoring projects led by the Yurok Tribe, which are intended to be multi-year and encompass before, during, after dam removal conditions. They included:

1. Foothill yellow-legged frog egg mass surveys (2010-2011), which are conducted in coordination with USF&WS and Yurok Tribal Fisheries and funded by Future for Wildlife Foundation. Walking surveys of pre-identified gravel bars with appropriate substrate and post-amplexus, within each of four reaches within the Yurok Reservation. Very few egg masses were identified, when compared to the Trinity River and other tributaries.
2. Western Pond Turtle surveys (2018) which were conducted in coordination with Cal Poly Humboldt students and funded by Sequoia Park Zoo Foundation. These surveys included randomized 5-mile surveys within each of the four 11-mile reaches. Few sightings were recorded (n=10), which likely included duplicates
3. North American Bat Program Monitoring (2021-2023) which is conducted in coordination with USF&WS, the USGS, and Cal Poly Humboldt as part of a river length study. The work is funded by USF&WS. The data support baseline insectivorous bat population monitoring pre-dam removal and before the potential arrival of bat White-Nose Syndrome. Five grid locations were surveyed, including both stationary and mobile acoustic surveys, and 10-12 bat species identified across all sites including: Townsend's big eared bat (*Corynorhinus townsendii*), the big brown bat (*Eptesicus fuscus*), western red bat (*Lasiurus frantzii*), hoary bat (*Lasiurus cinereus*), silver haired bat (*Lasionycteris noctivagans*), California myotis (*Myotis californicus*), long-eared myotis (*Myotis evotis*), little brown bat (*Myotis lucifugus*), fringed myotis (*Myotis thysanodes*), long-legged myotis (*Myotis Volans*), Yuma myotis (*Myotis yumanensis*), and Mexican free-tailed bat (*Tadarida brasiliensis)*.

As a follow up to the Yurok Tribe's Bat monitoring program, Ryan Matilton and Barbara Clucas at Cal Poly Humboldt are partnering with the Yurok Tribe, the Karuk Tribe, and USF&WS to expand bat monitoring prior to dam removal to include sites from Iron Gate Dam to Terwer Riffle near the Klamath River Estuary. The purpose of this project is to establish a baseline for bat species diversity and activity pre-dam removal and to determine seasonal variation in bat species.

Voight also highlighted Resighini Rancheria Natural Resources Department wildlife projects including:

1. The Resighini Rancheria Humboldt Marten Camera Project (2021-2022), which was conducted to study Humboldt marten (*Martes caurina humboldtensis*) and other carnivores in the Lower Klamath River and included 10 baited and 4 non-bated game cameras. The project was funded by the Bureau of Indian Affairs (BIA). Ten carnivore species were detected including fisher (*Pekania pennanti*), bobcat (*Lynx rufus*), coyote (*Canis latrans*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), gray fox (*Urocyon cinereoargenteus*), black bear (*Ursus americanus*), river otter (*Lontra canadensis*), mink (*Neogale vison*), and long-tailed weasel (*Neogale frenata*).
2. Dragonfly diversity study (2019-2022)
3. American Bullfrog Monitoring, Removal, and Prey Impact Study (2018-2022)
4. Spring Bird Migration Point Counts (2019-2022)
5. Wetland Amphibian Monitoring (2018-2023)

2.3 Breakout Groups Day 1

2.3.1 Geomorphology and Hydrology

The geomorphology/sediment & hydrology breakout group consisted of both in person and online subgroups. The group facilitators were Jenny Curtis with the USGS and Mike Belchik with the Yurok Tribe. Participants in the geomorphology/sediment & hydrology breakout group included Jay Stallman (Stillwater Sciences), Kayla Fitzpatrick (CPH), Dave Coffman (RES), Grant Johnson (Karuk Tribe), Bonnie Bennett (Quartz Valley Indian Reservation), William Nuckoles (OSU), Mitzi Wickman (Mid Klamath Watershed Council), DJ Bandrowski (Yurok Tribe), Nate Bradley (USBOR), David Gaeuman (Yurok Tribe), Liam Schenk (USGS), Julie Alexander (OSU), Qualla Ketchum (CPH), Hans Voight (Resighini Rancheria), Chauncey Anderson (USGS), and Felicity Cross (Yurok Tribe). The online group consisted of Cleo Woelfle-Hazard (Facilitator)(UW), Sheena Sidhu (Jasper Ridge Preserve), Rick Colwell (OSU), and Brian Cluer (NOAA).

Objective: Identify current projects, gaps in research and monitoring, and opportunities for collaboration and conducting needed geomorphology and hydrology studies related to Klamath River dam removal.

Question 1: What are gaps within this topic that are not yet being addressed?

- How does flow management relate to dam removal? Results from USGS/USBR Integrated Water Availability Assessment (IWAA) study are needed because dam removal will be an inflection point on the flow management timeline. Habitat restoration success could depend in part on understanding what flows will mobilize the bed sediments and impact the ecological processes in the river post-removal, and some predictive models were predicated on specific flows regimes that could now change.
- How will coarse sediments move into the reservoir reaches during drawdown(s)? Future sediment releases from hydroelectric reach and tributaries to the reservoirs are largely unknown.
- What is the residence time of sediment in rearing habitats and thermal refuges?
- What is the right timeframe upon which to repeat hydrogeomorphic monitoring? What is a good temporal resolution for system-wide repeat surveying?
- Why does the river stay turbid for so long following surface flushing flows? How is turbidity related to dissolved oxygen in the system, and what are the lasting impacts on annelid distribution and abundance? How will turbidity affect GPP post-drawdown and dam removal?
- How can we implement low-tech, or observation-based methods for documenting shifts in sediments (e.g., sandbars, spawning gravels) to connect geomorphic change to changes in the culturally important species that use them (e.g., sandbar willow, lamprey larvae, beavers, etc.)? How can we use these methods to improve spatial coverage and engage communities?
- Because bed sediment texture determines some microbial community characteristics, what changes to the riverine microbiome can be expected with changes to suspended sediment regimes and depositional process? How will these changes affect how the microbial community processes methane? How will these changes affect thiamine availability?
- Will spawning gravels below Iron Gate Dam be buried? What will the long-term impact of reservoir drawdown and dam-removal be on those areas? How can we best prioritize both ecology and geomorphology studies?
- The group agreed that the most pressing data gaps are:
    - Bedload characterization
    - Tributary geomorphology

- Water surface elevations – for the calibration and refinement of hydrodynamic models
- Future sediment releases from hydroelectric reach

Question 2: What opportunities exist for addressing identified gaps?

- The Yurok Tribe are planning a full system-wide multi-beam and topo-bathy survey to integrate multibeam and side-scan sonar datasets.
- USGS, RES, and the Yurok Tribe are conducting suspended sediment modeling and monitoring changes in bed sediment textures. USGS is conducting qualitative sediment distribution tracking.
- Oregon State University researchers continue to study sediment effects on annelid distribution and abundance.
- McKinney Fire debris flows could serve as a useful model.
- Side-scan sonar will be useful for modeling annelid distribution and predicting *C. shasta* concentrations.
- Worldwide Hydrobiogeochemistry Observation Network for Dynamic River Systems (WHONDRS)[37], a project of Pacific Northwest National Laboratory, river metabolism, has a program (a system of volunteer scientists who collected samples from N American rivers) where they would do metabolomic measurements and microbial community characterizations. This could be useful.

Question 3: What are the top 3-5 priority areas to address in this topic?

1. The re-examination of flushing flows under a different channel condition post-dam removal. (e.g., what post-dam removal flows will mobilize bed sediments and affect annelid ecology?)
2. Sediment movement and characteristics below the hydroelectric reach
3. Integration of physical processes with ecological response
4. Defining spatial and temporal resolution of data collection for different kinds of data (repeat measurements, time series, etc.)

2.3.2 Water Quality, Food Webs, and Ecology

The water quality, food webs, and ecology breakout group consisted of both in person and online subgroups. The group facilitators were Laurel Genzoli, PhD candidate from the University of Montana, and Randy Turner, Coordinator for the Klamath Basin Monitoring Program. Participants in the water quality, food webs, and ecology breakout groups included representatives from the Klamath Basin Monitoring Program, Oregon State University, USGS, Cal Poly Humboldt, University of Montana, the North Coast Regional Water Quality and Control Board, Hoopa Valley Tribal Fisheries, Riverbend Sciences, the Karuk Tribe, Save California Salmon, Oregon Department of Environmental Quality, Camas, LLC., Yurok Tribe Environmental Department, Cal Poly Pomona, McBain Associates, USFWS, UC Berkeley, and Stillwater Sciences.

Objective: Identify current projects, gaps in research and monitoring, and opportunities for collaboration and conducting needed water-quality and food webs/ecology studies related to Klamath River dam removal.

[37] https://www.pnnl.gov/projects/WHONDRS

Question 1: What are gaps within this topic that are not yet being addressed?

- A conceptual model to link water quality to ecological outcomes is missing. Specifically, a conceptual model to create and test hypotheses related to the effects of water quality/quantity/distribution changes (i.e. temperature, pH, nutrients, sediment, discharge, hydrograph, etc.) on ecosystem responses such as stream metabolism (gross primary productivity and ecosystem respiration) or *C. shasta* and other disease responses, and secondary or tertiary responses such as fish health, fish survival, and abundance of culturally and economically valuable fishes.
- Samples collection and archiving for posterity is missing. Specifically, ecological samples such as eDNA, sediments, water, tissue, and others should be collected now for comparison to post dam removal samples.
- What microbial community changes will occur with dam removal, which will affect biogeochemical cycling of nutrients and carbon? Microbial communities downstream of the dams in the Klamath River may be less diverse and more similar to those of the reservoirs, pre-drawdown, because microbial diversity tends to be lower in lakes/reservoirs than in rivers. Taxa in river sediments downstream may be less efficient at processing carbon, particularly allochthonous (terrestrial-derived) carbon because the enzyme expression has been filtered out by the autochthonous (algae-derived) carbon in reservoirs over time. This could change when the reservoirs are removed.
- Mercury methylation may be important pre and post dam removal and mercury methylation genes could be picked up by the microbial community. Methane producers, iron-reducing, sulfate-reducing, and mercury methylation genes can be picked up in the microbial community through metatranscriptomics. Beaver ponds have a lot of methylmercury as well. Tributaries with BDAs could become a more prolific environment for mercury methylation once the reservoirs are removed.
- Will new microbial taxa migrate upstream with fish post-dam removal? Ocean microbial community members may be reintroduced to the Klamath River system as fish migrate into upper reaches again. How will this affect carbon and nitrogen cycling in general?

Question 2: What opportunities exist for addressing identified gaps?

- Tribal water quality monitoring has filled in gaps in coverage and research for a long time. This is a great resource. Additionally, the RES water quality database will be a good resource for researchers.
- The work of Laurel Genzoli (University of Montana) with Gross Primary Productivity (GPP), Megan Skinner with Upper Klamath Basin nutrient dynamics, Desiree Tullos (Oregon State) with water quality and food webs, Julie Alexander with *M. occidentalis,* and Alison O'Dowd (Cal Poly Humboldt) with macroinvertebrates may present an opportunity to build a conceptual model of ecological outcomes and examine potential linkages between other water quality parameters and *M. occidentalis* distribution and abundance.
- Smaller fish/biosentinels and Tribal fish collections could be used for mercury fish tissue sampling. eDNA baseline samples could be used for metatranscriptomics to evaluate mercury methylation changes before/after dam removal.

Question 3: What are the top 3-5 priority areas to address in this topic?

- The group identified that creating a repeatable method for identifying research and monitoring gaps like a formal literature review would be a prudent first step.
- Prioritization of the collection of metrics that require baseline data rather than those monitoring activities that can take place after dam removal was deemed important.
- Building the conceptual model linking water quality outcomes such as temperature, GPP, and pH, to *C. shasta* and other diseases, to fish health and survival, to fish abundance is a priority.
- Measuring the chemical, biological, and food web recovery within the reservoir and dewatered reaches is essential.

2.3.3 Fisheries and Fish disease

The fisheries and fish disease breakout group consisted of both in person and online subgroups. The group facilitators were Crystal Robinson, Senior Environmental Scientist with California Department of Fish and Wildlife, Nicholas Som, Biological Statistician with the US Fish and Wildlife Service and Adjunct Professor of Statistics at Cal Poly Humboldt, Bob Pagliuco, Habitat Restoration Specialist with the NOAA Restoration Center, and Tommy Williams, Research Fisheries Biologist with the NMFS Southwest Fisheries Science Center. Participants in the fisheries and fish disease breakout group included representatives from NOAA Fisheries, Trout Unlimited, USGS, the Yurok Tribal Fisheries Department, the Salmon River Restoration Council, Oregon State University, NMFS Southwest and Northwest Fisheries Science Centers, UC Berkeley, USFWS, CalTrout, Resource Environmental Solutions, the Middle Klamath Watershed Council, UC Davis, the Hoopa Valley Tribal Fisheries, Karuk Tribal Fisheries, ODF&W, CDF&W, Six Rivers National Forest, Thomas Gast and Associates, and the Resighini Rancheria.

Objective: Identify current projects, gaps in research and monitoring, and opportunities for collaboration and conducting needed fisheries studies related to Klamath River dam removal.

Question 1: What are gaps within this topic that are not yet being addressed?

- How will persisting barriers (Keno and Link River dams) impact passage of all life stages of reestablished salmonid populations?
- How will survival of juvenile salmonids change after dam removal?
- What is the distribution and abundance of *C. shasta* and other fish pathogens basin-wide?
- Lost River and shortnose suckers (*C'waam* and *Koptu* or *Deltistes luxatus* and *Chasmistes brevirostris*) in the Upper Klamath Basin have not had detectable recruitment for 30 years. Sucker recruitment in the Upper Basin is not understood but is likely connected to degraded water quality. What is preventing successful sucker recruitment and how will these conditions impact reestablished populations of anadromous salmonids?
- Will the Lake Ewauna and the Keno Impoundment reach be a water quality barrier to upstream migration of spring-run Chinook salmon (*O. tshawytscha*)? Will this potential water quality barrier result in an overlap of spawning distribution for spring-run and fall-run Chinook salmon?
- What is the current distribution and abundance of fish pathogens and how will they change after dam removal?
- What are the specific habitat requirements of spring-run Chinook salmon in the Upper Klamath Basin? Which cold-water refugia are most important for the reestablishment of anadromous

salmonids above the dams? Where are the highest priority reaches above the dams for additional restoration?

- What are the *GREB1L* and *OMY05* genotype distributions within populations of *O. mykiss* between and above the dams currently? How do genotype (and phenotype) distributions change following dam removal?
- To what extent do resident, adfluvial/allacustrine, and anadromous forms of *O. mykiss* in the Klamath Basin interact under current conditions? How do resident/adfluvial/allacustrine/anadromous interactions change after dam removal? Will these interactions be related to body size and physical location? How will *O. mykiss* interact with other reestablished salmonids?
- How will heavy metal levels, microcystin toxicity, and nutrition levels of commonly consumed fish species change following dam removal? Following the McKinney fire debris-flows? If there are health risks associated with consuming Klamath fishes for a period of time following dam removal, how can people who rely on the river for food mitigate those risks?
- How can water managers best allocate water to encourage the reestablishment of salmonids after dam removal?
- What is the best way for managers, regulators, contractors, researchers, and the public to share fisheries information about the Lower Klamath Project?
- How will distribution of Pacific lamprey (*Entosphenus tridentatus*) and other lampreys of the Klamath Basin (*Entosphenus* spp.) change following dam removal? How will distribution of green sturgeon (*Acipenser medirostris*) white sturgeon (*Acipenser transmontanus*) change?

Question 2: What opportunities exist for addressing identified gaps?

- Utilization of USGS PIT tag infrastructure in the upper basin and the tribes' PIT tag infrastructure in the lower basin to develop a PIT tagging tracking program.
- Openscapes, the workflow organizer, can be a helpful tool to organize shared information because it is user-friendly.
- Klamath researchers and managers need an ongoing vehicle for collaboration. A forum for the gathering and sharing of ideas could lead to discussion of what is working and things that are not working - adaptive process. This could result in a larger-scale collaboration project like a multi-entity database that is publicly available and could lead to opportunities to compare experiences from the Klamath to those of other dam removal projects.
- Although the IFRMP attempts to address some of the collaboration shortcomings, it has limitations for participation because of funding shortfalls. Sometimes, opportunities for communication happen more organically. Some of the previous efforts to prioritize restoration in the Klamath have not been well captured.
- Interdisciplinary coordination efforts in the basin are not new; KBMP formed from a need to understand Klamath wide water quality concerns 20 years ago, in recognition of the need to communicate water quality issues to fisheries managers.
- The Columbia River Inter-Tribal Fisheries Commission (CRITFC) may be a good model for Tribal collaboration in the Klamath.

- There can be a danger in sharing information for some groups, which is a concern that needs to be addressed to facilitate information sharing.
- If we had increased genetic tools, better understanding of when rare stocks were entering the mouth or where they are distributed in the system would be possible. This may be more important when stocks are developing in the Upper Basin. Examples like Bristol Bay or the Tyee gill-net test fishery on the Skeena River offer good models for in-season management with a genetic stock index.

Question 3: What are the top 3-5 priority areas to address in this topic?

- How will the life histories, distributions, abundances, and interactions of fishes (especially Salmonids, Catostomids, Petromyzontids, and Acipenserids) change after dam removal?
- How will fish disease severity and distribution change after dam removal?
- What are the persistent limiting factors to fisheries recovery after dam removal (i.e., passage, disease, water withdrawals, climate change, degraded habitat, and water quality)?

2.3.4 Vegetation

The group facilitators were Josh Chenoweth, Senior Riparian Ecologist with the Yurok Tribe and Gwen Santos, Senior Wetland Ecologist with Resource Environmental Solutions. Participants in the vegetation breakout group included representatives from the Quartz Valley Indian Reservation, the Karuk Tribe Natural Resources program, Stanford University, and Southern Oregon University.

Objective: Identify current projects, gaps in research and monitoring, and opportunities for collaboration and conducting needed vegetation studies related to Klamath River dam removal.

Question 1: What are gaps within this topic that are not yet being addressed?

- Soil studies are needed in coordination with vegetation plots. Analysis for soil texture, water availability, depth and organics would be especially valuable.
- Localized climate data is needed. Changes in temperature, precipitation, and other localized metrics need to be collected before and after revegetation.
- Vegetation survival studies are needed. Following tagged plants through establishment and growth can inform what perennial species are important for survival and shepherding annual reestablishment.
- Cultural use quality studies are needed. Culturally important species need to be evaluated for pliability, insect infestations, disease, etc. and should be conducted by Tribal ethnobotanists.
- Pollinator surveys should be conducted.
- Measurement of downstream riparian response is warranted. Changes in nutrient dynamics, sediment load, water quality and availability, as well as greater connectivity to upstream seedbeds have the potential to alter riparian habitat and vegetation downstream.

Question 2: What opportunities exist for addressing identified gaps?

- Dr. Chhaya Werner has applied for funding for remote sensing work, mapping reservoir drawdown lines, community assembly and succession studies, terrestrial temperature and moisture monitoring within vegetation plots, and to test IEV management methods through creation of competition gradients through selective weeding.
- Dr. Werner is additionally teaching a field course with guest lectures on vegetation reestablishment in the Lower Klamath Project.

Question 3: What are the top 3-5 priority areas to address in this topic?

- Soil studies and environmental studies were identified as the top priorities for addressing data gaps regarding reestablishment of native vegetation after dam removal.

2.3.5 Wildlife

The group facilitators were Barbara Clucas, Associate Professor of wildlife at CPH, and Ryan Matilton, a graduate student at CPH. Participants in the wildlife breakout group included representatives from Cal Poly Humboldt, Resighini Rancheria Natural Resources, Greencoast GIS, Six Rivers National Forest, Oregon Department of Fish and Wildlife, and California Department of Fish and Wildlife.

Objective: Identify current projects, gaps in research and monitoring, and opportunities for collaboration and conducting needed water-quality and food webs/ecology studies related to Klamath River dam removal.

Question 1: What are gaps within this topic that are not yet being addressed?

- Data management and sharing infrastructure is lacking to ensure that projects are not replicating each other.
- Many taxa are not sufficiently monitored across such a large and rugged region. Capacity and staffing continue to be challenging for wildlife managers/researchers, and many native taxa within the Klamath Mountains region are difficult to sample or cryptic.
- Wildlife has been a secondary focus to fish in this project and has received less funding. Additional funding must be allocated to wildlife projects if population, demographic, body condition, disease, and other data for key wildlife species are to be collected.
- How can researchers ensure wildlife studies from the Klamath will inform and improve future dam removal projects?
- How can researchers find funding to support important wildlife studies and projects in such a short period of time before the dams are removed?
- Will dam removal result in any short-term or permanent decreases in wildlife populations that have been artificially increased by the presence of the reservoirs?

Question 2: What opportunities exist for addressing identified gaps?

- Considering species of cultural importance to the Tribes of the Klamath Basin may increase the probability of getting wildlife projects funded from Bureau of Indian Affairs sources
- Framing studies around indicator species or guilds of species may be a way to expand inference with limited available funding for wildlife studies.
- Pre-proposals to the Wildlife Conservation Board are open year-round now that CDF&W has simplified the application process.
- Additional opportunities may exist for funding graduate students from Tribal backgrounds

Question 3: What are the top 3-5 priority areas to address in this topic?

- Acquiring funding for wildlife projects
- Fostering collaboration and communication to prevent the duplication of efforts
- Create a literature review document for Klamath Basin wildlife researchers
- Encourage better data management

2.4 Invited Speakers Day 2

2.4.1 Klamath Funding Coordination and Opportunities – Bob Pagliuco, NOAA Restoration Center

Pagliuco presented on Klamath Basin funding coordination and opportunities. He began by acknowledging that a high amount of funding is generally available due to the Bipartisan Infrastructure Law, the Inflation Reduction Act, as well as the California budgetary surplus. However, the available opportunities for funding are broad and difficult to navigate. Pagliuco sits on the Klamath Funding Coordination Group (KFCG) whose purpose is to track projects funded in the Klamath Basin, organize funding opportunities, and provide a space where organizations can communicate. He emphasized that this coordination is essential because although the Klamath Basin Restoration Agreement was not enacted, there are many opportunities to fund restoration and monitoring, which taken together and strategically applied, have the potential to bring up to a $1 billion into the Klamath Basin.

The current collaborators of the KFCG include: NOAA, USFWS, NRCS Oregon, NCRS California, USDA, USFS, DOI, BLM, USBR, FEMA, EPA, CDFW, CAL OES, OWEB, ODF&W, ODEQ, and NFWF. He introduced the KFCG spreadsheet[38] that is tracking 173 funding opportunities to coordinate on funding opportunities and sharing information. This spreadsheet helps with developing a list of good projects that could not be reached with annual funding levels to fund in the future.

Pagliuco then presented on the challenges for funding research and monitoring. Of the 173 funding opportunities tracked on the KFCG spreadsheet, only five have explicit categories for monitoring projects. These include the NFWF 5 Star Program[39], the CDF&W/NOAA Fisheries Restoration Grant

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[38] https://resourceenvironmentalsol-my.sharepoint.com/:x:/g/personal/dkeel_res_us/EWBTw6D2z5hMp_WENVp-CSkBlZuppbiV0LBJslMuPVz88A?e=v2ZDfC

[39] https://www.nfwf.org/programs/five-star-and-urban-waters-restoration-grant-program

Program[40], the Dept. of Energy's Environmental System Science Program[41], the USF&W S Recovery Challenge Fund[42], and the CDF&W Drought, Climate, and Nature-Based Solutions Grant Program[43]. He noted that coupling research/monitoring with restoration projects is often successful and gave the following examples: Shasta River Water Conservation Projects, Lower Freshwater Creek Off Channel Habitat Project, Little River Estuary Restoration Project, and the Sugar Creek Coho Refugia Project. These projects tend to include about a maximum of one third of the total cost associated with research and monitoring and are often incrementally funded (Prairie Creek and Martin's Slough are good examples). The same strategy can be used to include outreach and education.

2.4.2 Data Management in the Klamath Basin – Randy Turner KBMP/SFEI

Randy Turner from the Klamath Basin Monitoring Program (KBMP)[44] presented on Klamath Basin data management. He summarized the data available and how it is stored on the KBMP site. Turner used USGS flow data as the gold standard for data management in that it includes clear protocols, regular quality assurance and quality control (QA/QC), thorough review before finalization, and it is publicly available on a user friendly platform. KBMP was formed in 2008 with the goal of bringing water quality stakeholders together, reducing redundant data collection, enhancing cooperation and collaboration, sharing data and research, and establishing QA/QC standards. KBMP manages a monitoring metadata spreadsheet and interactive map[45] that include data from over thirty organizations, nearly 1,000 monitoring locations, 68 parameters, over variable time series and frequencies of sampling. KBMP organizes and tracks standard operating procedures and encourages documenting methods and protocols, including good QA/QC practices, organizing, and reviewing data, and keeping the final use of the data in mind. Turner explained that data storage is highly variable across the Klamath Basin and that storing data on the KBMP website offers a parsimonious solution and commended the USGS real-time water quality station monitoring[46], the Karuk and Yurok sonde data sharing platform[47], and the Klamath Basin Fisheries Collaborative[48] for their publicly available and easily accessible data sharing efforts. Building secure, user friendly, and searchable tools for visualizing and sharing these data are essential. Turner closed by acknowledging that outstanding data management challenges include sharing and management, integration across disciplines, identification of knowledge gaps, and finding new and important questions.

2.4.3 Lower Klamath Project Access and Coordination Considerations -Dave Coffman Klamath Restoration Program Manager

Dave Coffman, the Klamath Restoration Program Manager with RES, presented on Lower Klamath Project access and coordination considerations that are essential for researchers to understand considering the construction and restoration activities occurring from 2023 onward. He discussed the considerations for safety and activities within the hydroelectric reach and along the mainstem Klamath

[40] https://wildlife.ca.gov/Grants/FRGP
[41] https://ess.science.energy.gov/
[42] https://www.fws.gov/service/recovery-challenge-grants
[43] https://wildlife.ca.gov/Conservation/Watersheds/Restoration-Grants/Concept-Application
[44] https://kbmp.net/
[45] https://kbmp.net/maps-and-data/monitoring-locations
[46] https://or.water.usgs.gov/proj/klamath_wq_mapper/
[47] https://waterquality.karuk.us/
[48] https://www.kbfishc.org/

River downstream to Interstate 5. He noted that dam removal and restoration construction activities are intentionally compact, access to hydroelectric reach will be limited due to safety concerns, and that primary requests for access into the project area by anyone need to be directed to KRRC and McMillan LLC. (client representative for KRRC). This coordination will include safety trainings, jobsite check-ins, instructions, and in some cases an escort. This coordination will be run through KRRC, McMillan LLC., and RES, and will include sign in/sign out and no access to active work zones. Following restoration and dam removal in 2025, access coordination is expected to evolve to reflect the reduced amount of construction activities. Additionally, RES is focused on collecting data to meet compliance obligations and therefore has limited capacity to support outside data collection activities. It will be important for researchers to plan ahead, and communicate their access needs ahead of time, by following the established channels.

Coffman noted that if equipment is going to be installed, a proposal and confirmation with McMillen will be required. Due to the nature of the project, it is unlikely that further ground disturbing activities will be approved in time because the environmental and cultural resources review will be run through the FERC office in Portland, OR. If monitoring equipment can be installed to existing infrastructure that will be more likely to be approved. He then shared key contact information for project leads available in SI-2, as well as that of the RES Director of Community Affairs, Dave Meurer, dmeurer@res.us.

2.5 Breakout Groups Day 2

2.5.1 Lower Basin (Weitchpec to Estuary)

The Lower Basin breakout group facilitator was Chauncey Anderson with the USGS and notetaker was Jeff Abrams with NOAA Fisheries. Participants in the Lower Basin breakout group included representatives from NOAA Fisheries, USGS, Stanford University, Resighini Rancheria, the Yurok Tribe, Thomas Gast and Associates, and Oregon State University.

Objective: Identify current projects, gaps in research and monitoring, and opportunities for collaboration and conducting needed Lower Basin studies related to Klamath River dam removal.

Question 1: What are gaps within this topic that are not yet being addressed?

- The estuary has changed drastically due to sedimentation. Yurok Tribal members used to travel out of the mouth regularly and now it is much too shallow to do so. There is the potential for this change to impact fisheries as well because the mouth of the river closes more often and pinnipeds can more easily use the shallow waters to beach migrating salmon, making their predation more effective. There is evidence to suggest that dredging could ameliorate these conditions, and there are efforts now to bring this issue before the Yurok Tribal Council (although it could not be completed before dam removal).
- The effects of the McKinney Fire debris flows were not sufficiently understood in the estuary and offer an opportunity to better understand impacts from dam removal. The elevated turbidity and corresponding decrease in dissolved oxygen impacted the fishery. The Yurok Tribe only harvested about half of their quota, and there were likely a lot of deceased fish that were not recorded. Tribal fishers observed lots of impacted gills on adult salmon. A better understanding is needed of the effects of reservoir sediments on fish health and if

they differ from McKinney Fire debris flow sediment effects. During the debris flow, pH decreased and was slow to recover, which is a strong indicator of reduced primary productivity. How will primary productivity respond to similar increases in turbidity from dam removal?

- Communication and coordination in and of itself is a gap in the Lower Basin. There is redundancy in data collection (e.g., temperature data) due to lack of coordination.
- The extent of flocculation and sedimentation in the estuary that will occur due to dam removal is not well understood, as well as its effects on juvenile salmon, lamprey, and returning adults.
- The Klamath salmon fisheries lack real-time management tools for management upstream based on genetic stock identification (GSI) for timing and distribution of fish coming into the mouth of the river. GSI would allow for the protection of recovering stocks within the basin. Additionally, a higher proportion of coded wire tagged fish would help with in-season fisheries management decisions.
- Better understanding is needed about how agriculture from the Upper Basin influences water quality in the estuary. Most HABs related to agricultural runoff in the Upper Basin do not extend to the estuary due to salinity, but the toxins may not be entirely denatured. The water quality in the Lower Basin in the summer gets so bad that it can cause rashes on humans spending a lot of time in the water.
- The downstream movement and survival of exotic fishes found in the reservoirs warrants additional attention.
- Additional research is warranted into thiamine deficiency in sturgeon and salmon.

Question 2: What opportunities exist for addressing identified gaps?

- No concrete plans to do bathymetry collection in the estuary post dam removal, but there are side-scan sonar opportunities, and Resighini Rancheria is planning to collect repeat topography and bathymetry.
- RES is working with Gybe[49] to conduct hyperspectral monitoring to use satellite data to look at sediment transport and HABs. These data have the potential to fill some gaps in coverage.
- Salinity data is now being collected via handheld YSIs and a real-time sonde at the mouth of Hunter Creek.
- There is a camera pointed at the river mouth that takes three pictures per day with the intention to monitor dynamics at the mouth (takes photos at 10 am, 2 pm and 6 pm). There is a potential to have these images hosted live to track changes during drawdown and dam removal.
- Keith Parker has genetic pre-dam removal genetic data (100% broodstock sampling for Trinity River Hatchery and in-river sampling) for spring and fall Chinook. He also has scales for 26 years for the entire basin that can be genotyped to look at pre vs. post dam removal genetic changes or build a GSI baseline.
- The Yurok Tribe may have some underutilized fisheries technicians that could opportunistically help with estuary monitoring.
- Digital grainsize analysis could be extended to the estuary, and sediment fingerprinting work will apply there as well (this work began in 2023).

[49] https://www.gybe.eco/

- Yurok Tribe Estuary Workshop[50] findings could be reviewed.

Question 3: What are the top 3-5 priority areas to address in this topic?

- Recollect bathymetry of the estuary after dam removal.
- Use the library of Chinook salmon tissue to update the genetic baseline and implement a GSI.
- Build a basin-wide conceptual model that includes the estuary to link land management, wildfire, and water quality to ecological outcomes.

2.5.2 Mid-Klamath (Iron Gate to Weitchpec)

The Mid-Klamath breakout group facilitator was Jenny Curtis with the USGS and notetakers were Julie Alexander with Oregon State University, and Nicholas Som with USF&WS. Participants in the Mid-Klamath breakout group included representatives from the University of Montana, the Yurok Tribe, the Klamath Tribes, the Quartz Valley Indian Reservation, the Karuk Tribe, Cal Poly Humboldt, RES, USFS, Stillwater Sciences, UC Berkeley, Stanford University, USF&WS, USGS, Oregon State University, the Mid-Klamath Watershed Council and Save California Salmon.

Objective: Identify current projects, gaps in research and monitoring, and opportunities for collaboration and conducting needed Mid-Klamath studies related to Klamath River dam removal.

Question 1: What are gaps within this topic that are not yet being addressed?

- A conceptual model to link water quality and fisheries to the impacts of fire is needed to answer the questions:
    - How will the McKinney fire sediment load interact with dam sediment load?
    - How will management affect fire on top of a highly erodible landscape?
    - How will management and wildfire impact in-stream conditions for fish?
    - Will debris flow sediments prevent access to tributary habitats for fish?
- Will tributaries serve as refugia from high suspended sediment concentrations during drawdown and dam removal? Or will they be ecological traps because of temperature or delayed migration?
- Will morphological changes resulting from upstream sediment transport degrade or benefit current cold water refugia? How will these changes impact hyporheic flow interactions?
- The impacts to native freshwater mussels have received little attention.
- During wet years, how will the benthic community respond to more dynamic sediment processes, bed infiltration of fines, deposition, and increased scour? How will macroinvertebrates and larval lamprey respond?
- How will vegetation dynamics change?
- What are the biophysical changes that will affect people's lives/cultural practices?
    - Mental health, wellbeing
    - Sand bars, scour, flushes- better willow materials?

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[50] https://www.kbmp.net/images/stories/pdf/Meeting_Materials/Meeting_22/13_Klamath_Estuary_Workshop_Overview.pdf

    - Broader set of life histories in fish
    - Where is cultural resource access now, how is this shifting?
    - Perceptions of holistic health, mental, physical, spiritual, community health and wellbeing
- There is a lot of local knowledge and less capacity to communicate it. How do we get this information out there? Development of strategies to share information quickly and concisely are warranted.
    - Some colleagues are hesitant to share data widely and make it public. Data sovereignty is tricky and important.

Question 2: What opportunities exist for addressing identified gaps?

- A dams-out scenario 2D, morpho-dynamic, sediment-transport model could help answer many questions.
- An interdisciplinary annual float trip to track changes in the river would be good for teambuilding, collaboration, and monitoring.
- Klamath Basin Fisheries Collaborative PIT tag database, which includes 32 different participants is a good opportunity to ask fisheries questions basin wide.
- Practice communication beyond dataset sharing: useful metadata should include a narrative about the scope, purpose, and clear findings of data shared.
- Stanford University and Karuk Tribe research collaboration on social impact analysis of Klamath Dam Removal with a focus on tribal community wellbeing could begin to answer how dam removal is impacting people's lives.
- Future reanalysis of TMDL (total maximum daily load) should include cultural uses. Water quality targets can align with ceremonial use of the river.

Question 3: What are the top 3-5 priority areas to address in this topic?

- Sediment impacts on ecosystem processes
- Benthic Zone characterization
- Ground water / Surface water interactions
- Spawning distribution
- Human dimensions

2.5.3 Reservoir Reach (Link River to Iron Gate Dam)

The Reservoir Reach breakout group facilitator was Desiree Tullos with the Oregon State University and the notetaker was Dylan Keel with Cal Poly Humboldt/RES. Participants in the Reservoir Reach breakout group included representatives from the NOAA Fisheries, NOAA Restoration, USGS, the Yurok Tribe, RES, Oregon State University, Cal Poly Humboldt, and others.

Objective: Identify current projects, gaps in research and monitoring, and opportunities for collaboration and conducting needed Reservoir Reach studies related to Klamath River dam removal.

Question 1: What are gaps within this topic that are not yet being addressed?

- Funding has been slow to materialize for systematic surveys of species distribution of reservoirs and tributaries, pre-drawdown, and post-dam removal. Distribution of anadromous salmonid and petromyzontid spawners and juvenile rearing will require significant effort. This should include a passage assessment at Moonshine Falls in addition to volitional passage monitoring past former dam sites.
- Fate and transport of invasive freshwater fish and other invasive species, their habitats, and changes in exotic species occupancy in off-channel ponds is warranted.
- Uncertainty exists regarding the conditions for pathogens within the former reservoir reach. Because Keno Dam will now be the compliance point for management of flows for temperature and *C. shasta*, disease-flow management will need to be evaluated.
- Responses of non-restored tributaries will be important. It is possible that the gaging network downstream of Iron Gate and the new mainstem Klamath River gages will not be sufficient to measure or estimate tributary flows.
- Additional restoration funding may be warranted for golden eagle upland habitat and additional wood placements in untreated streams.
- An archive for tissue, scales, whole bodies of fish could be useful for tracking population demographics and life-histories over time.
- Additional monitoring of small mammals and pollinators may be warranted.

Question 2: What opportunities exist for addressing identified gaps?

- Environmental DNA baseline and subsequent sampling can fill gaps in unfunded fisheries distribution monitoring, invasive species monitoring, disease monitoring, ecosystem recovery, and microbiome monitoring. RES has implemented an eDNA sampling program throughout the reservoir reach to fill gaps in monitoring, archive samples, and share with researchers.[51]
- Continue collection of imagery, topography, and bathymetry for ongoing Condor Aviation flights for additional research questions.
- Fisheries salvage efforts present an opportunity to apply PIT tags, collect tissue, and track movement and survival.
- Soil studies and mycorrhizae studies to monitor reservoir sediment conversion to soil, nutrients, and lacustrine sediment depth will be useful for gaging terrestrial ecosystem recovery.
- The data collection undertaken by RES is substantial, data collected in order to comply with permit requirements will be made publicly available either in real-time or by request, and includes, water quality, fish passage/presence, bathymetry, photogrammetry, LiDAR, photo

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[51] https://resourceenvironmentalsol-my.sharepoint.com/:b:/g/personal/dkeel_res_us/EbGetPZIrFNIqKzDFbHziJEB6K72ZQ4kDnNCOPZWezN5pg?e=ExA61F

monitoring, FLIR thermal imaging, reservoir elevations, spawning habitat distribution, wildlife surveys, tributary assessments, cross-sections, longitudinal surveys, and cultural resources monitoring (confidential). For more information on RES-led data collection see SI-3 and the FERC filed Management Plans for the Lower Klamath Project[52].

Question 3: What are the top 3-5 priority areas to address in this topic?

- Extend *C. shasta* disease risk modeling[53] into the reservoir reach.
- Revaluate flushing flows under a different channel conditions post-dam removal.
- Utilize the RES eDNA baseline dataset to fill species distribution monitoring gaps.
- Acquire funding for biology and hydrology monitoring on non-restored tributaries.

2.5.4 Upper Klamath Lake and above

The Upper Klamath Lake and above breakout was co-facilitated by Liam Schenk – USGS, Clayton Creager – Regional Water Quality Control Board, Chris Stine -Oregon Department of Environmental Quality, Gwen Santos – RES, and Kathleen O'Malley – Oregon State University. This breakout group chose to simplify the questions to discuss the major challenges of water quality and fisheries impacts in the Upper Klamath Basin. A summary of the discussion is as follows:

The primary sources of anthropogenic degradation in the Upper Klamath Basin are nutrient inputs from Upper Klamath Lake and the Link River, the loss of wetlands, and the reduction of environmental water availability from the USBR Klamath Project. The transfer of nutrients/water quality issues from Upper Klamath Lake and the Klamath Project led to downstream increases in stress factors for fish. Although likely to improve water quality conditions downstream of the former reservoirs, dam removal does not address any of the water quality issues stemming from Upper Basin. Additionally, dam removal is expected to increase nutrient pollution availability downstream of the former reservoirs because the reservoir reaches are currently acting as a nutrient sink, therefore Upper Basin restoration and restoration of floodplain wetlands downstream will be important for improving water quality.

Phosphorus delivery from legacy sediments and current inputs to Upper Klamath Lake drives the current ecosystem cascade (bimodal HABs) that results in degraded water quality conditions in the Klamath River. Therefore, a multipronged approach to remove, stabilize, and reduce inputs of phosphorus as well as sequester phosphorus through treatment and floodplain wetlands in the Upper Basin should be implemented.

Water quality and loss of habitat have resulted in many stress factors for native fishes and have resulted in almost no successful reproduction of *C'waam* and *Koptu* in the Upper Basin for decades. Many unknowns remain about how migratory fishes returning to the Upper Basin will respond to these same stress factors, and whether current niche availability will encourage or discourage their reestablishment. Complex interactions are expected following dam removal, and better conceptual models are needed to

[52] https://elibrary.ferc.gov/eLibrary/filelist?accession_num=20221205-5047
[53] Robinson HE, Alexander JD, Bartholomew JL, Hallett SL, Hetrick NJ, Perry RW, Som NA. 2022. Using a mechanistic framework to model the density of an aquatic parasite *Ceratonova shasta*. PeerJ 10:e13183 https://doi.org/10.7717/peerj.13183

describe ecosystem response to dam removal, nutrient pollution reduction, and reestablishment of native species.

Key Research Questions Resulting from the Discussion:

- Can water quality be improved enough in Upper Klamath Lake to make positive changes to lower reaches?
- Will the "infectious zone" of Klamath River pathogens (including *C. shasta*) shift upstream following dam removal?
- How will Upper Basin water quality concerns impact health and survival of Chinook salmon?
- How does the potential for thiamine deficiency impact salmonids in the Klamath Basin? How does it impact endangered suckers? Is the ecosystem cascade that leads to degraded water quality also the reason for thiamine deficiency in suckers?
- Is bioturbation a significant mechanism driving the export of phosphorus from lake sediments? If so, can this be managed?
- Is Upper Klamath Lake survivable for anadromous salmonids? Will Chinook salmon utilize the same refugia as Klamath redband trout? Will salmonids compete in Upper Klamath Lake and its tributaries?

2.5.5 Tributaries to the mainstem Klamath River

The Tributaries breakout group was co-facilitated by Betsy Stapleton – Scott River Watershed Council, Karl Seitz – Hoopa Valley Tribal Fisheries Department, and Doug Parkinson of Parkinson Associates.

Objective: Identify current projects, gaps in research and monitoring, and opportunities for collaboration and conducting needed Reservoir Reach studies related to Klamath River dam removal.

Question 1: What are gaps within this topic that are not yet being addressed?

- Tributaries make up more total habitat area than the mainstem Klamath River and will provide refugia during dam removal but have received proportionally less attention and funding than the mainstem Klamath River.

- How will the impacts of climate change affect tributaries (streamflow, riparian vegetation, fish habitat, wildfire)? How will it differ from the mainstem? How will water extraction patterns change? Will continued water extraction compound climate change impacts to tributaries?

- Understanding of tributary use by steelhead and Pacific lamprey is lacking. Limited observations indicate that steelhead use of tributaries is highly variable. Is tributary use in steelhead related to population abundance? Local conditions? Life history plasticity? What is the population substructure on Klamath Mountains Province steelhead, and should they be managed as a single stock?

- Collective tributary influences (positive and negative) need to be accounted for. Tributaries contribute significantly to fisheries productivity and habitat and provide thermal, pathogen, water quality refugia, but they also can have substantial legacy mining or logging impacts and can have land-owner access issues.

- Tributaries that will be reopened to volitional fish passage following dam removal have been surveyed for available habitat, but modeling to predict potential fish production has not been completed. This could be especially important for coho salmon, steelhead, and Pacific lamprey, who utilize tributary habitat to a greater extent than Chinook salmon.

- Will harvest pressure on Trinity River origin fish increase in the Lower Klamath due to the potentially reduced Klamath River production following dam removal?

- Which (if any) tributary populations of Chinook salmon and steelhead will contribute to repopulating the Upper Basin without human intervention? Will known populations of spring-run Chinook salmon contribute? Have other tributary subpopulations of Chinook salmon retained spring-run alleles at low (or undetected) levels and will that life history be expressed following dam removal?

Question 2: What opportunities exist for addressing identified gaps?

- Expand the conceptual model linking water quality, pathogens, climate change, management, and fish health and abundance to the tributaries. Perhaps develop tributary individual based models (IBMs) or continue expansions of the Stream Salmonid Simulator[54] into other tributary habitats, especially the Trinity River, and include harvest effects.
- Use existing genetic libraries to update the Klamath Mountains Province steelhead genetic baseline.
- Valuation of local knowledge and TEK that develops from living in an area is especially important in tributaries. Coordination with local Tribes and other organizations should be prioritized when working in tributaries.
- Tributaries can be more accessible for students, stakeholders, and community members and can provide good opportunities for community engagement and educational outreach.

Question 3: What are the top 3-5 priority areas to address in this topic?

- Include tributaries in a basin wide conceptual model
- Increased monitoring and research on Klamath Mountains Province steelhead
- Engagement and inclusion of local Tribes and organizations located along Klamath River tributaries

2.5.6 Basin-wide

The Basin-wide breakout group facilitator was Randy Turner with KBMP and the notetaker was John R. Oberholzer Dent with the Karuk Tribe. Participants in the Basin-wide breakout group included

[54] Perry, R.W., Plumb, J.M., Jones, E.C., Som, N.A., Hardy, T.B., and Hetrick, N.J., 2019, Application of the Stream Salmonid Simulator (S3) to Klamath River fall Chinook salmon (*Oncorhynchus tshawytscha*), California—Parameterization and calibration: U.S. Geological Survey Open-File Report 2019–1107, 89 p., https://doi.org/10.3133/ofr20191107.

representatives from Stanford University, NOAA Fisheries, Trout Unlimited, USBR, Cal Poly Humboldt, Oregon State University, and Stillwater Sciences.

Objective: Identify current projects, gaps in research and monitoring, and opportunities for collaboration and conducting needed Reservoir Reach studies related to Klamath River dam removal.

Question 1: What are gaps within this topic that are not yet being addressed?

- A mechanism of organization for coordinating sampling between research groups to enable groups to work together and economize fieldwork is warranted.
- The Lake Ewauna/Keno Impoundment Reach is potentially a water quality barrier for summer and fall migrating fishes. What actions should be taken if fish are moving into the reach but not surviving? What are the additional data needs?
- Fish assessment funding is needed and eDNA metabarcoding for fish, invertebrates, and other taxonomic groups can fill gaps and preserve genetic material found in water samples for future analysis.
- Effects of climate change including changes in precipitation, run-off, snowpack coverage, and temperature, groundwater-surface water relationships, groundwater withdrawal and recharge, wildfire, fuels, nutrient pollution, forest management, and wetland restoration/loss are interrelated. A conceptual model is needed to understand the cascading effect of climate change on the Klamath River Basin.
- How will the Klamath River Renewal Project affect climate change? There is potential for a large CO_2/CH_4 release from flux of oxygen and organic matter from the former reservoirs. Will this be offset by the potential decrease of CH_4/N_2O released from decreased anaerobic microbial processes following dam removal?
- Nutrient pollution may be the primary basin-wide problem and a better understanding of resulting water quality conditions impact on aquatic ecosystem biogeochemistry is needed.
- Improved data management and accessibility is needed including expanded access to continuously collected water quality data, increased funding for long-term data management storage infrastructure, development of a universal naming system for sites and parameters, funding for KBMP, and a centralized data-hub available for researchers with updated research requests from managers.
- Basin-wide sediment modeling needs refinement as does discharge. More sites for monitoring suspended sediment and flow are needed.
- A conceptual model linking water quality, flow, and fish movement basin-wide is needed, this could be linked to the KBFC PIT tagging database.
- Expanding pathogen monitoring in the reservoir reach and Upper Basin could help with understanding of pathogen dynamics downstream. This monitoring should include assessing more species for disease susceptibility.
- What is the fate of the organic matter released from the former reservoir sediments? How will the shift from lentic to lotic impact nutrients released to the coastal marine environment?

- Cyanotoxin degradation is thought to be slow. Do we need more information on how long cyanotoxins last in sediments?

Question 2: What opportunities exist for addressing identified gaps?

- An expansion of the KBMP map[55] and spreadsheet of monitoring/sampling locations, which includes contact information and planned/upcoming visits for fieldwork coordination would be useful to the group.
- USBR has continuous sondes from Link River to Keno Dam and they collect vertical profiles once per year to inform their water quality model. This model can be refined.
- Germination in reservoir sediments is better than previously expected.[56]

Question 3: What are the top 3-5 priority areas to address in this topic?

- Additional WQ monitoring in the Keno/Lake Ewauna reach to address WQ concerns for fish once they can migrate u/s of hydroelectric reach.
- Collecting pre-dam removal baseline samples
- Securing long term funding for a data repository with FAIR principles (findable, accessible, interoperable, reusable)
- Basin-wide fish movement studies

3 Conclusions and Wrap-Up

3.1 Next Steps for Coordinating Dam Removal Studies

The coordination for dam removal studies will involve the continuation of organized and collaborative meetings and communication. Following an intensive brainstorming session led by Chauncey Anderson held during the workshop, the next steps were identified to continue coordinating dam removal research.

It was proposed that a valuable component would be the facilitation of monthly online webinars with varying topics, which Laurel Genzoli, Julie Alexander, Jenny Curtis, and Chauncey Anderson expressed interest in leading. These webinars could aim to address critical research gaps identified during the workshop, specifically those of interest to academia. Concurrently, fieldwork coordination for 2023, focusing on the allocation of resources and locations, remains a priority. This includes the coordination of research logistics in the reservoir reach, in collaboration with RES. It was agreed upon at the workshop that Dylan Keel will lead the compilation of a comprehensive workshop summary report by reviewing, transcribing, and organizing breakout session notes. Engaging partners, especially the Tribes, will be crucial for this effort. Simultaneously, the group expressed interest in establishing online workgroups for discussions categorized by specific topics. This will be supported by a self-populating newsletter that has been completed for February through November of 2023[57], allowing individuals to

[55] https://kbmp.ecoatlas.org/map.php
[56] Chenoweth, J., Bakker, J.D. and Acker, S.A. (2022), Planting, seeding, and sediment impact restoration success following dam removal. Restor Ecol, 30: e13506. https://doi.org/10.1111/rec.13506
[57] https://drive.google.com/drive/folders/1iT7Ea6E-3SjawvrVkheRaQ0dVaYvKLdc?usp=sharing

contribute updates directly. The content will be organized by discipline and geographic area, ensuring a comprehensive and structured approach.

Additionally, efforts are underway by the Lower Klamath Project Aquatic Resources Group to ensure smooth communication and resource sharing during the draw-down period, anticipated in early winter. Moreover, plans for future in-person and online meetings, especially around late summer, or early fall, were discussed but have not materialized. Special sessions on dam removal at conferences like AFS, AGU, SRF, SFS, ESA, and SER are in the pipeline, including an upcoming session at the Oregon AFS meeting in Eugene, OR. Recognizing the importance of aligning with other relevant groups to avoid duplication, efforts are being made to collaborate with organizations such as PSMFC, IFRMP, and KBMP. Randy Turner is actively exploring possibilities to expand his role and responsibilities within the workgroup and seeking potential funding sources.

Several key tasks have already been accomplished, including the sharing of registrants' information within the group for future contact, coordination of urgent field data collection via a Google spreadsheet, initiation of a self-populating newsletter, establishment of an online calendar, and the commencement of regular follow-up meetings. The ongoing efforts aim to establish a cohesive, structured approach to drive the dam removal studies forward, emphasizing collaboration, resource sharing, and strategic planning.

3.2 Wrap up – Keith Parker Yurok Tribal Fisheries

Keith Parker, Senior Fisheries Biologist for the Yurok Tribe provided a closure for the workshop in a brief presentation. He began by outlining the commonalities from recent dam removals such as the Sandy River dam removal in Oregon, the Condit Dam removal on the White Salmon River and the Elwha Dam removals in Washington, as well as the San Clemente Dam removal on the Carmel River. All of these projects found lamprey ammocetes and juvenile salmon upstream, sometimes even before the dam removal was complete. Dam removal provides for the capacity for self-renewal (as described by Aldo Leopold) and the potential for the ecosystem to begin healing itself with minimal help from humans. Parker went on to describe the gravity and importance of the Klamath Dam removals by sharing his personal connection with the fisheries resources of the Klamath River. He said:

> *"These fish carry the genes of their ancestors. Another connection that my people have with salmon: I am the offspring of those that have survived genocide, as are many people in this room, and so are the salmon. They had their own type of genocide that has been done to them […] and yet they persist, just like our people do."*

Parker went on to share that genetic and phenotypic diversity still present in the Chinook salmon of the Klamath River[58] provides for the opportunity for nature to heal once the dams are removed and that the preservation of this diversity has been continuously utilized by Tribal subsistence fisheries through time and to this day. He shared how the TEK of the variability of the fat content and nutritional value of different Chinook salmon run timings have been

[58] Andrew P. Kinziger , Michael Hellmair , David G. Hankin & John Carlos Garza (2013) Contemporary Population Structure in Klamath River Basin Chinook Salmon Revealed by Analysis of Microsatellite Genetic Data, Transactions of the American Fisheries Society, 142:5, 1347-1357, DOI: 10.1080/00028487.2013.806351

confirmed by research that incorporates TEK[59], that these run timings are still present, and that the only thing left to do was to take out the dams.

Parker discussed how while this workshop has largely focused on the important tangible outcomes possible from dam removal, including fish abundance, hatchery/wild interactions, suspended sediment concentrations, dissolved oxygen concentrations, bedload deposition, water flow regimes, effective database structure, and revegetation strategies, there are potentially more important "intangibles" that have not been discussed at this workshop. These include love, life, family, culture, community, and relationships. He expressed that we are all here because we love what we do, and that love is the most significant intangible of all.

Acknowledgements

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Supplemental Information (SI) -1: Klamath River Fisheries, Water Quality, and Dam Removal Resources

Organization/Group/Agency	Web Address	Summary of Resources
Klamath River Renewal Corporation	**http://www.klamathrenewal.org/**	Dam removal background and links to regulatory documents
Klamath Tribal Water Quality Consortium	**https://klamathwaterquality.com/**	Water Quality Reports and Memos (Mid and Lower Klamath)
Klamath Basin Monitoring Partnership	**http://www.kbmp.net/**	Maps, monitoring data, water quality and fisheries reports, news, and meeting information
Integrated Fisheries Restoration & Monitoring Plan	**https://kbifrm.psmfc.org/**	Information about the IFRMP, document library
PacifiCorp Klamath River	**https://www.pacificorp.com/energy/hydro/klamath-river.html**	Dam stats, KHSA information, Water quality reports and data
Resource Environmental Solutions	**https://res.us/home/restoring-at-scale/klamath-river-restoration/**	Restoration planning, project scope and metrics, and documentary links
Resource Environmental Solutions	**https://klamath-data-management-platform-klamath.hub.arcgis.com/**	KRRP Data management Platform, explore or request fisheries, water quality, wildlife, wetlands, construction, and vegetation data
State of California State Water Resources Control Board	**https://www.waterboards.ca.gov/waterrights/water_issues/programs/water_quality_cert/docs/401_cert/lkp_wqc.pdf**	Final Water Quality Certification for Federal permit or License, Klamath River Renewal Corporation, Lower Klamath Project License surrender, FERC Project NO. 14803
Oregon Department of Environmental Quality	**https://www.oregon.gov/deq/FilterDocs/ferc14803report.pdf**	Evaluation and Findings Report Section 401 Water Quality Certification for the Removal of the Lower Klamath Project, FERC Project NO. 14803
Oregon Department of Environmental Quality	**https://www.oregon.gov/deq/wq/tmdls/Pages/uklrNutrient.aspx**	Upper Klamath and Lost River Subbasins Nutrient Total Maximum Daily Load and Water Quality Management Plan
Oregon Department of Environmental Quality	**https://www.oregon.gov/deq/wq/tmdls/Pages/uklrTemperature.aspx**	Upper Klamath and Lost River Subbasins temperature Total Maximum Daily Load and Water Quality Management Plan
OSU Aquatic Animal Health Laboratory	**https://aahl.microbiology.oregonstate.edu/research/fish-pathogens**	Information about salmon disease (background, methods, monitoring, and data)
Bureau of Reclamation, Klamath Basin Area Office	**https://www.usbr.gov/mp/kbao/**	Operating plans and biological assessments related to water supply in the Klamath Basin

CA Dept. of Fish & Wildlife; Klamath/Trinity Program	**https://nrm.dfg.ca.gov/documents/ContextDocs.aspx?cat=KlamathTrinity**	Links to annual reports focused on salmonid monitoring studies
US Geological Survey, Oregon Water Science Center	**https://www.usgs.gov/centers/oregon-water-science-center/science/klamath-basin-studies**	Links to USGS reports, data, and maps related to Upper Klamath Basin water quality, fish ecology and hydrology
US Geological Survey	**https://www.usgs.gov/node/279992**	USGS Klamath Basin Mapper showing real time gauges
US Geological Survey, California Water Science Center	**https://www.usgs.gov/centers/california-water-science-center/science/klamath-dam-removal-studies**	Primary Web Page for USGS Klamath Dam Removal Studies
Arcata, CA US Fish and Wildlife Service Office	**https://www.fws.gov/office/arcata-fish-and-wildlife**	Description of monitoring activities, news and reports related to Klamath River Fisheries
California-Nevada Fish Health Center	**https://fws.gov/office/californianevada-fish-health-center**	Publications related to fish health monitoring in the Klamath River
Yreka, CA US Fish and Wildlife Service Office	**https://fws.gov/office/yreka-fish-and-wildlife**	Archived documents related to Klamath Restoration, including the original EIS/EIR and Secretarial Determination Overview Report
USGS Dam Removal: Synthesis of ecological and physical response	**https://www.usgs.gov/centers/powell-ctr/science/dam-removal-synthesis-ecological-and-physical-responses?qt-science_center_objects=0#qt-science_center_objects**	Publications synthesizing the current state of ecological and geomorphic knowledge of river response to dam removal
Oregon Department of Fish and Wildlife	**https://www.dfw.state.or.us/fish/CRP/klamath_reintroduction_plan.asp**	Klamath Anadromous Fisheries Reintroduction program: Reintroduction and implementation plans, FAQs, maps, and timelines of anadromous fish reintroduction
The Upper Klamath Basin Watershed Action Plan Team	**https://www.ukbwap.com/**	Report and prioritization tool for restoration in the Upper Klamath Basin

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SI-3: Current monitoring activities in the Klamath Basin Relevant to Dam Removal

Organization	**Monitoring Activity**	**Location**	**Frequency**	**Start**
AECOM Technical Services Inc./KRRC	Cultural resources monitoring	Confidential	Continuous, Year Round	NA
CA Dept Fish and Wildlife	Thermal Refugia Monitoring, juvenile salmonid presence/absence snorkel surveys	Scott River, Shasta River, Big Springs Creek	Jul, Aug, Sep	2023
CA Dept Fish and Wildlife	Coastal Monitoring Program	Klamath River below Iron Gate, Tributaries Below Iron Gate, Estuary, Coastal Wetlands, or Near Shore	Annually	2000
CA Dept Fish and Wildlife	FRGP project monitoring	Klamath River below Iron Gate Dam, Tributaries Below Iron Gate Dam, Shasta and Scott Rivers and their tributaries	Project by project implementation	enacted with FRGP
Cal Poly Humboldt (O'Dowd Lab)	Macroinvertebrates, fish, stable isotope, diet, and drift sampling	Tributaries below Iron Gate Dam	Spring, annually through 2026	2023
Cal Poly Humboldt (Ward Lab)	Assessment of tributaries for Coho Salmon production	Klamath River (Reservoir Reach), Tributaries Below Iron Gate	Monthly May to Sept	2018
Cal Poly Humboldt (Ward Lab)	Tributary Coho Salmon tagging	Tributaries Below Iron Gate Dam	Monthly year round	2011

Organization	Monitoring Activity	Location	Frequency	Start
Cal Poly Humboldt (Ward Lab)	Water Temp. & Spec. cond.	Creek Mouths from Shovel Creek to Beaver Creek (below Iron Gate Dam)	Continuous, Year round	2018
Cal Poly Humboldt (Ward Lab), UC Davis, ODFW	Chinook salmon outmigration survival	Upper Klamath Lake, Link River, Keno Impoundment	Spring	2021-2023
DOC - NOAA - NMFS - NWFSC - Fish Ecology - Watershed Program	Restoration benefits of beaver dam analogs in the Scott River	Scott River	Seasonally	NA
Green Diamond Resource Company	Water Temp.	Klamath River Tributaries from Weitchpec to Requa	Continuous May - Oct	NA
Green Diamond Resource Company	Discharge, Gage height, Suspended Sediment, Turb.	Forks of Ah Pah Creek	12 or more times/year May - Oct	NA
Hoopa Valley Tribe	Water Temp.	Trinity River and Tributaries (19+ locations)	Continuous, Year round	NA
Hoopa Valley Tribe	Water Temp.	Klamath-Trinity Confluency	Continuous, Year round	NA
Hoopa Valley Tribe	Fecal Coliforms	Trinity River Tributaries	4-11 times/year, Jun-Oct	NA
Hoopa Valley Tribe	Spec. cond., pH, DO, Blue-green Algae, Turb. – Sonde, Air Temp., NH3, NO2+NO3, TN, TP, SRP, TOC, Alk., Calcium, Magn., Chlorophyll-a, Phaeophytin, Microcystin, Macros, TSS, Total DOM	Trinity River (11+ locations)	Continuous & 4-11 times/year, Jun-Oct	NA

Organization	Monitoring Activity	Location	Frequency	Start
Hoopa Valley Tribe	Juvenile salmonid outmigrant production	Trinity River Tributaries	Variable	2023
Hoopa valley Tribe	Ecological Flow Assessment stream gaging, water temp.	Hoopa Valley Tributaries	Variable	2023
Hoopa Valley Tribe	eDNA parasite monitoring	Trinity River	Summer/Fall	2023
Karuk Fisheries and USFWS	Spawning Surveys below Iron Gate Dam	Klamath River below Iron Gate Dam	Between Oct and Dec.	2001
Karuk Fisheries	Water Temp. monitoring	Klamath River below Iron Gate Dam, Tributaries Below Iron Gate Dam	Varies	2003
Karuk Fisheries	Spring-Run Chinook salmon Life Cycle Monitoring	Middle Klamath	Varies	2023
Karuk Fisheries	Klamath River Coho Salmon Ecology Studies	Klamath River below Iron Gate Dam, Tributaries Below Iron Gate Dam	All year	2008
Karuk Pírish Plants Division	sudden oak death and fire effects monitoring	Karuk Ancestral Homelands	year round	NA
Karuk Tribe and Mid Klamath Watershed Council	Monitoring activities associated with the implementation of process-based restoration techniques	Mid Klamath Basin	Variable	2023
Karuk Tribe, U. Wash., Stanford	Beaver distribution and habitat	Klamath River (Scott River to Bluff Creek)	NA	2022
Karuk Water Quality Program	Baseline discrete grab sampling	Klamath River below Iron Gate Dam	Mar-Dec	2005

Organization	Monitoring Activity	Location	Frequency	Start
Karuk Water Quality Program	Baseline discrete grab sampling	Tributaries Below Iron Gate Dam	Mar-Dec	2005
Karuk Water Quality Program	Continuous Water Quality Monitoring	Klamath River below Iron Gate Dam	Year Round	2005
Karuk Water Quality Program	Continuous Water Quality Monitoring	Tributaries Below Iron Gate Dam	May - Oct	2005
Karuk Water Quality Program	C. shasta Monitoring	Klamath River below Iron Gate Dam	Year Round	2005
Karuk Water Quality Program	Public Health Sampling (microcystin)	Klamath River below Iron Gate Dam	Jun to Oct	2005
Karuk Water Quality Program	Nutrient collection	Klamath River below Iron Gate Dam	Mar-Dec	2005
Karuk Water Quality Program	Nutrient collection	Tributaries Below Iron Gate Dam	Mar-Dec	2005
Klamath Bird Observatory	Riparian Habitat Assessment	12+ Sites Basin-Wide	12 or more times/year	NA
Klamath Tribal Water Quality Consortium	Periphyton	Klamath River (10+ Sites Downstream of IGD)	1-3 times/year Jun - Jul	NA
Mid Klamath Restoration Council	stream restoration monitoring	Klamath River between Tree of Heaven and Gottesville	Continuous, year round	2023

Organization	**Monitoring Activity**	**Location**	**Frequency**	**Start**
North Coast Regional Water Quality Control Board	E. coli	Big Springs Crk, Parks Crk, Shasta River	4-11 times/year Mar -Sept	NA
North Coast Regional Water Quality Control Board	Water Temp. and Water Quality	Scott River and Tributaries	Continuous/ 1-3 times/year in May, Aug, & Sept.	NA
Oregon Department of Agriculture	NO2, NO3, TN, TKN, TP, DOC, DO	Upper Klamath Lake and Tributaries (~20 sites)	Variable	NA
Oregon Department of Environmental Quality	UKL Harmful Algal Blooms	Upper Basin (Above JC Boyle Reservoir)	Twice Monthly	2016
Oregon Department of Environmental Quality	UKL Phosphorus Sampling	Upper Basin (Above JC Boyle Reservoir)	Weekly	2021
Oregon Department of Environmental Quality	Water Temp.	Klamath R., Reservoirs, Klamath Straits Drain, Link R., Lost R., Sprague R., Upper Klamath Lake, Williamson R.	Continuous, Year round	NA
Oregon Department of Environmental Quality	Spec. cond., pH, DO, NH3, NO2+NO3, TN, TKN, TP, SRP, DOC, Total Organic Carbon, Alk., BOD, Turb. – Sediment, TSS, TDS, Chlorophyll-a, Phaeophytin, E coli	Klamath R., Reservoirs, Klamath Straits Drain, Link R., Lost R., Sprague R., Upper Klamath Lake, Williamson R.	4-11 times/year May -Sept	NA

Organization	**Monitoring Activity**	**Location**	**Frequency**	**Start**
Oregon Department of Fish & Wildlife	Genetic characteristics of O. mykiss throughout the Klamath Basin prior to dam removal	Basin-wide	1/year	Spring 2019
Oregon Department of Fish & Wildlife	Assessment of potential Coho Salmon habitat in Spencer Creek - CPH/ODFW	Tributaries in the Reservoir Reach	1/year	Summer 2019
Oregon Department of Fish & Wildlife	Characteristics of resident fishes in Spencer Creek - HSU/ODFW	Tributaries in the Reservoir Reach	1/year	Summer 2019
Oregon Department of Fish & Wildlife	Life cycle monitoring of salmonids (video/capture weir, juvenile downstream trap, spawner/redd surveys)	Klamath River (Reservoir Reach), Spencer Creek	Weekly spring-fall	Spring 2020
Oregon Department of Fish & Wildlife	Feasibility study for the monitoring of fisheries from Keno Dam to stateline.	Klamath River in the Reservoir Reach	Weekly spring-fall	Spring 2020
Oregon Department of Fish & Wildlife	Limiting factors of Klamath juvenile O. mykiss in the Sprague River	Upper Basin	Weekly spring-fall	Spring 2019
Oregon Department of Fish & Wildlife	Adfluvial spawner/redd surveys in tributaries of Upper Klamath Lake	Upper Basin	Weekly spring-fall	2011
Oregon Department of Fish & Wildlife	Habitat use, energetics, thermal physiology of O. mykiss - OSU/ODFW	Klamath River between J.C. Boyle Reservoir and Keno Dam	Year-round	2017
Oregon Department of Fish & Wildlife	Habitat use, movement ecology, foraging ecology, life-cycle functions of O. mykiss - OSU/ODFW	Upper Basin	Year-round	2016
Oregon Department of Fish & Wildlife	Riverscape-level distribution of juvenile O. mykiss on the Sprague River - OSU/ODFW	Upper Basin	Year-round	2019

Organization	Monitoring Activity	Location	Frequency	Start
Oregon State University (Bartholomew Lab)	Waterborne abundance of the myxozoan parasite Ceratonova shasta	Upper Basin Klamath River & below Iron Gate Dam	UB once a year, LB weekly all year	UB 2010, LB 2006
Oregon State University (Bartholomew Lab)	Sentinel fish exposures (C. shasta)	Upper Basin (Above JC Boyle Reservoir), Klamath River below Iron Gate Dam	2-4/year	2004
Oregon State University (Bartholomew Lab)	Annelid sampling (distribution and ecology; C. shasta)	Upper Basin (Above JC Boyle Reservoir), Klamath River below Iron Gate Dam	Once each season	2004
Oregon State University (Bartholomew Lab)	Distribution and density of C. shasta myxospores in adult salmon carcasses	Klamath River below Iron Gate Dam	Periodically	2018
Oregon State University (Tullos lab)	Dissolved oxygen and sediment dissolved oxygen	Iron Gate Dam to Scott River	Continuous	2023
Oregon State University & University of Montana	Filamentous algae changes across dam removal: hydraulic habitat, light, nutrients, algae cover	Klamath River, Tree of Heaven to Big Bar	Summer	2023
Oregon Water Resources Department	Water Temp., Discharge, Gage Height	15 tributaries above Keno Dam	Continuous, Year round	NA
PacifiCorp	Anatoxin-a, Phytoplankton, Microcystin, Water Temp. – Sonde, Spec. cond., pH, DO, NH3, NO2+NO3, TN, TP, SRP, DOC, Part. C, Alk., Chlorophyll-a, Phaeophytin, TSS	Various locations throughout the Klamath River Hydro. reach and reservoirs	Variable	NA

Organization	Monitoring Activity	Location	Frequency	Start
Quartz Valley Indian Reservation	Water Temp.	Scott River and Tributaries	Continuous, Year round	NA
Quartz Valley Indian Reservation	Water Temp. - Sonde ,Spec. cond., pH ,DO, NO2+NO3, TN, TP, SRP, Turb., Coliform, E coli	Scott River and Tributaries	12 or more times/year Jun - Oct	NA
Quartz Valley Indian Reservation	Juvenile and adult salmonid monitoring	Scott River and Tributaries	Variable, year round	NA
Quartz Valley Indian Reservation	Well Monitoring: depth, water quality, contaminants	Scott River Sub-basin	4-11 times/year	NA
Resighini Rancheria	Water Temp., eDNA, and water quality	Lower Klamath River, Tributaries, and off-channel ponds	4-11 times/year Apr - Oct	NA
Resighini Rancheria	Bathymetry	Resighini Rancheria and nearby	Fall 2023	2023
Resighini Rancheria	Carnivorous mammal camera trapping	Resighini Rancheria and nearby	annual	2015
Resighini Rancheria	Long-term amphibian, bird, insect, and invasive species monitoring	Resighini Rancheria and nearby	annual	2018

Organization	Monitoring Activity	Location	Frequency	Start
Resource Environmental Solutions	Lower Klamath Project wildlife salvage and observations	Lower Klamath Project Boundaries	Year-round	2023
Resource Environmental Solutions	Discharge, Water temp., turb., spec. cond., pH, DO	Basin Wide	Continuous, Year Round	2023
Resource Environmental Solutions	Nutrients, POC, DOC, methylmercury, settleable solids, part. & dis. aluminum, turbidity	Basin Wide	Monthly, year round	2023
Resource Environmental Solutions	Microcystin	Klamath River, Downstream of Stateline	May - Oct	2024
Resource Environmental Solutions	Chlorophyll-a	Basin Wide	Year Round (OR) May – Oct (CA)	2023 (OR) 2024 (CA)
Resource Environmental Solutions	Suspended Sediment Concentration	Klamath River, Downstream of Stateline	Monthly, year round (2023) Every other week (2024)	2023
Resource Environmental Solutions	Suspended Sediment Concentration	Klamath River, Upstream of Stateline	Every other week, year round (monthly with end of drawdown)	2023
Resource Environmental Solutions	Bed sediment sampling	Copco to Iron Gate Dam	Pre and post-drawdown	2023 & 2025
Resource Environmental Solutions	Sediment load	Basin Wide (6 locations)	Monthly	2024

Organization	Monitoring Activity	Location	Frequency	Start
Resource Environmental Solutions	Dissolved oxygen, temperature	Klamath River above Shasta confluence	Continuous, year round	2024
Resource Environmental Solutions	UAV FLIR monitoring	Keno to Cottonwood	summer/fall	2025
Resource Environmental Solutions	salmonid spawning distribution and spawning habitat surveys	Lower Klamath Project Area	fall/winter	2023
Resource Environmental Solutions	fish passage monitoring	Lower Klamath Project Area	continuous, year Round	2024
Resource Environmental Solutions	Monthly aerial monitoring, LiDAR, and photogrammetry	Lower Klamath Project Area	monthly, year Round	2023
Resource Environmental Solutions	fixed photo point monitoring	Lower Klamath Project Area	daily year Round	2023
Resource Environmental Solutions	bathymetric monitoring for sediment export volume estimation	IGD to Cottonwood Crk	Pre and post-drawdown	2023-2025
Resource Environmental Solutions	reservoir elevation	Klamath Reservoirs	daily, during drawdown	2024
Resource Environmental Solutions	Observational surveys for wildlife	Lower Klamath Project Area	Continuous, Year Round	2023
Resource Environmental Solutions	restored tributary assessments (USFWS stream condition assessment protocol)	Lower Klamath Project Area tributaries	annually	2024

Organization	Monitoring Activity	Location	Frequency	Start
Resource Environmental Solutions	Repeat cross-sections and longitudinal sections	Lower Klamath Project Area	annually	2023
Resource Environmental Solutions	Wetland delineations	Lower Klamath Project Area	before/after	2023
Resource Environmental Solutions	Sucker Salvage and relocation, genetics, morphometrics	Lower Klamath Project Boundaries	May 2023	2023
Resource Environmental Solutions	eDNA/eRNA Baseline	Lower Klamath Project Boundaries & Scott River (45 sites)	July	2023
Resource Environmental Solutions	Special Status Plants and Rare Plant Occurrences	Lower Klamath Project Boundaries	Year-round	2018
Salmon River Restoration Council	Adult Chinook and steelhead count	Salmon River Sub-basin	Annually, Jul/Aug	1995
Salmon River Restoration Council	Water Temp.	Salmon River Sub-basin (24+ locations)	Continuous, Jun - Oct	NA
Salmon River Restoration Council	Discharge	Salmon River Sub-basin (12+ locations)	Continuous, Jun - Oct	NA
Salmon River Restoration Council	Air Temp. & Relative Humidity	Salmon River Sub-basin (8+ locations)	Continuous, Jun - Oct	NA
Scott River Watershed Council	Water Temp., DO, gage height	Scott River and Tributaries (many locations)	Continuous, Year round	NA

Organization	**Monitoring Activity**	**Location**	**Frequency**	**Start**
Shasta Valley Resource Conservation District	Water Temp., Spec. cond., pH, DO, discharge	Shasta River and Tributaries	Continuous Apr - Oct	NA
Southern Oregon University	Upland Vegetation Ecology	Former Reservoirs	Year round	2024
Stanford University	Surveys on Social Impacts of Dam Removal	Basin-wide	Annually	2023
The Freshwater Trust	Restoration Effectiveness Monitoring	Sprague River Mile 43.5	1-3 times/year Aug	NA
The Klamath Tribes	Water quality and Temp. monitoring	Upper Basin (Above JC Boyle Reservoir)	Varies	Early 1990s
The Klamath Tribes	Fish population monitoring	Upper Basin (Above JC Boyle Reservoir)	Throughout the year	Early 1990s
The Klamath Tribes	Instream flow monitoring	Upper Basin (Above JC Boyle Reservoir)	Continuous	Early 1990s
The Klamath Tribes	Geomorphic assessment	Williamson River	TBD	2023
The Watershed Research and Training Center	Water Temp., Air Temp., Discharge, & Snow Depth	Trinity River and South Fork Trinity River Tributaries	Continuous, variable	NA
Trinity River Restoration Program / USBR	Periphyton	Trinity River and Tributaries	1-3 times/year	NA
Trinity River Restoration Program / USBR	Water Temp. – Probe, TSS, Turb.	Trinity River (18 locations)	1-3 times/year	NA

Organization	Monitoring Activity	Location	Frequency	Start
UC Berkeley; Dept. of Environmental Science, Policy & Management	Agroecosystem Condition Assessment	Klamath River below Iron Gate Dam, Tributaries Below Iron Gate Dam	May and Aug	2018
UC Berkeley; Dept. of Environmental Science, Policy & Management	Elk ecology and Management	Klamath River below Iron Gate Dam, Tributaries Below Iron Gate Dam	Oct to Jun	2018
UC Berkeley; Dept. of ESPM	Klamath Basin Tribal Food Security Assessment	Basin-wide survey	Survey was conducted once, from ~2014- 2017	~2014
University of Montana	Benthic algae and aquatic plant surveys	Klamath River below Iron Gate Dam	1/year	2019
University of Montana	Benthic cyanobacteria surveys	Klamath River below Iron Gate Dam	summer, opportunistically	2018
University of Montana	Ecosystem Primary Production and Respiration	Klamath River below Iron Gate Dam	Daily May-Oct	2007
US Bureau of Land Management	Water Temp.	Tribs., wetlands, and Reservoirs Upstream of JCB	Continuous, Year round	NA
US Bureau of Land Management	Water Temp.	Klamath River Below JC Boyle	Continuous, Year round	NA
US Bureau of Land Management	Spec. cond., pH ,DO, NH3, NO2+NO3, TN, TP, SRP, Turb. -Sonde	Wood River Wetland,	4-11 times/year Apr -Sept	NA
US Bureau of Land Management	Phytoplankton	Gerber Reservoir	1-3 times/year Jul – Oct	NA

Organization	Monitoring Activity	Location	Frequency	Start
US Bureau of Reclamation	Water Temp. – Sonde, Spec. cond., pH, DO, NH3, NO2+NO3, TKN, TP, SRP, Alk., Calcium, TDS, Secchi Disk, Air Temp., Wind, Turb. – Sediment, Turb. - Sonde	Klamath Project canals, tunnels, diversions, and drains	4-11 times/year May – Oct	NA
US Bureau of Reclamation	Turb. – Sediment, Water Temp. – Sonde, Spec. cond., pH, DO, Secchi Disk, Air Temp., Wind, Turb. - Sonde	Upper Klamath Lake Tributaries	4-11 times/year May – Oct	NA
US Bureau of Reclamation	Water Temp. – Sonde, Spec. cond., pH, DO, NH3, NO2+NO3, Part. N, TP, SRP, Part. P, DOC, Part. C, Alk. ,Phytoplankton, Chlorophyll-a, Phaeophytin, TSS, Secchi Disk, Air Temp., Wind, TKN, TN, Turb. – Sediment, Microcystin, Calcium, Turb. - Sonde	Upper Klamath Lake, Clear Lake, Tule Lake, Agency Lake	4-11 times/year May – Oct	NA
US Bureau of Reclamation	Water Temp. – Sonde, Spec. cond., pH, DO, NH3, NO2+NO3, TKN, TP, SRP, Alk., Calcium, TDS, Secchi Disk, Air Temp., Wind, Turb. - Sediment	Lost River and Tributaries	4-11 times/year May - Oct	NA
US Fish & Wildlife Service	Fish Disease, juvenile salmonid monitoring, eDNA	Klamath River Mainstem (12 sites)	12 or more times/year	NA
US Fish & Wildlife Service	Water Temp.	Klamath and Trinity Rivers, and tributaries	Continuous, Year Round	NA
US Forest Service	Water Temp.	Basin-wide (127+ locations)	Continuous Jun - Oct	NA

Organization	Monitoring Activity	Location	Frequency	Start
US Forest Service	Bed Sediment	Basin-wide (12+ locations)	1-3 times/year Jun - Oct	NA
US Forest Service	Marine Derived Nutrients in Animal Tissues	Above and below former reservoirs	Annually	2023
US Geological Survey	Water Temp. – Sonde, Spec. cond., pH, DO, NH_3, NO_2+NO_3, Part. N, TN, TP, SRP, DOC, Total Organic Carbon, Chlorophyll-a, Secchi Disk	Klamath Project canals, tunnels, diversions, and drains	4-11 times/year Feb - Nov	NA
US Geological Survey	PIT Tag Antennae	Upper Basin (11+ locations)	Continuous, Year Round	NA
US Geological Survey	UAS flights	Basin Wide (mostly ds of IGD)	Summer/fall	2023
US Geological Survey	Sidescan Sonar	Basin Wide (mostly ds of IGD)	Summer/fall	2023
US Geological Survey	Sediment Deposition potential mapping	Basin Wide (mostly ds of IGD)	Summer/fall	2023
US Geological Survey	Sand supply & riparian willow study	Basin Wide (mostly ds of IGD)	Summer/fall	2023
US Geological Survey	Endangered sucker movement and survival monitoring	Above Keno Dam	Year round	NA
US Geological Survey	Stream gaging	Klamath River and Tributaries	Continuous /Real Time	Varies
US Geological Survey	Real-time WQ monitoring (incl. Turb.)	Klamath River and Tributaries	Continuous /Real Time	2018 & 2019
US Geological Survey	Suspended Sediment Sample Collection	Klamath River and Tributaries	Continuous /Real Time	2018 & 2019

Organization	Monitoring Activity	Location	Frequency	Start
US Geological Survey	Sediment Source Analysis (aka "Fingerprinting)	Klamath River and Tributaries	Summer/Fall	fall 2018
US Geological Survey	Intensive Geomorphic Analysis	Klamath River below Iron Gate (10 short reaches) to estuary	~2x each reach before dam removal	fall 2018
US Geological Survey	Estuary Sediment Characterization	Estuary	1/year	fall 2018
US Geological Survey Yurok Fisheries, Hoopa Valley Tribe, Karuk Tribe	Acoustic Telemetry of tagged salmonids and other fish	Below Iron Gate Dam	Continuous	2022
USGS – USBR - ODFW	Keno Dam evaluation studies	Keno Dam	As needed	2024
YTWD, KTNR, USFWS, USFS, CPS	bat diversity monitoring	7 sites below IGD	year round	2021
Yurok Fisheries and YTEP	Monitoring activities associated with McKinney Fire Restoration	Mid Klamath Basin	Variable	2023
Yurok Fisheries and YTEP	Klamath River Carcass Survey	Klamath River below Iron Gate Dam	Weekly/Oct-Dec	NA
Yurok Fisheries and YTEP	*C. shasta* monitoring eDNA	Klamath River below Iron Gate Dam	Weekly/Ma r-Oct	NA
Yurok Fisheries and YTEP	*C. shasta* monitoring Fish	Klamath River below Iron Gate Dam	Weekly /Jun-Aug	NA
Yurok Fisheries and YTEP	Ich monitoring projects	Klamath River below Iron Gate Dam	Weekly /Jun-Oct	NA
Yurok Fisheries and YTEP	Thermal refugia monitoring	Klamath River below Iron Gate Dam	Weekly /Jun-Sept	NA

Organization	Monitoring Activity	Location	Frequency	Start
Yurok Fisheries and YTEP	Juvenile salmonid outmigrant trapping	Klamath River below Iron Gate Dam	Daily/Mar-July	NA
Yurok Fisheries and YTEP	Coho ecology studies	Klamath River below Iron Gate Dam	Year round	NA
Yurok Fisheries and YTEP	Macroinvertebrate Sampling	Tributaries Below Iron Gate Dam	NA	NA
Yurok Fisheries and YTEP	Water temperature monitoring	Klamath River below Iron Gate Dam	Hourly/Ma r-Dec	NA
Yurok Fisheries and YTEP	Water Quality Monitoring (temp, sp. Cond., pH, DO%, DO mg/L, BGA, Turbidity)	Klamath River below Iron Gate Dam	Every 15 minutes, year round	NA
Yurok Fisheries and YTEP	Water Quality Monitoring (temp, sp. Cond., pH, DO%, DO mg/L, BGA)	Klamath River below Iron Gate Dam	Every 30 minutes, May-Oct.	2001
Yurok Fisheries and YTEP	Sediment Accretion Klamath River Estuarine Wetlands	Estuary, Coastal Wetlands, or Near Shore Ocean	Every few months Adapted to high flows	2019
Yurok Fisheries and YTEP	Hydrology monitoring	Tributaries Below Iron Gate Dam	Year round	2002
Yurok Fisheries and YTEP	Water Quality & Hydrology monitoring (temp, sp. Cond., pH, DO%, DO mg/L)	Klamath River South Slough	Every 15 minutes, year round	2018
Yurok Fisheries and YTEP	Water Quality Monitoring (temp, sp. Cond., pH, DO%, DO mg/L)	Tributaries Below Iron Gate Dam	Monthly	2015
Yurok Fisheries and YTEP	Water Quality Grab sampling	Klamath River below Iron Gate Dam	Monthly, Mar-Dec	2004

For additional information regarding monitoring activities, precise locations, contact information, funding status, and updated details, use the following links:

Klamath Researcher Group - https://docs.google.com/spreadsheets/d/1TRX1x1ghxogjBKOuRo1kVG-hRWefzKN0Pb4ckoLuNb4/edit?usp=sharing

KBMP Monitoring Metadata - https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fkbmp.net%2Fimages%2Fstories%2Fpdf%2FMonitoring_Locations%2FKBMP_Monitoring_Location_Table_2019-2020_Updated_20230309.xlsx&wdOrigin=BROWSELINK

Klamath Funding Coordination List 9-9-23 - https://resourceenvironmentalsol-my.sharepoint.com/:x:/g/personal/dkeel_res_us/EWBTw6D2z5hMp_WENVp-

CSkBlZuppbiV0LBJslMuPVz88A?e=v2ZDfC&CID=A6B8BB5F-1285-4BF7-90C4-321AA8CDFC9C&wdLOR=c193487C3-F8A6-4F8A-9D6B-B769598FCC89

SI-4: 2023 Klamath Dam Removal Science Collaboration Workshop Schedule

Klamath Dam Removal Science Collaboration Workshop
Cal Poly Humboldt (Arcata, CA)
January 10 & 11, 2023

DAY 1 – Tuesday, January 10, 2023

8:00-9:00 am	Arrive and gather in Great Hall (1 Rossow St, Arcata, CA) - breakfast provided
9:00 am	Wiyot Tribal Opening (Chairman Ted Hernandez)
9:15 am	Cal Poly Humboldt welcome (Dean Eric Riggs)
9:20 am	Overview/purpose of workshop (Tommy Williams – NMFS)
9:30 am	Dam removal update (Mike Belchik – Yurok Tribe)
9:45 am	TEK panel & discussion (Barry McCovey, Keith Parker, Charley Reed, Shahnie Rich)
10:45 am	Break
11:00 am	Overview of how rivers respond to dam removal (George Pess – NOAA)
11:30 am	Lunch
1:00 pm	Overview of existing monitoring related to Klamath dam removal • Compliance monitoring - Dan Chase (RES) • Fisheries (Crystal Robinson and Tommy Williams) • Geophysical (USGS personnel) • Water Quality & Ecology (Laurel Genzoli) • Wildlife
3:00 pm	Breakout groups by topic 1. Fish disease 2. Fish distribution, movement, abundance, genetics 3. Water quality 4. Food webs and Ecology 5. Geomorphology, sediment 6. Hydrology 7. Wildlife 8. Vegetation 9. Human Dimensions 10. TEK *Zoom participants will form breakout groups in Zoom*
4:30 pm	Report backs from breakout groups
5:30 pm	End for day
6:00-8:00 pm	Evening social at Humbrews (856 10th St, Arcata, CA)

DAY 2 – Wednesday, January 11, 2023

8:00-9:00 am Arrive and gather in Great Hall (1 Rossow St, Arcata, CA) - breakfast provided

9:00 am Series of presentations on funding opportunities, data management and access/permitting requirements

10:00 am Breakout groups by location

1. Lower Basin (Weitchpec to Estuary)
2. Mid-Klamath (Iron Gate to Weitchpec)
3. Reservoir Reach (Link River to Iron Gate Dam)
4. Upper Klamath Lake and above
5. Tributaries to the mainstem Klamath River
6. Basin-wide

Zoom participants will form breakout groups in Zoom.

12:00 pm Lunch

1:30 pm Report backs from breakout groups

3:00 pm Wrap-up and Next Steps

3:30 pm Workshop ends (all meeting rooms will available until 5 pm for further discussion and coordination)