The Resources Agency
California Department of Fish and Wildlife

LOWER MAINSTEM EEL RIVER CHINOOK SALMON
MONITORING PROJECT FINAL REPORT

SONAR ESTIMATION OF CALIFORNIA COASTAL (CC) CHINOOK SALMON (*Oncorhynchus tshawytscha*) and NORTHERN CALIFORNIA (NC) STEELHEAD (*Oncorhynchus mykiss*) ABUNDANCE IN THE LOWER MAINSTEM EEL RIVER, HUMBOLDT COUNTY, CALIFORNIA 2019-2020

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June 1, 2020

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Abstract

The California Department of Fish and Wildlife (CDFW) in partnership with Pacific States Marine Fisheries Commission (PSMFC), the National Oceanic and Atmospheric Administration (NOAA) and Trout Unlimited (TU), operated a Dual-frequency Identification Sonar (DIDSON) 'camera' to enumerate adult and jack salmon escapement into the lower mainstem Eel River above the confluence with the South Fork Eel River during the fall and winter of 2019-2020. This was the second year of a two-year project, and the primary intent was to estimate the returns of California Coastal (CC) Chinook Salmon (*Oncorhynchus tshawytscha*) and if possible, estimate returns of Northern California (NC) Steelhead (*Oncorhynchus mykiss*).

We estimate the abundance of Chinook Salmon returning to the mainstem Eel River above the confluence of the South Fork Eel River from November 25 through December 31, 2019 equaled 4,231 (CI = 3,925 – 4,538; CV = 3.62%). This number represents both adults and jacks as we the project did not separate Chinook Salmon into age classes due to uncertainty of measurements. The project analyzed 20-minutes of each hour-long file and then adjusted these raw counts for expansion to full hour counts and filling data gaps (e.g. hours the camera was not running). Daily movement of fish during the Chinook Salmon run ranged from 3 to 405 and averaged 114 fish per day. The peaks of migration occurred on November 28th (N = 405 fish), December 2nd (N = 345 fish), December 7th (N = 263 fish), and November 29th (N = 252 fish), and accounted for 30% of total abundance. These peaks aligned with the arrival of the first significant rain event of the season followed shortly thereafter by a second, lesser rain event. During the Chinook Salmon run there were a total of 799 hours sampled, accounting for 90% of the total potential sampling time.

It was also the project's objective (along with the strong support and interest of Trout Unlimited) to enumerate the steelhead population. Stream flow conditions this project year allowed an extended sampling time and the project was able to effectively capture the beginning to the mid-late portion of the total steelhead run. It is estimated that 4,032 (CI = 3,820 – 4,243; CV = 2.63%) steelhead migrated past the DIDSON camera during the time sampled from January 1 – March 20, 2020. Daily movement of fish during the steelhead run ranged from 0 to 183 and averaged 53 fish per day. The peaks of migration occurred on February 16th (N = 183), February 14th (N = 165), February 6th (N = 126), and February 23rd (N = 120), and accounted 15% of the total abundance. Thereafter, the project ceased operations due to complications with the COVID-19 outbreak, preventing collection of data for the entire steelhead run.

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Introduction

Chinook Salmon have experienced considerable declines in abundance over the last 50 years, particularly in California. As a result of these significant declines the California Coastal (CC) Chinook Salmon Evolutionarily Significant Unit (ESU) was first listed as threatened under the Endangered Species Act (ESA) in 1999, and three 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 composes a significant proportion of the overall CC Chinook Salmon ESU range and natural production; however, the quality and quantity of recent and historical CC Chinook Salmon population data are very limited. 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 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).

Due to its overall large size, remote geography, limited access, flashy hydrology and high turbidities, monitoring the returning CC Chinook Salmon populations in the mainstem Eel River has been difficult and previous studies are mostly limited in their scope and duration. Three data sources – i.e., the California Department of Fish and Wildlife's (CDFW) fish counts at Van Arsdale Fish Station (at Cape Horn Dam) and spawner surveys for the upper mainstem Eel River (below Cape Horn Dam) and Tomki Creek - are among the best available long-running data sets, but they all have significant limitations (Yoshiyama & Moyle 2010). The updated status review for west coast salmon and steelhead by NMFS (2005) 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 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. The counts at VAFS represents 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 flows. 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 617 fish. The carcass surveys performed in the upper mainstem (reaches downstream of Cape Horn Dam to Salt Creek) and in Tomki Creek drainage occurred in the mid-1980s to mid-1990s (Tomki Creek had additional years of surveys into the 2000s). These surveys produced yearly population estimates:

the upper mainstem ranged from 4 to 4,771 Chinook Salmon (adult and jack); and 0 to 3,558 Chinook Salmon (adult and jacks) in the Tomki Creek drainage (Steiner 1998).

While collecting valuable fisheries information for the upper mainstem, the VAFS and previous carcass surveys do not provide evidence for the status of the basin wide salmonid escapement. This project operated a *Sound Metrics* **D**ual-frequency **ID**entification **Son**ar (DIDSON) camera (Long Range model) to enumerate salmon escapement into the lower mainstem Eel River (RM 44) above the confluence with the South Fork Eel River. While single beam sonar systems have been used to enumerate fish migration in rivers since the early 1960's, it is within the last 20 years that sonar technology has greatly improved the counting accuracy by incorporating multiple high frequency beams, producing "video" quality images through highly turbid water conditions over a wide range of river discharges. Similar technology is being used to measure escapement in a number of commercial and sport fisheries in Alaska (Dunbar 2001; McKinley 2002), and Canada (Cronkite et al. 2006). 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). Based on the success of sonar technology to monitor salmon escapement in nearby northern California rivers (e.g. Mad River and Redwood Creek), CDFW believes DIDSON cameras are well suited to the highly variable discharge and water turbidity that characterize the Eel River during the period of salmon migration, and thus initiated the pilot year (2018-2019) study, which also continued this year (2019-2020).

Site Description

The Eel River is located in northern California, approximately 200 miles north of San Francisco, and 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 mainstem Eel, North Fork Eel (283 sq. mi.), Middle Fork Eel (753 sq. mi.), South Fork Eel (690 sq. mi.), and the Van Duzen (428 sq. mi.) rivers. The mainstem 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 mainstem Eel River has its headwaters in Mendocino County near Bald Mountain, and flows south to Lake Pillsbury, thence 12 miles west to Van Arsdale Reservoir, then northwest approximately 157 miles to the Pacific Ocean. Elevations on the mainstem range from sea level at the mouth to over 6,700 feet at the headwaters. The project area covers the portion of the mainstem Eel River from its confluence with the South Fork (SF) Eel River (approximately 40 upstream the Eel River's confluence with the Pacific Ocean) upstream (including the North and Middle Forks) to its headwaters (Figure 1). California Trout operated a separate sonar camera monitoring project on the lower SF Eel River during the 2019-2020 season and will produce its own report detailing their project results (M. Metheny, California Trout, personal communication 2020).

Figure 1. The Eel River watershed with location of DIDSON station, USGS Fort Seward Stream Gage and Van Arsdale Fish Station.

Methods and Materials

Sonar Site Selection

The DIDSON camera was located on the mainstem Eel River, approximately 4 miles upstream of its confluence with the SF Eel River (Figure 1), behind a locked gate on Humboldt Redwood Company Property (HRC). Considering the very limited access points along the lower mainstem Eel River, selecting a location for the DIDSON camera station was constrained to a few potential locations along the lower seven miles of Dyerville Loop Road which follows the mainstem Eel River from the rural settlement area of McCann downstream to the confluence with the SF Eel River. In February of 2018, CDFW and TU performed a reconnaissance-level floating trip on the Eel River from the McCann Bridge downstream to the SF Eel River to determine the best potential location for the DIDSON camera. The 2019-2020 operations occurred at the same location as the 2018-2019 season.

Ideal selection of a sonar site was based on the following primary factors: 1) a uniform stream bottom profile that offers adequate esonification (i.e. uniform, without large pits or boulders) as described by Maxwell (2007), and 2) a longitudinal profile that is characteristic of swift, laminar flow where up/down fish 'milling' behavior is minimized (Pipal et al. 2012). The project's camera site fit this description as it was 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 any salmonids would spawn in this section of the river considering the habitat conditions on high velocity flows during the fall and winter months. The nearest stream flow gage is located approximately 23 miles upstream at the USGS Fort Seward Gage (#11475000).

Sonar Installation

The DIDSON camera site was located at a remote site on a large river bar without access to any structure or power source. We determined that a cargo trailer with attachable solar panels (on top of trailer) could effectively house a laptop, sonar equipment and provide the needed power source. Trout Unlimited purchased the trailer and outfitted the trailer with the necessary equipment (including solar panels and batteries). New to this year's operations were incorporating upgraded lithium-ion deep cycle batteries with the intention of providing a longer lasting and more reliable power source. Trout Unlimited (North Bay and Redwood Empire chapters) purchased the batteries and provided technical assistance for the proper set-up and testing of the new batteries. Humboldt Redwood Company provided access as well as a locking gate security to the site.

On November 7, 2019 the project's staff temporarily installed the cargo trailer, solar panels, a long-range, DIDSON camera and associated equipment. The cargo trailer housed the computer, hard drive, and sonar top box used to operate the camera in addition to the battery bank, power inverter and solar panel controller that provided the external power source. The solar panels were secured on top of the trailer by bolting them to a metal frame and running a 0.25-inch steel cable through holes drilled in the solar panel frames and locking it to the trailer. After the panels were connected, CDFW and PSMFC project leads and CDFW scientific aids initiated testing and recording of sonar imagery.

Due to the lack of rain, low flows conditions (USGS Fort Seward Gage: 85 cfs; USGS Scotia gage: 149 cfs), and assuming no adult salmonid movement would occur, extra effort was taken to test the camera at several cross sections of the river channel to determine the best location for recording and conducting sonar camera operations. To represent fish movement, floating and submerged objects were passed through the sonar beams (or area of esonification) to ensure complete esonification of the water column. Weir panels were installed just downstream of the camera and extended from the dry stream bank to at least 1 meter (m) past the lens to prevent fish from passing the sonar undetected by swimming behind or too close to the camera (DIDSON window start range was set at 0.8 m). The camera was housed in an aluminum lock box attached to a H-frame stand and stabilized with rebar driven into the river bottom and lashed to the stand with 1 cm diameter nylon rope. The camera was secured to the gravel bar using an Earth Anchor duckbill, steel cable, and locks. Vehicles equipped with four-wheel drive were used to access the remote field site located on a large gravel bar.

Data Recording, Processing Sonar Files, and Sampling Strategy

During the first day of operations (November 7, 2019) the camera was deployed in the late morning and brought back to the CDFW Fortuna office in the late afternoon. Once additional security equipment was purchased and installed, the camera could then stay on location and begin recording data 24 hours/7 days a week. A second, multi-day trial run was performed November 20 – November 22 to ensure quality of data during extended temporal operations. Prior to the onset of the first significant rainfall of the season, the project staff deployed the camera on November 25th to continuously record data for the duration of the adult Chinook Salmon run and the majority of the steelhead run. A few exceptions occurred to continuous deployment and recording of data due to periods of excessive high flows and equipment failures (described in Results, Field Operation section).

Project staff checked the camera daily to ensure the quality of recorded sonar imagery and if necessary, repositioned 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), and while in operation the camera was maintained in a position where it could safely capture imagery of the entire channel. During storm events, project staff often made multiple trips per day to the field site to adjust the stand location, weir panels, and camera pitch for data quality purposes. If warranted, project staff removed the stand and camera from the river to prevent damages or loss of equipment. While removed from operations, project staff utilized the opportunity to rinse the camera to prevent silt and algal accumulation, which diminish video quality. If flows were predicted to rise above 10,000 cfs the cargo trailer would usually be moved to a safer location on the river bar.

Sonar imagery data was continuously recorded, arranged in 20-minute incremental files starting on the hour and stored on a 2-terabyte external hard drive. Project staff would copy data multiple days a week 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) occurred on desktop computers using Sound Metrics DIDSON software (version V5.26.24). 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 at 1-8 times faster than recorded speed. However, during times of high fish passage, those sequences generally required multiple 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, 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.

Reviewing data files is time consuming and a lengthy process; therefore, sampling is commonly used to reduce workload (Maxwell 2007). We used a non-replicated systematic sample of the first 20 minutes of each hour to enumerate fish, greater than 39 cm Total Length (TL), passage through the camera window (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 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 autocorrection. 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).

For total fish length data, we estimated sizes of individual fish using the measuring tool in the DIDSON V5.26.24 version software. The first 10 individuals (>39 cm TL) that passed through the window for each hour were measured to the nearest centimeter (cm). A preliminary total length cutoff of 65 cm was used to separate Chinook Salmon jacks (precocious males) from adult Chinook Salmon based on personal communication with Scott Harris (CDFW), who has compiled and reviewed extensive Chinook Salmon data collected at the Van Arsdale Fish Station. The DIDSON camera preset window lengths are limited, with only 40 meter (m) or 80 m focal lengths appropriate for the mainstem Eel River site. As river flows increased and thus the wetted channel widened, the camera stand would need to be reposition further back on the bank and the camera preset focal length would need to be changed from the 40 m to the 80 m preset length. This would generally occur when flows were greater than 500 cfs (USGS Fort Seward gage). The 80 m preset caused great difficulty to accurately measure fish (Figure 2); therefore, fish lengths were documented for only files recorded at 40 m. We assumed that fish migrating within the 40 m end range were similar in size to those migrating within 80 to 40 m window of the range. 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. Variability in fish measurements between the 40 m window range and 80 m window range led to an uncertainty in size classification.

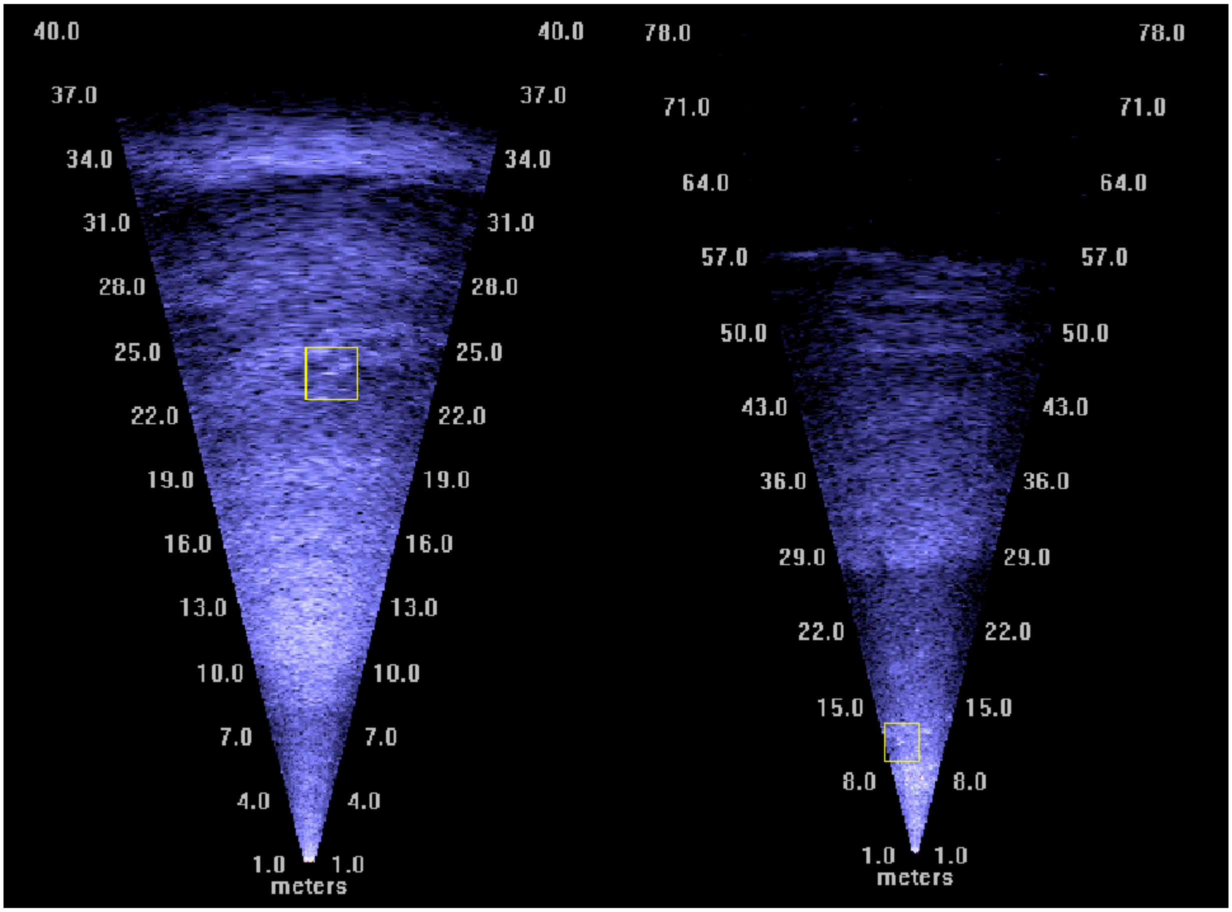

Figure 2. Side by side comparison of still-frame DIDSON imagery with end ranges set at 40 m (left) and 80 m (right). The yellow box outlines where a fish is located. This recording was taken on the mainstem Eel River, Humboldt County, CA.

Species Apportionment

Salmonid species cannot typically be differentiated by sonar imagery alone, however seasonal, single-run rivers does significantly assist in species apportionment efforts. The species assignment was based on the run timing of each species using current and historical observations at the VAFS on the upper mainstem Eel River and annual CDFW South Fork Eel River spawning ground surveys. Distinct, temporal migration patterns have been observed in the Eel River for Chinook Salmon, Coho Salmon (*Oncorhynchus kisutch*) and steelhead (Yoshiyama et al. 2010). Chinook Salmon begin to move from the ocean into the river's estuary in late August and September and hold in the lower reaches until rainfall and increases in discharge allow for passage through shallow riffles. Annually, a small number of steelhead have been observed migrating with the fall-run Chinook Salmon (Halligan 1997, 1998). More recently, the Eel River Recovery Project and local fishing guide, Eric Stockwell, have conducted weekly kayak and stand up paddleboard surveys in September through November in the lower Eel River to document the species present and their approximate numbers. In addition to hundreds of adult and jack Chinook Salmon, the 2019 surveys noted the presence of several fish species staging prior to migration, including adult steelhead, hundreds of half-pound steelhead, hundreds of

Sacramento Pikeminnow (*Ptychocheilus grandis*), several dozen Striped Bass (*Morone saxatilis*), and a few American Shad (*Alosa sapidissima*) (E. Stockwell, personal communication 2019). Of note, the majority of the pikeminnow appeared to be less than 40cm in TL.

We estimated that a large majority of the Chinook Salmon run was completed by the last week of December 2019. This is primarily based on two indicators: only one Chinook Salmon ascended the ladder at the VAFS after December 31 (S. Harris, personal communication January 13, 2020); and CDFW South Fork Eel River spawning ground surveys detected almost no new Chinook Salmon entering the watershed (M. Larson, CDFW, personal communication, April 15, 2020). Beginning in late December, the first couple of steelhead arrived at the VAFS. Continuing into January, their presence was observed through recreational angler reports and CDFW SF Eel River spawning ground surveys. 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 the project utilizes the January 1st timeline to separate the Chinook Salmon run from the steelhead run.

While a significant Southern Oregon / Northern California Coasts (SONCC) ESU Coho Salmon run persists on the SF Eel River, recent detections of Coho Salmon in the mainstem Eel River have been limited to a few observations of adult fish in the Outlet Creek watershed (Yoshiyama 2010). In recent years, a of lack funding, available staff time, and unfavorable flow conditions (extremely high in 2018/2019 vs exceptionally low flow conditions in 2019/2020) have resulted in very limited reconnaissance-level surveys in the Outlet Creek watershed. No detections of Coho Salmon or evidence of their presence were observed in 2018/2019 or 2019/2020 (S. Harris, personal communication, April 9, 2020). We considered it reasonable to assume that the negligible number of migrating adult Coho Salmon in the mainstem Eel River was not enough to compromise the project's adult escapement estimate of Chinook Salmon and steelhead.

Speciation and PIT Tagging Efforts

In addition to these listed salmonids, the Eel River supports other fish species that are likely to pass by the camera, primarily Sacramento Pikeminnow (*Ptychocheilus grandis*) and Sacramento Sucker (*Catostomus occidentalis*). Sparkman and Holt (2020) describe methods to discriminate other fish species from Chinook Salmon and steelhead movement, which project staff utilized during the data file review process. Taking these methods into account, the project performed additional measures to improve confidence involving speciation determination during data review. On October 25, 2019 project staff performed a reconnaissance-level, mask and snorkel dive survey in the large pool unit (> 400 feet) immediately upstream of the DIDSON site with the purpose of documenting any salmonids present, as well as any Sacramento Pikeminnow, Sacramento Sucker, or other species. A single fish was observed during the dive, but positive identification was not possible due to distance between the fish and diver. Excellent water visibility allowed surveyors to see the entire water column, including the deepest points of the pool (approximately 15'). Project staff also identified a potentially hazardous collection of boulders and old metal submerged underwater to avoid during seining operations. Due to the low flow conditions and suitable visibility, two additional mask and snorkel surveys were conducted in the same location during the 2019-2020 season: one on February 19th and the other on March 13th. While the February survey yielded no fish detections, project staff observed three steelhead (two adult-sized and one undetermined), two pikeminnow (25-30 cm), and five suckers (30-35 cm) during the March survey (Table 1).

In order to assist speciation determination and capture adult salmon to implant with passive integrated transponder (PIT) tags, the project conducted a seining operation on December 5, 2019 in the large pool located upstream of the sonar camera. Under the direction of project lead David Kajtaniak (CDFW) and crew leader Joshua Gruver (PSMFC), the project staff with additional assistance from other CDFW Scientific Aids, Wiyot Tribe staff, and AmeriCorps Watershed Stewards Project (WSP) members performed three seining passes in the pool. The project utilized the Wiyot Tribe's jet boat and a 400-foot by 20-foot seine. No adult salmonids were captured during any of the three seining passes and thus no PIT tags were deployed. All fish captured were Sacramento Pikeminnows and which were significantly less than the 39 cm threshold for fish being counted during the imagery review (Table 1). The seining effort along with the mask and snorkel dive surveys gave some assurance that nearly all fish being tallied through data review were salmonids. While the project intended to perform several additional seining events throughout the 2019-2020 season to further validate data collected with reviewed sonar imagery, the lack of available crew, limited resources, and lack of salmonids captured during the original seine did not allow for additional seining operations. Nonetheless, the project will utilize the acquired knowledge and experience to capture adult salmonids during future speciation efforts.

In addition to the seining effort, the project also performed four hook-and-line sampling efforts in January and early February to capture and implant adult steelhead with PIT tags for potential recapture at the Van Arsdale Fish Station (Table 1). The first two efforts were bank-based shore fishing but did not yield any captures for tagging. The other two sampling days occurred on a drift boat and was the most effective way of capturing adult steelhead for PIT tagging purposes. In total, 3 adult steelhead and 1 half-pounder were captured and released (Table 1). The experienced project staff collected scale samples, measured, sexed, and implanted 3 adult steelhead with a PIT tag before being released. USFWS will soon review data on scanned fish from the VAFS, so the project awaits to hear if any of the captured/tagged fish were scanned at the VAFS.

Table 1. Results of 2019-2020 speciation efforts including fish species and total number of fish captured.

Snorkel Survey Data						
Date	**Dive #**	**# of Divers**	**Species Observed**	**Number Observed**	**Size Estimation(s) (cm)**	**Streamflow (cfs) USGS Fort Seward Gage**
10/25/19	1	4	none	-	-	86
02/19/20	2	3	none	-	-	841
03/13/20	3	3	Steelhead	3	50, 65, unknown	407
			Sacramento Pikeminnow	2	25-30	407
			Sacramento Sucker	5	30-35	407

<table>
<tr><th colspan="7">Seining Operation Data</th></tr>
<tr><th>Date</th><th>Pass #</th><th colspan="3">Species</th><th># of Fish Captured</th><th>Size Range (cm)</th></tr>
<tr><td rowspan="3">12/05/19</td><td>1</td><td colspan="3">None</td><td>-</td><td>-</td></tr>
<tr><td>2</td><td colspan="3">Sacramento Pikeminnow</td><td>10</td><td>18-24</td></tr>
<tr><td>3</td><td colspan="3">None</td><td>-</td><td>-</td></tr>
<tr><th colspan="7">Hook and Line Sampling Data</th></tr>
<tr><th>Date</th><th>Samplers #</th><th>Method</th><th>Species</th><th>Sex (M/F)</th><th>Length (cm)</th><th>Tagged (Y/N)</th></tr>
<tr><td>01/09/20</td><td>4</td><td>Shore</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>01/10/20</td><td>4</td><td>Shore</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="3">02/07/20</td><td rowspan="3">3</td><td rowspan="3">Boat</td><td>Steelhead</td><td>F</td><td>59</td><td>Y</td></tr>
<tr><td>Steelhead</td><td>F</td><td>68</td><td>Y</td></tr>
<tr><td>Steelhead</td><td>F</td><td>51</td><td>Y</td></tr>
<tr><td>02/13/20</td><td>3</td><td>Boat</td><td>Steelhead (half-pounder)</td><td>F</td><td>35 (est.)</td><td>N</td></tr>
</table>

Results

Field Operations

The sonar camera was continuously deployed from November 25, 2019 through March 20, 2020 with only a few exceptions. There were intermittent periods of down-time primarily associated with extreme weather conditions and equipment power shortages (Table 2). From the time the camera was initially deployed to the time it was decommissioned for the season, there were 2,808 hours that could potentially be recorded. Of the 2,808 hours throughout the season, a total of 2,614 (93.1% of the total possible) hours were recorded for fish passage. During the Chinook Salmon run (November 25th through December 31st) the project sampled 799 hours, accounting for 90% of the total Chinook Salmon potential sampling frame (Table 2). The hours missed were attributed to electronic issues and large flow events, which resulted in higher water velocities at the site and keeping the camera secured became difficult to potentially impossible. Attempting to operate the camera at higher flows also posed a safety risk to the project staff and crew. The project determined it was safe and effective to operate the camera in flows up to 9,200 cfs (measured at the USGS Fort Seward gage). Some of the recordings during high flow events were challenging to process due the river's high sediment load or poor camera pitch creating background noise (such as increased reflections off the water surface). The positioning of the camera was paramount so that the water column was effectively esonified, therefore detecting individual fish movement (Faulkner et al. 2009).

During the steelhead run (January 1st through March 20th) there were a total of 1,920 potential hours to record data. Of the 1,920 hours, the project sampled a total of 1,815 hours comprising of 95% of the total steelhead sampling time. Typically, January through March see significant base flow increases making extended uninterrupted data recording more difficult. During this year's operation the entire month of February and most of March was captured because of lower than historical average streamflow conditions and dedicated staff efforts (Figure 3). Operating the camera during these unprecedented lower flows presented an unusual opportunity to collect uninterrupted and clear data for extended periods of time. Thus, offering a more concise view of the mainstem Eel River's winter steelhead run.

Table 2. Percent monthly time sampled and time missed due to streamflow and other factors during 2019-2020 season, mainstem Eel River, Humboldt County, CA.

Percent Time Sampled			Percent Sampling Time Missed					
Month	Total % Sampled		Flow (# hrs)	% Due to Streamflow		Other (# hrs)	% Due to Other	
*Nov.	0.9236	92%	0	0.000	0%	11	0.0764	8%
Dec.	0.8952	90%	39	0.0524	5%	39	0.0524	5%
Jan.	0.8970	88%	89	0.1196	12%	1	0.0013	0%
Feb.	1.0000	100%	0	0.0000	0%	0	0.0000	0%
*Mar.	0.9688	97%	0	0.0000	0%	15	0.0313	3%

*The month of November reflects the time period from when the project began recording 24/7. March reflects the time period until the camera was decommissioned on Mar. 20th.

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 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.

Chinook Salmon Abundance Estimate

We estimate the abundance of Chinook Salmon returning to the mainstem Eel River above the confluence of the South Fork Eel River from November 25th through December 31st, equaled 4,231 (CI = 3,925 – 4,538; CV = 3.62%). This number represents both adults and jacks as the project did not separate Chinook Salmon into age classes due to uncertainty of measurements.

Daily Passage Rates

Daily net upstream movement of fish during the Chinook Salmon run ranged from 3 to 405 and averaged 114 fish per day (SE = 15.4) (Figure 3). The peaks of migration occurred on November 28th (N = 405 fish), December 2nd (N = 345 fish), December 7th (N = 264 fish), and November 29th (N = 252 fish) (Figure 3). The periods of increased passage rates coincided with rain events, increased streamflow, and during the receding limb of the stream hydrograph. The first significant rainfall of the season came in late November (November 27th) as Fort Seward received nearly two inches of precipitation. Stream flows were at the lowest point of the season and accordingly this rainfall and subsequent minor increase in stream flow is barely detectable in the Average Daily Streamflow (USGS Fort Seward gage) line in Figure 3. However, the precipitation received in the overall watershed increased the hydrograph in the lower Eel River as evident at USGS Scotia gage (RM 21) (Figure 4). The increased stream flows allowed the hundreds to low thousands of fish holding in the lower reaches of the Eel River to pass shallow riffles and access the SF and mainstem Eel rivers (RM 40.5).

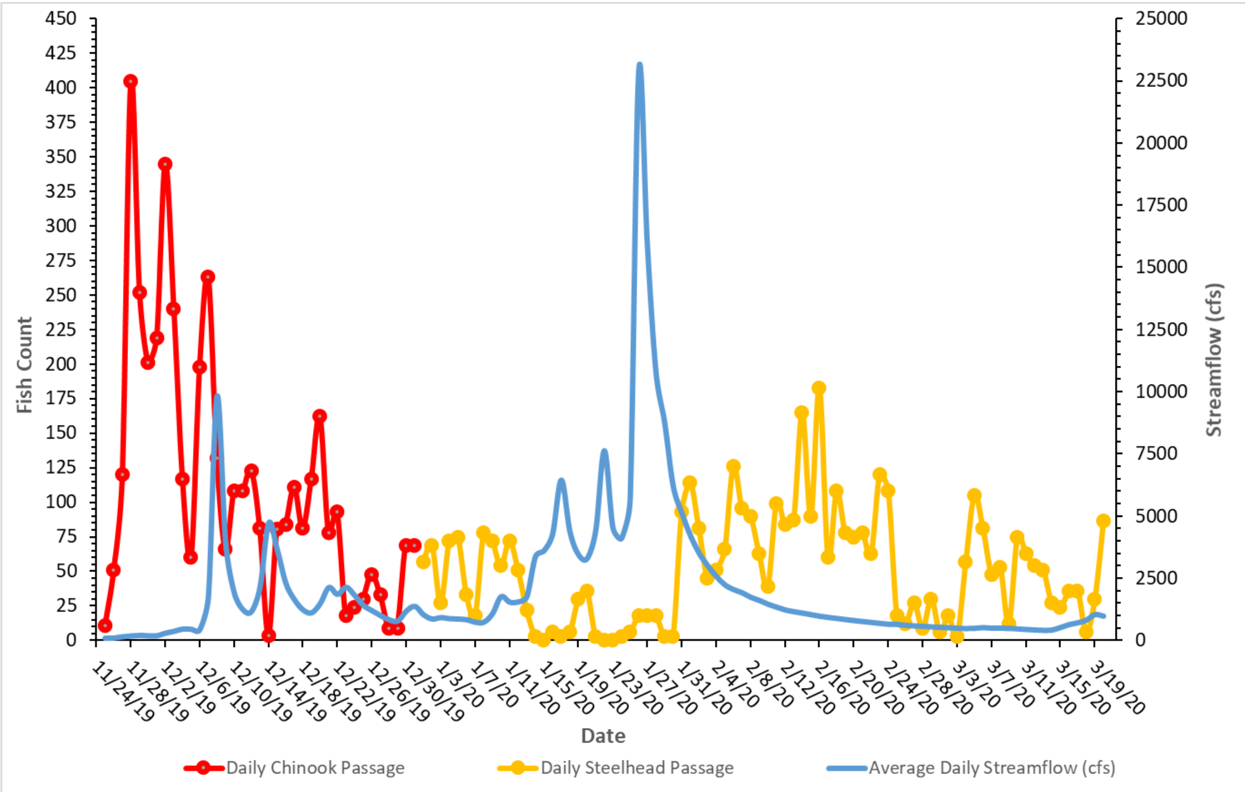

Figure 3. Daily, anadromous fish upstream movement counts at the lower mainstem Eel River DIDSON station plotted with USGS Fort Seward gaging station streamflow (cfs) measurements during the data collection period of November 25th – March 20th.

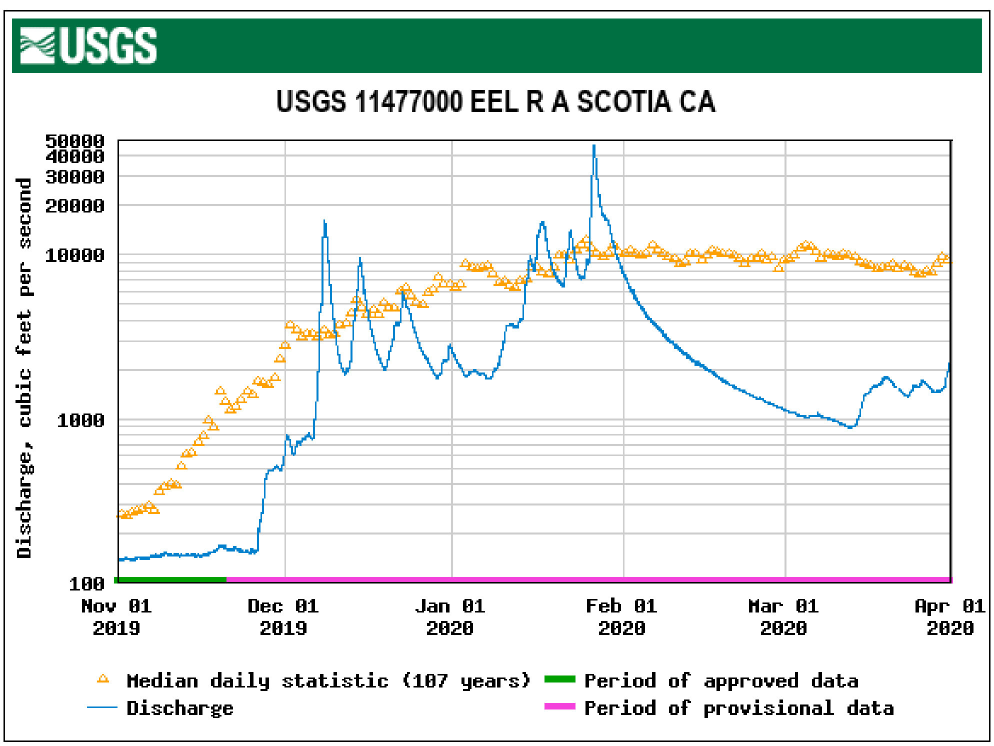

Figure 4. *Estimated daily streamflow (cfs) and historical median statistic during period of DIDSON deployment (November through March) measured from the USGS gauging station at Scotia, Humboldt County, CA.*

Daily net upstream movement of fish during the steelhead run ranged from 0 to 183 and averaged 53 fish per day (SE = 4.4). The peaks of migration occurred on February 16th (N = 183), February 14th (N = 165), February 6th (N = 126), and February 23rd (N = 120). The largest recorded peak in passage numbers occurred shortly after a sizeable storm (February 11, 2020), prompting increased migration. During the 2019-2020 season the project recorded water temperatures using a temperature data logger at the DIDSON station site for nearly the entire steelhead run. Preferred water temperatures for steelhead during spawning migration range from 46-52 degrees Fahrenheit (NOAA 2000a). There appeared to be no correlation between temperature and fish passage and temperature during the operational period ($r = 0.13$, $p > .05$) (Figure 4) perhaps due to the abnormally low flows. Near the end of February and first few days of March the camera pitch was less than ideal for complete esonification, and sonar data review was difficult with these files. Fish movement appeared to drop during this time which could have affected the results of our correlation. It is possible some steelhead were missed during this period. The project plans to record water temperatures throughout the steelhead run for the next year and hope to have a more historically representative water year.

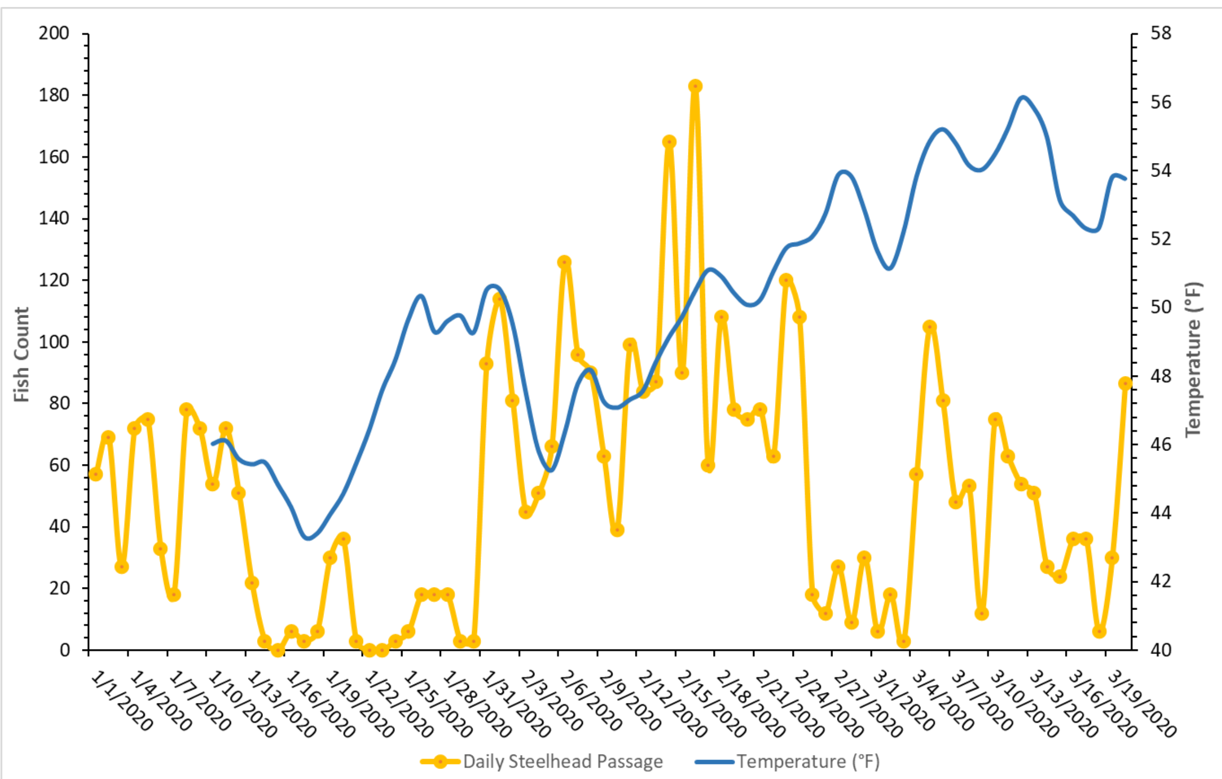

Figure 5. Daily fish movement with recorded water temperatures via a data logger at the DIDSON site during steelhead run on the mainstem Eel River, Humboldt County, CA.

Fish Measurements

As discussed in Data Recording and Processing section of this report, the 80 meter (m) preset focal length on the DIDSON does not allow for accurate fish measurements (Figure 2); therefore, fish lengths were documented for only files recorded at 40 m. The 40 m window was utilized during lower flow conditions (base flows averaging less than 500 cfs), which occurred during

November, the first week of December, and about half of the operational time in March. Twelve days (34.3%) of the associated files during the Chinook Salmon run were recorded at the 40 m preset. This period contained a large portion of the Chinook Salmon run and allowed for adequate fish length data estimates. Lengths estimated using DIDSON software version V5.26.24 for Chinook Salmon ranged from 39 cm (project's cutoff for anadromous fish) to 133 cm (Figure 6). The average length was 67.4 cm (SE = 0.58) with 50% of the fish measured at 55-78 cm (Figure 7).

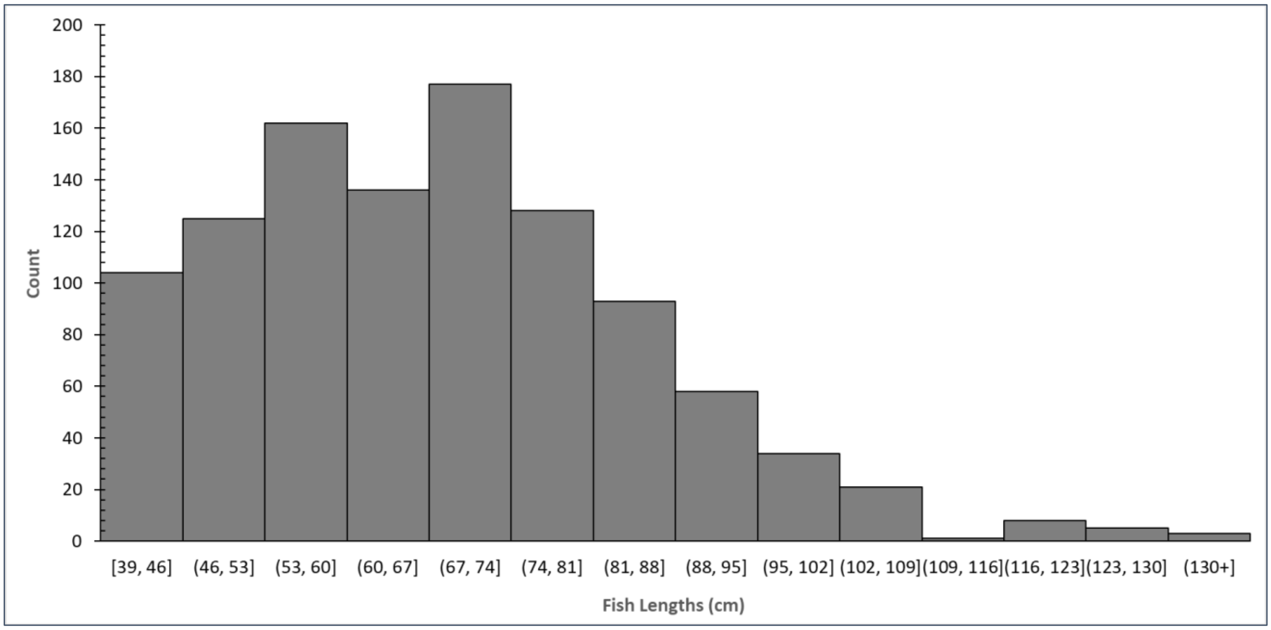

Figure 6. Estimated Chinook Salmon lengths (cm) using Sound Metrics software version V5.26.24 with the window end range set at 40 m on the mainstem Eel River, Humboldt County, CA.

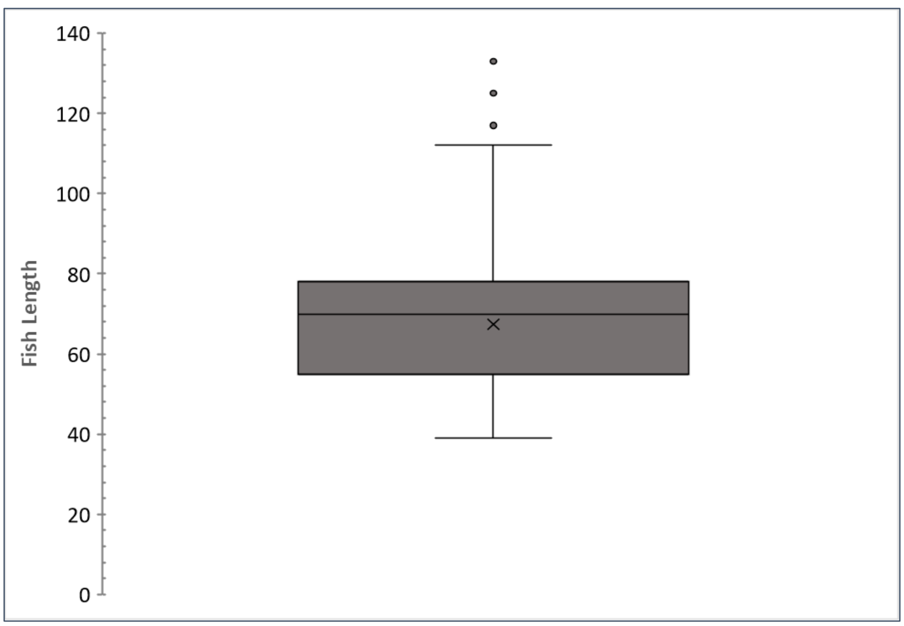

Figure 7. Distribution of estimated Chinook Salmon lengths measured using Sound Metrics software version V5.26.24 with the window end range set at 40 m on the mainstem Eel River, Humboldt County, CA.

Discussion

The Eel River, being the largest contributor to the CC Chinook Salmon ESU, is crucial for viability of the species (NMFS 2016). The dynamic landscape, weather, and remote tributaries increase the difficulty of effectively surveying the watershed with methods such as spawning ground surveys, adult weirs and traps. Capturing fish movements in a variety of conditions (turbid and nonlaminar water) is necessary for accurately estimating salmonid abundance in large river habitats (Reynolds 2007). Using hydroacoustic technology is the only logistically reasonable strategy to enumerate anadromous fish escapement in a watershed the size of the Eel River (Sparkman et al. 2017 and Kajtaniak and Easterbrook 2019).

Once supporting 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). The yearly steelhead run also numbered in the hundreds of thousands. Mid-century estimates indicated a drastic decline in Chinook Salmon numbers. The California Fish and Wildlife Plan (CDFG 1965c), using limited spawner surveys from the mid to late 1950s and professional judgment estimated Chinook Salmon spawning escapement of 26,000 fish (combined MF Eel River and mainstem Eel River). These number continued a downward trend into the 1980s and 1990s. Modern escapement estimates have been largely expert opinion based on a few indices throughout the watershed. The Van Arsdale Fish Station (VAFS) located high on the mainstem Eel River, has an extensive data set with many years of fish counts passing Cape Horn Dam. While collecting valuable fisheries information for the upper mainstem, the VAFS does not provide evidence for the status of the basin-wide salmonid escapement. The DIDSON Monitoring Project aims to produce relevant and comprehensive data for management of Eel River salmon, a significant contributor to the CC Chinook Salmon ESU.

Abundance of CC Chinook Salmon

For the first time since the canneries were last operational (early 1900s), the project efforts in 2018-2019 and 2019-2020 have allowed for a more accurate estimate of the CC Chinook Salmon run in the mainstem Eel River. The use of sonar capably detected fish movement 24 hours per day in variable flows and prominently highly turbid water; thereby providing counts used to estimate the CC Chinook Salmon run abundance. The project estimated that 4,231 (CI = 3,925 – 4,538; CV = 3.62%) Chinook Salmon migrated past the DIDSON camera on the mainstem Eel River. This number is slightly higher but compares similarly to the 2018-19 estimate of 3,844 (CI = 3,506 - 4,181; CV = 4.39%). Of note, the VAFS observed 153 Chinook Salmon ascend the ladder during this 2019-2020 season. This number increased from the 95 Chinook Salmon observed during the 2018-2019 season.

While the mainstem Eel River DIDSON saw a slight increase (less than 10%) in CC Chinook Salmon in 2019-2020, lower numbers of Chinook Salmon were observed in the Van Duzen River basin and the SF Eel River basin. Spawner surveys efforts in Lawrence Creek and Grizzly Creek, two significant Chinook Salmon spawning streams in the Van Duzen River basin, observed approximately half the number of Chinook Salmon redds from the prior year's similar efforts. The South Fork Eel River CDFW spawner ground surveys recorded a mere 28 redds during November and December of 2019, compared to 81 redds recorded in 2018 (M. Larson, personal communication April 15, 2020). Most likely due to the very delayed onset of fall rains and corresponding low flows, there were reports of redds below the SF Eel River and mainstem confluence (E. Stockwell, personal communication November 2019), and indicate salmon may have opted to spawn in the lower Eel River as opposed to accessing the SF Eel and mainstem Eel River under normal fall flow conditions.

California Trout is operating a second year of their South Fork Eel River DIDSON Sonar Monitoring project. The project has not completed a full data analysis of data collection; however, their preliminary and draft estimate of the Chinook Salmon run is 2,190 adult and jack fish (M. Metheny, personal communication April 21, 2020). This preliminary estimate is well below the 2018-2019 Chinook Salmon numbers of 3,800 fish. The SF Eel River DIDSON draft estimate combined with the mainstem Eel River DIDSON estimate indicates CC Chinook Salmon abundance in the SF Eel and mainstem Eel River (upstream the confluence with the SF Eel) combined was between 5,900 – 6,500 fish in 2019-2020. This comprises approximately 75% of the Eel River watershed's Chinook Salmon habitat. Additional data is needed to produce an Eel River basin-wide estimate, which would include the Van Duzen River watershed and several other tributaries downstream the confluence of the SF Eel and mainstem Eel rivers.

Abundance of NC Steelhead

It was the project's intention along with the strong support and interest of Trout Unlimited to enumerate the NC steelhead population. Favorable flow conditions allowed the project to effectively capture the majority of the 2019-2020 run, from its beginning in late December/early January till near the tail end in mid-late March. With the exception of a small number of steelhead that enter the river in the fall, the vast majority of the steelhead run on the mainstem Eel River typically occurs from the beginning of January through March (Busby et al. 1996). We estimate that 4,032 (CI = 3,820 – 4,243; CV = 2.63%) steelhead migrated past the DIDSON camera during the time sampled from January 1 – March 20. Thereafter, state-mandated restrictions due to the COVID-19 pandemic did not allow for continued operations of the project. This contrasts from the 2018-2019 project year when well above normal precipitation and high flow conditions persisted through most of February and all of March in 2019. Those conditions prevented operations of the camera and data collection for the majority of the steelhead run. It was estimated that 1,395 (CI = 1,284 – 1506; CV = 3.97%) steelhead migrated past the DIDSON camera during the truncated sampling period of January 1 – February 12, 2019 (Kajtaniak and Easterbrook 2019).

Since the project's end date of March 20, 2020, steelhead have continued to migrate up to the VAFS. During the last week of March and first two weeks of April, approximately 40-45 steelhead were counted at the fish ladder at VAFS, indicating the run was still on-going. Numbers quickly dropped after mid-April (N. Easterbrook, Garcia and Associates, personal communication April 30, 2020) and some of these steelhead arriving at the VAFS could be composed of the summer steelhead lifecycle variant. The final VAFS end of season total was 263 steelhead (S. Harris, personal communication May 28, 2020). Comparatively, the on-going count at the time of removing the DIDSON was approximately 220 steelhead. Considering a few steelhead arrived sporadically through mid-May at the VAFS, if intentions are to collect summer steelhead data in future years then the DIDSON would need to remain operational into May.

Downstream Migration

Behavior from downstream-migrating steelhead (or kelts) can impact population estimates when not properly accounted for (Pipal et al. 2010). The project estimates it observed the initiation of the downstream kelt movement beginning on/around March 10, 2020. Camera operations ceased shortly thereafter, March 20th, which only allowed a very brief period of data collection during kelt movement and observations were very limited. Therefore, we considered the number of steelhead moving downstream to be too insignificant when attempting to enumerate the upstream movement and did not adjust the overall steelhead run numbers. Of note, the VAFS began seeing numerous steelhead moving downstream in late March (N. Easterbrook, personal communication April 30, 2020). The sightings are considered unique to the extremely low flow condition present in the upper watershed as normal early spring flow conditions allow steelhead to move downstream over the dam and therefore would not be observed by VAFS staff.

Methods to differentiate between milling fish and kelts have been previously described and utilized by Sparkman et al. (2018). In future years, the project hopes to collect the entire steelhead run period in order to better understand the kelt portion of the steelhead run.

This project's location is ideal to minimize 'milling' behavior of fish and encourage direct, unobstructed passing through upstream or downstream. This should provide a good kelt estimation, provided the project can operate the camera throughout the tail end of the steelhead run. The project plans to record more kelt movement during the 2020-2021 season and will apply the 'kelt adjustment' method when determining steelhead abundance in the mainstem Eel River.

Temporal Migration Patterns

Very similar to the 2018-2019 run, the 2019-2020 adult Chinook Salmon run timing was influenced by the unseasonably late rainfall beginning in late November 2019 (Table 3 & Table 4). Prior to the first significant rainfall event, the project observed very low numbers of fish migrating past the DIDSON camera (Figure 3). During the 72 hours after the first rainstorm, the highest fish passage rate for the entire season was observed (Figure 3). The lack of rain in October and most of November inhibited Chinook Salmon passage upriver during their historical run timing (Halligan 1997,1998; Moyle 2017). As a result, this large, initial pulse of fish may have been a combination of several pulses of fish that normally would have been spread out during the month of November. Throughout December, migration pulses were associated closely with rain events increasing streamflow (Figure 3). On the descending limb of the hydrograph fish passage would increase and then taper off as flows continued to recede.

February is typically the peak migration period of the winter run steelhead on the mainstem Eel River. With almost no recorded precipitation this past February and less than half of the historical average in March throughout the watershed, stream flows ran at historically low levels and the project had the ability to capture most of the steelhead run. During wetter years, streamflow is highly variable, resulting in short periods of sonar recording or days to even weeks of temporary non-operation. According to the California Nevada River Forecast Center (CNRFC), Fort Seward received 0% of its monthly average rainfall for February 2020 (Table 4); in February of 2019 this location received 245% of its average rainfall. Similar dramatic swings occurred in February of 2018 vs 2017, as 2018 received 29% of its average but 2017 recorded 212%. The difficulties capturing the entire winter steelhead run are reflected in these historical precipitation averages. Extreme precipitation fluctuations year-to-year will influence the ability of projects to operate during inclement river conditions. These extensive annual variations represent the importance of several years' worth of data collection in order to accurately estimate steelhead runs in the Eel River basin.

Table 3. Daily average precipitation per week measured at NOAA stations in Fort Seward, Covelo, and Willits, Mendocino County, CA, November 1,2019 to March 26, 2020.

Daily Average Precipitation per Week (November 1, 2019 to March 26, 2020)			
Week(s)	**Fort Seward (in)**	**Covelo (in)**	**Willits (in)**
11/1/ - 11/7	0.00	0.00	0.00
11/8 - 11/14	0.00	0.00	0.00
11/15 - 11/21	0.01	0.00	0.01
11/22 - 11/28	**0.34**	0.02	0.27
11/29 - 12/5	0.14	0.07	0.17
12/6 - 12/12	**0.48**	**0.43**	**0.69**
12/13 - 12/19	0.23	0.14	0.22
12/20 - 12/26	0.16	0.04	0.24
12/27 - 1/2	0.10	0.05	0.08
1/3 - 1/9	0.14	0.17	0.13
1/10 - 1/16	**0.34**	0.11	0.24
1/17 - 1/23	0.23	0.12	**0.32**
1/24 - 1/30	**0.38**	**0.38**	**0.38**
1/31 - 2/6	0.00	0.00	0.01
2/7 - 2/13	0.00	0.00	0.00
2/14 - 2/20	0.00	0.00	0.00
2/21 - 2/27	0.00	0.00	0.00
2/28 - 3/5	0.00	0.00	0.00
3/6 - 3/12	0.03	0.02	0.01
3/13 - 3/19	0.24	0.19	0.31
3/20 - 3/26	0.05	0.00	0.08

Table 4. Monthly precipitation totals with % of historical average in parentheses () measured at NOAA stations in Fort Seward, Covelo, and Willits, Humboldt and Mendocino County, October 1, 2019 to March 26, 2020.

Monthly Precipitation Totals and % of Historical Average (in)			
Month	**Fort Seward (in)**	**Covelo (in)**	**Willits (in)**
October	0.66	0.29	0.29
November	3.28 (44%)	1.88 (26%)	2.72 (33%)
December	7.76 (80%)	5.52 (60%)	9.72 (110%)
January	7.68 (70%)	7.08 (71%)	7.60 (78%)
February	0.00 (0%)	0.00 (0%)	0.08 (1%)
March	2.52 (44%)	2.28 (36%)	3.20 (50%)
TOTAL (in)	21.90	17.05	23.97

Diel Migration Patterns of Salmonids

Although fish movement was observed throughout the day, there was a significant increase in movement during crepuscular periods (dawn and dusk) and periods of darkness (Figure 7). This was also case during 2018/19 operations and is consistent with other studies (Reynolds et al. 2007; Sparkman et al. 2017). The patterns of these movements are likely due the increased perception of security from predators and could be controlled by genetics. The perception of security is likely also linked to water clarity conditions: fish generally will not move during daylight when flows are low and clear.

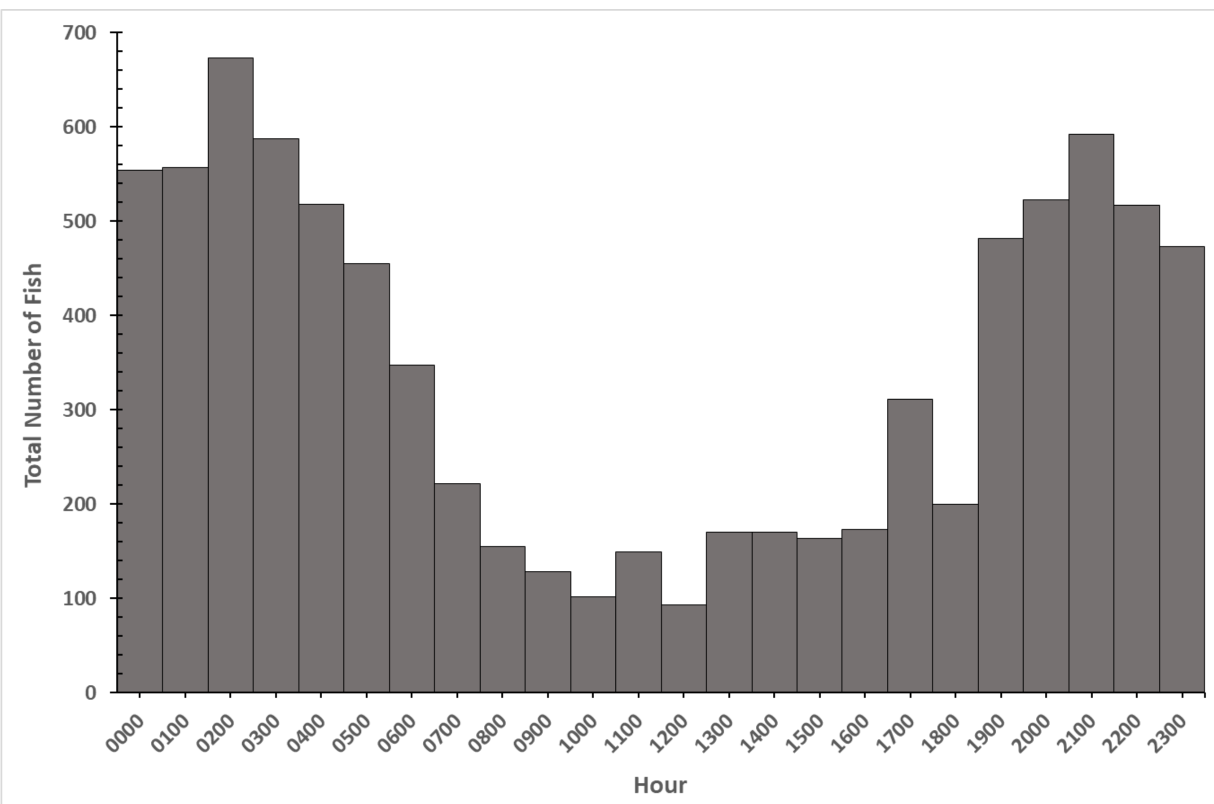

Figure 8. Diel migration pattern by hour of adult Chinook Salmon and steelhead (N = 8,315) in the Eel River from November 25 through March 20, Humboldt County, CA.

Green Sturgeon Presence

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). Marine distributions range from Ensenada, Mexico to the Bering Sea, Alaska (Scott and Crossman 1973; Moyle 2002). Two distinct population segments (DPS) of Green Sturgeon exist: (1) a northern California DPS and (2) southern DPS. Northern California DPS Green Sturgeon spawn in the Rogue and Klamath rivers (Israel et al. 2004). Historically, spawning also occurred in the Eel and Umpqua rivers. Green Sturgeon is a long-lived, late-maturing anadromous species vulnerable to habitat loss and exploitation (Moyle 2002; Adams et al. 2002; NMFS 2010). Similar to historical salmon abundance in the Eel River, Green Sturgeon spawning runs were once apparently robust, but inferences regarding population size are not possible with the 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 River to be extirpated. However, in multiple years after the flood (1967 through 1970), outmigrant trapping studies at McCann and Fort Seward documented over hundreds of juvenile Green Sturgeon on the mainstem Eel River (Puckett 1976). Periodic historical observations and more recent sightings of Green Sturgeon by fisherman and boaters encouraged the Wiyot Tribe in conjunction with Stillwater Sciences and Sweet River Sciences to conduct Green Sturgeon focused surveys (2014-2016). The overall study demonstrated a resolute spawning run of Green Sturgeon of the Eel River (Stillwater Sciences and Wiyot Tribe 2017).

Historical distribution of Green Sturgeon within the Eel River basin is not documented; however, with the exception of likely known barriers to adult upstream migration (such as Split Rock on NF Eel and Coal Mine Falls on MF Eel), the mainstems of the larger river channels should be accessible to adults (Sillwater Sciences and Wiyot Tribe 2017). Adults spawn in rivers during late winter and into early summer, every two to six years with a three to four-year interim being the usual (Moyle 2002; Adams et al. 2002; NMFS 2010; Doukakis 2014; Sweet River Sciences and Wiyot Tribe 2017). During summer months after spawning has occurred, Green Sturgeon reside in deep pools with low to minimal currents in the Rogue, Klamath, and Trinity Rivers (Sweet River Sciences and Wiyot Tribe 2017). Emigration is closely tied with an increased discharge within a system, especially after the first major precipitation events (NMFS 2000b).

The 2019-2020 season provided the opportunity to collect data on the passage of Green Sturgeon in the mainstem Eel River. Similar to steelhead, the ability to capture some migrating sturgeon was made possible due to the historically low streamflow and continuous operation of the sonar camera. The project captured footage of one Green Sturgeon passing the camera on March 16, 2020. Size estimation of the fish was approximately 2 m long (using Sound Metrics software version V5.26.24). The project feels confident in its speciation due to its body shape, overall length, and swimming behavior recorded by the sonar. Mean streamflow on this date was measured at 637 cfs (USGS Ft. Seward gage) and the daily mean temperature was recorded as 52.7° Fahrenheit via the camera station's data logger. There were additional occurrences of objects (larger fish) passing through the sonar field and were suspected to be sturgeon, but the degree of certainty was less due to sonar image aberrations and poor visual quality as a result of high sediment suspension or substandard camera pitch. The project is confident with sufficient funding and ability to operate through April, more vital data could be collected on passage of Green Sturgeon in the mainstem Eel River.

2019-2020 Lessons and Challenges

Species Run Timing and Seasonal Streamflow

Run timing for salmon and steelhead in the Eel River changes from year to year, but the general pattern remains the same with steelhead migrating later than Chinook Salmon and having some overlap with the end of the Coho Salmon run timing (Yoshiyama et al. 2010; Halligan 1997, 1998). During the late fall and early winter season (November through December) which coincides with the run timing of the adult Chinook Salmon, stream flows are maintained within a range (300 cfs to 3,000 cfs) that allow for effective and predominantly contiguous operation of the sonar camera (Figure 9). However, as the winter season progresses, the daily streamflow increases significantly with the historical median flow averaging between 6,000 cfs and 8,000 cfs (Figure 10) at the USGS Fort Seward gauging station.

The recorded Chinook Salmon run (November 25th through December 31st) estimated mean daily flows ranged from 89 cfs to 9,820 cfs. The minimum recorded hourly streamflow was 86.4 cfs on November 25, 2019 and the maximum was 12,600 cfs on December 8, 2019. Comparatively, the 2018-2019 season operational date minimum and maximums were 61.4 cfs (November 15, 2018) and 15,500 cfs (December 25, 2018), respectively.

During the 2020 recorded winter season (January 1st through March 20th), the USGS gauging station at Fort Seward estimated mean daily flows ranged dramatically from 408 cfs to 22,900 cfs (Figure 9). During this time the lowest recorded hourly streamflow was 404 cfs on March 14, 2020 and the highest was 32,000 cfs on January 26, 2020. The lowest and highest hourly flows during the previous year's operational dates were 854 cfs (January 5, 2019) and 46,100 cfs (January 17, 2019), respectively. The daily discharge fell well below the historical median flow for much of the season, illustrating this year's opportunistic effectiveness capturing the entire steelhead migration run in winter to early spring (January-April) (Figure 10). Anytime the watershed receives normal to higher than normal rainfall, it would be difficult if not impossible to continuously operate the camera, which was the case during last year's operations from mid-February till mid-April. During that period of inoperable flows, the project lead and staff explored the possibility of upstream deployment by viewing various locations from McCann to Fort Seward. Limited access combined with long drive times from the CDFW Fortuna office (and no off-site housing opportunities) eliminated any easy, feasible options. With continued application of sonar to estimate salmonid escapement in the Eel River, this project aims to identify a streamflow threshold at which fish movement is extremely limited or stops entirely (Metheny et al. 2016; Sparkman and Holt 2020).

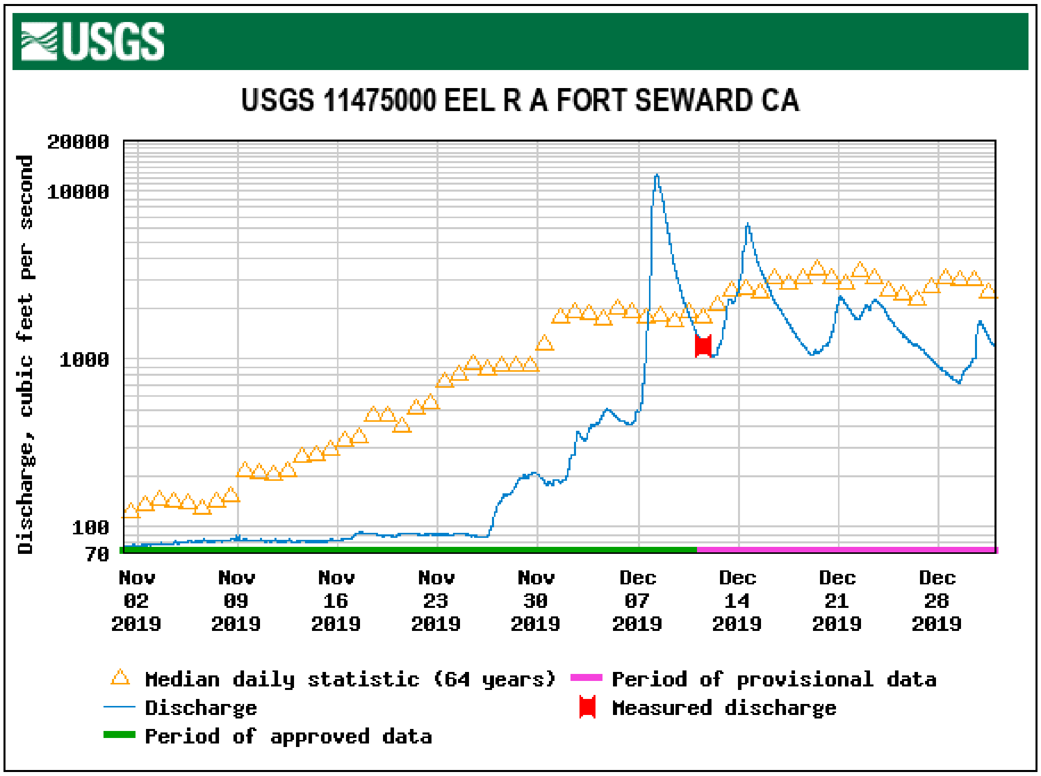

Figure 9. Estimated daily streamflow (cfs) and historical median statistic during period of typical, adult Chinook Salmon run timing (November thru December), measured from the USGS gaging station at Fort Seward, Humboldt County, CA.

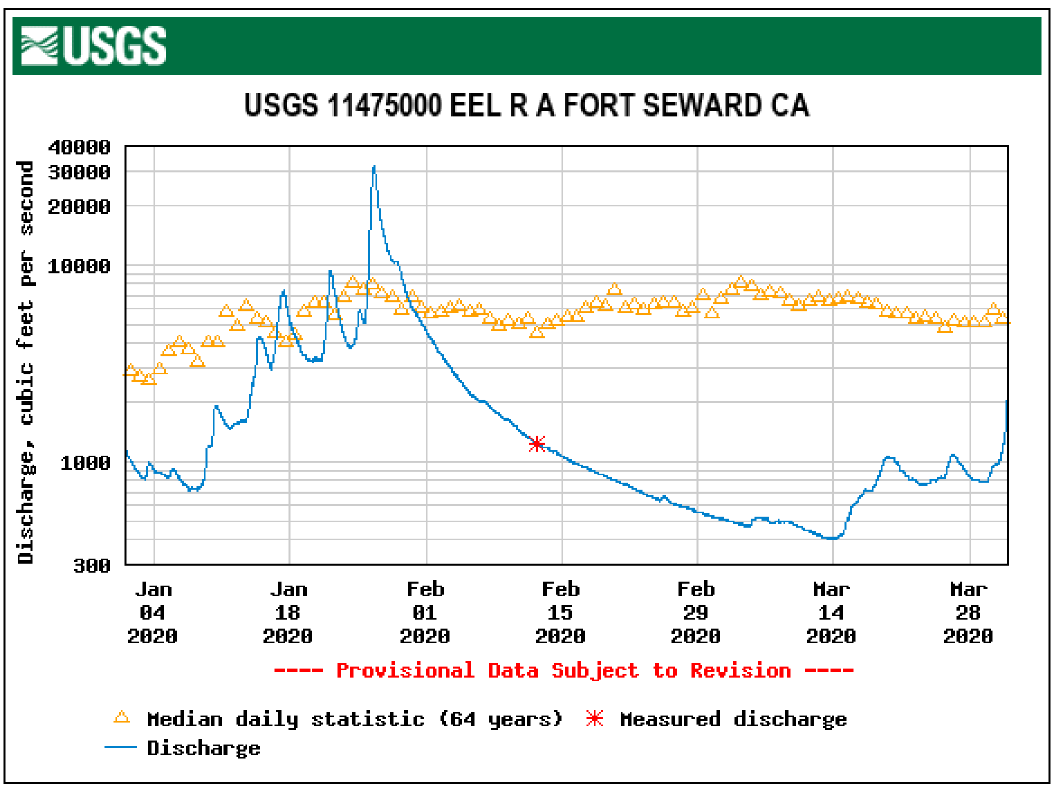

Figure 10. Estimated daily streamflow (cfs) and historical median statistic during period of typical adult steelhead run timing (January thru March) measured from the USGS gaging station at Fort Seward, Humboldt County, CA.

In the field there were a few challenges that altered the day-to-day routine while the camera was operational. The camera site was located very low in the Eel River watershed leaving a substantial upriver area for rain, surface runoff, and groundwater input above the site. The streamflow varied dramatically, sometimes with changes in thousands of cfs within hours and tens of thousands throughout the day (Figures 9 & 10). The sonar would need to be moved in response to ascending or descending water levels. Having a gauging station upstream (Fort Seward) was very useful for indicating real-time flow information. However, the gage readings would provide only a minimum of what was actually encountered, since additional run-off occurs below the gaging station. Often it was necessary to check flows throughout the day and night and be ready to move the sonar in order to collect valuable data with properly weighing field staff safety. The project found that the threshold at which the camera needed to be pulled from the river was approximately 9,500 cfs. The cargo trailer housing the power source, DIDSON top-box, and computer was vulnerable at high flows further adding to the precautionary measures. The Project would move the trailer to a higher terrace if the river forecast predicted flows over 10,000 cfs. With stationary in-stream sonar equipment, river flows dictated a vigilant staff commitment.

Weather and Solar Power Generation/Supply

Throughout the initial part of the season there were no issues with being able to power the DIDSON with the existing solar power setup. As the days became shorter and overcast/rainy weather occurred more frequently, the solar panels occasionally were not able to fully charge the batteries to power all the equipment. After running the camera throughout the night, the batteries could drain to a point of shutting everything off, therefore stopping the sonar data recording. Additionally, the project experienced an issue with 'battery drift' or operating voltage dropping too low when discharging (December 14-15th and January 11th). The resultant down-time from this can be attributed to learning and operating the new battery type and not having a full understanding of their capabilities or limitations. In the event the batteries were unable to charge utilizing solar energy, staff manually charged the batteries using a portable generator that would provide battery recharging capabilities through a charging outlet and power invertor. As the frequency of storms decreased, days became longer, the higher sun angle increased solar energy generation, the portable generator was no longer required to keep the batteries sufficiently charged. No further power issues were experienced during the season.

An obstacle encountered at the office was the work and time intensive data processing. Having personnel acquire an adequate level of confidence with manually counting and measuring fish requires more training and hands on experience when technicians are new to sonar review. Many hours are required to obtain the confidence to work through data review due to the uncertainty of subjectivity. Although imagery processing was demanding, the project found methods to streamline their efforts. Additionally, it was helpful having guidance from a team member with experience from the pilot year of the project. The use of paperless datasheets helped with the efficiency of data management. Data was entered in a Microsoft Excel workbook while imagery was being reviewed, eliminating the time required for transferring from paper to the computer and minimizing typographical errors. The ability to review with a secondary monitor saved time from minimizing and expanding windows constantly during review. Project staff were more easily able to view fish passage and adjust to rewind or fast-forward sonar data when required.

DIDSON vs. ARIS

For the two-year pilot project, a DIDSON long-range camera was utilized to capture fish movement. With the correct positioning during recording and using proper software settings while processing data, the project was able to detect fish passage at crucial migration phases. While functionality of the camera was appropriate for detecting fish movement, the project and quality of data collected would be benefitted by using an Adaptive Resolution Imaging Sonar (ARIS) on the Eel River in future studies.

DIDSON have preset focal ranges that are not adjustable, confining the project to use either a 40 m preset or an 80 m preset. The river's channel width changed dramatically in response to rain events making the presets a burden and potentially compromising the quality of data. A streamflow of 3,600 cfs at the USGS Fort Seward gauging station produced a channel width of approximately 57 m at the sonar site. There was a significant amount of time during the 2019-2020 season that the stream width extended slightly beyond the 40 m range forcing the recording window to be set at 80 m. This truncated the processing image, not allowing for accurate fish length measurements and increasing the potential for human error while reviewing imagery. With ARIS, the operator can set the end range and capture imagery at a much higher resolution and clarity than with DIDSON (Jing et al. 2018). Utilizing the latest sonar technology would provide increased data quality and quantity, helping to accurately estimate salmonid escapement, distinguish between Chinook Salmon size classes (adults vs. jacks), decrease the rate of false identification (salmonids vs. other native/non-native fishes), and strengthen fisheries management potential in the Eel River basin.

COVID-19

Beginning in March 2020, the COVID-19 pandemic concerns were becoming more prominent locally. For the first two weeks of the month, the project's field operations were largely unaffected. Social distancing was required for the project beginning March 16, 2020 as the on-site operations could safely be maintained by a single staff member. Unfortunately, the project was required to cease all field activities and end the season on March 20, 2020 as social distancing rules became more stringent for the safety of all staff members. As a result, data collection did not extend for the entirety of the steelhead run, however, the increased operational time during 2019-2020 captured a substantially higher percentage than the previous year and still allowed for a robust data set.

Acknowledgements

Funding for this year was provided by the U.S. Fish and Wildlife's Sport Fish Restoration Program, Pacific Coastal Salmon Recovery Fund, and additional NOAA funding for the crew lead position. We are very grateful for our project partners: Pacific States Marine Fisheries Commission, who hired a Fishery Biologist to run field operations, data review and assist in the production of this report; NOAA Fisheries, Joshua Fuller, for Biologist position funding; Trout Unlimited, who assisted with equipment purchasing, set-up, and technical support; and Humboldt Redwood Company for un-limited access to the sonar site location and additional security measures. An enormous thanks to CDFW field staff for daily operations and data review: Tiffany May, Kathlyn Stauffer, and Eric LeBlanc; CDFW Fisheries Branch for loaning the sonar cameras; CDFW Mike Sparkman, Northern Region Sonar Coordinator and Matt Metheny, California Trout, for technical project expertise and review of this document; CDFW Allan Renger and Seth Ricker for project support; TU project members: Charlie Schneider, Anna Halligan, Erik Young, and Brian Johnson; The Wiyot Tribe, Eddy Koch for operation of the tribe's jet boat; and California Conservation Corps for lending their portable generator;

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Photo Appendix

Date and Description

1.) 11.21.2019. Camera in position with installed picket weir and rock wall.

2.) 11.21.2019. View looking upstream gravel bar from DIDSON trailer. Prior to rainfall (90 cfs USGS Ft. Seward gage).

3.) 11.27.2019. View looking upstream from DIDSON 'camera' during first rain of 2019-2020 season (146 cfs USGS Ft. Seward gage).

4.) 11.27.2019. Looking downstream towards DIDSON and cargo trailer.

5.) 12.01.2019. Panels with buildup that must be removed early during season. As flows increase, detritus gets flushed downstream and eventually stops collecting on panels.

6.) 12.05.2019. Wiyot Tribe jet boat being unloaded above the riffle at beginning of unit (451 cfs USGS Ft. Seward gage).

7.) 12.05.2019. Jet boat with 400-foot seine and fish tubes loaded.

8.) 12.05.2019. 400-foot seine net being cleaned of debris before another pass.

9.) 01.22.2020. Camera operating at near maximum depth and streamflow (7,630 cfs USGS Ft. Seward gage). Small temporary rock wall place behind closest panel.

10.) 01.22.2020. Flooded back water area pictured at left. Cargo trailer and truck pictured on right.

11.) 01.22.2020. View upstream of where DIDSON trailer is usually located. Site is under water during high flows (excess of 10,000 cfs).

12.) 01.27.2020. Riffle area is where project trailer would be located. Flows reached 32,000 cfs (maximum flow during project) on January 26, 2020.

13.) 01.28.2020. Six days after high flow event. Riffle area where trailer would be staged still not reachable (10,800 cfs USGS Ft. Seward gage).

14.) 01.29.2020. Camera setup near maximum operational capacity. Rock wall constructed is approximately where 9,000 cfs brings water level to.

15.) 02.07.2020. Mainstem Eel River at McCann Ferry with green waters (1,920 cfs USGS Ft. Seward gage).

16.) 02.07.2020. Drift boat setup for speciation efforts at McCann Ferry on mainstem Eel River.

17.) 02.07.2020. Female steelhead captured (59 cm) and PIT tagged before release.

18.) 02.07.2020. Female steelhead captured (68 cm), and PIT tagged before release shown resting in fish sleeve.

19.) 03.02.2020. Camera setup pictured showing clarity of low flow in March during steelhead run. Streamflow 392 cfs at Ft. Seward USGS gage.

20.) 03.20.2020. Water clarity where DIDSON is located on final day of field operations. Streamflow 977 cfs at Ft. Seward USGS gage.


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