The Resources Agency
California Department of Fish and Wildlife

LOWER MAIN STEM EEL RIVER and VAN DUZEN RIVER CHINOOK SALMON MONITORING PROJECT

SONAR ESTIMATION OF CALIFORNIA COASTAL (CC) CHINOOK SALMON (*Oncorhynchus tshawytscha*) ABUNDANCE IN THE LOWER MAIN STEM EEL AND VAN DUZEN RIVERS, HUMBOLDT COUNTY, CALIFORNIA 2023 - 2024

FINAL REPORT

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Abstract

The California Department of Fish and Wildlife (CDFW) in partnership with Pacific States Marine Fisheries Commission (PSMFC), National Oceanic and Atmospheric Administration (NOAA) Fisheries West Coast Region, and Pacific Gas & Electric (PG&E), operated an Adaptive Resolution Imaging Sonar (ARIS) 'camera' and a separate Dual-frequency Identification Sonar (DIDSON) 'camera' to enumerate adult and jack salmon escapement into the lower Main Stem Eel River above the confluence with the South Fork Eel River and in the lower Van Duzen River during the fall and winter of 2023-2024. This was the sixth year of the Main Stem Eel River (and second year for Van Duzen River) sonar monitoring project, and the primary intent was to estimate the returns of adult California Coastal (CC) Chinook Salmon (*Oncorhynchus tshawytscha*) and if possible, estimate returns of adult Northern California (NC) steelhead (*Oncorhynchus mykiss*).

The estimated abundance of Chinook Salmon returning to the Main Stem Eel River above the confluence of the South Fork Eel River from October 10, 2023 through December 20, 2023 was 8,161 fish (95% CI 7,171 – 9,055; with a coefficient of variation (CV) of 5.8%). Due to favorable stream flow conditions and the enhanced clarity of ARIS imagery, project staff were able to separate the Chinook Salmon run into age classes (adults and jacks). Of the 8,161 fish estimated to have migrated upstream of the camera site, 4,958 were adults and 3,203 were jacks. We analyzed the first 20-minute file of each hour and then adjusted these raw counts for expansion to hourly counts, species composition, and filling data gaps (e.g. hours the camera was not running). Daily movement of fish during the Chinook Salmon run at the Main Stem Eel River sonar site ranged from 0 to 2376 and averaged 33 fish per day. The peaks of migration occurred on consecutive days in early November; November 6 (N = 2376 fish), November 7 (N = 1386 fish), and November 8 (N = 363 fish), which accounts for 50.3% of total abundance. This peak aligned with the arrival of the first significant rain and flow event of the season. During the Chinook Salmon run on the Eel River there were a total of 1,752 hours sampled, accounting for 92.1 % of the total potential sampling time (October 10 – December 20).

We estimate the abundance of Chinook Salmon returning to the Van Duzen River from November 3, 2023 through December 18, 2023 equaled 1,867 fish (95% CI 1,660 – 2,073; with a coefficient of variation (CV) of 5.5%). Of the 1,867 fish estimated to have migrated upstream of the camera site, 997 were adults and 870 were jacks. We analyzed the first 20-minute file and then adjusted these raw counts for expansion to hourly counts, species composition, and filling data gaps (e.g. hours the camera was not running). Daily movement of fish during the Chinook Salmon run at the Van Duzen River sonar site (November 3 through December 18, 2023) ranged from 0 to 396 and averaged 41 fish per day (Figure 9). The peaks of migration occurred on consecutive days in early November: November 6 (N = 387 fish), November 7 (N = 396 fish), and November 8 (N = 315 fish), which accounts for 58.8% of the total abundance. This peak also aligned with the arrival of the first significant rain event and rise in hydrograph of the season. During the Chinook Salmon run on the Van Duzen River there were a total of 738 hours sampled, accounting for 66.85 % of the total potential sampling time (November 3 – December 18).

It was also the project's objective to enumerate the winter-run steelhead population on the Main Stem Eel River. However, prolonged high stream flow conditions this project year prevented camera operations for much of the run (mid-January till early April); therefore, camera operations were limited to the beginning of the run and the end of the run. Accordingly, during the time sampled from December 21, 2023 – January 10, 2024, it is estimated that 1,476 winter-run steelhead migrated past the sonar camera. Daily movement of fish ranged from 33 to 168 and averaged 49 fish per day. The peaks of migration occurred on December 24 (N = 168), December 27 (N = 99), and January 5 (N = 156). During this period, there were a total of 264 hours sampled, out of 504 total possible hours (52.4%). The camera was non-operational from January 11 to April 8, 2024; therefore, overall data collection during the winter steelhead run was limited to approximately 12.5% of the typical run period. Once reinstalled, it is estimated that 156 adult steelhead migrated past the sonar camera from April 8, 2024 to April 28, 2024. Daily movement of fish ranged from 0 to 21 and averaged 7 fish per day. The peaks of migration occurred on April 12th (N = 15), April 20th (N = 66), and April 28th (N = 21). During this period, there were a total of 494 hours sampled, out of 552 total possible hours (98.2%).

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Introduction

Once supporting thousands of California Native Tribe members with sustenance and cultural resources and subsequently robust commercial and sport salmon fisheries, the Eel River has a legacy of wild salmon abundance. Estimates of over a half a million Chinook and Coho salmon combined were harvested per year at the turn of the 19th century (Moyle et al. 2017). Historic runs of Chinook Salmon probably ranged between 100,000 fish during low return years and peak years approach 800,000 (Yoshiyama and Moyle 2010). These historic run-sizes dropped significantly by mid- 1900s as the CDFW Fish and Wildlife Plan (1965) estimated Chinook Salmon spawning escapement of 26,000 fish (Main Stem Eel River upstream of the SF Eel). More recently, Chinook Salmon runs have crashed to far less than 5% of the historical abundance of fish remaining. Similar declines have been observed with steelhead. Yoshiyama and Moyle (2010) estimated historic numbers of likely 100,000-150,000 adults per year (winter and summer runs combined), declining to an estimated spawning escapement of 38,000 fish by the 1960s (CDFW 1965).

As a result of these significant declines, the California Coastal (CC) Chinook Salmon Evolutionarily Significant Unit (ESU) was first listed as a federally threatened species under the Endangered Species Act (ESA) in 1999, and subsequent status reviews have reaffirmed the threatened status (Good et al. 2005; Williams et al. 2011; & Seghesio et al. 2016). This ESU of Chinook Salmon has a geographic range which extends from rivers and streams south of the Klamath River in northern Humboldt County to and including the Russian River in Sonoma County. As California's third largest watershed, the Eel River is the largest contributor to the CC Chinook Salmon ESU and is crucial for viability of the species (NMFS 2016).

Due to its overall large size, remote geography, limited access, flashy hydrology, and high turbidities, monitoring the returning CC Chinook Salmon populations in the Main Stem Eel River has been difficult, and most previous studies are limited in their scope and duration. Two data sources – i.e., the fish counts at Van Arsdale Fish Station (at Cape Horn Dam) and spawner surveys in the upper Main Stem Eel River (below Cape Horn Dam) and in Tomki Creek - are among the best available long-running data sets, but they have significant limitations (Yoshiyama & Moyle 2010). The Van Arsdale Fish Station (VAFS) has fish counts from 1933 to present; however, major modifications to the fish ladder and provisions to provide attraction flows did not occur until 1987, thus limiting the accuracy of prior years' data. Furthermore, approximately 90% of the watershed is located downstream of Cape Horn Dam and counts at VAFS represent a small and highly variable portion of the run (Berg Associates 2002); spawning access to VAFS and other headwater habitats in the Eel River Basin is influenced by hydrologic alteration and is likely to depend strongly on the timing and persistence of suitable river flow.

While collecting valuable fisheries information for the upper Main Stem, the VAFS and historic and on-going upper Eel River carcass surveys do not provide evidence for the status of the basin-wide salmonid escapement. Accordingly, the National Oceanic and Atmospheric Administration

(NOAA) Fisheries status review (2005) for West Coast salmon and steelhead noted, “These data are not especially suited to rigorous analysis of population status for a number of reasons, and sophisticated analyses were not pursued.” The lack of monitoring data and a comprehensive monitoring plan for California Coastal (CC) Chinook Salmon have made it difficult to establish population status and trend, consequently decelerating the development of direct fishery assessment and abundance-based fishery management (O’Farrell et al. 2012). The most recent NOAA Fisheries status review (Seghesio et al. 2016) recommended the need for monitoring specifically in the Eel River watershed, “CC Chinook salmon monitoring in the Eel River should be the top monitoring priority for that ESU”. To address these issues, the California Department of Fish and Wildlife (CDFW) developed a strategic monitoring approach and plan for near-future and longer-term implementation, which included recommendations for deploying **D**ual-frequency **ID**entification **SON**ar (DIDSON) technology in the Eel River to monitor CC Chinook Salmon populations (Lacy et al. 2016).

The underwater camera’s sonar technology transmits and receives sound pulses that allow it to identify objects in underwater habitats, such as rivers. Considering the effectiveness to monitor salmon escapement in nearby northern California rivers (e.g. Mad River and Redwood Creek), CDFW believed DIDSON cameras could also be well suited to the highly variable discharge and water turbidity that characterize the Eel River during the period of salmon and steelhead migration. CDFW and partners initiated a pilot study in the fall of 2018, operating a DIDSON camera to collect fish migration run timing data and enumerate salmon and steelhead escapement into the lower Main Stem Eel River above the confluence with the South Fork Eel River (SF Eel River). Based on the success of the pilot study, the project has seasonally operated for a total of six monitoring seasons (2018 – 2024). In fall of 2023, funding provided by NOAA Fisheries West Coast Regions allowed for the acquisition of the newer, updated sonar camera model: an **A**daptive **R**esolution **I**maging **S**onar (ARIS) Explorer 1200, the next generation of DIDSON technology. ARIS technology uses higher operating frequencies to provide increased image resolution and clarity, allowing for greater accuracy in determining population estimates and run composition.

In the fall of 2022, NOAA Fisheries West Coast Region provided separate funding to initiate a pilot-project study in the lower Van Duzen River, which has now successfully concluded its second season. The goal of this study is to monitor the timing of fish passage and enumerate the Chinook Salmon run into the Van Duzen River. The Van Duzen monitoring site is located approximately 4½ miles upstream of its confluence with the Eel River. The Van Duzen study, in conjunction with the on-going lower Main Stem Eel River monitoring site and additional sonar sites in the SF Eel River and Middle Fork Eel River will provide a more complete Chinook Salmon abundance estimate for the Eel River watershed.

Study Area

The Eel River, known as Wiya't, Taanchow, and ch'idiyu to the region's tribes, located in northern California approximately 200 miles north of San Francisco, drains into the Pacific Ocean just south of the city of Eureka, Humboldt County. It is the third largest river in California with a drainage basin of 3,684 square miles (CDFW 1995), and a discharge of 5.4 million-acre feet (CDFW 1995). The Eel River watershed is comprised of the Main Stem Eel, North Fork Eel (283 sq. mi.), Middle Fork Eel (753 sq. mi.), SF Eel (690 sq. mi.), and the Van Duzen (428 sq. mi.) rivers. The Main Stem Eel River is approximately 197 miles in length with 832 tributaries – totaling 3,526 miles of blue line stream according to the USGS 7.5" maps. The Main Stem Eel River has its headwaters in Mendocino County near Bald Mountain, flowing south to Lake Pillsbury, then 12 miles west to Van Arsdale Reservoir, and then northwest approximately 157 miles to the Pacific Ocean. Elevations on the Main Stem range from sea level at the mouth to over 6,700 feet at the headwaters. The Main Stem Eel River sonar site project area covers the Main Stem Eel River (including the North and Middle Forks) from its headwaters downstream to near its confluence with the SF Eel River (Figure 1).

The Van Duzen River is a major tributary of the lower Eel River, and the watershed is located primarily in Humboldt County with a small portion of its headwaters in Trinity County. The river is approximately 63 miles in length and is one of the few remaining un-dammed rivers in California. Elevations range in its headwaters from near 6,000 feet to about 60 feet at its confluence with the Eel River. The Van Duzen River and its tributaries contain about 153 miles of accessible stream miles for anadromous fish. The Van Duzen River sonar site project area includes its mainstem and all its significant tributaries from its headwaters downstream to near its confluence with the Eel River.

There are two non-CDFW sonar camera operating stations monitoring adult salmonid fish passage within the Eel River watershed. Beginning in the fall of 2021, Round Valley Indian Tribes (RVIT) and McBain and Associates have operated a DIDSON camera (Standard-Range model) in the lower Middle Fork (MF) River near Dos Rios. California Trout (CalTrout) has also operated a DIDSON sonar camera (Long-Range model) in the lower SF Eel River beginning in the fall of 2018. Both entities also began utilizing an ARIS 1200 model in the fall of 2023 at their respective sonar monitoring sites. RVIT and CalTrout produce separate reports detailing their project operations and results (Wyatt Smith, RVIT and Matt Metheny, CalTrout, personal communication 2023 & 2024).

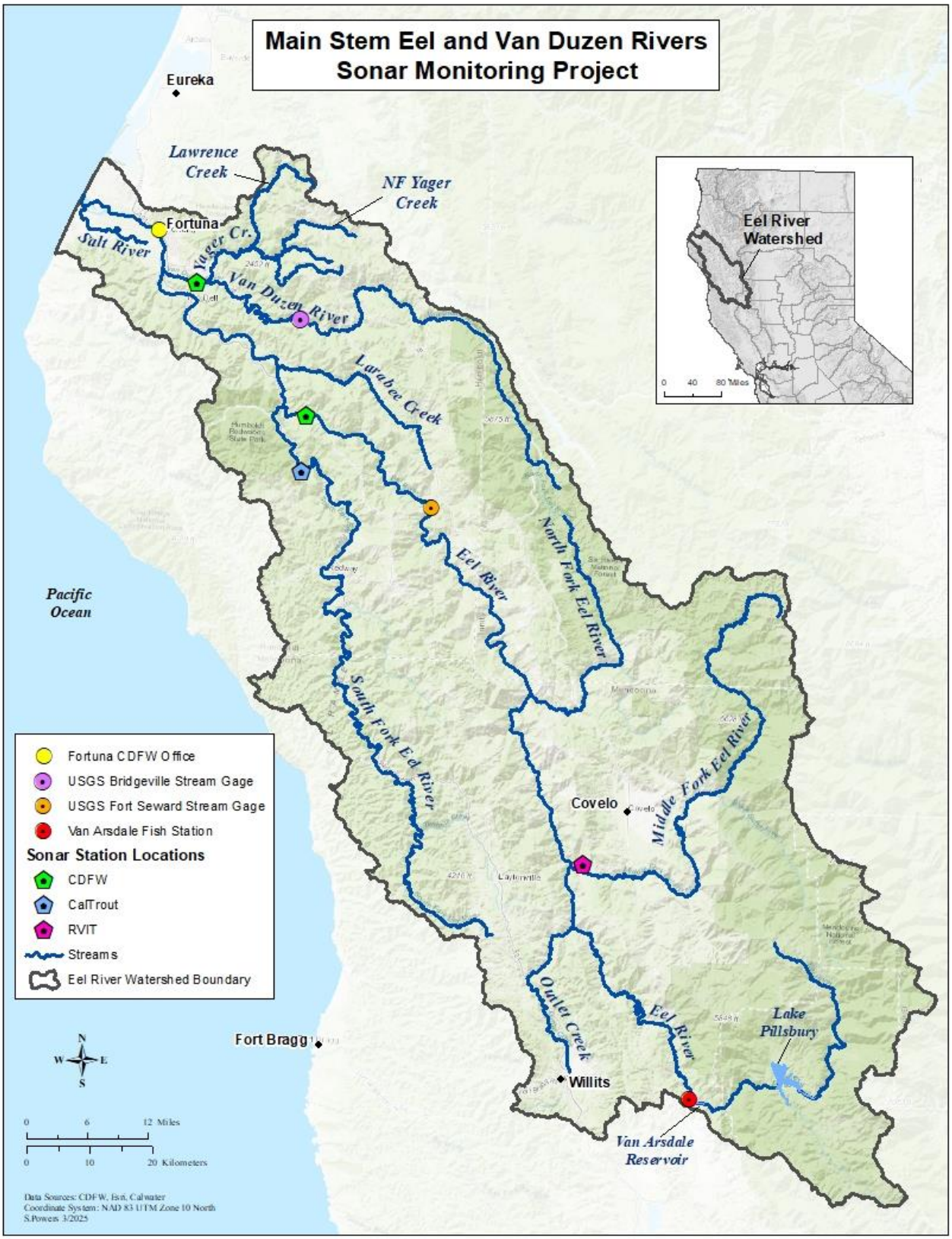


Figure 1. The Eel River watershed and location of CDFW Main Stem Eel River and Van Duzen River sonar monitoring stations and additional sonar locations in the SF Eel River (CalTrout) and MF Eel River (Round Valley Indian Tribes).

Methods and Materials

Sonar Camera and Site Selection

The CDFW identified DIDSON technology as a non-intrusive survey method for meeting the adult count station requirements of a life-cycle monitoring station as outlined in Fish Bulletin 180 (Adams et al. 2011). CDFW's Coastal Watershed Planning and Assessment Program (CWPAP) in conjunction with PSMFC operates the *Sound Metrics* ARIS 1200 and DIDSON long-range model units in the lower Main Stem Eel River and lower Van Duzen River, respectively. This season was the first in which an ARIS unit was used in place of a DIDSON on the Main Stem Eel River. ARIS 1200 and DIDSON long-range model are both capable of capturing images from the camera extending outwards to an 80-meter distance.

The Main Stem Eel River sonar site is at River Mile (RM) 44, approximately 4 miles upstream of its confluence with the SF Eel River behind a locked gate on Humboldt Redwood Company Property (HRC); the Van Duzen River site is also located behind a locked gate on private property, approximately 4½ miles upstream of its confluence with the Eel River (Figure 1). Site selection for the Main Stem site began with examining USGS topographical maps and utilizing Google Earth to view the lower Main Stem Eel River within a reasonable distance from the CDFW Fortuna field office. It became apparent that selecting a sonar camera station would be constrained to a few potential river sites accessed from the lower seven miles of Dyerville Loop Road, which roughly follows a portion of the Main Stem Eel River from the rural settlement area of McCann downstream to the confluence with the SF Eel River. In February of 2018, CDFW and Trout Unlimited staff conducted a reconnaissance-level raft floating trip on the Eel River from the McCann Bridge (RM 48) downstream to the SF Eel River (RM 40) to determine the best potential location for the sonar station.

Ideally, a sonar site contains the following criteria: 1) a uniform stream bottom profile that offers adequate esonification as described by Maxwell (2007) (i.e. uniform topography without large pits, boulders, or other structures that create blind spots); 2) a longitudinal profile that is characteristic of swift, laminar flow where fish 'milling' behavior is minimized (Pipal et al. 2012); and 3) safe, secure site for the camera and associated equipment to occupy. Project staff found a location that fit this description: the site is situated in a confined, swiftly flowing run unit with a uniform channel bottom, just downstream of a large pool and riffle unit. No significant tributaries are located downstream of the site to the confluence with the SF Eel River, and it is unlikely that salmonids would spawn in this section of the river considering the habitat conditions in high velocity flows during the fall and winter months. All project years have occurred at this location. The USGS Fort Seward Gage (#11475000) is the nearest stream gage, located approximately 23 miles upstream of this project site, and provides important real-time stream flow data and stream water temperatures.

A similar process was performed for determining the Van Duzen River site: due diligence with mapping software, determining a location with a proper river configuration/profile by boat floating the Van Duzen River from just upstream of Yager Creek downstream to its confluence with the Eel River, and coordination with landowners to determine the security of the site. The lower Van Duzen River is similarly limited by access points and multiple stream channel configurations. Nonetheless, project staff identified a site that fit enough of the criteria to believe it could function adequately as a pilot-year sonar site for the fall Chinook Salmon run. The river channel at the selected site underwent significant reconfiguration over the course of the pilot season (fall/winter of 2022); the stream channel widened considerably, transforming the run into a wide riffle unable to be effectively esonified. For the 2023 season, the site was moved approximately 800 feet upstream from the original pilot site. The USGS Bridgeville Gage (#11478500) is located approximately 18 miles upstream of the sonar site, providing important real-time stream flow data.

Sonar Installation and Operations

The sonar camera sites are located at remote locations on large river bars without access to any structure or power source. As in the case of previous project years, the Main Stem site utilized a cargo trailer with attachable solar panels (on top of trailer) to house a laptop, portable hard drive, sonar equipment, and batteries needed to provide the external power source for camera operations. Trout Unlimited (North Bay and Redwood Empire chapters) purchased and outfitted the trailer with the necessary equipment (including solar panels and lithium-ion batteries). Humboldt Redwood Company (HRC) provided access, maintenance of the gravel bar road as well as locking gate security to the site. The Van Duzen River site utilizes a similar set-up, a cargo trailer equipped with solar panels and lithium-ion batteries to house and power all sonar related equipment. NOAA West Coast Fisheries provided funding for the trailer and Trout Unlimited helped outfit the trailer for the project needs.

On September 25, 2023, prior to the onset of the first significant rainfall of the season, CDFW project lead and scientific aids with assistance from AmeriCorps Watershed Stewards Project (WSP) corpsmembers transported the cargo trailer, a long-range model DIDSON camera, laptop, hard drives, and associated equipment to the Main Stem Eel River site. After the solar panels were connected and sonar equipment was powered up, staff-initiated testing and recording of sonar imagery. On October 17, the long-range DIDSON was removed, and an ARIS 1200 explorer was installed for the remainder of the Main Stem season. A similar process was performed for the Van Duzen site on November 3, 2023, with project staff (now including PSMFC field lead) installing a long-range model DIDSON camera.

At both sites, weir panels were installed approximately one meter (m) downstream of the camera and extended almost one meter past the lens to prevent fish from passing the sonar undetected by swimming behind or too close to the camera (ARIS window start range was set at 0.7m; DIDSON at 0.8 m). The camera was housed in an aluminum lock box attached to an H-frame

stand and stabilized with rebar driven into the river bottom and lashed to the stand with 1 cm nylon rope. The camera was secured to the gravel bar using an Earth Anchor duckbill, steel cable, and locks.

Project staff checked the cameras daily to ensure the quality of recorded sonar imagery and if necessary, repositioned it in response to changes in flow and channel width. The pitch of the camera was manually adjusted to properly esonify the water column (Holmes et al. 2006). With stationary in-stream sonar equipment, river flows dictated a vigilant staff commitment. During storm events, project staff often made multiple trips per day to the field site(s), adjusting the stand location, weir panels, and camera pitch for data quality purposes. If warranted, project staff removed the stands and cameras from the rivers to prevent damage or loss of equipment. The threshold at which the camera needed to be pulled from the Main Stem Eel River site was approximately 7,500 cfs, and approximately 800 – 1,000 cfs at the Van Duzen River site. The cargo trailer housing the power source, ARIS top-box, and computer were also vulnerable at higher flows, requiring additional precautionary measures. If the Main Stem Eel River forecast predicted flows over 10,000cfs then project staff would move the trailer to a higher terrace. If flows were predicted to exceed 25,000 cfs then all equipment was transported back to the CDFW Fortuna office. While removed from operations, project staff utilized the opportunity to rinse and clean the camera to prevent silt and algal accumulation, which diminishes video quality.

Data Recording

Sonar imagery data was recorded at both sites for almost the entirety of the duration of the adult Chinook Salmon run: October 10 through December 20, 2023, at the Main Stem Eel River site, and November 3 through December 18, 2023 at the Van Duzen site (See Results section for further details of camera operations). The Main Stem Eel River site was also deployed temporarily in late September/early October when a brief rise in the hydrograph lead to some upstream passage of jack and adult-sized fish. While the Van Duzen River site was intended to capture only the fall run of Chinook Salmon, the Main Stem site continued to record data for winter-run steelhead starting on December 21, 2023. Beginning in late December, the Eel River watershed area experienced numerous atmospheric river rain events that persisted into the spring of 2024, significantly limiting camera operations due to prolonged periods of high river flows. See Results section for further details of camera operations during the winter Steelhead run.

Data Processing

All recorded data files were arranged in 20-minute incremental files starting on the hour and stored on a 2-terabyte external hard drive. Project staff would copy data at the site on a weekly basis to an additional hard drive that would be brought back to the CDFW Fortuna office for processing. The data processing (manually counting and measuring fish greater than 39 cm in total length) occurred on desktop computers using Sound Metrics ARIScope and ARISFish proprietary software to review ARIS data files and Sound Metrics DIDSON proprietary software

(version V5.26.37) to review DIDSON data files. Adjusting software settings provided proper contrast and resolution allowing one to distinguish between fish, debris, and potentially other animals. Unprocessed data files were played back 4 to 12 times faster than recorded speed to more easily detect fish presence/movement. However, during times of high fish passage, those sequences generally required multiple playbacks, using the average number of all playbacks for accurate fish detection. Daily fish movement counts were entered into individual Excel Spreadsheets that separated the following: date recorded, date reviewed, camera window length, reviewer, stream flow (cfs recorded at the sonar site's corresponding USGS gage) 20 minute per hour counts of upstream and downstream fish movements, net hourly fish movements, fish size and general comments (e.g. quality of the video, additional animals observed, etc.). Daily fish movement refers to the sum of net hourly fish movements.

To separate adults from jack (precocious males) salmon, project staff estimated sizes of individual fish in camera footage using the measure tool in the ARIS and DIDSON review software. We measured the first 10 individuals (>39 cm TL) that passed through the window for each hour to the nearest centimeter (cm) and recorded lengths were placed in either the adult (≥ 62 cm) or jack (39 – 61 cm) category for further comparison. A preliminary total length cutoff of 62 cm was used to separate adult Chinook Salmon from jacks based on the same size classification employed by PG&E staff when collecting and reporting data from the VAFS (A. Andrews personal communication 2025).

Reviewing data files is time consuming and a lengthy process; therefore, sub-sampling is commonly used to reduce workload and produce a reliable estimate of abundance (Maxwell 2007). We used a non-replicated systematic sample of the first 20 minutes of each hour to enumerate fish and generate fish passage estimates (Metheny et al. 2016; Sparkman et al. 2017). Net movement was determined for each 20-minute file and defined as the sum of positive upstream movements and negative downstream movements. To estimate abundance of Chinook Salmon the project used the net movement of all fish observed for the 20-minute subsample expanded to the hour. Daily counts were simply the sum of net hourly counts. To properly assess error arising from using a 20-mintute subsample to represent hourly fish passage, we used the V5 variance estimator and determined 95% confidence intervals for the total yearly passage (Xie and Martins 2014; Metheny et al. 2016; Sparkman et al. 2017). The V5 estimator was used to account for missed sampling time and the nonlinear patterns of anadromous fish movement, which can increase the variance estimate (Reynolds et al. 2006). The estimator looks at the passage rate before any given hour and after any given hour to best represent the migration pattern and account for temporal autocorrelation. Studies comparing different sampling methods have shown that systematically sampled, non-replicated data has the highest precision and accuracy (Holmes et al. 2006; Xie and Martins 2014).

Multiple reviewers were utilized throughout the project season to process the large amount of video data collected. Any bias in reviewers' counts or in recorded fish lengths could affect the

resulting population estimates. The correlation of counts from independent reviewers watching the same video was examined to determine repeatability of the estimation process. We also compared fish lengths taken from the same video by independent reviewers to assess repeatability of the software's length measuring process. Project leads had multiple years' experience reviewing sonar data from the Main Stem Eel River sonar monitoring project and performed extensive Quality Assurance (QA) and Quality Control (QC) allowing for both consistent and accurate counts.

As noted, this was the first year that an ARIS model camera was utilized to capture fish movement on the Main Stem Eel. The ARIS camera provided better image quality, fully adjustable focal range, and improved data review software. Flows on the Eel River fluctuate dramatically throughout the sonar monitoring period, and with that comes changes in wetted width. In previous seasons, the project would be confined to 20m, 40m, and 80m focal ranges. For example, if the channel was 45 m wide, the 80m focal range would be the only option, dramatically decreasing image quality (Figure 2). This issue of decreased image clarity at longer focal lengths is greatly remedied by the ARIS camera. The ARIS can produce images of superior resolution and clarity due to its use of higher operating frequencies and narrower beam spacing (Figure 3).

Data Quality Assurance

To ensure the quality of data and accuracy while enumerating fish movement, files were reviewed multiple times. Typically, files were reviewed independently by two technicians and/or crew lead, and the counts were compared for hourly passage rates to QA/QC. In some cases, files would be reviewed an additional time if there was significant disagreement in counts. On high passage days (greater than 100 fish/day), data was reviewed by multiple staff members and independent counts were averaged.

Estimating Missed Hours

There are several methods to account for passage estimates when the sonar is non-operational due to high stream flows or other technical/software issues. The most common method, when there are missing hours on a given day, is to calculate an average value for each missed hour using previous and post day counts for that same hour. When the camera is out for multiple days, the days preceding and following are used to average missing values. An exception is made when hours are missed due to exceptionally high flows. We do not estimate fish passage during these peaks in streamflow because at some point there would be turbidity and velocity thresholds that limit upstream passage (Sparkman et al. 2017). If present, fish movement during this time would be in relatively low numbers and estimating fish passage during these peaks would most likely overestimate fish passage numbers.

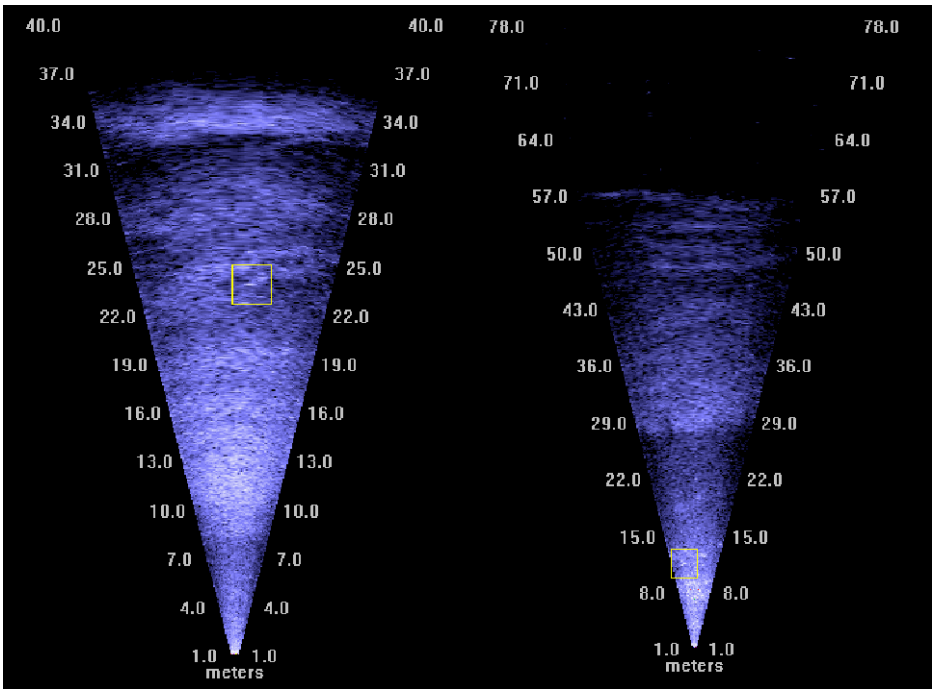


Figure 2. Side by side comparison of still-frame DIDSON imagery with end ranges set at 40 m (left) and 80 m (right). The yellow box outlines where a fish is located. This recording was taken at the Main Stem Eel River sonar site in the fall of 2022.

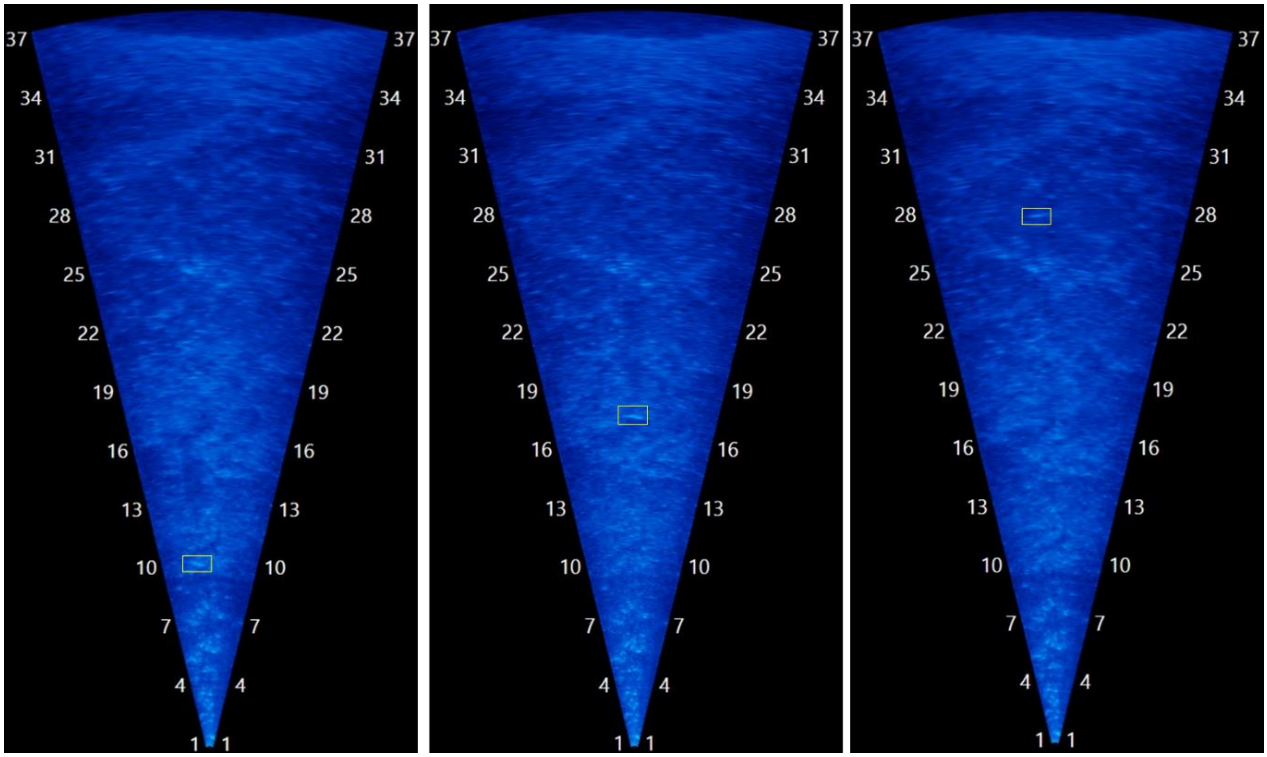


Figure 3. Side by side comparison of still-frame ARIS imagery featuring presumed adult Chinook Salmon, at various distances from the camera. The yellow box outlines where a fish is located. This recording was taken at the Main Stem Eel River sonar site in the fall of 2023.

Species Apportionment

Salmonid species cannot typically be differentiated by sonar imagery alone; however, seasonal, single-run rivers more easily lend themselves to species apportionment efforts. Distinct, temporal migration patterns have been observed in the Eel River for Chinook Salmon, Coho Salmon (*Oncorhynchus kisutch*) and steelhead (Yoshiyama et al. 2010). Species assignment for this monitoring year was based on the run timing of each species using current and historical observations at the VAFS on the upper Main Stem Eel River and seasonally overlapping salmon carcass surveys performed by Kleinfelder in the upper Eel River and associated tributaries. Chinook Salmon begin to move from the ocean into the river's estuary in September and hold in the lower reaches until rainfall and increases in discharge allow for passage through shallow riffles. Annually, a small number of adult steelhead have been observed migrating with the fall-run Chinook Salmon (Halligan 1997, 1998). Evidence of this continues to the present as prior to increases in the hydrograph adult steelhead are observed in the late summer/early fall holding with Chinook Salmon in the lower river.

We estimated that a large majority of the Chinook Salmon run was completed by December 20, 2023. This is primarily based on two indicators: the VAFS observed its last Chinook Salmon ascending the ladder on December 21 (one adult and one jack) and prior to those fish the last Chinook Salmon was on December 13; and no new Chinook Salmon redds were observed during the two weeks in December via weekly Garcia and Associates/Kleinfelder spawner surveys conducted in the upper Eel River below Van Arsdale and the tributaries of Tomki Creek, Longbranch Creek, and String Creek (A. Anderson, PG & E Personal Communication 2024).

The VAFS observed their first steelhead arrivals during the week of December 18-24 (A. Anderson and N. Easterbrook, personal communication 2023). Continuing into January, increasing numbers of steelhead observations were made at the VAFS. Some overlap does occur between the end of the Chinook Salmon run and the beginning of the steelhead run, but in the absence of an accurate method to discern the two species in sonar footage, project staff postulated December 20, 2023, as the date to separate the Chinook Salmon run from the winter-run steelhead.

While a significant Southern Oregon / Northern California Coast (SONCC) ESU Coho Salmon run persists in the SF Eel River, typically arriving in mid-to-late December and continuing till mid to late February, recent detections of Coho Salmon in the Main Stem Eel River have been limited to a small number of adult fish in the Outlet Creek watershed (Yoshiyama 2010), a few observations at the VAFS, and Matt Horne saw a spawning pair in Short Creek (MF Eel River) in 2015 (Matt Horne, RVIT Fisheries Program, Personal Communication March, 2025). Currently, due to a lack of funding and available staff time, no monitoring activities are occurring in the Outlet Creek watershed, but it is believed that a very small run of Coho Salmon persists in Outlet Creek. In the future, project staff hope to implement summertime mask and snorkel dive surveys in the Outlet Creek watershed to detect locations and general occupancy of Coho Salmon.

Similarly, Coho Salmon occupancy in the Van Duzen River has been limited; they were considered nearly extirpated from the basin in the early 2000s with multiple years of no observations. A few spawning adult sightings in the Lawrence Creek watershed (Fish Creek) resumed in the winter of 2010. In recent years, approximately 3.5 miles of stream habitat have been occupied, and low spawning densities have been observed in the winter, suggesting approximately 6.5 redds per stream mile (CDFW 2023 and E. Stockwell personal communication 2023 & 2024). Overall, we considered it reasonable to assume that the low numbers of migrating adult Coho Salmon in the Main Stem Eel River and Van Duzen River in the winter of 2023/24 were not enough to compromise the project's adult escapement estimate of Chinook Salmon and steelhead counts.

The Eel River supports additional fish species that are likely to be discernable in camera footage review, primarily Sacramento Pikeminnow (*Ptychocheilus grandis*), Sacramento Sucker (*Catostomus occidentalis*) and Green Sturgeon (*Acipenser medirostris*). Sacramento Pikeminnow, and to a lesser extent, Sacramento Sucker in their adult phase can be large enough (>39 cm) to potentially be counted as salmonids passing the camera; however, their migration patterns are generally different enough from salmonids, thereby decreasing the likelihood of passing the camera during salmonid migration season. As noted in Harvey & Nakamoto (1999) adult Sacramento Pikeminnow upstream movement is generally muted during the winter months with higher flows and colder water temperatures within the Main Stem Eel River. Harvey and Nakamoto findings are further supported by similar observations through the six years of conducting this monitoring project – both in data review and biological surveys. Project staff have documented limited adult Sacramento Pikeminnow movement during most of the time frame the sonar camera is deployed. It appears that upstream movement of large, adult Pikeminnow (potentially of steelhead-size) commences when the colder, Eel River stream temperatures increase to above 15^{o}C and flows are on a continually descending pattern. These conditions usually do not occur until the winter steelhead run nears its end in April.

Data Review Techniques and Field Speciation Methods

To further diminish the possibility of tallying non-salmonid species, project staff employs speciation efforts in the field and in data review. Staff utilize data review methods and techniques described in Sparkman and Holt (2020), which provides the reviewer insights to possibly discriminate other fish species from Chinook Salmon and steelhead movement. For example, Sacramento Suckers almost always exhibit schooling behavior, move slowly through the sonar field, and are smaller in body length (rarely >40 cm) and body height. Distinguishing non-salmonid species is also aided by experienced, knowledgeable staff performing QA/QC of data files containing difficult to decipher fish species images.

In prior years, project staff conducted field speciation efforts which included the following: mask and snorkel dive surveys during periods of low flow conditions and suitable visibility; boat seining efforts in the pool unit immediately upstream of the camera location; and hook and line sampling at or near the camera location (Kajtaniak and Easterbrook 2019; Kajtaniak and Gruver 2020).

While limited, these speciation efforts are useful early in the season and in when species run timing overlap to determine which species are migrating past the camera site. These surveys may also document the presence of non-salmonids in the sonar site area that may be misidentified as a salmon or steelhead during footage review.

Project staff conducted one mask and snorkel survey during the 2023-2024 season, which occurred on November 29, 2023 in the run unit where the Eel River camera operates and in the large pool unit above the camera site. During this survey, 4 divers spread out across the width of the river and floated downstream in a parallel line, working to keep pace with each other throughout the survey to ensure complete coverage of the channel. A single Chinook salmon was observed within the pool unit, suspended in the water column, approximately 70 cm in length. Additionally, several Sacramento Pikeminnow were observed consisting of one large individual (approximately 35-40 cm) and a school of smaller individuals (approximately 12 fish at 15-20 cm). At the time of the survey, flows were approximately 300 cfs as recorded at the Fort Seward USGS gage.

The Van Duzen River sonar site is located downstream of its confluence with Yager Creek whose tributaries provide spawning habitat for Chinook and Coho Salmon. Citizen scientist, Eric Stockwell performs spawner surveys in these tributaries throughout the Chinook and Coho Salmon migration period and provides timely communication with the project lead concerning the timing of species migration and fish and redd counts. Project staff occasionally accompanies Eric on these surveys (Table 1) for project-related data collection purposes. These surveys also afford the opportunity to discuss protocols and share information between CDFW and local citizen scientists.

Table 1. Spawner survey results conducted by CDFW and E. Stockwell in Lawrence Creek tributaries (Lower Eel River: Van Duzen River - Yager Creek - Lawrence Creek - Booths Run Reach 85/Shaw Creek Reach 87).

Stream	Date	Coho	Chinook	Redds	Carcasses
Booth's Run (Reach 85)	12/12/2023	13 (4M, 7F, 2 Jacks)	0 (0M, 0F, 0 Jacks)	11	0
Shaw Creek (Reach 87)	12/14/2023	1 (0M, 1F, 0 Jacks)	28 (8M, 17F, 3 Jacks)	21	10

Due to low catch per unit effort from seining and hook and line sampling in previous years, these sampling methods have not been performed since the 2020-2021 season. Looking forward to the 2024-2025 season, project staff will implement the use of tangle nets to further speciation efforts.

Late Summer/Early Fall Lower Eel River Surveys

As mentioned previously, Chinook Salmon begin to enter the Eel River in early to mid-September and generally hold in several locations (staging areas) in the lower river until suitable flows

(generally greater than 250 cfs at the USGS Scotia gage) and likely a combination of other environmental factors are present which encourage upstream movement. CDFW and local citizen scientists Eric Stockwell and David Sopjes have conducted kayak and stand-up paddleboard excursions in the lower Eel River to observe species present, the timing of their arrival, approximate expansion of fish numbers as they continue to arrive, and their appearance/condition. These surveys usually begin in mid-September and continue to the onset of continuous higher river flows, which leads to dispersal of the fish. The citizen scientists incorporate recreational drone flights to capture fish images and further the accuracy of their counts from systematic review of drone imagery footage. These surveys provide important information regarding where salmon hold on a yearly basis, the habitat conditions, and water quality (YSI digital water quality meter measurements and CDFW deployment of stream temperature loggers). Surveyors also note the presence of additional fish species staging and/or occupying these habitats, including the following: several dozen adult steelhead, hundreds of half-pounder steelhead, hundreds to low thousands of Sacramento Pikeminnow consisting of some adult-sized fish but mostly fish less than 40cm in length, several Striped Bass (*Morone saxatilis*), two small schools of American Shad (*Alosa sapidissima*), and 7-9 adult Green Sturgeon (CDFW and E. Stockwell, personal communication 2023).

Results

Field Operations

Main Stem Eel River Site – Fall-run Chinook Salmon

Previous project years did not initiate sonar camera operations until migration flows began in mid-October or November, but a late September (2023) storm was forecasted to produce high amounts of rainfall and subsequently higher stream flows. Therefore, the Main Stem Eel River camera was deployed on September 25 in advance of increased flow to document any fish movement and acquire a better understanding of the potential for fish movement in relation to changing stream flows in the month of September/early October. The storm resulted in less rain than originally predicted and the rise in the stream hydrograph was minor. Flows began to recede on September 27 and due to the lack of fish movement observed during data file review the sonar was temporarily removed October 5 through 9. Stream flows again rose to what staff considered an operable threshold and the DIDSON was re-installed October 10, 2023. On October 17, the long-range DIDSON was removed, and an ARIS 1200 explorer was installed and utilized for the remainder of the season. The first significant precipitation event within the Eel River watershed occurred the week of November 6, with flows rising from approximately 98 cfs to 339 cfs at the USGS Fort Seward gage (Figure 4). The camera operated almost continuously through the duration of the Chinook Salmon run (October 10 through December 20, 2023). Only a couple exceptions occurred, which temporarily halted operations: a few, minor software malfunctions in October and a high flow event at the end of the run (December 18-22). During the project's

operational period beginning on September 25 till December 18, the sonar camera recorded 1,852 hours, accounting for 94.1% of the total potential sampling frame for the Chinook Salmon fall-run (Table 2.) This was above the project's 6-year average (88.6%) of percent sampled during the yearly adult Chinook Salmon run.

Table 2. Percent of time sampled and time missed due to high streamflow and other factors for all project years 2018-2024 during the fall-run Chinook Salmon, Main Stem Eel River, Humboldt County, CA.

Main Stem Eel Rive Sonar Operations during adult Chinook Salmon Migration Season				
Project year and timing of fall-run Chinook Salmon migration	**Sampled Total %**	**Sampled # Hours**	**Not Sampled Total %**	**Not Sampled # Hours**
2023 Sept 25 – Dec 20	94%	1852	6%	116
2022 Nov 1 – Dec 22	90%	1115	10%	119
2021 Oct 20 - Dec 23	76%	1176	24%	371
2020 Nov 12 – Dec 31	98%	1162	2%	23
2019 Nov 25 – Dec 31	91%	799	9%	78
2018 Nov 15 – Dec 31	88%	1,058	11%	108
6 – Year Average	*88.6%*	*1,194*	*11.4%*	*136*

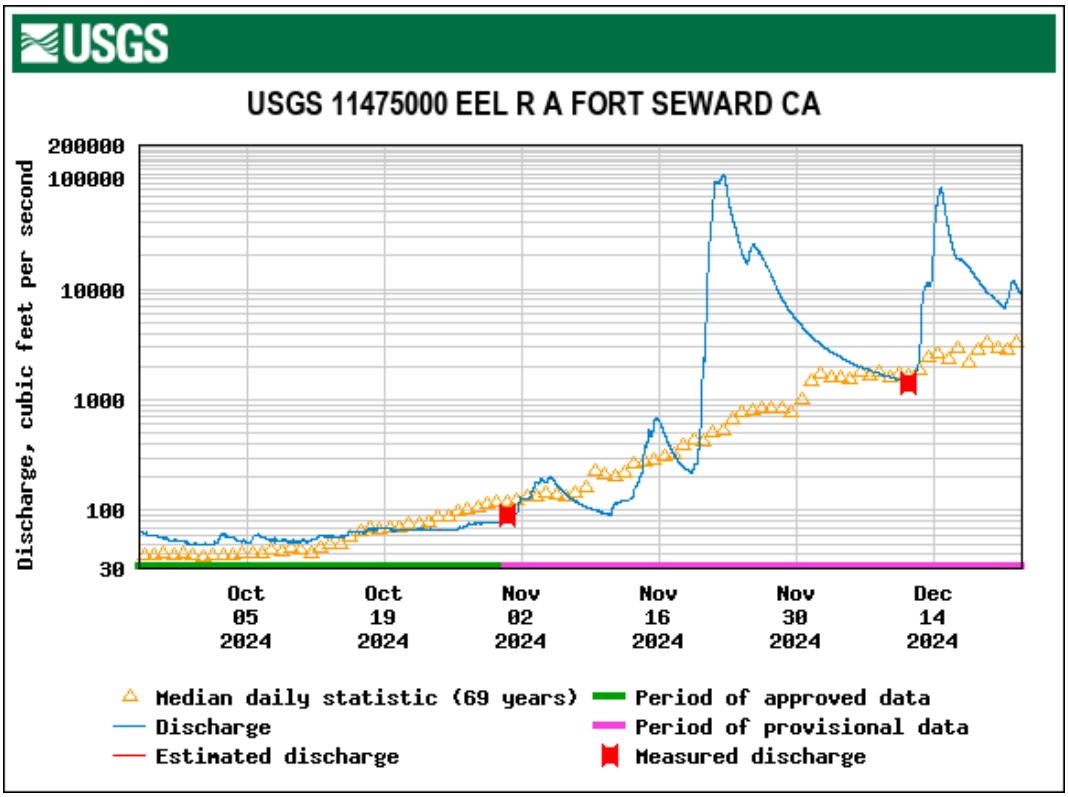


Figure 4. Estimated daily streamflow (cfs) and historical median daily statistic measured from the USGS gauging station at Fort Seward, Humboldt County. Time period covers the Main Stem Eel River fall-run of adult Chinook Salmon.

Van Duzen River Site – Fall-run Chinook Salmon

While the Main Stem Eel River experienced seasonally higher than normal stream flow conditions during the early to mid-autumn period, the Van Duzen River experienced prolonged low flow conditions – less than 10 cfs measured at the USGS Bridgeville gauge for most of September and October (Figure 5). Therefore, Van Duzen camera operations did not commence until November 3, which was just prior to the first seasonal rise in stream flow (above 50 cfs at the Bridgeville USGS gauge) beginning on November 6. Stream flows again receded below our operable threshold November 11-14, and the DIDSON was removed from the river. The DIDSON was re-installed on November 14 and was operational through December 18, except for when the flows exceeded 800 cfs (our operable threshold) at the Bridgeville USGS gauge, which warrants removing camera from the river. On December 18 the DIDSON camera was removed due to predicted high stream flows. Flows peaked on December 20 at 5,080 cfs and remained elevated through December 31. The Van Duzen DIDSON camera was not re-installed after removal on December 18. During this time frame, the project recorded 738 hours, accounting for 66.9% of the total Chinook Salmon potential sampling frame (Table 3).

Table 3. Percent monthly time sampled, and time missed due to fluctuating streamflow and other factors during 2023-2024 season, Van Duzen River, Humboldt County, CA.

Month of Operations	Total % Sampled	Hours not sampled due to High flow	% Hours not sampled Due to High flow	Hours not sampled due to Low flow	% Time not sampled due to low flow	Hours not sampled due to Other Factors*
Nov. 3rd- 30th	70%	41	6%	76	11%	82
Dec. 1st - 18th	61%	160	37%	0	0%	6

*Other factors were electrical issues with the solar panels not properly charging the batteries to provide sufficient power for camera operations. Staff was eventually able to resolve this issue.

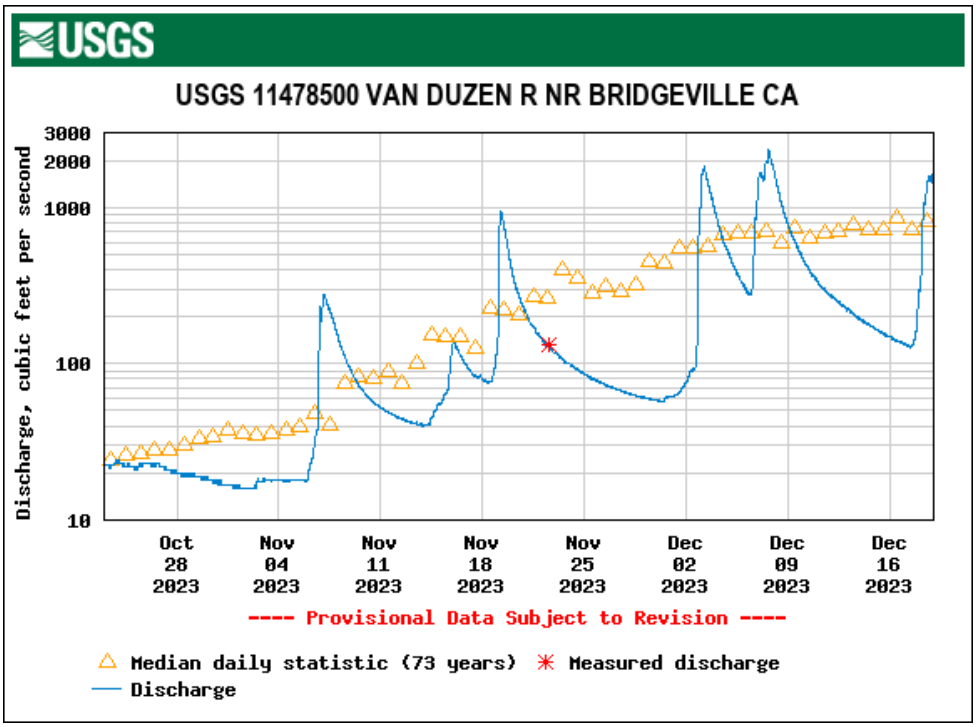


Figure 5. Estimated daily streamflow (cfs) and historical median daily statistic measured from the USGS gauging station at Bridgeville, Humboldt County, CA. Time period covers the potential Van Duzen River fall-run of adult Chinook Salmon. Flows were too low for fish passage until Nov 6, 2023.

Main Stem Eel River Site – Winter-run Steelhead

The steelhead sampling period of December 21 through May 2, 2024, experienced drastic fluctuations in stream flow conditions, resulting in minimal sampling. There were 3,086 potential hours to record data, and of these, the project sampled 843 hours, comprising 27.3% of this sampling time frame. However, when considering the likely winter-run steelhead migration period, late December to early April, the camera operations were limited to 14 days in late December and early January. Subsequently, we estimate the camera only operated during 11.5% of the winter-run. The hours missed were attributed to well above historical average streamflow conditions as measured at the Fort Seward USGS stream gauging station beginning in late December and continuing through mid-April 2024: estimated mean daily flows averaged 14,753 cfs during this period (Figure 6). Attempting to operate the camera at higher flows poses a safety risk to the project staff and crew. The project could operate the camera in flows up to 7,000 cfs (measured at the Fort Seward gage); flows exceeding this threshold would require staff to temporarily cease operations and remove the stand and camera from the river and move the trailer to higher ground. Moreover, it has been learned from previous monitoring seasons that a significant portion of the recordings during high flow events are challenging to process due to the river's high sediment load or poor camera pitch creating background noise (such as increased reflections off the water surface).

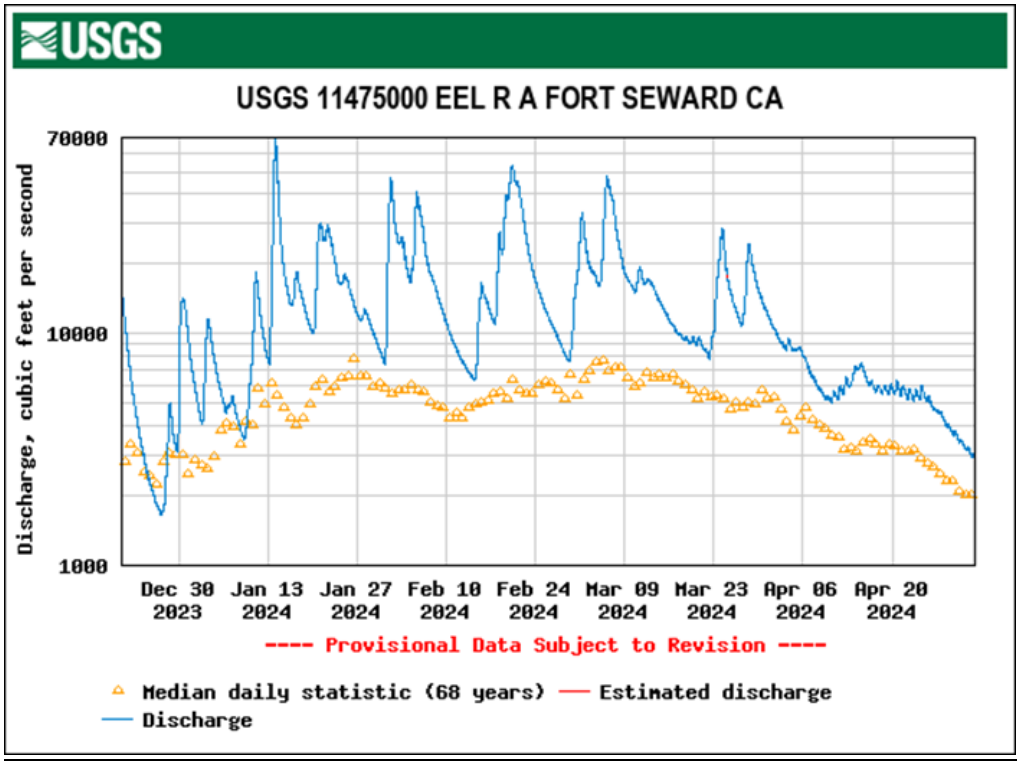


Figure 6. Estimated daily streamflow (cfs) and historical median statistic measured from the USGS gauging station at Fort Seward, Humboldt County, CA. Time period covers the typical migration period of Main Stem Eel River winter-run steelhead.

Daily Passage Rates of Chinook Salmon and Steelhead

With the early deployment of the sonar camera in late September, staff observed some very low numbers of adult-sized salmon/steelhead fish passage on September 26 and a few additional days in early October. Higher numbers of jacks and adults began passing the camera on October 17 and continued through the rest of October with an average of 48 fish per day. The Eel River watershed received its first significant rainfall of the season in the first week of November. Beginning November 3, 2023, and proceeding for the next 4 days, Fort Seward (mid-watershed) received nearly 2 inches of precipitation. The precipitation received significantly increased the hydrograph in the lower Eel River as evident at the USGS Scotia gage (RM 21) (Figure 7). Streamflow rose from approximately 160 cfs on November 1 to peaking at 423 cfs on November 4, 2023. The increased stream flows allowed the several thousand fish holding in the lower reaches of the Eel River to begin migrating through formerly impassible riffles and access the Van Duzen River (RM 13) and the confluence of the Main Stem and South Fork Eel River(s) (RM 40.5).

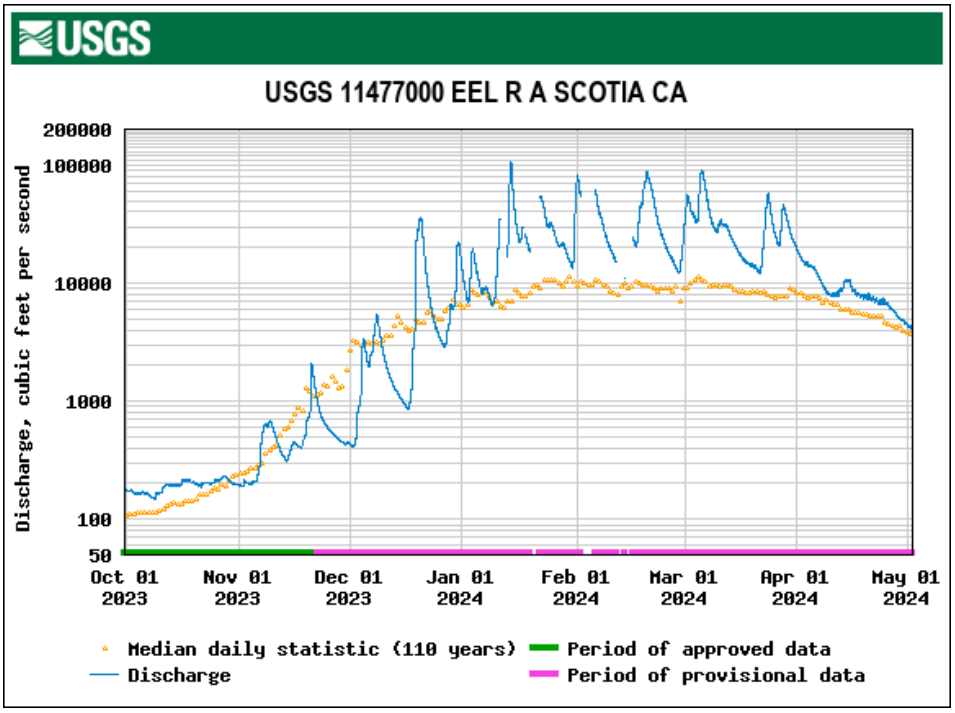


Figure 7. Estimated daily streamflow (cfs) and historical median statistic measured at the USGS gaging station at Scotia, Humboldt County, CA during period of sonar deployment (early Oct. through May 2nd).

Daily movement of fish during the fall Chinook Salmon run at the Main Stem Eel River sonar site (October 10 through December 20, 2023) ranged from 0 to 2,376 and averaged 98 fish per day (Figure 8). The peak of migration occurred October 31 through November 21: a total of 6,810 fish (4,317 adults and 2,493 jacks) accounting for 83% of the total run. Peak fish passage days were observed on November 6 and 7, coinciding with the first significant precipitation event of the season to occur within the watershed. November 6 had a net upstream movement of 2,376 fish (1,926 adults and 450 jacks), while November 7 had 1,386 fish (639 adults and 747 jacks) (Figure 8).

Daily movement of fish during the Chinook Salmon run at the Van Duzen River sonar site (November 3 through December 18, 2023) ranged from 0 to 396 and averaged 41 fish per day (Figure 9). The peaks of migration occurred on consecutive days in early November: November 6 (N = 387 fish), November 7 (N = 396 fish), and November 8 (N = 315 fish), which accounts for 58.8% of the total abundance. This peak also aligned with the arrival of the first significant rain event and rise in hydrograph of the season.

Daily movement of fish during the estimated winter-run steelhead period (December 21 to January 10, 2024) ranged from 0 to 168 and averaged 70 fish per day. There were two larger pulses of fish seen in late December, early January: The first in late December on the descending limb of the hydrograph (December 27, N = 99), and the second beginning shortly thereafter (January 5, N = 156). High streamflow conditions prevented sonar camera operation from January 11 through April 7 (Figure 6 and 10).

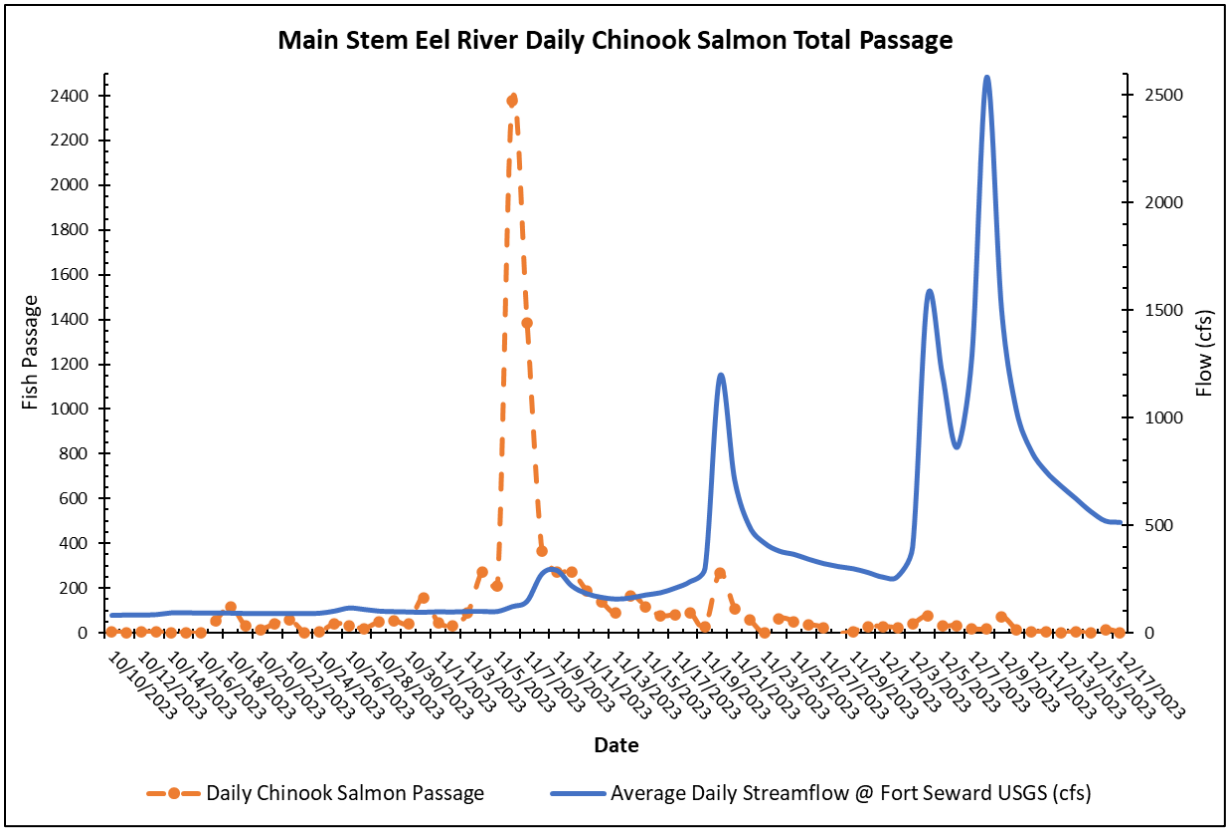


Figure 8. Streamflow (cfs) measured from the USGS gauging station at Fort Seward and the daily expanded Chinook Salmon (adults and jacks) movements from Oct. 10 to Dec.18, 2023 at the Main Stem Eel River sonar site, Humboldt County, CA.

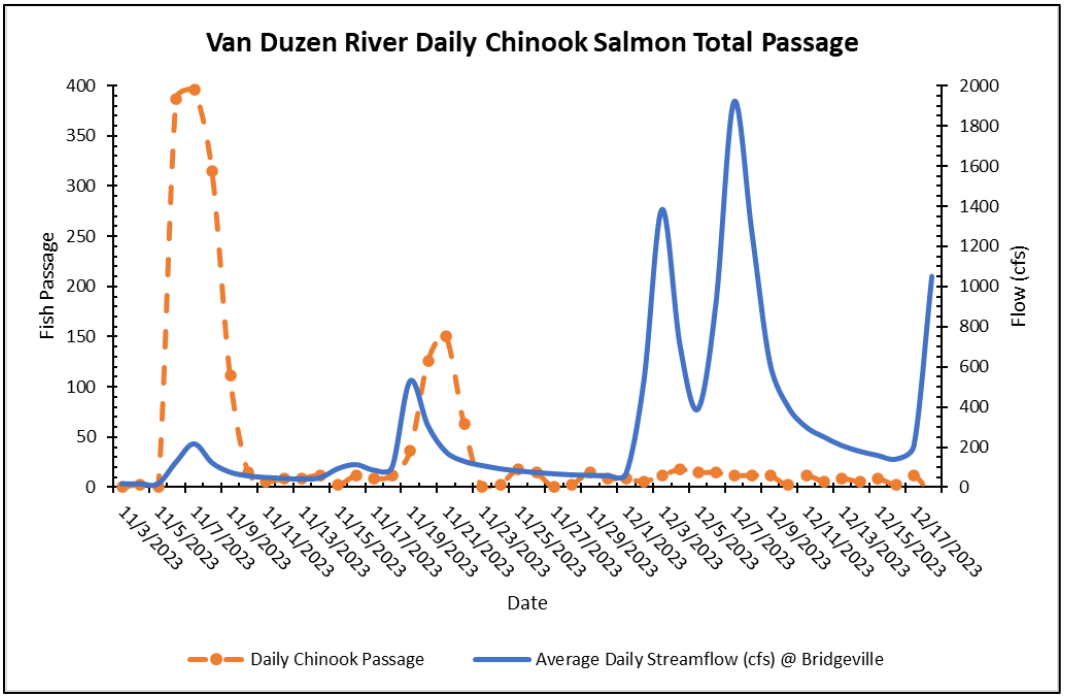


Figure 9. Streamflow (cfs) measured from the USGS gauging station at Bridgeville and the daily expanded Chinook Salmon (adults/jacks) movements from Nov. 3 to Dec. 18, 2023 at the Van Duzen River sonar site, Humboldt Co., CA.

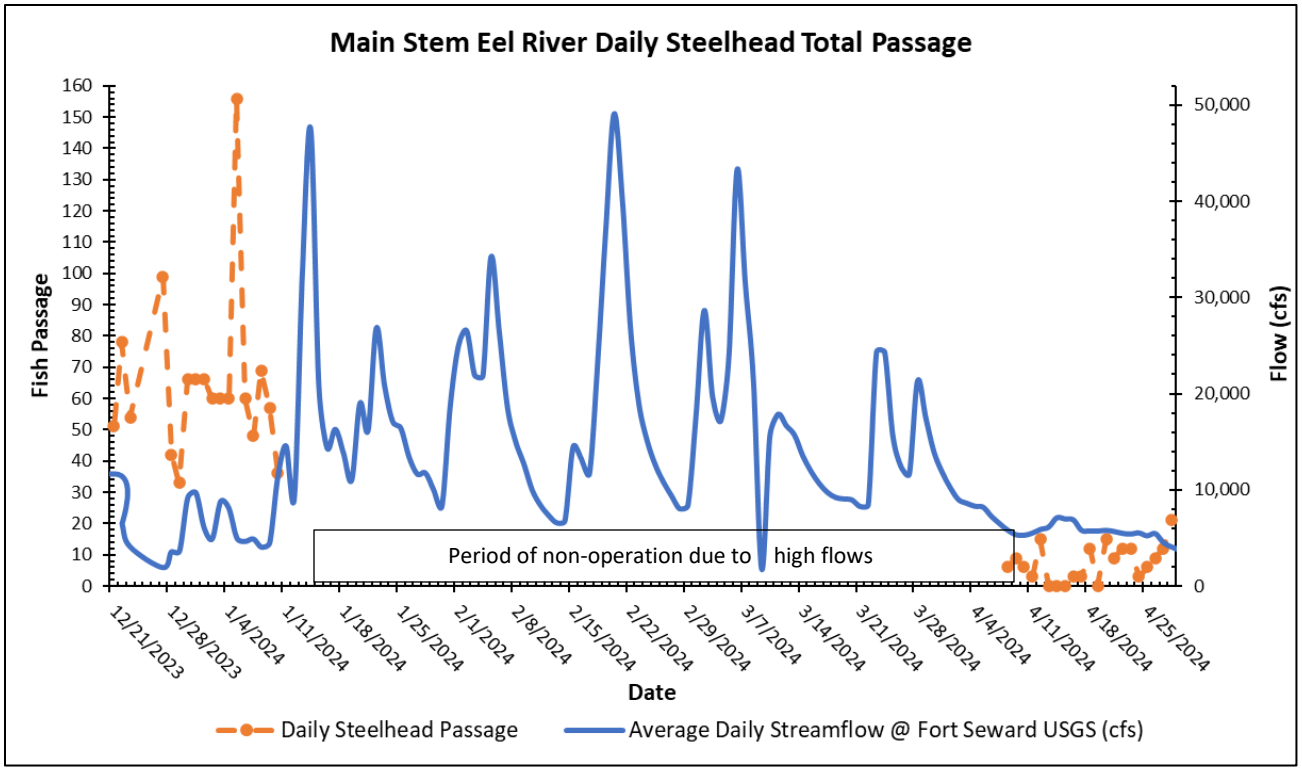


Figure 10. Streamflow (cfs) measured from the USGS gauging station at Fort Seward and the daily expanded steelhead movement from December 21st – May 2nd at the Main Stem Eel River sonar site, Humboldt County, CA.

Table 4. Monthly precipitation totals with % historical average in parentheses () measured at NOAA stations in Humboldt and Mendocino Counties September 1, 2023– April 30, 2024. Main Stem Eel River watershed stations: Fort Seward, Covelo, and Willits. Van Duzen River watershed station: Bridgeville.

Month	Fort Seward (in) (Main Stem Eel)	Covelo (in) (Middle Fork Eel)	Willits (in) (Main Stem Eel)	Bridgeville (in) (Van Duzen)
September	1.11 (119%)	0.69 (97%)	0.44 (49%)	1.2 (93%)
October	1.16 (32%)	1.40 (53%)	1.63 (51%)	2.52 (58%)
November	3.52 (47%)	1.84 (27%)	3.34 (41%)	4.16 (42%)
December	8.52 (88%)	7.75 (99%)	10.74 (122%)	11.84 (103%)
January	12.40 (112%)	9.57 (113%)	12.32 (127%)	Non-operating
February	13.36 (168%)	11.20 (176%)	15.91 (213%)	Non-operating
March	15.88 (249%)	10.29 (170%)	12.86 (179%)	Non-operating
April	1.80 (55%)	1.88 (79%)	1.63 (53%)	Non-operating
TOTAL (in)	57.75	44.62	58.87	

Main Stem Eel and Van Duzen Rivers Chinook Salmon Abundance Estimate

We estimate the abundance of Chinook Salmon returning to the Main Stem Eel River above the confluence of the South Fork Eel River from October 10, 2023, through December 20, 2023 equaled 8,161 (95% CI 7,171 – 9,055; with a coefficient of variation (CV) of 5.8%). Of the 8,161 fish estimated to have migrated upstream of the camera site, 4,958 were adults and 3,203 were

jacks for a ratio of 60.8% adults to 39.2% jacks. This ratio is similar to the ratio observed at the VAFS in 2023/24: 65% adults to 35% jacks (A. Andrews, PG&E, personal communication 2024).

We estimate the abundance of Chinook Salmon returning to the Van Duzen River from November 3, 2023 through December 18, 2023 equaled 1,867 fish (95% CI 1,660 – 2,073; with a coefficient of variation (CV) of 5.5%). Of the 1,867 fish estimated to have migrated upstream of the camera site, 997 were adults and 870 were jacks for a ratio of 53.4% adults to 46.6% jacks. Due to the difficulty measuring fish during Van Duzen DIDSON file review, we are less confident in the accuracy of the adult to jack ratio on the Van Duzen River.

Fish Measurements

On the Main Stem Eel River, lengths estimated using ARISFish or ARISScope software measuring tools ranged from 39 cm to 130 cm (a very large fish observed on November 18, 2024). The average adult Chinook Salmon length was 72.64 cm, and the average jack Chinook Salmon length was 51.45cm. The highest number of fish measured occurred in the 50-55 cm category (278 individuals) and the second highest number of fish measured were in the 62-67 cm category (260 individuals) (Figure 14).

On the Van Duzen River, lengths estimated using the DIDSON software version V5.27.51 measuring tool ranged from 39 cm to 98 cm. The average adult Chinook Salmon length was 71.77 cm, and the average jack length was 49.19 cm. The highest number fish measured occurred in the 44-49 cm category (83 individuals) and the second highest number of fish measured in the 62-67 cm category (67 individuals) (Figure 15).

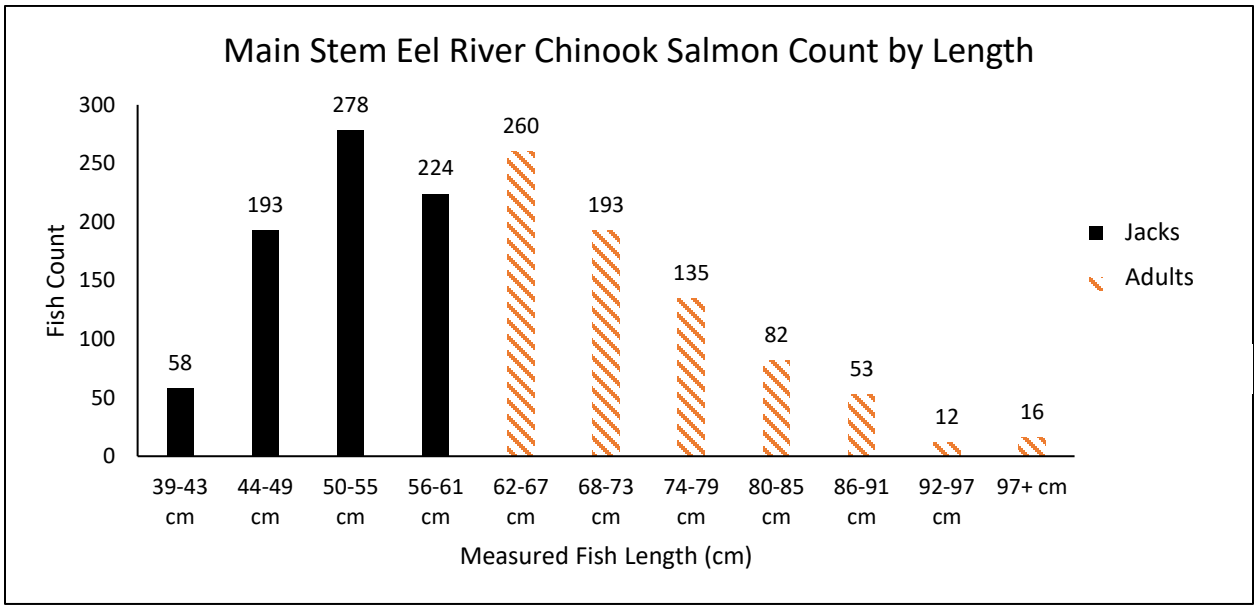


Figure 11. Estimated fish lengths (cm) using Sound Metrics ARIScope and ARISFish proprietary on the Main Stem Eel River, Humboldt County, CA. Total number (N) of fish measured = 3,054 from October 10 through December 20, 2023

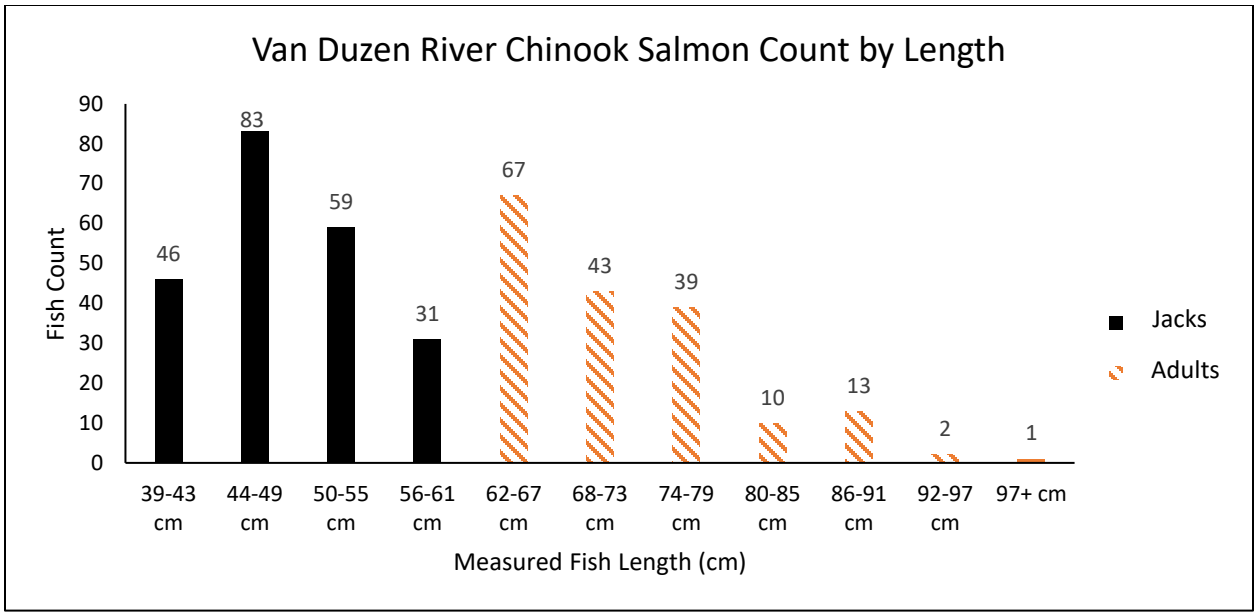


Figure 12. Estimated fish lengths (cm) using Sound Metrics DIDSON proprietary software (version V5.26.37) for data files recorded on the Van Duzen River, Humboldt County, CA. Total number (N) of fish measured = 422 from November 3 through December 18, 2023.

Main Stem Eel River Steelhead Counts

From December 21, 2023 through January 10, 2024, 1,476 winter-run steelhead were estimated to have returned to the Main Stem Eel River above the confluence with the South Fork Eel River; from April 8 through April 28, 2024, 156 steelhead were estimated to have returned. These 156 steelhead were likely composed of both the summer-run and the winter-run life history variant.

Downstream Steelhead Migration

Steelhead are considered iteroparous, meaning they can undertake multiple rounds of reproduction throughout their lives. Behavior from downstream-migrating steelhead (or kelts) can impact population estimates when not properly accounted for (Pipal et al. 2010). The 2023-24 season was unable to capture the vast majority of the winter steelhead run due to well above average flows in the Eel River between January and April (Figure 10). The monitoring period of late December and early January is very early in the winter steelhead run and the possibility of kelts migrating past the camera is unlikely or rare in occurrence. During the monitoring period of April 8th - May 2nd, minimal movement of kelts was observed, likely signifying that the bulk of kelt movement had occurred prior to resuming camera operations on April 8, 2024.

Stream Water Temperature Data and Sacramento Pikeminnow Movement

From April 10 till May 1, 2024 a HOBO Temperature Logger was deployed at the Main Stem Eel site to collect water temperature data during sonar camera operation (Figure 11). During that time frame, a water temperature reading was taken every half hour. The upper Eel River

watershed, including the MF Eel had built up a significant snowpack throughout the winter, which impacted both flows and temperatures throughout the month of April (Figure 12 and 13). During the second week of April, warm air temperatures caused increased melt and water temperatures fell, with the lowest recorded temperature reaching 10.29°C on April 14. The Main Stem Eel experienced warming water temperatures during the second half of April, with temperatures reaching 15.34°C on April 23. From April 15 through April 23, water temperatures increased an average of .48 °C/day. This period experienced the 2, 3, and 4 highest passage days for fish over 39cm during the month of April (Figure 11). Another dip in water temperatures and fish passage was observed from April 23 -April 26, followed by a spike in fish passage on April 30 and May 1 during rising temperatures and decreasing flows. The spike in fish numbers are attributed to the likely increase in upstream passage of Sacramento Pikeminnow, which coincides with the warming water temperatures and decreasing river flows. Reviewers noted passage of numerous fish sized between 40-55 cm as well as fish < 39cm long that were not officially tallied as we suspected the majority of these fish were Sacramento Pikeminnow.

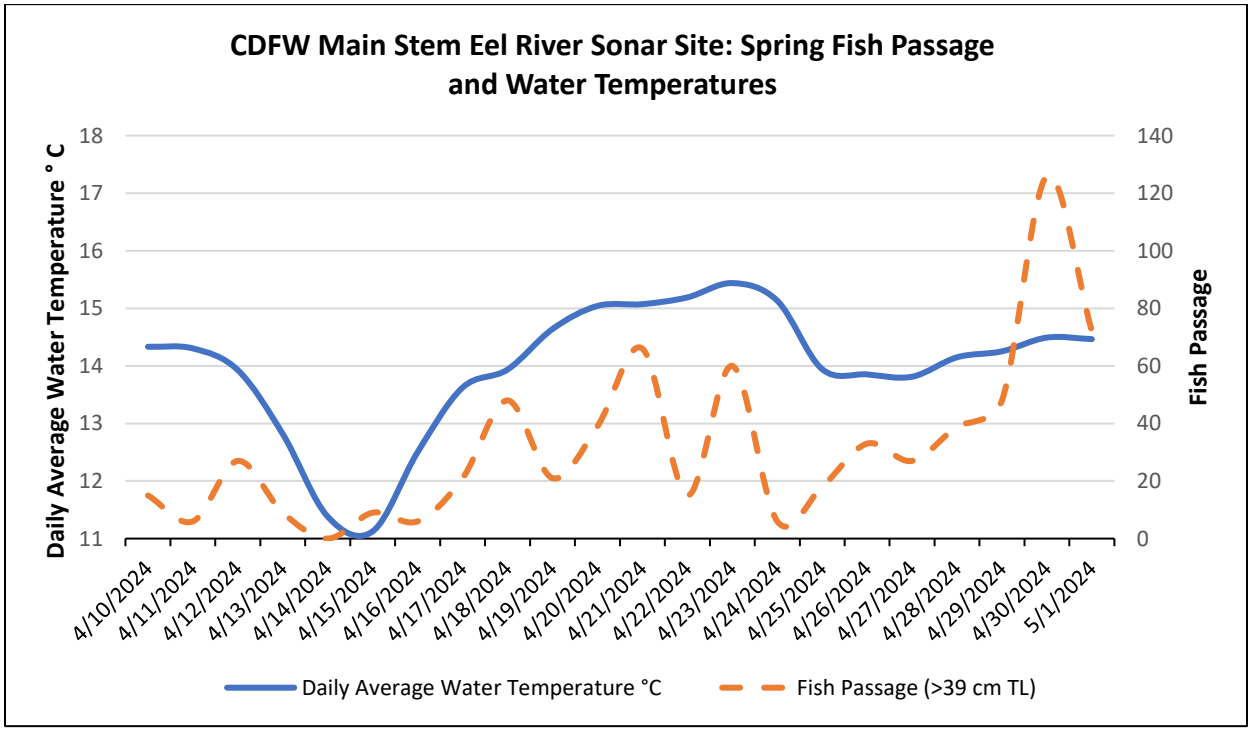
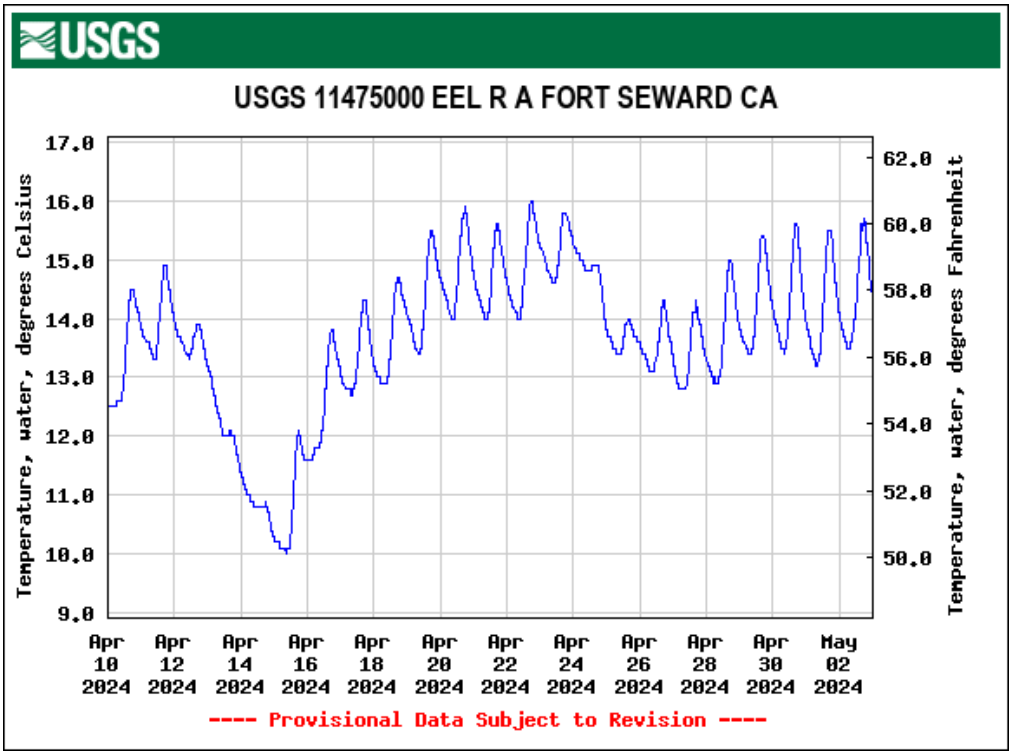
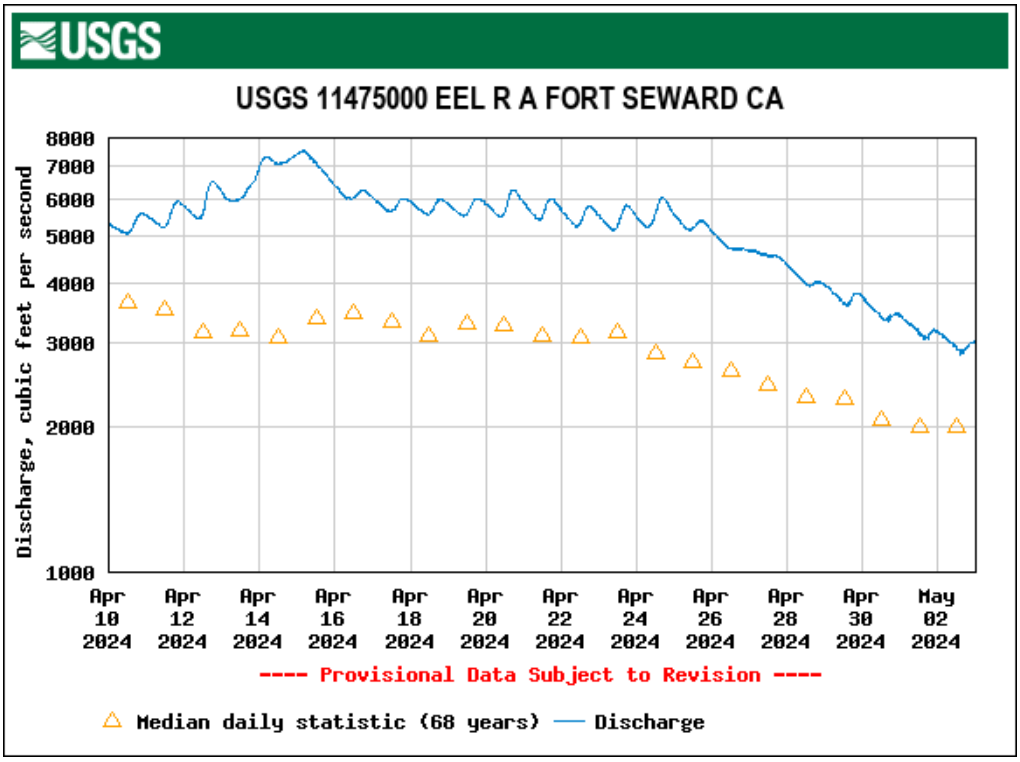


Figure 13. Daily Average Water temperatures (°C) and daily fish movement on the Main Stem Eel River from April 10th, 2024-May 1st, 2024, Humboldt County, CA.





Figures 14 & 15. Estimated daily water temperatures and streamflow (cfs) and historical median statistic during spring 2024 sonar camera deployment. Flow and water temperatures measured from the USGS gauging station at Fort Seward, Humboldt County, CA.

Discussion

2023-24 Chinook Salmon Abundance Estimates and Previous Project Years Summation

This Sonar Monitoring Project aims to produce relevant and comprehensive data for management of Eel River salmon, a significant contributor to the CC Chinook Salmon ESU. Since the project's inception in the fall of 2018, it has successfully allowed for a more accurate estimate of the CC Chinook Salmon run in the Main Stem Eel River (upstream of the SF Eel River). The sonar capably detected fish movement 24 hours per day in variable stream flows; thereby providing counts used to estimate the CC Chinook Salmon run abundance. The 2023-24 project estimated 8,161 (CV = 4.52%) Chinook Salmon migrated past the sonar camera on the Main Stem Eel River. The first four years of the project witnessed slightly increasing yearly counts, each abundance estimate increasing about 5% each year. The last two years experienced significantly higher numbers, as the 2022-23 project year had the highest abundance estimate of the six project years, followed closely by 2023-24 (Figure 16). While recent years have shown promising trends, it is important to note that even with these increases, the abundance estimate is still falling short of the NMFS spawner abundance target for delisting of 10,600 adult Chinook Salmon for the Main Stem Eel River (NMFS 2016).

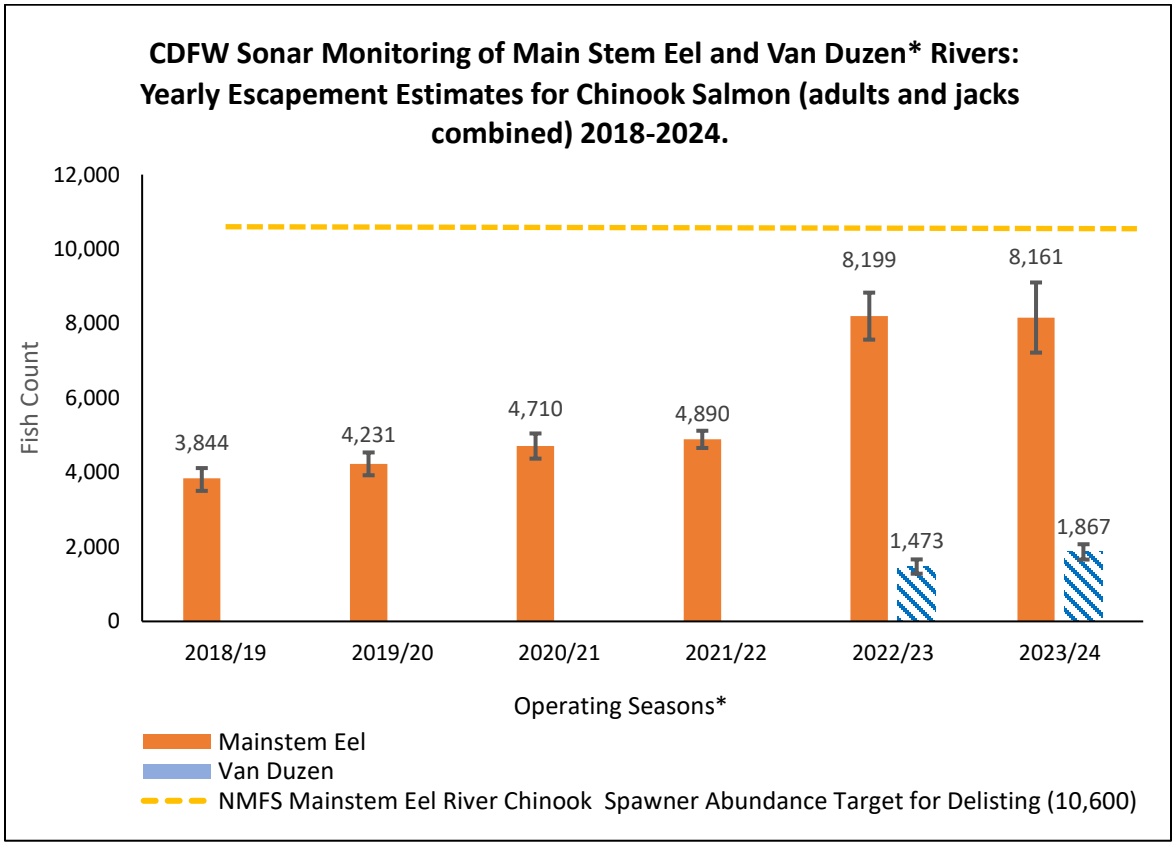


Figure 16. Lower Main Stem Eel River abundance estimates for Chinook Salmon for six seasons of sonar operations: 2018-19 through 2023-2024 (spring). * Van Duzen River sonar operations began in the fall of 2022.

NMFS Main Stem Eel River Spawner Abundance Target for Delisting derived from the NMFS Coastal Multispecies Recovery Plan (NOAA 2016)

As noted previously, the other long-standing data source for the Main Stem Eel River is the adult/jack fish counts at the VAFS. CDFW records of ladder counts of combined adult and jack Chinook Salmon from 1986/87 to present range from 0 (1990/91) to 3,471 (2012/13), with a yearly average of 575 Chinook Salmon. The counts at VAFS are subject to high interannual variation, most likely due to stream flow conditions with lower stream flows hindering the ability of Chinook Salmon to access the upper portions of the river, thus disproportionally affecting VAFS counts. Since the sonar project's inception during the fall of 2018, VAFS counts have been a small fraction, usually less than 5% than those estimated passing at the sonar camera station (Figure 17). For example, the 2022/23 and 2023/24 project years had an average yearly run estimate of 8,180 Chinook Salmon (jacks and adults) while average yearly tallies at VAFS were 266 (about 3% of the sonar abundance estimates).

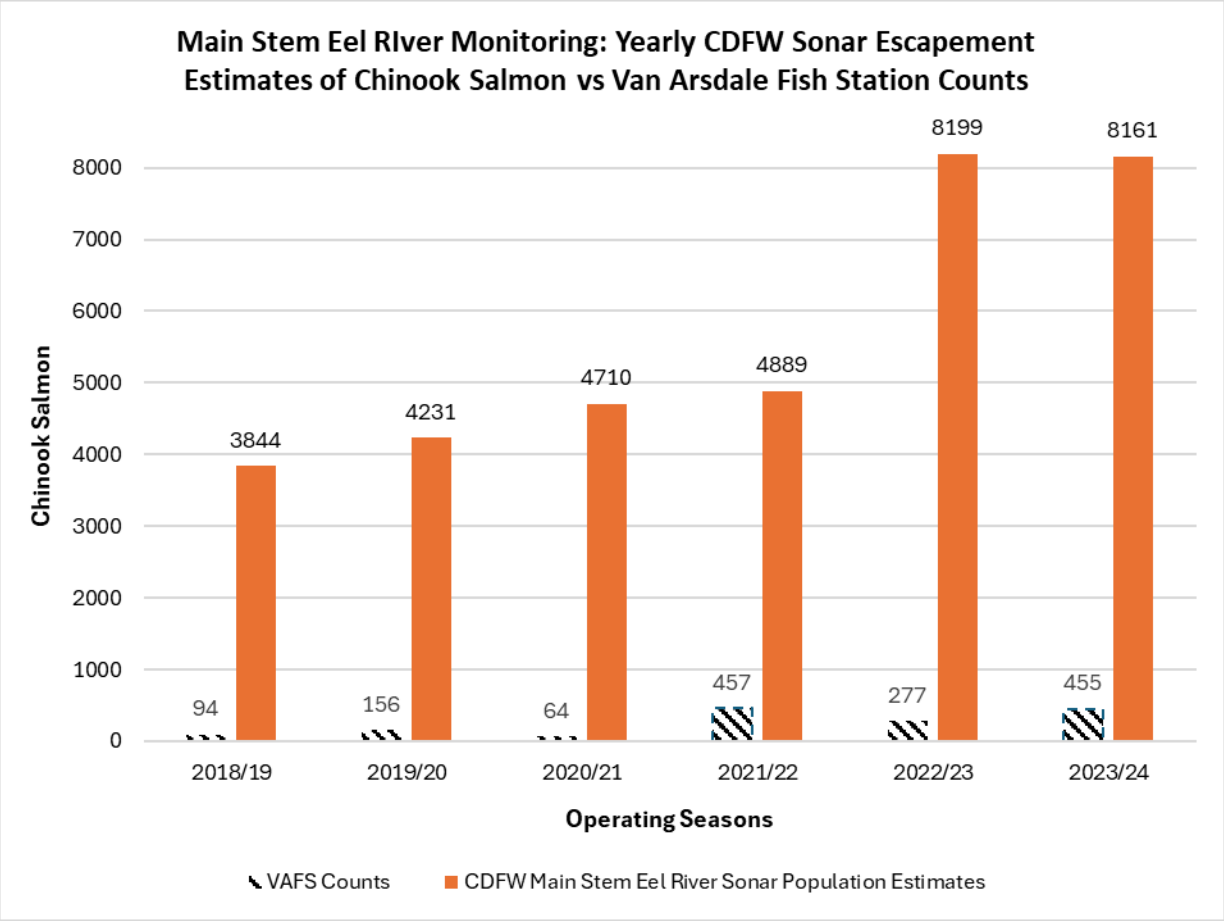


Figure 17. CDFW lower Main Stem Eel River yearly sonar escapement estimates of Chinook Salmon vs Van Arsdale Fish Station (VAFS) counts during the project years 2018-2024. Both escapement estimates and counts are adults and jacks combined.

This project year's consistent, early fall rainfall initiated what is considered a seasonally appropriate upstream migration period for Chinook Salmon (Halligan 1997,1998; and Moyle 2017) from the lower holding areas near the estuary to potential spawning grounds in various locations in the watershed, including the upper watershed above the VAFS. The lack of rainfall in most previous project years delayed the timing of their migration (Table 5) and in some instances, Chinook Salmon spawned in the lower river, downstream of the Main Stem and SF Eel rivers. Broader geographic and temporal spawning distributions may improve overall odds of success and lead to more life history diversity.

Table 5. Julian week fish passage counts of Chinook Salmon at the Main Stem Eel River sonar site during all project years. Totals do not include missing data during non-operation.

Julian Week	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023	2023-2024
10/1-10/7						24
10/8-10/14						0
10/15-10/21				63		240
10/22-10/28				2227		195
10/29-11/4				599	1866	690
11/5-11/11				172	3762	5064
11/12-11/18			915	165	186	750
11/19-11/25	1509	11	1443	387	264	573
11/26-12/2	585	1593	87	312	723	141
12/3-12/9	603	1076	6	423	660	285
12/10-12/16	273	588	312	329	276	27
12/17-12/23	378	660	1197	214	114	117
12/24-12/31*	300	291	750	63	174	411
Total	3648	4219	4710	4954	8025	8517

**Final week in December includes steelhead counts in addition to Chinook Salmon counts*

Eel River Basin Population Estimates

Population estimates for returning Chinook Salmon for the Eel River basin were largely unknown until the establishment of sonar cameras stations in the fall of 2018 in the Main Stem Eel River (CDFW) and SF Eel River (CalTrout). Sonar sites have since been expanded to include the Van Duzen River (CDFW) and the MF Eel (Round Valley Indian Tribes, RVIT) (Figure 1). These provide data collection sites and enable more reliable population estimates in the major sub-basins to inform an overall Eel River Chinook Salmon population estimate. Accordingly, combining estimates at the Van Duzen River, Main Stem Eel River, and SF Eel River sonar sites the 2023-24 fall-run Chinook Salmon abundance estimate of the Eel River Basin is approximately 14,500 - 17,500 adults and jacks combined (Metheny and Shaffer 2024 and Kajtaniak, Nordstrom, and Davis 2025). This estimate excludes the lower Eel River and tributaries below the SF Eel and Main Stem confluence.

SF Eel River Coho Salmon estimates are based on CDFW annual spawner surveys conducted since 2010 and more recent interpretations from CalTrout sonar monitoring counts and range from approximate 500 -2,500 adults (CDFW 2024 and personal communication Metheny and Shaffer 2024). Winter-run steelhead abundance estimates are more difficult to determine based on run-timing overlapping with Coho and Chinook Salmon and duration of high stream flows limiting camera operations; therefore, they are denoted as counts vs abundance estimates. Nevertheless, these counts provide some indication of run size/trends and are discussed below.

Steelhead Counts (winter-run)

Apart from a small number of steelhead that enter the river in the fall, most of the winter steelhead run on the Main Stem Eel River typically occurs from the beginning of January through mid-March (Busby et al. 1996). High flow conditions prevented the project from effectively capturing most of the 2023-24 winter steelhead run: the project experienced historically well above average flows preventing camera deployment for nearly 3 straight months (January 10 till April 8). The 1,476 winter-run steelhead observed from December 21, 2023 to January 10, 2024 was a promising start to the run, especially considering the historically low numbers of steelhead observed in 2022/23. Additionally, 156 fish, mostly presumed to be steelhead are estimated to have migrated past the Main Stem Eel River sonar camera from April 8-April 28. For the April data we used a cutoff of ≥ 55 cm TL to tally and assign fish species as steelhead. This is based on two factors: there were also a significant number of fish passing the camera that were between 39 cm and 54 cm that could have included a large number of Sacramento Pikeminnow, and we did not want to overestimate our steelhead count by including this size class. The ≥ 55 cm threshold is based on CalTrout and Wiyot Tribes's six years of data collection performing Sacramento Pikeminnow suppression efforts (2018-2024) on the SF Eel River in which the number of Pikeminnow caught greater than 55 cm composed less than 3% of their total catch (G. Rossi and M. Matheny, CalTrout, pers. comm. 2024).

Typically, during the fall and early winter season (late October through December), which coincides with the fall-run of Chinook Salmon, stream flows are maintained within a range that allows for effective and predominantly continuous operation of a sonar camera in the lower Main Stem Eel River. However, as the winter season progresses, the daily streamflow increases significantly with the historical median flow approaching 8,000 cfs in mid-February at the Fort Seward USGS gauging station. Overlapping with the winter-run steelhead run, these higher flow conditions hinder continuous deployment of the camera and create gaps in data collection (Figure 10.

The first (2018/19) and last 2 project years have experienced this extreme interannual variability in precipitation and high flows throughout much of the winter steelhead season and subsequently, we could not produce annual steelhead abundance estimates (Table 6). Alternatively, the winters of 2019/20, 2021/22 and 2021/22 were drought years, and the

associated lower than normal stream flows provided the opportunity for longer periods of camera operations/data collection. Notably, the 2021/2022 winter received very little precipitation from February to mid-April, and the dry stretch and abnormally low flows seemed to have delayed some fish movement. Camera operations ceased prior to a late rain event that anecdotally noted upstream migration of steelhead that had been holding in the lower river. These extensive annual variations represent the importance of continuous, multiple years of sonar data collection to provide potential future trend analysis of steelhead runs in the Eel River basin, including aiding the ability to help correct fish passage estimates during periods/years when staff cannot operate the camera due to high stream flows.

Table 6. Main Stem Eel River winter-run steelhead counts tallied at the CDFW sonar site and percent (%) time the camera was in operation during the winter steelhead run.

CDFW Sonar Monitoring Project Years	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24
Steelhead (winter-run)	1,395	4,032	2,632	2,933	396	1,476
% of camera operations during yearly steelhead migration period	40%	82.2%	85%	82.2%	31.9%	12.5%

Summer-Run Steelhead

The Eel River is currently the southernmost river with summer-run steelhead in North America (Jones, 1992). Summer run steelhead enter the river (freshwater) sexually immature and migrate upstream from late March to early June depending on flow conditions. Currently, there are two locations in the Eel Basin where summer-run individuals are routinely observed: the Van Duzen and Middle Fork (MF) Eel rivers with the MF Eel being the far more robust of the two (Kannry et al. 2020). CDFW has monitored adult summer steelhead abundance in the MF Eel through annual direct observation census of all summer holding habitat since 1966. The result of this census is an index of adult abundance with a mean size of 770 individuals per year (Harris, 2019).

This project investigated the possibility of collecting summer steelhead run data during the spring of 2020 by operating a DIDSON camera continuously till the end of May (Kajtaniak & Roberts 2021), and again with an ARIS camera operating throughout April into early May in 2024. During data file review of April and early May files from both project years, staff observed some fish that were presumed to be summer steelhead due to their large size (greater than 55 cm) and swimming motion. However, some portion of adult Sacramento Pikeminnow also begin their migration from the lower river to upstream reaches to feed and/or spawn during this time period (Harvey and Nakamoto 1999, Georgakakos 2020). Large, adult Sacramento Pikeminnow can be of similar size to steelhead and subsequently are very difficult to impossible to distinguish from steelhead during data file review. We experienced similar results during both project years: high fish passage days, (as indicated in Figure 11), and the inability to accurately identify the fish to species. Therefore, project staff believe it is difficult to accurately assign fish species < 55 cm and subsequently produce summer steelhead data for population estimates via the sonar camera.

Green Sturgeon Observations

Green Sturgeon (*Acipenser medirostris*) are found in coastal waters and rivers of North America where they feed in marine and estuarine environments and spawn in a few select rivers (Adams et al. 2002; Moyle 2002). Being one of the larger rivers in the state, it was believed the Eel River historically maintained an important spawning run of Green Sturgeon, although inferences about population size are impossible because of lack of historical data (Adams et al. 2002). After the 1964 flood Moyle et al. (1992) considered the spawning run of Green Sturgeon on the Eel to be extirpated. However, outmigrant trapping studies documented juvenile green sturgeon nearly 100 km upstream on the Main Stem Eel River twelve years after the flood (Puckett 1976), and periodic observations of Green Sturgeon by fisherman and boaters indicated a run persisted on the Eel River. Stillwater Sciences and the Wiyot Tribe (2017) conducted a three-year study between 2014-2016 and concluded, "while the size of the spawning run in the Eel River basin and the degree of spawning success remain unknown, the Eel River can be added to the official list of spawning rivers used by green sturgeon, along with the Klamath, Rogue, and Sacramento rivers." In recent years, CDFW and Stockwell and Sopjes (Pers. Comm. 2020, 2021, 2022, & 2023) have reported yearly, late summer observations of adult Green Sturgeon in the lower Eel River (below the confluence with Van Duzen River), including September of 2023 in which 7-9 Green Sturgeon were present.

The 2023-2024 project year identified 8-9 different Green Sturgeon observations while performing review of April 10 till May 2 sonar files. One of the observations was of a fish moving downstream shortly after a similar sized individual was seen moving upstream, so a minimum of 8 and a maximum of 9 individuals were observed (Table 7). These fish were seen moving past the camera during flows of 3,000-7,000 cfs. The project identifies Green Sturgeon to be any fish that has a total length greater than 100 cm measured using the measuring tool on Sound Metrics ARIScope and ARISFish proprietary software during the steelhead run. By January/February, the Chinook run has completely wrapped up, eliminating the chance of any other species being present with individuals of such large size. The largest steelhead observed during the 2023-2024 season was 87cm TL.

Table 7. CDFW Main Stem Eel River sonar site Green Sturgeon observations (N = 9) from April 10 through May 1, 2024, Humboldt County, CA.

Date Observed	Flow @ Ft Seward (cfs)	Hour Observed	Length of Fish (cm)	Fish Movement Direction
4/10/2024	5296	2000	127	Upstream
4/15/2024	6988	2100	160	Upstream
4/17/2024	5819	0200	120	Upstream
4/28/2024	4077	1900	120	Upstream
4/29/2024	3773	0100	112	Downstream
4/29/2024	3773	2300	132	Upstream
4/30/2024	3506	0400	130	Upstream

4/30/2024	3506	0500	127	Downstream
5/1/2024	3245	1900	155	Upstream

The eight to nine sturgeon identified this year via the Main Stem Eel River sonar station was the highest number during the project's six years of operation. It is important to note that camera operations are somewhat limited during the Green Sturgeon spawning migration period, approximately February through June, and the project is only reviewing a sub-sample of all data files. Subsequently, camera operations and data review likely miss additional upstream/downstream movement of these fish and project data is not being reported as population estimates but is still a valuable tool in tracking this rare species. Table 8 displays prior project year's observations of Green Sturgeon at the Main Stem Eel River sonar site.

Table 8. CDFW Main Stem Eel River sonar site Green Sturgeon observations by project year.

Project Year	Date of observation; # of fish denoted (); and direction of movement (upstream↑) or (downstream↓)
2021-22	2/2/22 (1) ↓; 3/6/22 (1) ↑; 3/11/22 (1) ↑; 3/12/22 (2) milling; 3/13 - 3/23 (2 fish observed milling on an almost nightly basis)
2019-20	3/16/20 (1) ↑

Acknowledgements

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Photo Appendix

Date and Description

1. 11.10.2022. Aerial view of Main Stem Eel River Sonar Site, looking downstream. Photo Credit, David Sopjes.
2. 11.10.2022. Aerial view of Main Stem Eel River sonar site, looking upstream. Photo Credit, David Sopjes.
3. 11.11.23. Camera in position during Chinook Salmon sampling period (400 cfs as recorded at USGS Ft. Seward gage).
4. 12.08.2023. ARIS Camera in position with installed picket weir after rain (3070 cfs at USGS Fort Seward gaging station).
5. 12.13.2023. Otters on the shore across from Main Stem Eel sonar site (684 cfs USGS Ft. Seward gage).
6. 01.09.2024. Camera in position during steelhead sampling period (3,500 cfs at Ft. Seward gage).
7. 01.22.2024. Main Stem Eel sonar site (non-operable) during high flows (29,300 cfs USGS Ft. Seward gage).
8. 11.13.2023. Van Duzen River sonar site.
9. Aerial view of Van Duzen River sonar site, red box is approximate location of sonar unit. Photo Credit, David Sopjes.
10. 03.25.2022. Pacific Lamprey on redd observed during speciation efforts via mask and snorkel survey on Main Stem Eel River from McCann downstream to DIDSON site.
11. Cargo trailer with mounted soalar panels.
12. Equipment setup inside cargo trailer.
13. Screenshot of Main Stem Eel River ARIS footage of a Green Sturgeon - 04/15/2024, 160 cm.

1.) 11.10.2022. Aerial view of Main Stem Eel River sonar site, looking downstream. Photo Credit, David Sopjes

2) 11.10.2022. Aerial view of Main Stem Eel River sonar site, looking upstream. Photo Credit, David Sopjes

3) 11.11.2023. Main Stem Eel River ARIS camera in position with installed picket weir during Chinook Salmon sampling period (400 cfs recorded at USGS Ft. Seward gage).

4.) 12.08.2023. ARIS camera in position following a rain event (3070 cfs at USGS Fort Seward gaging station).

5.) 12.13.2023. Otters on the shore across from Main Stem Eel sonar site (684 cfs USGS Ft. Seward gage).

6.) 01.09.2024. ARIS camera in position during steelhead sampling period (3,500 cfs at Ft. Seward gage).

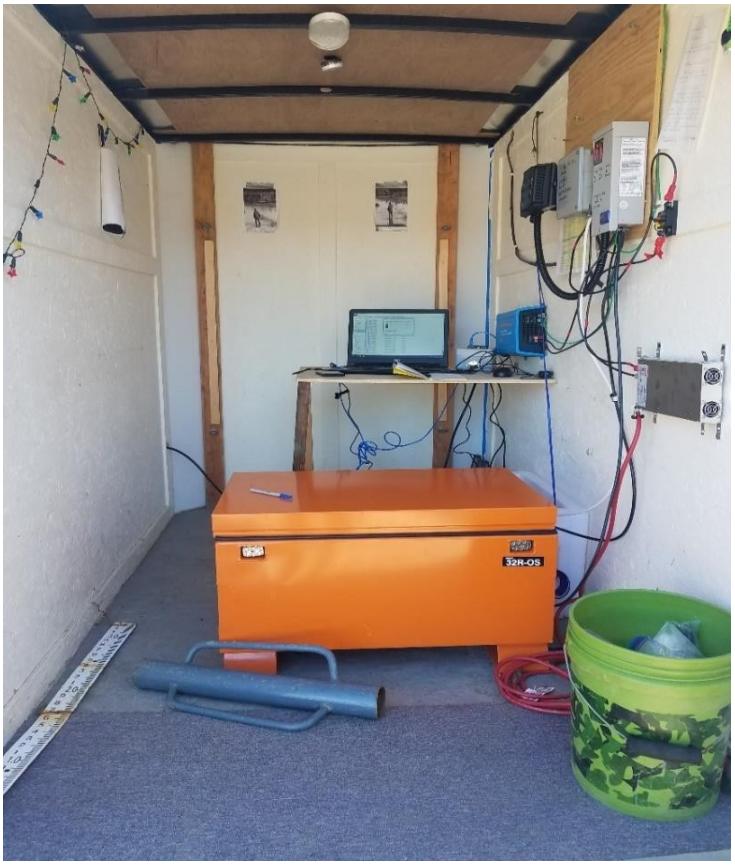
7.) 01.22.2024. Main Stem Eel sonar site (non-operable) during high flows (29,300 cfs USGS Ft. Seward gage).

8.) 11.13.2023. Van Duzen River Sonar Site.

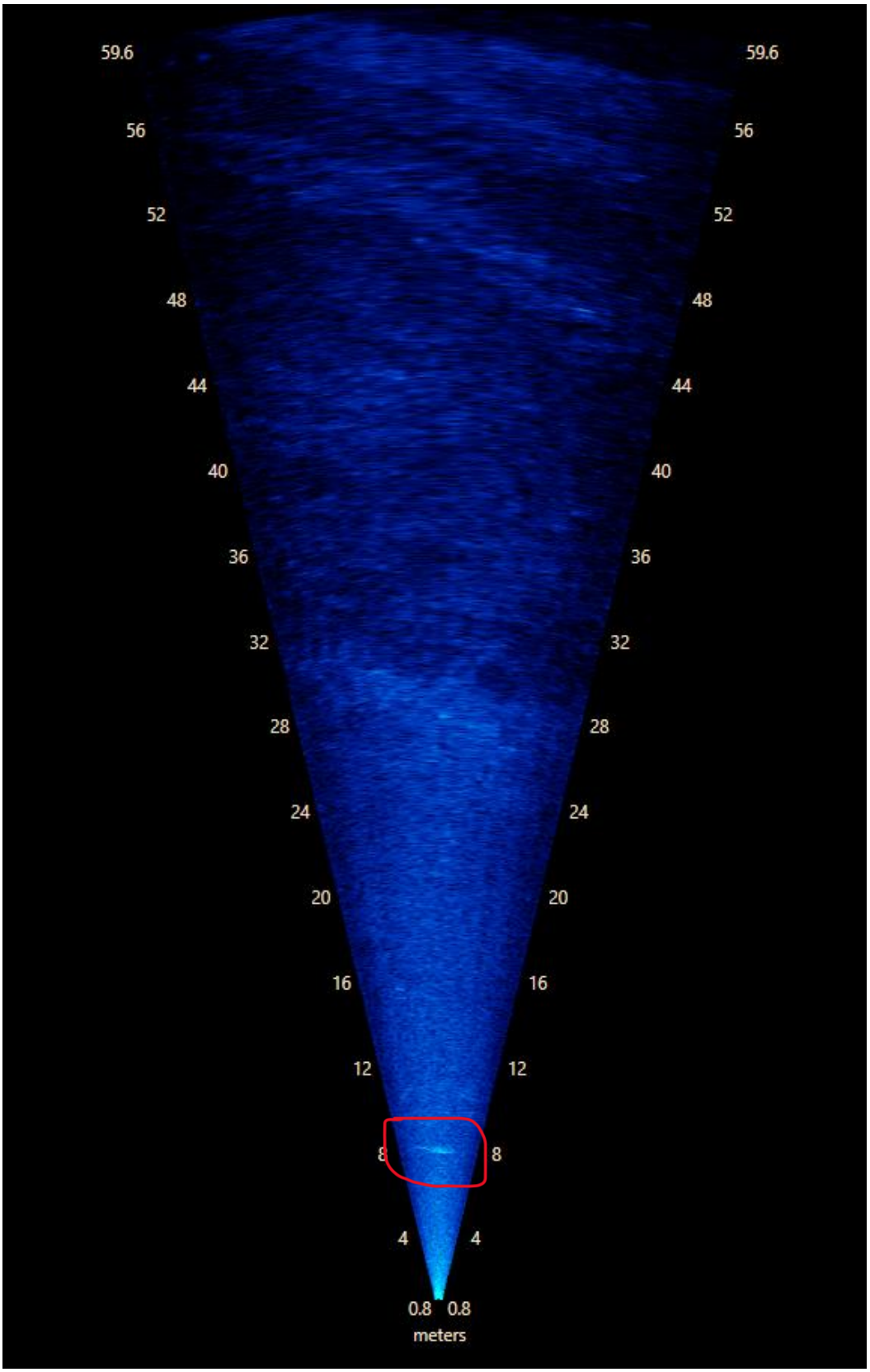
9.) Aerial view of Van Duzen River sonar site, red box is approximate location of sonar unit. Photo Credit, David Sopjes.

10.) 03.25.2022. Pacific Lamprey on redd observed during speciation efforts via mask and snorkel survey on Main Stem Eel River from McCann downstream to sonar site.

11.) Cargo trailer with mounted soalar panels at Main Stem Eel River sonar site.



12.) Equipment setup inside cargo trailer.



13.) Screenshot of Main Stem Eel River ARIS footage of a Green Sturgeon - 04/15/2024, 160 cm total fish length.