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Klamath Iron Gate SONAR Project: Estimated Salmonid Abundance Above Prior Limits of Anadromy

2024 REPORT

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Abstract

In 2024, four dams on the Klamath River were removed, restoring longitudinal connectivity to over 640 km of previously inaccessible habitat for anadromous fish. To evaluate fish passage in the first migration season following dam removal, we implemented a multi-beam ARIS SONAR system just downstream of the former Iron Gate Dam — the former limit to anadromy prior to removal.

Between October 1 and December 24, 2024, the SONAR recorded 2,034 hours (about 3 months) of imagery (97.6% of total possible hours), capturing 9,646 fish passage events. Species-specific passage estimates for Chinook Salmon (*Oncorhynchus tshawytscha*), Coho Salmon (*O. kisutch*), and Rainbow Trout/steelhead (*O. mykiss*) were developed using a combination of length-based and timing-based Bayesian classification models informed by field-collected data. Species specific net upstream passage estimates included 7,742 (95% CI: 7,702 – 7,778) Chinook Salmon (including approximately 310 jack Chinook Salmon, and 324 (95% CI: 292 – 355) Coho Salmon.

Additionally, we estimated that 54 (95% CI: 27-85) *O. mykiss* moved upstream past the SONAR unit, and 16 (95% CI: 9-24) passed in a downstream direction during the period of the project. Our estimate of upstream Chinook passage accounted for 18% of the total Klamath Basin adult run in 2024, consistent with pre-dam removal proportions contributed by Iron Gate Hatchery and Bogus Creek. Uncertainty was minimized by high-quality SONAR imagery, minimal data gaps, clear upstream movement patterns, and limited overlap between species in length and timing.

Comparison with redd and carcass surveys highlights the importance of SONAR as a complementary method, particularly under turbid post-removal conditions and large spatial domains that hinder visual surveys. This first-year monitoring effort provides a critical benchmark for assessing ecological responses to dam removal and establishes a foundation for long-term monitoring of anadromous fish recolonization in the upper Klamath Basin.

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The project team celebrates the return of salmon to the Klamath River. Courtesy: Pusher Media / CalTrout.

Introduction

Connectivity of freshwater habitats such as river networks is vital to the wellbeing of humans, the resilience of ecosystems, and is the foundation for biological diversity (Beechie et al. 2010; Munsch et al. 2023; Keel et al. 2025). Protecting or recovering connectivity, whether it be longitudinal, lateral, or vertical, has become the basis for restoring and recovering river systems (Ward,1989; Beechie et al. 2010; Mason et al. 2025). Restoring connectivity allows for ecological processes and functions to be re-awakened, and allows for ecological, economic, and culturally important taxa such as salmonids to re-establish themselves (Pess et al. 2024). Over the past several decades, large river dam removal has been used as a tool to restore river connectivity, with an increasing number of case studies attempting to quantify the ecosystem response (Magilligan et al. 2016; McCaffery et al. 2024; Pess et al. 2024, Keel et al. 2025).

A focus of ecosystem response has been the re-establishment of migratory fishes upstream of former barriers or dams. Dam removal typically increases the density, biomass, diversity, and abundance of fish and fish assemblages upstream of the former barrier area (Hitt et al. 2012; Hogg et al. 2015; Pess et al. 2024). Linking habitats such as tributaries, large main stems, estuaries, and marine environments also allows for the re-expression of life history strategies that have been muted or entirely removed for 10s to 100s of years (Fraik et al. 2021; Duda et al. 2021; Munsch et al. 2023; Pess et al. 2024). The expression of life history strategies is foundational to the long-term increase and resilience of migratory fish populations (Cordoleani et al. 2021; Munsch et al. 2022; Connors et al. 2022).

The Klamath River, stretching over 400 km, from its headwaters in southern Oregon to its mouth on the northern California coast, is the third largest river basin on the west coast of the contiguous United States and one of the most ecologically significant river systems in the western United States. Its watershed spans approximately 40,000 sq. km, encompassing a diverse range of habitats including high desert, spring creeks, alpine lakes, coniferous forests, and coastal estuaries (NRC 2008). This geographic and ecological diversity supports a rich array of aquatic life, including over 30 species of native fish (NRC 2004; NRC 2008; Hodge et al. 2016). Among these, salmonids—particularly Chinook Salmon (*Oncorhynchus tshawytscha*), Coho Salmon (*Oncorhynchus kisutch*), and Rainbow Trout/steelhead (*Oncorhynchus mykiss*), hereafter referred to as *O. mykiss* —play a central role in the river's ecological integrity, cultural heritage, and economy. The Klamath River salmon fishery holds profound ecological, economic, and cultural importance (Diver et al. 2024). Salmon are a keystone species, contributing essential nutrients to both aquatic and terrestrial ecosystems during their spawning runs (Schindler et al. 2003). Economically, the salmon fishery supports commercial and recreational fishing industries, as well as tribal subsistence harvesting (Sowerwine et al. 2019). For each of the seven indigenous communities in the watershed, salmon are integral to traditional lifeways, ceremonies, and food security (Sowerwine et al. 2019). Primarily as a response to the decline in the river's salmon

Before and after removal of Iron Gate Dam—the lowermost dam removed on the Klamath River—marking the entrance to newly reopened upstream habitats. This site also hosts the Klamath River SONAR monitoring unit. Credit: Shane Anderson, Swiftwater Films.

populations, including a large die-off of Chinook Salmon in 2002, a movement coalesced to remove four upper river dams (NRC 2004). This monumental effort culminated in September of 2024 when deconstruction of the four dams was completed. The four dams were, from the furthest upstream to the furthest downstream: JC Boyle (rkm 366.9, 18 meters high, constructed in 1958), Copco 1 (rkm 324.9, 36 meters high, constructed in 1917), Copco 2 (rkm 324.4, 7.5 meters high, constructed in 1925), and Iron Gate (rkm 310.8, 50 meters high, constructed in 1964). This historic ecosystem restoration project represents the largest dam removal project in the world and has provided access to over 640 kilometers of mainstem habitat and tributary habitat that has been inaccessible to anadromous salmon for over 100 years (Diver et al. 2024).

While the number of dam removals and associated studies globally increases, basic questions still need to be explored for any large dam removal such as the Klamath removals. These include, how many migratory fish move up and downstream through areas that were disconnected for multiple decades? How does this migration allow for the population to change over time? What are some of the potential reasons as to why there are changes to the migratory populations and do they include the re-connectivity?

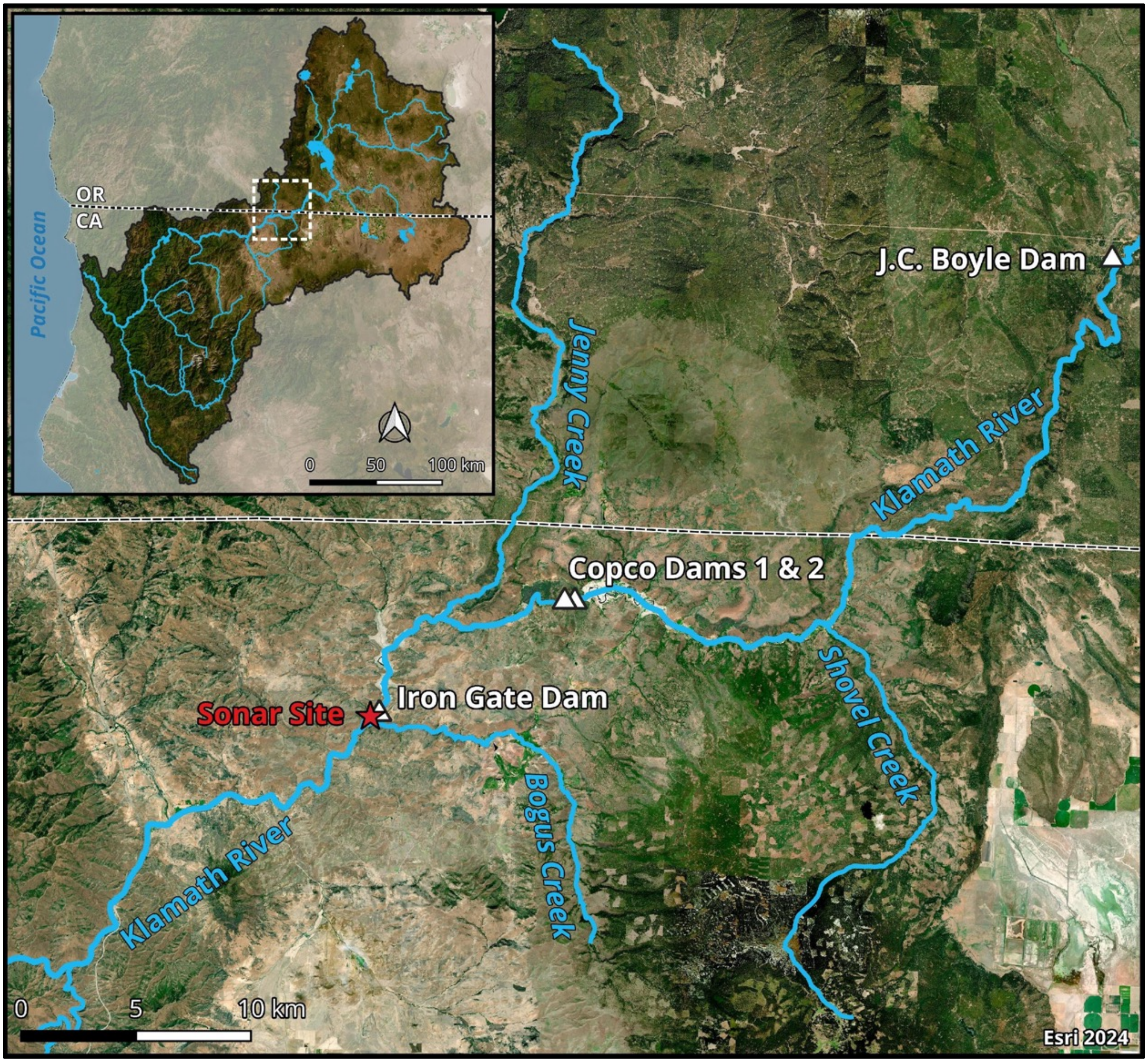
While the basic questions concerning the population dynamics of migratory fishes are straightforward, estimating salmon population sizes, specifically for an area as large the Klamath River Basin upstream of the former lowermost dam is challenging. Multiple methods have been used to estimate populations of migrating adult salmonids, including aerial surveys, counting towers, fish weirs, redd surveys, mark-recapture studies, and SONAR technology (Cousens et al. 1982). Each of these methods has quantitative strengths and weaknesses as well as differences in their accuracy and precision (Parsons and Skalski 2010; Murdoch et al. 2019). In addition, dam removal typically results in compromised conditions due to high turbidity levels that reduce visibility to nominal levels for periods of weeks to years in some cases (Ritchie et al. 2018; Pess et al. 2024). Large scale dam removal, by design, also opens 100's of kilometers of newly accessible habitat to migratory fishes, greatly increasing the logistical demands of many monitoring techniques.

One method that combats the lack of visibility due to turbidity and provides a point estimate of fish passage into the newly accessible habitat with limited logistical constraints is multiple beam SONAR. SONAR has recently been successfully used for population enumeration of returning adult salmonids before, during, and after dam removal and associated high turbidity levels in the Pacific Northwest (Pess et al. 2024). Imaging SONAR uses multiple high frequency beams to produce "movie" like imagery which allows for the derivation of several other fish characteristics including direction of travel, timing, distance from bank, length, and swimming speed, without being compromised by sediment effects (Belcher et al. 2001, 2002). Furthermore, direct comparisons between adult salmon counts derived from DIDSON imaging systems to other enumeration methods such as weir passage (Holmes et al. 2006), visual counts (Enzenhofer et al. 1998), mark-recapture (Cronkite et al. 2006, Holmes et al. 2006), and test fisheries (Faulkener and Maxwell, 2020) suggest that DIDSON counts have consistently had relatively low error rates when compared to the more traditional methods.

We used a newer version of SONAR, the ARIS (Adaptive Resolution Imaging Sonar), to provide detailed information on the number and species of salmonids that pass the lowermost point of dam removal, the former Iron Gate Dam, to quantify the number of salmon that are accessing the newly available habitat upstream of the former dams. This study aims to: 1) enumerate the number of Chinook Salmon, Coho Salmon, and *O. mykiss* that migrated upstream passed the Iron Gate SONAR site in the initial year after dam removal; 2) present and calculate sources and magnitudes of uncertainty in estimates for each species, and 3) provide operational recommendations in coming years.

The Iron Gate SONAR site, Klamath River, California. The SONAR itself is attached to the ladder. The SONAR recorded imagery from this location from October 14, 2024 through December 24, 2024. Courtesy: CalTrout

Figure 1. Map showing the location of the four former dams and the SONAR site, Klamath River, Oregon and California. The former Iron Gate Hatchery was located just upstream of the confluence of Bogus Creek and the Klamath River.



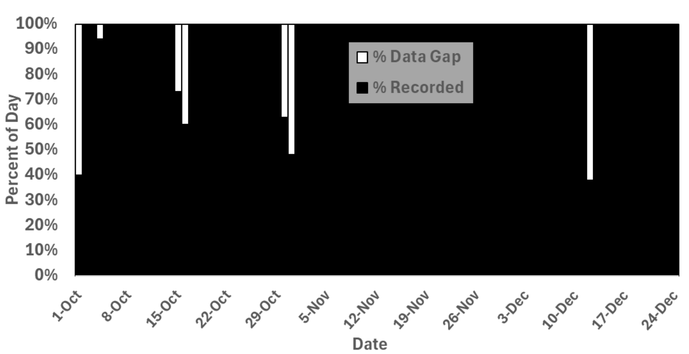
Methods

FIELD METHODS

The primary SONAR site on the Klamath River was located at rkm 310.7 (41°55′54.8″N 122°26′24.9″W) (Figure 1, on page 6). This site is approximately 100 meters downstream from the base of the former Iron Gate Dam. We used an ARIS 1200 SONAR device (1.2/1.8 MHz, Sound Metrics, Bellevue, WA). The site was selected for its proximity to the former dam site. The site also fit three basic criteria for acoustic imaging: 1) narrow enough to accommodate the effective range of the SONAR, 2) the ability to monitor the entire cross section of the river (i.e. no blind spots across the channel), and 3) fish generally move in an upstream direction with little to no milling behavior. The SONAR was connected to continuous line power from a nearby building.

The SONAR was initially installed at a location approximately 25 meters upstream of the above detailed primary site on October 1, 2024. Assessment of the data from that location revealed suboptimal imagery from too many entrained bubbles, thus it was moved to its final location on October 14, 2024. Data were recorded almost continuously, in 30-minute files, until the SONAR was disabled on December 24 due to a high-water event. There were 6 short data gaps during this time period totaling 54 hours or 2.4% (54/2,208) of the total available hours between installation into the river and removal (Figure 2).

Figure 2. Percent recorded and percent data gaps of SONAR operations for each day during the period of time presented in this report: 1 October 2024 through 24 December 2024, Klamath River, California.



DATA REVIEW

All ARIS data were processed using ARIS proprietary software (V2.8). All 30-minute files were reviewed in their entirety; we made no attempt to sub-sample in this initial year of data collection. This census of the SONAR data will be used as a basis for informing sub-sample data review processes in subsequent years. Raw data were transformed in a two-step process that enabled empty periods of time to be efficiently reviewed, while highlighting fish passage events for closer inspection. Files were background subtracted, using the default parameters, to remove rocks and make it easier to discern moving objects, such as migrating fish.

Then each file was transformed into an echogram using the default parameters. An echogram is a graph of data with distance from the SONAR head on the y-axis and time on the x-axis. If no targets are present, the echogram will be blank. If a fish swims through the ensonified area, the echogram will have a series of targets connected along the x-axis, whose overall length correlates with the length of time it took the fish to pass through the ensonified area. The string of targets along the x-axis may trend up or down along the y-axis if the fish was swimming diagonally away or towards the sonar head during its passage.

To count fish passage events, target echograms were simultaneously reviewed along with the raw video file. This enabled the reviewer to quickly scan through an echogram until a target pattern that could potentially represent a fish was encountered.

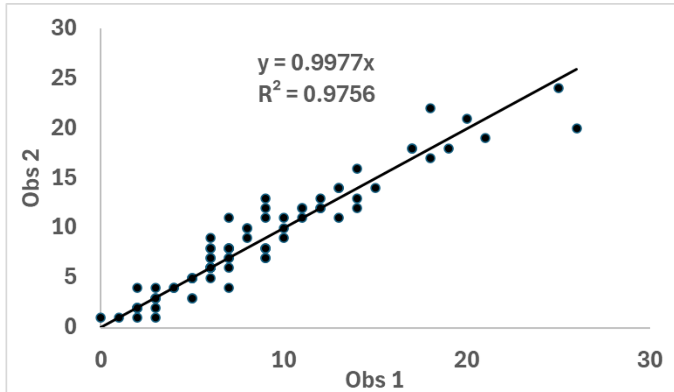
Raw data was then reviewed to ensure identified targets were indeed fish. Fish passage events were marked and measured within the ARIS software and then .csv files with each file's counts were outputted by the software and subsequently collated to produce a master fish passage file. This master fish passage file was then transformed into species specific fish passage estimates through the following data analysis process.

DATA ANALYSIS

Observer Error

One observer with over 10 years of SONAR review experience counted all the SONAR data presented in this project. To verify that there was no consistent error or bias in this observer's counts, another observer with more than 10 years of experience reviewing SONAR imagery reviewed 80, 30-minute files during a period of high salmon passage in late October that were then compared to the counts of the primary observer for the same files (Figure 3). The total counts of all these files showed very similar net upstream passage (678 vs 690). Additionally, a trendline fit through the two observers counts had a slope 0.99 and an R_2 of 0.98 indicating that, across a range of passage rates, the independent counts by two reviewers produced very similar results. Therefore, no attempt was made to correct the primary observer's raw counts.

Figure 3. Independent net upstream counts from two different observers for each of 80 different 30-minute files of sonar data, Klamath River, California.

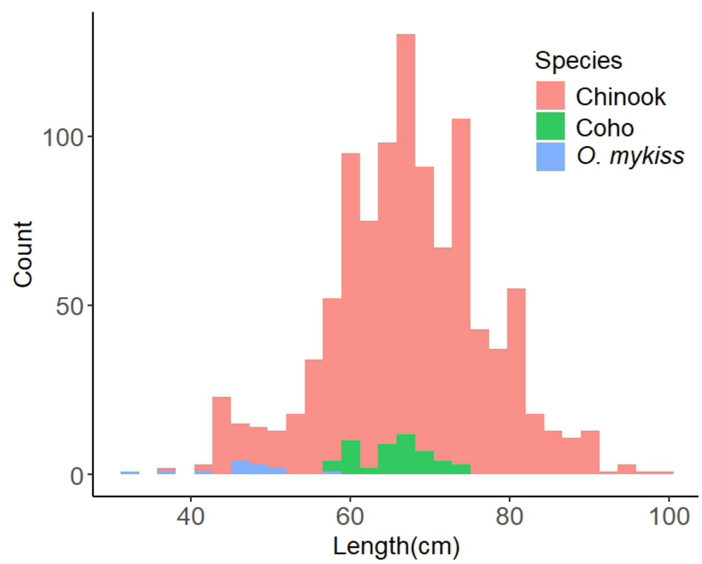


External Data Inputs

SALMON AND *O. MYKISS* LENGTH DATA

To compare the lengths of different species of salmonids in the vicinity of the SONAR to each other, and to the SONAR measured lengths, we used multiple data sources. The Oregon and California Departments of Fish and Wildlife (ODFW, CDFW), the U.S. Fish and Wildlife Service (USFWS), the Yurok Tribe of the Yurok Reservation (Yurok Tribe), and the Karuk Tribe conducted multiple adult spawning surveys in the mainstem and tributaries upstream of and directly downstream of the former Iron Gate Dam. These surveys produced measurements of 1,173 Chinook Salmon carcasses and 54 Coho Salmon carcasses in 2024. Almost all of these fish would have been detected and measured by the SONAR as they passed by (Figure 4). Additionally, a radio telemetry project conducted by the Karuk Tribe, ODFW, CalTrout, and their partners used tangle net sampling throughout the former Iron Gate reservoir reach to capture adult salmonids during the period of operations of the SONAR. This project produced measurements of four Chinook Salmon, two Coho Salmon, and 14 *O. mykiss* (Table 1, on page 9).

Figure 4. Length frequency histogram of Chinook and Coho Salmon measured upstream of the former Iron Gate Dam during spawning ground surveys in 2024 and *O. mykiss* sampled upstream of the former Iron Gate Dam during tangle net sampling in 2024, Klamath River, California.



SONAR MEASURED VS. FIELD MEASURED LENGTHS

The SONAR project measured a combined 9,646 raw targets moving in upstream and downstream directions. The proportional length frequency histogram of these targets closely aligns with the proportional length frequency histograms of the field measured lengths of Chinook and Coho Salmon and *O. mykiss*, indicating a lack of bias in SONAR estimated fish lengths (Figure 5). Additionally, the mean length of all field measured salmonids was 68 cm while the mean length of all SONAR measured lengths was 69 cm.

We performed an additional evaluation of error between SONAR measured lengths and directly measured fish lengths and found similar results. In this evaluation we acquired two different sized Chinook Salmon carcasses from the California Department of Fish and Wildlife (CDFW) Yreka office, tethered them through the jaw and tail and repeatedly moved them back and forth in front of the SONAR. Each carcass was then measured multiple times within the ARISFish software by two independent observers and compared to the actual carcass lengths (Table 2). Mean SONAR measured length differed from actual length by an average of 0.7 cm and ranging from 0.6 to 3.2 cm depending on observer and fish.

CHINOOK AND COHO SALMON TIMING DATA

During the 2024 salmon season, CDFW operated one video weir in a tributary ~400 meters downstream of the SONAR site at Bogus Creek and two video weirs upstream of the SONAR site at Jenny Creek (~7 km upstream of the SONAR site) and Shovel Creek (~27 km upstream of the SONAR site) (CDFWa, 2025). These video weirs, specifically using data on the upstream passage of fish, gave us an opportunity to produce timing curves for fish passing the SONAR. The record of each salmonid passing through the weir was time-stamped and thus could be used to produce species-specific timing curves for both Chinook and Coho Salmon (Figure 6, on page 10).

Modeling Species-Specific Escapement

To turn SONAR counts into species-specific abundance estimates, we explored variation in arrival timing and size among Chinook Salmon, Coho Salmon, and *O. mykiss* using the data sets as defined in the preceding three sections. We began with graphical analysis, and based on visual assessments, proceeded to fit statistical models with arrival timing or size covariates. The models were then applied to the SONAR data to create specific abundance estimates, as described below.

Table 1. Anadromous fish sampled in the former Iron Gate Reservoir with a tangle net, Klamath River, CA.

DATE	SPECIES	LENGTH (CM)
10/24/2024	Chinook	52.5
10/24/2024	Chinook	46.0
10/24/2024	*O. mykiss*	50.5
10/30/2024	Chinook	43.0
10/30/2024	*O. mykiss*	48.0
11/6/2024	*O. mykiss*	33.0
11/14/2024	*O. mykiss*	46.5
12/3/2024	Coho	63.0
12/3/2024	Chinook	64.0
12/4/2024	Coho	72.0
12/4/2024	*O. mykiss*	40.5
12/4/2024	*O. mykiss*	49.0
12/4/2024	*O. mykiss*	46.5
12/4/2024	*O. mykiss*	46.0
12/12/2024	*O. mykiss*	37.5
12/18/2024	*O. mykiss*	49.0
12/19/2024	*O. mykiss*	50.0
12/19/2024	*O. mykiss*	47.0
1/29/2025	*O. mykiss*	50.0
1/29/2025	*O. mykiss*	57.0

Figure 5. The proportion of lengths in 5 cm bins from field-measured Chinook and Coho Salmon and *O. mykiss* (the same data presented in Figure 3) and SONAR measured fish, Klamath River, California.

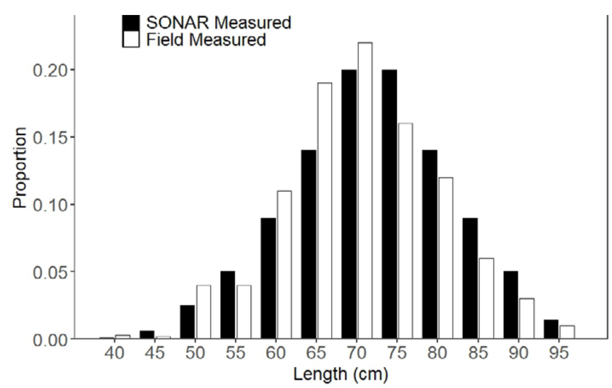


Table 2. Actual lengths and SONAR measured lengths for Chinook Salmon carcasses of two different lengths by two different observers, Klamath River, California. Data collected June 10, 2025.

	Actual Length (cm)	SONAR Measured Mean (cm)	SONAR Measured SD (cm)
Obs. 1	58	61,2	7,4
Obs. 1	66	65,4	7,1
Obs. 2	58	59,6	0,8
Obs. 2	66	64,7	4,1
Comb.	58	60,7	5,9
Comb.	66	65,1	6,2

We fit a binary generalized linear model, with logit link function, to estimate the probability a fish observed by the SONAR unit as either an *O. mykiss* or salmon. Conditional on the predicted classification of being a salmon, a binomial generalized linear model, again with a logit link function, was fit to estimate the probability of being either Chinook Salmon or Coho Salmon. The statistical models had the following form:

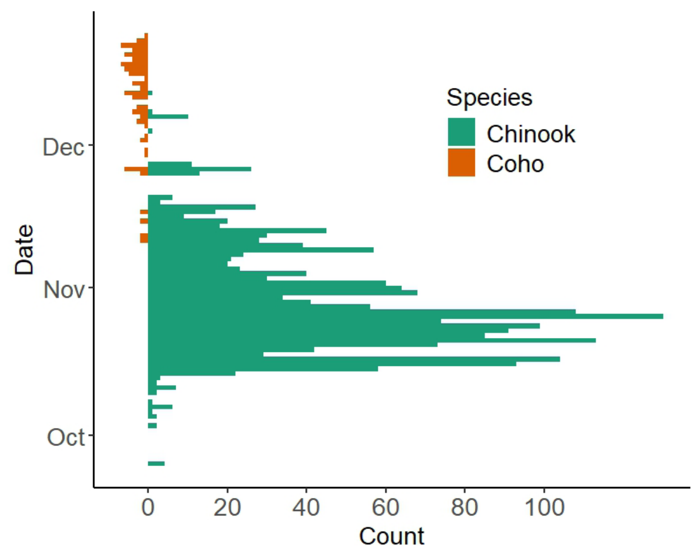
$$y_i \sim Bernoulli(\pi_i)$$
$$logit(\pi_i) = \beta_0 + \beta_1 x_i$$

where y is the outcome of a binary process of being either *O. mykiss* or salmon, π is the probability an observed fish is an *O. mykiss*, the βs are standard regression parameters, and x is the length of each fish. Similarly, the next probability model is:

$$w_i \sim binomial(\rho_i, N_i)$$
$$logit(\rho_i) = \alpha_0 + \alpha_1 z_i$$

where w is the outcome of a daily binomial process consisting of Chinook and Coho Salmon observations (where counts of zero for each species are possible), ρ is the probability a salmon is a Chinook Salmon, N is the total number of Chinook and Coho Salmon observed per day, the αs are standard regression parameters, and z is the within-year date of the season. With this framework, the probability an observed fish in the SONAR footage is a Chinook Salmon is (1-π)ρ and the probability an observed fish in the SONAR footage is a Coho Salmon is (1-π)(1-ρ). For model fitting, dates were first converted to Julian days as defined by R, where day 1 was January 1, 1970 (R Core Team 2005), and then centered and scaled by subtracting the mean value and dividing by the standard deviation.

Figure 6. Timing frequency histogram of Chinook Salmon and Coho Salmon at three different video weirs operated by CDFW on the Klamath River, California. These data from all three weirs were pooled together. The three different weirs were located at Bogus Creek (400 m downstream of the SONAR), Jenny Creek (7 KM upstream of the SONAR) and Shovel Creek (27 KM upstream of the SONAR).



California Department of Fish and Wildlife, Karuk Tribe, Keith Denton and Associates and CalTrout establishing the SONAR sensor.

We constructed the likelihood and specified prior distributions using BUGS language and called the R package nimble (de Valpine et al. 2024) from R (R Core Team 2025) to use Markov chain Monte Carlo (MCMC) simulation to draw samples from the joint posterior distribution of the parameters. For all regression coefficients, we specified mean-zero Gaussian priors with precision (variance–1) values equaling 0.0001. We ran three simultaneous MCMC chains and retained 3000 samples per chain after a burn-in period of 10000 samples and a thinning rate of 5 (i.e., 9000 samples per parameter were summarized for inference). Convergence was assessed visually from the traceplots of each MCMC chain and quantitatively by ensuring all Rhat statistics were less than 1.1 (Gelman et al. 2014).

Estimating Species-Apportioned Abundances

To translate the counts of fish obtained from SONAR footage into abundance estimates, we relied on the statistical modeling results to create an abundance calculating function. The function inputs included the length of the fish as measured by the SONAR unit and the date of observation. The SONAR unit also allows observers to note if the fish is swimming upstream or downstream. It was our intention to estimate the abundance of salmon remaining upstream of the SONAR unit. To accomplish this, we generated separate abundances estimates for each directionality for each species and then subtracted the downstream estimates from the upstream estimates.

Abundances were generated by first calculating probabilities based on the probability equations described above, and then simulating binomial draws for each species, conditional on those probabilities. This allowed for estimation uncertainty to be retained over the MCMC samples used to generate the species-specific probabilities, Because of their complex migration patterns, both upstream and downstream movements are presented for *O. mykiss*. All computations were done across the variation in MCMC samples for each parameter to ensure that we properly propagated estimation error through to the final estimates.

Estimating the Number of Jack Chinook

To align with standard management practices for Klamath River fall-run Chinook Salmon, we apportioned our total Chinook Salmon abundance estimate into two age classes: jacks (2-year-olds, also referred to as “grilse”) and adults (3-year-olds or older). This classification is consistent with the reporting structure used by the Klamath River Technical Team (KRTT), which primarily relies on scale age data to determine age class but may also use length-frequency distributions in the absence of scale data. Because our SONAR observations do not provide direct age information, we used external datasets to inform jack/adult apportionment. The primary dataset used was provided by the Yurok Tribe (K. Parker, pers. comm.), which included 2,940 scale-aged Chinook Salmon samples collected throughout the Klamath Basin in 2024. Of these, 4% were identified as jacks.

To assess the robustness of this proportion, we considered two alternative approaches:

1. Coded Wire Tag (CWT)-based aging: A set of known aged fish indicated a jack proportion near 2.4%.

2. Subsampled scale data restricted to fish upstream of Iron Gate Dam: This approach yielded a higher jack proportion, approximately 9% (63/683), suggesting spatial variability in age composition.

These results provide a range for the expected proportion of jacks in the Chinook run. While the 4% basin-wide estimate serves as our primary value, we consider 2.4% a conservative lower bound and 9% an upper bound for jack abundance in 2024. These percentage values form the basis for representing the range in jack Chinook Salmon abundances presented below.

Closeup of the ladder and pole mount. The SONAR itself is attached to the bottom of the pole mount and is positioned just below the water surface. Courtesy: CalTrout.

Results

Between October 1 and December 24, 2024, we recorded 2,034 hours of SONAR imagery, or 97.6% of the total possible hours. During this time period we identified and measured a total of 9,646 targets in the SONAR imagery (8,875 upstream, 771 downstream). From these raw targets we estimated that a total of 7,742 (95% CI: 7,702 – 7,778) Chinook Salmon and 324 (95% CI: 292-355) Coho Salmon migrated past and remained above the location of the SONAR unit during the period of the project. Of the total Chinook Salmon, we estimated 310 (lower bound of 186 to upper bound of 697) were jacks. Additionally, we estimated that 54 (95% CI: 27-85) *O. mykiss* passed upstream of the SONAR unit, and 16 (95% CI: 9-24) passed in a downstream direction during the period of the project. Daily passage estimates from our modeling suggest that individual fish were passing the SONAR in early October and the Chinook Salmon run began in earnest by mid-October and tapered in mid-November (Figure 7, on page 13), with Coho Salmon passage increasing in later November and continuing until the end of the project period on December 24 (Figure 8, on page 13). There were relatively low levels of daily *O. mykiss* passages distributed relatively uniformly across the survey window.

For MCMC sampling, all trace plots showed no trends and appeared well-mixed. Further, all Rhat values were close to 1 which further bolstered confidence that all chains had converged and were sampling stationary distributions. Graphically, there was tremendous overlap among the lengths of Chinook and Coho Salmon (Figure 4, on page 8), with a noticeable increase in the variation of lengths for Chinook Salmon. Given the wider range in the ages of returning Chinook Salmon, this result is unsurprising. Although the relative sample size is much smaller, the lengths of *O. mykiss* in this dataset are noticeably at the smaller end of the range between salmon lengths. The statistical model estimating β_1 showed very strong evidence that the probability a fish was an *O. mykiss* decreased with increasing length, as 100% of all MCMC draws for that parameter were negative. The strength of the estimated effect is evident where near-certain predictions of salmon assignment are achieved above 55cm in length (Figure 9, on page 13).

Conditional on being a salmon species, there is a clear visual pattern in the arrival timing as the bulk of the Chinook Salmon arrival distribution is much earlier in the season than that for Coho Salmon (Figure 6, on page 10). Visually, the early season observations are all Chinook Salmon, and the later season observations are all Coho Salmon. The statistical evidence is equally as convincing, as 100% of all MCMC draws for α_1 were negative, suggesting the probability of an arriving salmon being a Chinook decreases with increasing days into the sampling season (Figure 10, on page 13).

Karuk Tribe, Klamath Tribe, California Department of Fish and Wildlife, and CalTrout deploying tangle nets

Figure 7. The primary axis displays the estimated daily counts of Chinook Salmon remaining upstream of the SONAR unit (thick solid line) with 95% credible intervals (thin solid lines). The secondary axis reveals the relative cumulative percent abundance (dotted) line, based on daily increment of point estimates of daily abundance, Klamath River, California. Data from 2024.

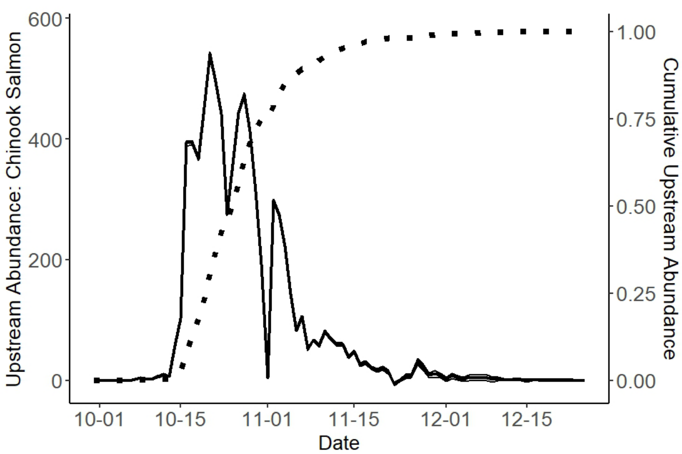


Figure 8. The primary axis displays the estimated daily counts of Coho Salmon remaining upstream ofthe SONAR unit (thick solid line) with 95% credible intervals (thin solid lines). The secondary axis reveals the relative cumulative percent abundance (dotted) line, based on daily increment of point estimates of daily abundance, Klamath River, California. Data from 2024.

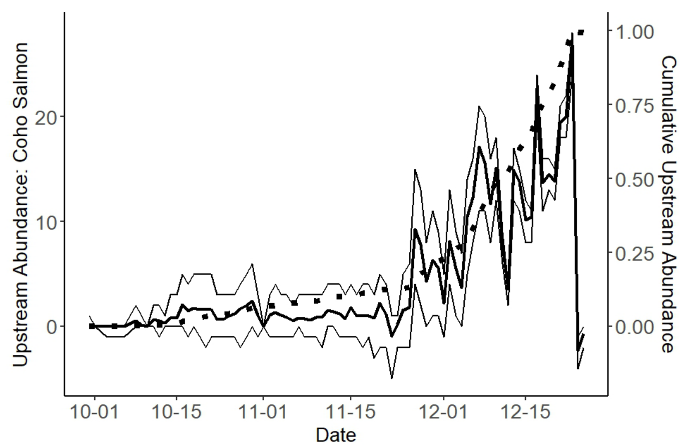


Figure 9. The estimated probabilities of a fish being an adult *O. mykiss* as a function of total length, Klamath River, California. The solid line represents that mean predictions based on the MCMC draws, and the dotted lines represent 95% credible intervals in the predicted values.

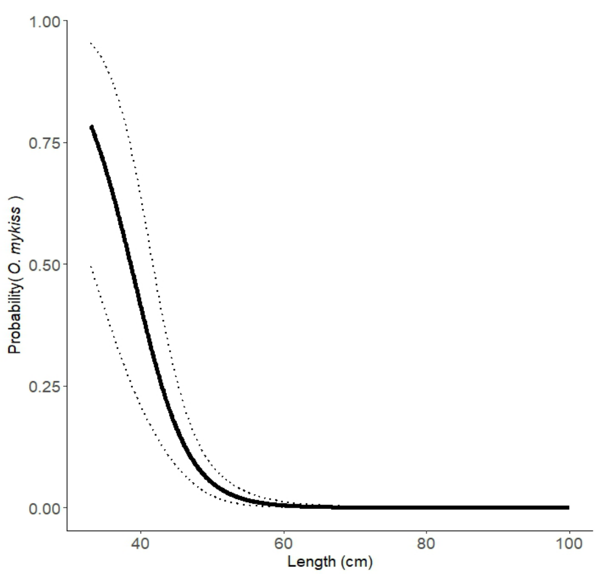
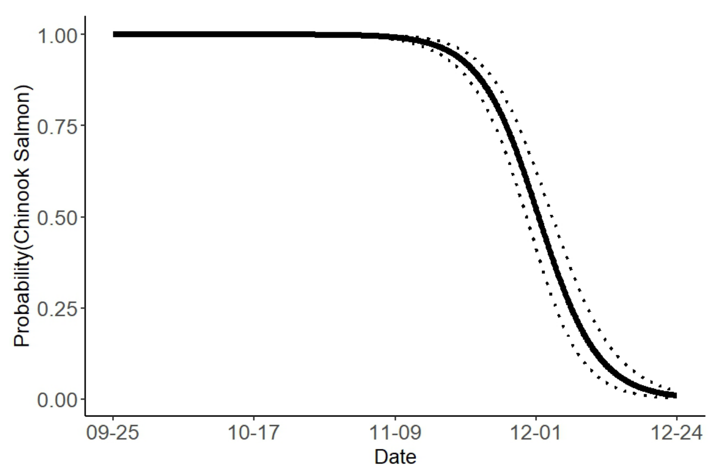


Figure 10. The estimated probabilities of a salmon being a Chinook Salmon as a function of days into the sampling season, Klamath River, California. The solid line represents mean predictions based on the MCMC draws, and the dotted lines represent 95% credible intervals in the predicted values. Date formats are "month-day". Data from 2024



Discussion

Dam removal results in the need to quantify the restoration of longitudinal connectivity for migratory fishes. This quantification is important for several reasons. First, dam removal is typically the most influential freshwater restorative habitat action that can occur to restore migratory fishes (Thieme et al. 2023; Magilligan et al. 2016). Dam removal can result in an immediate response from migratory fishes (Pess et al. 2014; Magilligan et al. 2016; Bunt and Jacobson 2024). Second, restoring large-scale connectivity allows for the expansion of habitat use and the re-expression of life history diversity which can lead to a population-level response for fishes utilizing the entire river network (Bellmore et al. 2019; Duda et al. 2021; Pess et al. 2024). Lastly, dam removal is typically expensive, so quantifying the benefit of the action, in the form of returning salmon and *O. mykiss*, is as important as understanding the cost of the action (Brown et al. 2008; Duda et al. 2023). The primary "benefit" metric for large dam removals associated with salmon and *O. mykiss* populations is returning adults (Anderson et al. 2014).

SONAR is an effective tool that has been used to monitor returning adult salmon and *O. mykiss* for the last two largest dam removals – the Elwha River and the Klamath River. In the Elwha River, SONAR was used to determine the annual abundance of adult Chinook Salmon and winter steelhead (Pess et al. 2024). The SONAR was able to capture changes in the before, during, and after annual abundance estimates with a coefficient of variation that ranged between 1% and 6% for 11 years (Pess et al. 2024). This was the case even during the most turbid and difficult years to enumerate (Pess et al. 2024). We used SONAR in the Klamath to enumerate the return of adult Chinook and Coho Salmon migrating upstream of the former Iron Gate Dam, the lowest point of the four dams removed, and provide migration information for *O. mykiss* during the period of the project. The coefficient of variation, which typically includes uncertainty sources in the enumeration estimate for each species, observer error (although not in the case of the Klamath), and species composition identification, was also quantified. As with the Elwha River, knowing, and quantifying the sources of uncertainty is important because it gives us a better indication of the range of the estimates, and more importantly during the initial implementation it allows for the identification of a series of actions to improve SONAR operations and the associated estimates in the future.

Local and Regional Context for Passage Estimates

Our estimate of 7,742 (95% CI: 7,702 – 7,778) fall-run Chinook Salmon migrating upstream of the former Iron Gate Dam represents a robust indicator of fish passage success into the newly accessible habitats. This value accounts for 18% of the total run-size, 43,653, for the Klamath Basin in 2024 (CDFW 2025b). This proportion is comparable to pre-dam removal contributions from nearby index sites. For example, in 2023, Bogus Creek and Iron Gate Hatchery together contributed over 13,000 adults, accounting for approximately 20% of the total Klamath Basin adult run-size. Following dam removal and the closure of Iron Gate Hatchery (IGH), returns to IGH dropped from over 10,000 in 2023 to zero in 2024, while Bogus Creek returns fell from 3,000 to around 300, likely reflecting shifts in fish distribution due to upstream passage opportunities. Notably, both the former IGH and the confluence of Bogus Creek lie within 400 meters of our SONAR site.

When contextualized across the last two decades (2004–2023), the combined IGH and Bogus Creek returns accounted for an average of 18% of the total Klamath Basin adult run-size, with an observed range between 10% and 30%. Our current estimate thus falls at the mean of this historical range and reflects anticipated shifts in migration patterns following dam removal.

The initial response of fishes in the Klamath River can be compared to the decade of post-dam removal monitoring in the Elwha River. The Elwha River dam removal estimated an average number of naturally spawning Chinook Salmon before, during, and after dam removal of 1,393 (± 1,218), 1,930 (± 747), and 3,523 fish (± 1,949), respectively (Pess et al. 2024). In addition, most Chinook Salmon redds have been above the former barriers (Pess et al. 2024). The estimates of returning adult winter *O. mykiss* to the Elwha River from 2014 to 2020 ranged between 890 and 1,985 fish (average 1,400 ± 350), with the vast majority of the natural spawning *O. mykiss* above the former dam sites (Pess et al. 2024). Coho Salmon have increased from a few thousand to averaging 5,353 (± 298) since dam removal (Denton et al. 2024). Again, most of the spawning occurs upstream of both former dam sites with most occurring between the two former dam sites (McHenry et al. 2022). Importantly, the anadromy barrier prior to dam removal on the Klamath River was several orders of magnitude higher in the system than it was on the Elwha River.

Sources of Uncertainty

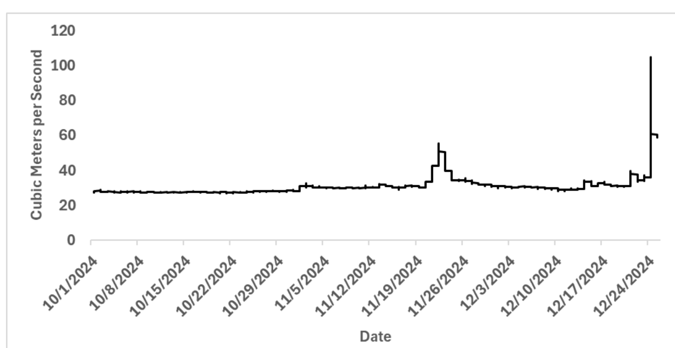
The strength of the estimates presented begins with the clear and straightforward review of SONAR imagery that was recorded in the first year of operation. There was also a general lack of milling behavior exhibited by all migrating species at the SONAR site that allowed for greater certainty in direction of movement. This is evidenced by only 8% of the total passage events recorded by the SONAR being downstream (771/9,646). These two factors produced negligible differences in counts between the two experienced reviewers. Species apportionment of the raw SONAR targets was relatively unambiguous with jack Chinook and *O. mykiss* exhibiting limited size overlap with either adult salmon species and Chinook Salmon and Coho Salmon exhibiting limited temporal overlap with each other. Lastly, although we did not make any attempt to fill data gaps, they were minimal as we recorded data for over 97% of the operational period. Disabled time likely represented a disproportionately high amount of fish passage events with >300 fish passing per day during the equipment outage that occurred during October 30-31. Regardless, given the small amount of missing data we did not attempt to infill for analysis.

Our confidence in the raw SONAR passage numbers, the most critical piece of our overall estimate, is high for several reasons. First, the Klamath River is approximately 30 meters wide at the Iron Gate SONAR site, well within the effective range of the ARIS 1200 SONAR used in this study. Second, stream flow during the operational period of this study was within the average flow of approximately 28.3 cubic meters per second (cms; 1,000 cfs) during the Chinook Salmon migration. Later in the season, flows remained low except for one 56.6 cms (2,000 cfs) event in late November 2024. After late November, the hydrograph steadily increased into late December, until a 235.9 cms (8,300 cfs) event, the highest since 2019, dismantled the equipment on December 24 and ended our recording season (Figure 11). This low and stable hydrograph aided in capturing high quality imagery. Uncertainty estimates due to stream flow conditions that result in data gaps on the Elwha River were, on average, greater for estimates that occurred during the winter and spring due to rain-on-snow and snowmelt stream flow events, than for those that occurred during the summer and fall seasons (Denton et al. 2015).

We recorded high quality imagery during most of the Chinook Salmon run that was straightforward to review as indicated by the close agreement of almost 700 fish passage events by two expert observers. While there was some inconsistency between observers at a smaller scale, indicated by the points on the graph that do not lie on the 1:1 line (Figure 3), there was no consistent bias across the 80 30-minute files counted by both observers, indicating that the overall counts produced by the primary observer have little error associated with them. We are currently increasing the size of the data review team, with the assistance of CalTrout and the Yurok Tribe, and preliminary results indicate strong agreement with the expert reviewer counts. For example, one reviewer has completed the training and has reviewed over 1,000 passage events during the highest passage periods of the Chinook Salmon run in late October. Over this period, they recorded only 6.8% fewer fish than the primary data reviewer (1,278 vs 1,367).

Another source of uncertainty in our passage estimates was apportioning the raw passage numbers to species-specific passage. Segregation of the length of salmon of the same species and overlap of length and run timing of those that are different species is a common occurrence (Waples et al. 2004; Kovach et al. 2013). This can cause issues with SONAR passage data if species apportionment is not quantified in some fashion. We relied on carcass and tangle net sampling for species specific length data and on video weirs operated by CDFW in tributaries near the SONAR site for species specific run timing information. The size differentiation between adult Chinook and Coho Salmon versus jack Chinook and *O. mykiss* along with the temporal segregation of the Chinook Salmon and Coho Salmon runs made the species apportionment relatively unambiguous.

Figure 11. The hydrograph at the U.S. Geological Survey Iron Gate Dam monitoring station (11516530) during the period of SONAR operation, Klamath River, California.



The adult Chinook and Coho Salmon lengths having minimal overlap with the lengths of *O. mykiss* and jack Chinook Salmon greatly increases our confidence in our adult salmon passage estimates. It is important to note that our *O. mykiss* length data is based on only 14 individuals and therefore may not accurately represent the true population length histogram. Based on the small size of *O. mykiss* in the Klamath, it is unlikely that we are mis-apportioning raw SONAR targets as *O. mykiss* instead of adult Chinook Salmon or Coho Salmon (Hodge et al. 2016). Furthermore, the largest *O. mykiss* we measured, 57 cm and 7 cm longer than the next closest *O. mykiss* was sampled on January 29, more than a month after SONAR operations ceased and potentially not representative of the *O. mykiss* population in the vicinity of the SONAR site during the salmon season presented in this report (Table 1, on page 9).

Further, the probability of a SONAR target being an *O. mykiss* decreases to almost zero at lengths longer than approximately 53 cm (Figure 9, on page 13), indicating that SONAR targets measuring over this length are almost certainly adult salmon and only need to be apportioned between Chinook and Coho based on timing data.

We compared the lengths of carcasses measured in the field to those of fish measured with the SONAR and found very close agreement when investigated at the population level through visual investigation of proportional length frequency histograms (Figure 4, on page 8) or by simply comparing the mean length of field measured salmonids (68 cm, n = 1,248) to the mean length of SONAR measured targets (69 cm, n = 9,592). Additionally, we developed a tethered carcass experiment that also indicated agreement between SONAR measured lengths and individual carcass lengths (Table 2, on page 9). Thus, our SONAR measured lengths are an accurate representation of actual fish lengths and likely do not add significant uncertainty to our population estimates. Only 9% (885/9,650) of our SONAR targets measured between 55 cm and 60 cm, indicating that even if there was a 5 cm over measurement error in our SONAR data, which a comparison of carcass to SONAR length frequency histograms does not support, this potential source of error would have a limited effect on our overall adult salmon escapement estimates.

Once SONAR targets were segregated into *O. mykiss* and salmon, we separated adult Chinook Salmon and Coho from each other using timing data. Our main source of timing data was the CDFW weirs, which showed limited overlap between Chinook Salmon and Coho Salmon (CDFW, 2025a). Over 92% (1,849/1,994) of the recorded Chinook Salmon moved upstream past the tributary weirs before the first Coho Salmon was observed, and 67% (63/94) of the recorded Coho Salmon moved past the weirs after the last Chinook Salmon. These data indicate that our Chinook Salmon estimate likely experienced very little error due to species apportionment. Only fish numbering in the tens would be apportioned in late November during the period when Chinook Salmon and Coho Salmon overlap. This would have little effect on the thousands of fish passing upstream when only Chinook Salmon were present in the system. However, the much smaller Coho Salmon run is more susceptible to the mis-apportionment of raw targets during this same time period simply because ~50% of the Coho Salmon run passed while there were still Chinook Salmon in the system (Figure 6, on page 10).

We introduced two potential biases with our timing data sources that would introduce inverse effects. First, we treated all weir data as synchronous, without accounting for any travel time between the furthest downstream weir (Bogus Creek) and the furthest upstream weir (Shovel Creek). Shovel Creek is 27 km upstream of Bogus Creek and we could have lagged that timing data to reflect when those fish passed the SONAR. Presumably, because of the weir's location further upstream, the Shovel Creek weir data shows later Chinook Salmon entry which thereby drives most of the temporal overlap between Chinook Salmon and Coho Salmon. Therefore, the weir data, we used potentially shows more temporal overlap between Chinook Salmon and Coho Salmon than exists at the SONAR site. Second, Chinook Salmon and Coho Salmon may not enter the tributaries at the same rate that they pass the SONAR site. It is possible that Coho Salmon spend more time in the mainstem before entering the tributaries and being detected on the CDFW weirs. This would result in the weir data we used indicating that coho entry into the tributaries was later than when they passed the SONAR site.

We have lower confidence in our ability to differentiate species for smaller SONAR targets. This primarily influences differentiation between *O. mykiss* and jack Chinook Salmon. Fortunately, only 8% of SONAR targets measured smaller than 53 cm (777/9,650) indicating that very few fish are influenced by this uncertainty. Similarly, the proportion of Chinook Salmon that are jacks was estimated using a post-hoc analysis. We selected the Klamath Basin wide estimate of jacks using scale-based aging data to reduce sample bias from small sample sizes found in the code-wired tag data, as well as fine scale sampling bias if relying on a sub-set of scale samples collected upstream of Iron Gate dam. We found the influence of these alternate jack rates to be negligible in our estimate of adult Chinook Salmon with a maximum change of less than 400 fish. Improving our ability to speciate smaller targets is a top priority in subsequent years of this study and includes focused data collection.

Aside from distinguishing *O. mykiss* from jack Chinook Salmon, generating a population estimate for *O. mykiss* entails additional complications including accounting for their unique life history patterns of iteroparity and nonanadromy. Iteroparity leads to the possibility that they may successfully spawn above the SONAR and then return downstream past the SONAR (kelting) resulting in a net zero count on the SONAR. Resident *O. mykiss* may have complicated life history patterns that involve multiple migrations past the SONAR site, making it difficult to assess simply upstream passage. An indication of these more complex migration patterns among smaller sized fish are evident in the SONAR data, whereby targets measuring under 55 cm have a downstream/upstream ratio of 27% (166/610) while targets measuring over 55 cm have a downstream/upstream ratio of only 7% (606/8,266). Two final issues for accurately estimating the *O. mykiss* population that migrated past the SONAR site are the ability of the data reviewer to focus on the smallest size class of targets and the SONAR's ability to accurately detect these targets, especially on the far bank. To focus on the thousands of salmon sized targets in the SONAR data the reviewer did not focus on the far less abundant targets less than 45 cm, only recording 78 such targets. Twenty percent of the *O. mykiss* we measured in our net sampling were less than 45 cm.

A final source of uncertainty in our passage estimates are data gaps, times where the SONAR was not collecting passage data due to hydrologic conditions or computer outages. Although we made no attempt to infill missing data, we had few data gaps because streamflow was relatively low and stable during the time of deployment. Data gaps did occur but were after the bulk of salmon passage (Figure 2, on page 7). The one gap that did occur during a period of time with significant upstream passage was a gap of approximately 24 hours from October 30 into October 31 which, based on passage immediately before and after the outage, could have resulted in not detecting several hundred Chinook Salmon. The end of the Coho Salmon run was truncated due to a large flood that disabled our equipment on December 24, 2024. Data from the CDFW weirs upstream and immediately downstream of the SONAR site showed the last recorded Coho Salmon in Shovel Creek on December 24 and the last recorded Coho in Bogus Creek on December 22. It is important to note that CDFW weirs experienced the same hydrograph-related issues as the SONAR project and were also not operational beyond a similar date. There is a high likelihood that the SONAR project recorded data from the entire Chinook Salmon run and much of the Coho Salmon run. The netting portion of the project had one sampling date after the removal of the SONAR, on January 29, no Coho Salmon were sampled and two *O. mykiss* were sampled.

Chinook Salmon spawning upstream of the former site of Iron Gate Dam. Courtesy: Michael Wier / CalTrout.

Other Fish Observations

It is important to put our estimate of 7,742 Chinook Salmon in context with other observations in the watershed. CDFW, ODFW, USFWS, Karuk Tribe, and Yurok Tribe conducted extensive redd and carcass surveys to evaluate spatial distribution and spawning habitat use in the newly opened habitats. These surveys included portions of the mainstem Klamath River, Spencer Creek, Jenny Creek, Shovel Creek, Fall Creek, Camp Creek, and Scotch Creek. This information can also be analyzed to estimate the total Chinook Salmon escapement to the entire Klamath River basin, with reach scale breakouts for pre-determined sections. In 2024, the in-river run for the entire basin was 43,654 (36,569 adults, 7,085 grilse). The estimate for fish above the former Iron Gate Dam was 1,962 (1,793 adults and 169 grilse) (KRTT, 2025). The total estimate represents 25% of our estimate. Two major factors that help explain the discrepancy between the two estimates. First, the vast amount of upstream habitat above the former dams redd and carcass surveys could not fully cover. Secondly, the levels of turbidity following dam removal that greatly reduced visibility and made redd and carcass observations much more difficult.

The Klamath River dam removal opened over 640 km of additional spawning habitat, of which 113 km was surveyed. Although not all of the new habitat is spawnable, some of the previously unavailable habitats are essentially unsurveyable river reaches such as steeper canyons. Finally, a significant portion of the newly accessible habitat (~76%) was upstream of the Keno Dam, which is in a portion of the basin that was not surveyed. United States Bureau of Reclamation (BOR) personnel observed several salmon passing through their Keno Dam facility on two different occasions between late October and early November 2024 (Eric W. Reiland, USBR, pers. comm., 8/25/2025), which would have presumably spawned and died undetected upstream. Additionally, the Klamath Tribes and ODFW deployed an exploratory motion-sensing camera in the Link River fish ladder, which was operational during daylight hours from November 1, 2024, to January 2, 2025, and observed limited salmonid activity. Four salmonids were identified based on the presence of an adipose fin: three were confirmed as *O. mykiss*, and one was a large, unidentifiable silhouette with a forked tail, potentially indicative of a Chinook Salmon (Jordan Ortega, Klamath Tribes, pers. comm., August 1, 2025). Redd surveys showed peak abundance in the closest surveyed reaches downstream on October 31, so it is possible that additional Chinook Salmon passed through the Link River Dam before video monitoring began.

The second factor explaining the discrepancy between the SONAR counts and the redd and carcass surveys is that dam removal introduced enormous quantities of sediment in the system which caused visibility levels to drop to near zero during certain periods of the Chinook Salmon run in certain sections of the river above the SONAR. Recovering carcasses or identifying redds at the turbidity levels present during most of the Chinook Salmon spawning period certainly resulted in an undercount of both carcasses and redds. In the Elwha River, the population estimates between methods varied by species. Elwha River Chinook Salmon estimates using redd counts and broodstock capture could come within 15% of SONAR estimates, after the biggest turbidity impacts of dam removal had subsided, while *O. mykiss* estimates from redd count and broodstock capture were never closer than 25% of the SONAR estimate. In both cases redd counts, even including the broodstock programs, were consistently lower than SONAR population estimates (Deibner-Hanson, 2021; Pess et al. 2024). Regardless of the efficacy of redd counts and carcass surveys for estimating abundance, it is important to recognize their principal role of providing spatial distribution (redd surveys) and age data (carcass surveys).

Chinook Salmon netted and tagged by the Karuk Tribe and CalTrout. Courtesy: Karuk Tribe.

Collaboration in action: The Karuk Tribe, The Klamath Tribes, CDFW, Keith Denton & Associates, and CalTrout work side by side to process and tag a netted salmon. Courtesy: CalTrout.

Summary

In summary, our passage estimates measured by the SONAR show efficient and consistent movement of both Chinook Salmon and Coho Salmon through the former Iron Gate dam. These initial fish were able to access hundreds of kilometers of "new" habitat. Our SONAR effort was able to provide robust, species-specific passage estimates based on SONAR imagery which was clear and straightforward to review. We recorded over what was nearly the entirety of the Chinook Salmon run, and likely the majority of the Coho Salmon run. The discrepancy between two expert reviewers was minimal and there were limited data gaps that needed to be filled. Assigning raw SONAR targets to species was unambiguous because of the temporal distinction between Chinook Salmon and Coho Salmon, and the length distinction between *O. mykiss* and adult salmon. Assigning species to SONAR targets measuring less than 55 cm was more complicated because of the overlap in that size range between jack Chinook Salmon and *O. mykiss*, as well as the small sample size of *O. mykiss* lengths and the lack of timing data for *O. mykiss*. Nevertheless, SONAR targets measuring less than 55 cm only accounted for 7% of the total SONAR targets and any error in species apportionment for these smaller targets would have limited effect on our overall estimates.

Looking ahead

The first year of post-dam removal monitoring successfully demonstrated the utility of SONAR technology for enumerating fish migrating upstream and downstream of the former Iron Gate Dam site. One year of data is not sufficient to evaluate the long-term ecological benefits of dam removal or to fully capture population-level responses (McHenry and Pess 2008, Pess et al. 2024). Like other dam removals (Pess et al. 2024), multiple years of monitoring will be required to characterize interannual variability, assess long-term fish population trends, and evaluate how dam removal influences life history strategies and species recovery in the Klamath Basin.

There are several areas where the project could and will likely improve in the near and long term that will allow for greater expansion to multiple species, and greater confidence in our estimates. A primary limitation in the current species apportionment analysis is the limited information available on *O. mykiss*. Specifically, reach-specific length and timing data are sparse, constraining our ability to confidently differentiate between life history types. 2024 tangle net sampling yielded only 14 *O. mykiss* samples. In addition, the CDFW tributary weirs only identify a very limited number of *O. mykiss* since they typically do not enter the tributaries to spawn until well after salmon. Additionally, *O. mykiss*, being iteroparous, do not typically appear in carcass surveys. Access to the former Iron Gate reservoir and increasing the frequency and duration of our tangle net efforts will improve our success as well as the overall experience level for the individuals involved. In addition, conversations with local fishing guides are ongoing and we hope to be able to provide them with a standardized protocol for obtaining accurate and reliable lengths of *O. mykiss* in the reaches near the SONAR site as the project moves forward. Future *O. mykiss* work will emphasize investigation of resident versus anadromous forms, migration timing, and uncertainty associated with species apportionment. This effort is being advanced in collaboration with The Conservation Angler (TCA), CalTrout, and a basin-wide working group to ensure a shared understanding of *O. mykiss* responses to dam removal.

A second focus will be increasing our coverage of the migration season. SONAR operations were truncated in late December 2024 due to a major flood event and subsequent high-flow conditions that persisted throughout the spring. These conditions prevented data collection during critical migratory periods for Coho Salmon and *O. mykiss*. As a result, we were unable to fully characterize run timing or abundance for these species. Future objectives include extending monitoring to a year-round framework, with improved capacity to sample during high flows, ensuring that key portions of the migration season are captured.

Coupled with this effort will be additional tangle netting. Additional field samples, whether through tangle netting or other sources, will increase the amount of length data and our certainty of a smaller fish cutoff size that differentiates between *O. mykiss*, jack Chinook Salmon, adult Coho Salmon, and adult Chinook Salmon. An increase in the duration of the SONAR "in the water" collecting data will reduce any data gaps that may occur during the migration window. This will increase our ability to come up with a precise and accurate *O. mykiss* estimate in future years.

Although the project provided high-quality data in 2024, these outputs were not integrated into the Klamath Basin stock assessment or management processes. Moving forward, a priority will be to accelerate data processing to allow timely delivery of results to the Klamath River Technical Team in January. This will support incorporation into stock assessments and fisheries management decisions. To achieve this goal, we plan to further develop the data review process by increasing the number of individuals who have experience reviewing SONAR. In addition, we are also working with a collaborative team from CalTech and MIT to develop artificial intelligence (AI) and machine learning (ML) tools to automate at least some portion of the data review (https://fisheye-sonar.github.io/ and Kay et al. 2022). The team is advancing beta testing of AI–driven data processing with the goal of generating near-real-time insights from SONAR data.

Lastly, we will implement multiple actions to reduce the uncertainty of the smaller fish count. We will seek input from our partners on Chinook Salmon jack rate estimates and utilize that information to help make a more informed and more precise and accurate cut-off for delineating Chinook jacks, Chinook Salmon, and *O. mykiss*. We will increase the duration of SONAR data gathering to gain more samples of smaller fish, assuming they occur at different times of the year than adult Chinook Salmon. In addition, we will couple this with an increase in the duration of tangle net sampling to gain a better understanding of the correlation between the SONAR and field measured salmonids.

Looking upstream through the former site of Iron Gate Dam into the 640 km of newly opened river. Courtesy: Michael Wier / CalTrout.

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