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ARIS SONAR ESTIMATES OF ABUNDANCE AND MIGRATION PATTERNS OF CHINOOK SALMON, LATE SUMMER/FALL-RUN STEELHEAD TROUT, COHO SALMON, AND PINK SALMON IN THE MAD RIVER, HUMBOLDT COUNTY, CALIFORNIA

AUGUST 2017 – JANUARY 2018

Michael D. Sparkman
Steven C. Holt

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ABSTRACT

We used ARIS sonar and species apportionment methods to estimate the returns of anadromous salmonids to the Mad River during August 28, 2017 – January 2, 2018. The ARIS sonar did not experience any down time during the deployment period. We primarily used snorkel surveys to apportion species to fish passing through the sonar field and used angler creel surveys when stream turbidities increased. We conducted snorkel surveys nearly every other day and completed 188 dives over 32 dive days during sonar deployment. We observed 1,774 Chinook Salmon, 414 late summer/fall-run steelhead, 164 Coho Salmon, 184 Pink Salmon, 32 winter-run steelhead, 3 Chum Salmon, and 2 Striped Bass.

We estimate a total of 18,153 anadromous salmonids (TL > 41 cm) (95% CI = 17,691 – 19,335; CV = 2.2%) migrated upstream of the sonar site from August 28, 2017 – January 2, 2018. The abundance of small adults (TL = 42 – 54 cm) equaled 6,159 (95% CI = 5,801 – 6,517; CV = 2.9%), and for larger adults (TL > 54 cm) equaled 12,354 (95% CI = 11,768 – 12,940; CV = 2.4%). The total Chinook Salmon escapement equaled 12,667 (95% CI = 12,010 – 13,324; CV = 2.6%) and was considerably higher than abundances in the previous three years. October and November accounted for 87% of total abundance in 2017. The number of Chinook Salmon adults (TL > 54 cm) equaled 9,906 (95% CI = 9,390 – 10,423; CV = 2.6%), and for Chinook Salmon jacks (TL 42 – 54 cm) equaled 2,761 (95% CI = 2,551 – 2,966; CV = 3.7%). The abundance estimate for late summer/fall-run steelhead (TL > 41 cm) equaled 2,808 (95% CI = 2,684 – 2,932; CV = 2.2%) and was also the highest of record. Most of the late summer/fall-run steelhead were of natural origin (77%). The abundance estimate for Coho Salmon (TL > 41 cm) equaled 1,575 (95% CI = 1,482 – 1,668; CV = 3.0%) and represented the first time we could produce a reliable estimate due to few observations in past years. The abundance estimate for Pink Salmon equaled 750 (95% CI = 694 – 807; CV% = 3.8%), and very likely represented straying from areas north of California. We also estimate 712 winter-run steelhead (TL > 41 cm) returned from December 1, 2017 – January 2, 2018.

The ARIS sonar and species apportionment methods worked well to enumerate multiple runs of anadromous salmonid species to the Mad River, and with CV values that were acceptable for long-term monitoring.

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INTRODUCTION

Population monitoring of Pacific Salmon and steelhead (genus *Oncorhynchus*) is vital in California, where many Evolutionarily Significant Units (ESUs) and Distinct Population Segments (DPS) are listed under the Federal Endangered Species Act. Mad River supports annual runs of California Coastal (CC) Chinook Salmon *(Oncorhynchus tshawytscha*) ESU, Northern California (NC) steelhead (*O. mykiss*) DPS, Southern Oregon/Northern California Coasts (SONCC) Coho Salmon (*O. kisutch*) ESU, and Southern Oregon/California Coasts Coastal (SOCC) Cutthroat Trout (*O. clarkii clarkii*) ESU. With exception to Cutthroat Trout, (50 CFR Parts 223, 224, 226) all of these species are listed as 'threatened' under the Federal Endangered Species Act (NMFS 2014; NFMS 2016). The SONCC Coho Salmon ESU is also listed as 'threatened' under California's Endangered Species Act (CDFG 2004). CC Chinook Salmon, NC steelhead, and SONCC Coho Salmon in the Mad River are considered functionally independent populations, and Mad River is considered 'essential' for recovery of these species (NMFS 2014; NMFS 2016). Pink Salmon (*O. gorbuscha*) occasionally stray into the Mad River (CDFW, in house data), and in the fall of 2017 relatively large numbers were present.

Mad River also provides a popular, recreational sport fishery for NC steelhead, and Mad River Hatchery (MRH) produces hatchery winter-run steelhead for angler harvest (Sparkman, 2003; CDFW, 2016; NMFS, 2017). Although MRH propagated small numbers of Chinook Salmon and Coho Salmon in the past, this program was discontinued in 1999 and both species within the Mad River are currently considered wild.

The CC Chinook Salmon once supported economically important in-river commercial fisheries in the late 1800's and early 1900's (Van Kirk, 2004), in-river sport fisheries up to the initial Federal Listing (64 FR 50394), and contributes to the mixed stock Chinook Salmon ocean fisheries. A common theme across the CC Chinook Salmon ESU is the paucity of historic and current population level data (O'Farrell et al., 2012; Lacy et al., 2014; NMFS, 2016), which limits the ability to manage and conserve this ESU. The CC Chinook Salmon ESU is currently susceptible to the mixed stock Chinook Salmon ocean fishery along the California coast, and therefore spawner escapement data for the CC Chinook Salmon is of particular interest and concern (O'Farrell et al., 2012; Lacy et al., 2014; Satterthwaite et al., 2014; NMFS, 2016). In response to Federal and State listings of anadromous salmonids and the lack of reliable monitoring data, California Department of Fish and Wildlife (CDFW) and National Oceanic and Atmospheric Administration (NOAA Fisheries) developed and published the California Coastal Salmonid Monitoring Plan (CMP) (Adams et al., 2011). The primary goal was to standardize acceptable methods for enumerating adult salmon and steelhead returns to various streams and rivers for status and trend information (Adams et al., 2011).

Monitoring returning adult CC Chinook Salmon populations (spawner escapement) over years has been difficult because most streams are relatively large and wide (e.g. Redwood Cr, Mad R, Eel R, Mattole R, and Russian R), with limited access, flashy hydrology, and high turbidities. Thus, in many cases adult counting weirs and spawning ground surveys are either logistically impossible, or economically unfeasible to obtain quality spawner escapement data (Maxwell, 2007). The Mad River (Humboldt County) falls within these sampling limitations (CDFW, in house data), and population abundances of adult CC Chinook Salmon returns to the Mad River had not been determined (Sparkman et al., 2017). However, recent advances in hydroacoustic (sonar) technology (DIDSON, ARIS) have provided a much needed tool for enumerating adult salmonid returns to various streams and rivers (Holmes et al., 2006; Maxwell, 2007; Larson, 2015; Atkinson et al., 2016; Metheny et al., 2016; NMFS, 2016; Sparkman et al., 2017a,b), and with less difficulty and more accuracy compared to past sonar applications (Maxwell and Gove, 2004; Maxwell, 2007; Maxwell et al., 2011). A thorough examination of the history, methods, and use of sonars is provided by Maxwell (2007).

Prior to the National Marine Fisheries Service (NMFS) Coastal Multispecies Recovery Plan (2016), CDFW Anadromous Fisheries Resource Assessment and Monitoring Program (AFRAMP) considered Mad River to be an important contributor to the CC Chinook Salmon ESU, and initiated a sonar program (and species apportionment methods) to enumerate the returns of CC Chinook Salmon, NC steelhead, and SONCC Coho Salmon (if present in quantifiable numbers). Currently, this study fulfills many of the annual reporting requirements for Mad River Hatchery's Hatchery and Genetic Management Plan (HGMP) and Fishery Management and Evaluation Plan (FMEP). Additionally, the Chinook Salmon abundance data we produce is being used by CDFW and NMFS to assess status and trends of the CC Chinook Salmon ESU in context of environmental conditions and the mixed-stock ocean fishery off the California coast. Beginning in 2018, CDFW (and various partners) and CAL TROUT (partnering with CDFW) used sonar to enumerate CC Chinook Salmon returns to the Eel R (upstream of confluence with SF Eel R) (Kajtaniak and Easterbrook, 2019) and the SF Eel River (Metheny, 2019).

This paper presents sonar estimates of abundances for wild CC Chinook Salmon, natural and hatchery-origin late summer/fall-run NC steelhead, wild SONCC Coho Salmon, and Pink Salmon returns to the Mad River from August 28th, 2017 – January 2nd, 2018. We also provide comparisons to previous years' abundance estimates for Chinook Salmon and late summer/fall-run steelhead.

SITE DESCRIPTION

The Mad River, a regulated stream (Ruth Dam, Rm 77), drains a watershed area of 497 mi^2 within the Coast Range Geomorphic Province and empties into the Pacific Ocean north of

Humboldt Bay, Humboldt County, California (Fig.1). The geomorphic province consists of complex folding, faulting, tectonic uplift, volcanism, alluvial valleys, and a broad deltaic

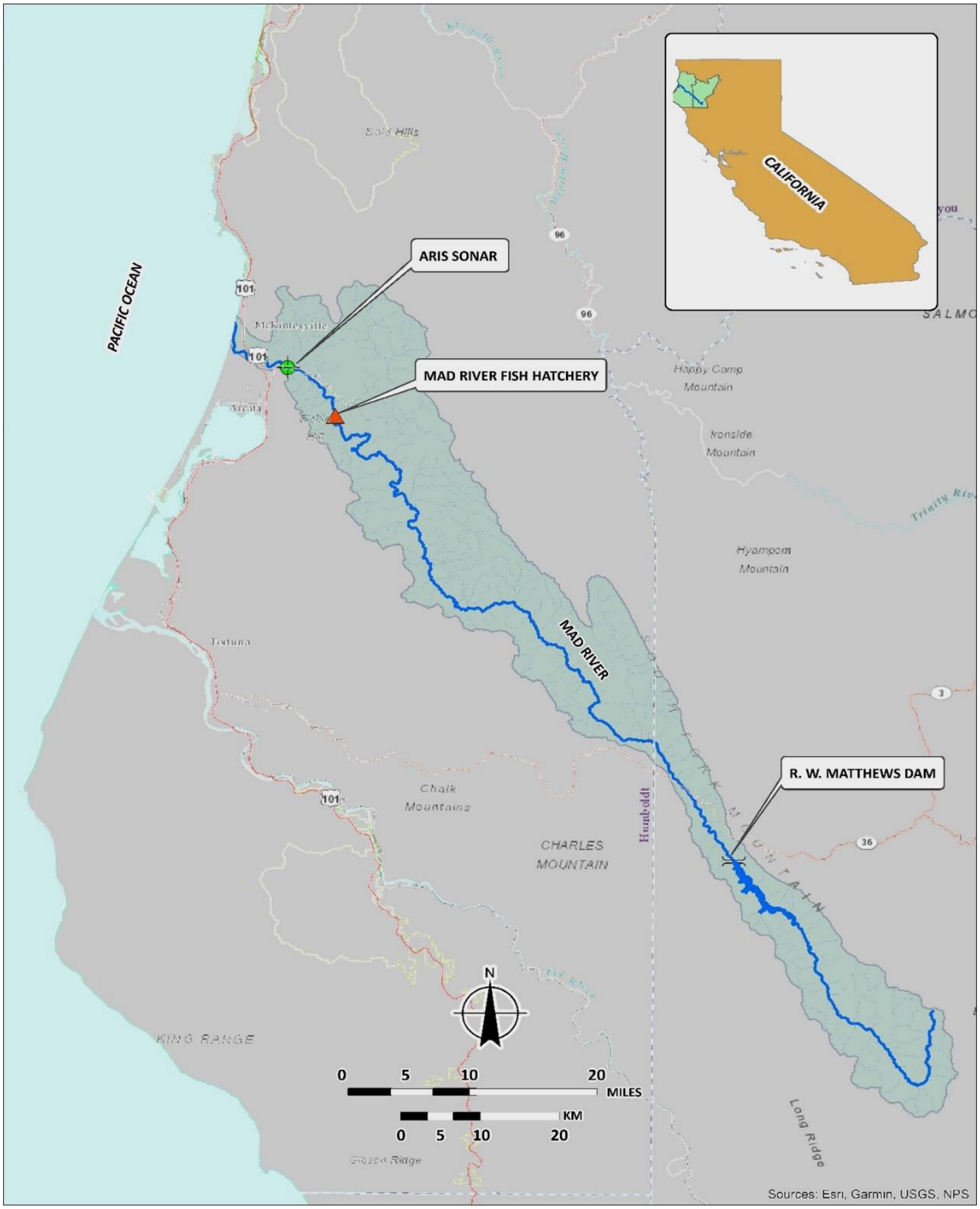

Figure 1. Mad River watershed with location of sonar site, Mad River Hatchery, and Robert Mathews Dam, Humboldt County, CA.

floodplain at the terminus of the river (USGS, 1973; Tolhurst, 1995). Sections of the lower river also have a series of levees to prevent flooding. Mad River basin, elongate in a northwesterly direction, is about 100 miles long, and averages six miles in width (Stillwater Sciences, 2010). The United States Geological Survey (USGS) and California Department of Water Resources (CDWR) operate a gaging station (ARC, #11481000) on the lower Mad River at US HWY 299 bridge (RM 6.5), near Arcata, California. Mad River was listed as sediment, turbidity and temperature impaired in 2002 under section 303(d) of the Clean Water Act (CWA, 2002; SWRCB, 2003; USEPA, 2003). In 2005, NMFS designated the Mad River as critical habitat for the CC Chinook Salmon ESU, NC steelhead DPS, and SONCC Coho Salmon ESU (50 CFR Part 226). Stillwater Sciences (2010) and NMFS (2016) provide a more detailed description of the Mad River basin, including land use, and past and current environmental conditions.

METHODS/MATERIALS

Sonar Site Selection

The sonar site was located in the lower Mad River (Rm 7.0) on Humboldt Bay Municipal Water District (HBMWD) property (Fig. 1). The ARIS sonar was placed in a glide habitat unit just upstream of a low gradient riffle. The site was chosen because HBMWD has at least one to two personnel on site 24 hrs/day, which ensured some level of security. Additionally, few anadromous species will spawn downstream of this location as evidenced by surveying downstream areas for redds. The sonar site also contained a stream bottom profile that was adequate for sonar use as described by Maxwell (2007). A processing station was constructed at the site to house the computer, hard drives, surge protectors, battery-backup surge protector, command module, and portable air conditioner.

Sonar Deployment, Settings (ARIScope Software), and Aim

We deployed a long-range ARIS 1200 (n = 48 beams, Adaptive Resolution Imaging Sonar, Sound Metrics, 11010 Northup Way, Bellevue, WA 98004) at Rm 7.0 in the Mad River on August 27th, 2017 (Fig. 1). The sonar operated continuously (24 hrs/d) from August 28th, 2017 – January 2nd with no periods of down time. The deployment period encompassed the entire CC Chinook Salmon, NC late-summer/fall-run Steelhead Trout, and Pink Salmon runs. Although there may have been some adult Coho Salmon entering after January 2, 2018, our species apportionment methods which extended into March 2018 did not detect any. Therefore, we feel confident the deployment period encompassed the vast majority if not the entire Coho Salmon run. This deployment period encompassed only part of the winter-run steelhead, which enter Mad River from December – March in a given year. However, we operated the sonar through March 31st, 2018 to encompass winter-run steelhead returns (separate report, in progress).

We used ARIScope software (Sound Metrics) with updated firmware to run the sonar. Within the software program, we selected 'auto' for frequency, 'max' for transmit, 'auto' for pulse, '' 'max' for frame rate, 'auto' for detail, and 'continuous' for timing mode. The corresponding frame rate usually equaled 4.2 fps, however the exact value depended upon the end range. Detail (or resolution) equaled 2.9 cm.

We aimed the ARIS sonar perpendicular to the current, and esonifed the entire channel width which ranged from 48 to 70 m wide depending upon stream flow. The average channel width during deployment was about 50 m, and most of the fish swam within 10 -30 m of the sonar when passing through the sonar beams. The tilt or pitch of the sonar was manually set between -0.4° to -3°, which allowed for complete esonification of the channel from stream bottom to stream surface at various stream flows and water depths. Common pitch values equaled -0.40°during low flow conditions (Aug – Oct), and -1.60° during higher flow conditions (Nov-Dec). We simply tilted the camera slightly up or down to achieve pitch values that gave the best sonar images. Although the stream bottom was continuously esonified as recommended by Maxwell (2007) and Faulkner and Maxwell (2009), we periodically floated sticks on the surface to ensure detections of any fish moving near stream surface areas. Weir panels were placed immediately downstream of the sonar and extended from the stream bank 1 - 2 m beyond the sonar to prevent fish from swimming behind the sonar camera or too close to the sonars' image start (0.7 m). The sonar was checked daily to ensure correct esonification, and manually adjusted as necessary. During storm events and periods of high fish passage, technicians returned to adjust the sonar camera depth and pitch if necessary. Our general rule of thumb was to move the sonar towards the bank during high flows and back to the original position during low flows. For safety concerns, the maximum stream depth (at the sonar stand) to move the sonar to shallower water was about 3 feet (waist deep). We often anticipated higher stream flow events and moved the camera to shallower water when the stream would begin to rise (ascending limb of hydrograph). Conversely, we moved the sonar to deeper water when the stream dropped (descending limb). The USGS and CDWR gaging station, located about 0.5 miles downstream of the sonar, provided real-time flow data which greatly assisted with operating the sonar and investigating relationships of fish passage and stream discharge.

Recording and Processing Sonar Files

Recording Files

The sonar continuously recorded files in 20-minute time increments throughout a given day to an external 4 tb hard drive. Each 20-minure file contained about 4,900 frames. Data was then copied onto a second hard drive and brought to the CDFW office in Arcata, CA for processing. Depending upon sonar software settings and end range, 24 hours of recording equaled about 31 gb of data.

V5 Population and Variance Estimator

We used a non-replicated systematic sample of the first 20 minutes of each hour to estimate adult passage through the sonar beams (Reynolds et al., 2007; Lilja et al., 2008; Xie and Martens, 2014). For each 20-minute file, net movement was defined as the sum of positive upstream movements and negative downstream movements (un-expanded) (Xie et al., 2002). Net movement was multiplied by a factor of three to derive hourly estimates of fish passage (expanded), and net movement of adults per day was simply the sum of hourly net movements. The un-expanded data was then used with the V5 variance estimator to assess error arising from using a 20-minute sample to represent hourly fish passage, and to determine population abundances with 95% confidence intervals (95% CI) and the coefficient of variation (CV) for total and monthly passage (Reynolds et al., 2007; Xie and Martens, 2014; Metheny et al., 2016; Sparkman et al., 2017a,b).

Reviewing Files (ARISFish Software Settings)

We used the ARISFish software program (Sound Metrics) to review files and manually count fish, and adjusted software settings to provide the greatest contrast (and resolution) between fish, debris, and stream bottom in relation to water quality (clear to turbid conditions). Within the image control of ARISFish software, we chose 'sharpen' for effects (to increase clarity), selected 'cross talk reduction' as a filter (to reduce image 'ghosting'), and manually adjusted the Signal Intensity Histogram by moving the sliding bar (below the histogram) to slightly cut off the right end tail of the histogram. These adjustments were important for clearly seeing and accurately measuring passing fish.

ARISFish allows the user to review files at 1 – 50 frames per second (fps), and the exact rate depended upon: fish passage, water clarity, and reviewer experience. During low passage (< 20 fish/hr), fps was set at 40 - 50, and during high passage (> 20 fish/hr), fps was set at 20 - 30 fps. During periods of greater turbidity, fps was set at lower values, and during periods of increased clarity, set at higher values depending upon fish passage rates. The exact fps setting ultimately depended upon the experience and comfortability of the reviewer(s) to observe and count every fish (TL > 41 cm) passing through the sonar beams. The time required to review 24 twenty-minute files depended upon: fish passage, fps, and experience of the reviewer(s). During periods of relatively low passage (e.g. 0 - 20 fish/hr), we could complete a day in about 4 hours. During periods of higher passage (> 40 fish/hr), we could complete a day in about 8 – 10 hours.

Counting and Measuring Fish

We used ARISFish software to manually count and measure all fish > 41 cm (TL) moving upstream or downstream through the sonar beams within the 20 minute sample file (Maxwell, 2007; Burwen et al., 2010; Gurney et al., 2014; Metheny et al., 2016; Sparkman et al., 2017a,b), and recorded this information onto data sheets in the CDFW office in Arcata, CA (Appendix 1). Fish had to be seen entering (downstream) and exiting (upstream) the sonar field to be counted. Fish that were observed in-between the downstream and upstream edge of the sonar field, when first starting the file, were not counted.

In general, we found the best way to measure a fish was to first observe it swimming through the sonar field, which ranged from 2 – 23 m wide. Then we would reverse the file using the 'left' arrow on the computer keyboard, and use 'right' and 'left' arrow to pick the frame that gave the most accurate size for that fish. We frequently used the zoom function to measure any fish that was below or near the lower threshold (42 cm TL), or near the cutoff from small adults (42 – 54 cm) and larger adults (> 54 cm TL). The common resolution value, as seen under sonar status in ARISFish software, equaled 2.9 cm.

We recorded fish counts and measurements of each fish to place in either of two size categories: 42-54 cm (TL) and > 55 cm (TL). We used a 54 cm (TL) cutoff to separate Chinook Salmon jacks (precocious males) from Chinook Salmon adults, based upon adult salmonid seining efforts in the Mad River during 2000 – 2002 (CDFW, in house data). For Coho Salmon, late summer/fall run steelhead, and Pink Salmon, we report abundance estimates > 41 cm (TL) which combined the (expanded) number per species in each size category.

Discriminating Small Adults (TL 42 - 54 cm) from Half-Pound Steelhead Trout and Suckers

The Mad River supports relatively large numbers of half-pound steelhead (*O. mykiss*) and suckers (*Catostomus* sp.) (CDFW in house data). Most of the half-pound steelhead are present from September – December, with fewer numbers present from January – March. The peak in half-pound steelhead numbers in the lower river usually occurs in October. We suspect the half-pound steelhead follow the Chinook Salmon run, and to a lesser degree the late summer/fall-run steelhead. Mad River also supports suckers, and they also pass through the sonar field in large numbers, often in tight schools. We used several methods to discriminate small adult salmonids (TL 42 – 54 cm) from half-pound steelhead and suckers when reviewing files:

1. **Size**:
   Half-pound steelhead are smaller in length (and body height) than small adult fish that we count. CDFW used seines in the Mad River and measured half-pounders that were captured. The range in TL (cm) was 33 -38 (Avg. TL = 36 cm) (CDFW in house data). The diver (snorkeling) also sees half-pounders mixed with adult steelhead and salmon, and they are noticeably smaller than what we consider small adult salmonids (TL 42 – 54 cm).

Suckers are also smaller in body length and body height than small adult fish we count. However, there may be a few, out of the 1000's present that could be near 42 cm TL. Based upon snorkeling and visual observations of large schools near the sonar site, most suckers are smaller than half-pound steelhead, and therefore not as large as the small adult salmonids we count.

Given time and experience, the reviewer(s) are able to visually distinguish countable fish vs those we don't count (half-pound steelhead, suckers). As mentioned before, if a small fish appeared to be countable, we would carefully measure it using the zoom function.

2. **Thickness of Image and 'Flicker' Effect**: Half-pound steelhead and suckers are not as thick as small adult salmonids, nor do they have the body height as small adults. When half-pounders and suckers swim through the sonar beams, they often appear 'stick like', and their image will flicker on and off because there is less area for the sonar beams to bounce back to the sonar after striking the fish. In contrast, the small adult salmonids will appear much thicker and not flicker on and off as they pass. They have enough body size that they illuminate as they pass through the beams, and their image appears brighter and thicker.

3. **Travel Speed through Sonar Field**: The width of the sonar field ranges from about 2 m (at 4 m from the sonar) to 23 m at an end range of 50 m, and most of the half-pound steelhead and suckers will travel up or downstream at 15 – 28 m (sonar field width of 13 m) from the sonar. Half-pound steelhead and suckers do not swim through the sonar field as fast as small adult salmonids, which is very noticeable when increasing the frame rate for reviewing video files. When reviewing files at higher frame rates (20 – 50 fps), the smaller and larger adult salmonids 'zip' through the field, whereas half-pound steelhead and suckers slowly go through the field. Frequently we will see half-pound steelhead, suckers, and countable adult salmonids swimming upstream or downstream at the same time.

4. **Swimming Motion**: Half-pound steelhead and suckers have a different swimming motion than small adults when passing through the sonar field. Small adults show a greater wave-like amplitude along the body when swimming than half-pound steelhead and suckers. As previously mentioned, half-pound steelhead and suckers appear more rigid and 'stick like' than small adults.

5. **Schooling Behavior**: Half-pound steelhead and suckers are usually in schools as they migrate upstream or downstream through the sonar field. Suckers are often in tighter schools than half-pound steelhead. Conversely, small and large adult salmonids rarely travel through the sonar field as a school. Usually they swim alone and only sometimes as a pair. Once in a while we will see schools of 6 – 8, and only on a few occasions have we seen them travel in a school that numbers 10 – 20. Beginning in January 2018, we are quantifying the amount of single vs pairing vs schooling migratory behavior at the sonar site. On a preliminary basis we speculate that 95^{+}% of the fish travel through the sonar field as a single fish, even though other fish might be traveling upstream at the same time.

Estimating Missed Hours of Sonar Deployment

Although we did not miss any hours or days during the time period of sonar deployment, there are several methods to account for fish that are missed when the sonar is intermittingly not in use (down time). The most common method, when missing hour(s) of a given day, is to interpolate or average a value for each hour missed based upon the same hour for previous and post days. When estimating missed hourly values on the descending or ascending limb of the hydrograph, it may prove more useful to interpolate across different hours of each limb (Glick and Faulkner, 2019). A caveat to our method of estimating missed hours when the stream is rising, is that we do not estimate fish numbers at relatively high peaks in stream flow if these hours are missed. We are finding that, in the Mad River, fish passage on the ascending and descending limb of the hydrograph can be high, whereas during certain peak(s) in streamflow numbers drop off dramatically. At some point, there will be velocity and turbidity thresholds that limit upstream passage. If the fish are to move on these relatively large flow events, they migrate along the edges of the river, and once again, in very low numbers. Thus, if we estimated missed fish passage at these peaks, we would over-estimate passage.

Species Apportionment

There were four species of fish migrating upstream (Chinook Salmon, steelhead, Coho Salmon, and Pink Salmon) during the sonar deployment period (August 28, 2017 – January 2, 2018). The ARIS sonar cannot discriminate between adult salmonid species therefore species apportionment methods must be used when more than one run of fish is present, which is common in many streams from California to Alaska. Alaska Department of Fish and Game uses sonar in several streams where multiple runs of anadromous salmonids will be present at any given time and place (Glick and Faulkner, 2019).

We used various methods for species apportionment near the sonar site, including: snorkeling, foot surveys, angler creel surveys, hook-and-line sampling, and professional judgement.

Snorkel Surveys

By far the most effective and common method we used was snorkeling, which occurred nearly every other day from August 28, 2017 – January 2, 2018. The last survey was conducted on January 2nd, 2018 when we conducted dives at eight locations. We conducted a total of 188 dives over 32 dive days during the sonar deployment period, which averaged to 6 different locations each dive day. The term 'dive' includes all passes made in a habitat unit. For example, if the snorkeler made seven passes in a pool, that would equal one dive for reporting purposes. After each pass, data was relayed to the field technician. One-two divers (usually one) surveyed various stream habitat types (pools, runs, glides) upstream and downstream of the sonar site. At most locations, the snorkeler would swim in a downstream manner to minimize disturbance and the fright response to fish present. At each location the number and size class of each species were recorded, and if steelhead were present, the diver would determine the number of fish with and without an adipose fin clip. If large numbers of various species were present in a given habitat unit, multiple passes were completed.

Angler Creel and Hook/Line Surveys

We interviewed anglers above and below the sonar location when we could not snorkel survey. During this study period, we primarily used angler creel data from November 19th, 2017 – January 2nd, 2018. Similar to snorkel data, we determined the percent composition of each species, and applied those percentages to the day of capture/interview, and post days of the interview(s). If the sample size of catches was less than 10, we pooled each day's data until we reached 10 fish. Then we back-filled the percentages to day(s). Once a 10 fish cumulative catch was reached, we started the process over until 10 more fish were captured. This method was adapted from ADFG's use of fish wheels for species apportionment when catches are less than 20 fish per day (Glick and Faulkner, 2019). The Mad River has far fewer fish than most Alaska rivers, therefore we used 10 instead of 20. The anglers captured each species of fish that was present (Chinook Salmon, Coho Salmon, Steelhead Trout), with exception to Pink Salmon since their run ended in October based upon numerous snorkel surveys. We also asked anglers whether any steelhead captured had an adipose fin clip and fin erosion (e.g. dorsal fin). If not certain, those fish were not used for discriminating naturally produced steelhead from hatchery produced steelhead.

Hook/line surveys were conducted by CDFW project staff to augment the angler creel surveys and more importantly, to collect biometric data from Chinook Salmon. Methods included taking tissue samples, measuring each fish for fork length and total length measurements (cm), and removing up to 10 scales from fresh fish. The tissue samples were collected to assist with genotyping the Mad River Chinook Salmon stock, and scales were taken to potentially determine the age class composition of the Chinook Salmon returns.

Applying Apportionment Data to Sonar Counts

Species apportionment data, expressed as a percentage for a given species for each sampling day, was applied to daily sonar counts each day per size class: small adults 42 -54 cm TL and larger adults 55^+ cm TL. If most of the fish were seen below the sonar site (common scenario) we applied those percentages to the day of survey, and to post sampling days when species apportionment was not determined. Usually this equated to two days after the apportionment data was taken on any given day. If most fish were seen upstream of the sonar, we would back-fill days in a similar manner. For time periods that extended beyond the 2 – 3 days from a survey, we interpolated proportions between apportionment sampling dates (Carroll and McIntosh, 2011; McEwen, 2013), or just simply extended the survey data beyond 2 – 3 days.

V5 and Species Abundance Estimates

The daily apportionment percentages were then applied to each hours' count (unexpanded) for a given day in order to generate abundance estimates per species using the V5 estimator. The V5 also determined the 95% Confidence Interval (95% CI) and corresponding coefficient of variation (CV %) (Reynolds et al., 2007). This method, of applying apportionment percentages to hours, did not change the abundance estimate for any given species compared to applying the percentages to the day (i.e. the two were the same). We will never know exactly which species (or combination of species) was passing the sonar in any given hour. However, we have seen large migrations of fish moving upstream over a shallow riffle below the sonar that consisted of multiple species and size classes. Additionally, the diver(s) frequently observe all species of fish (Chinook Salmon, Steelhead Trout, Coho Salmon, and Pink Salmon) using the same pools or glides at the same time (mixing). Therefore, we have no reason to believe that only one given species will pass through the sonar in any given hour. Minimal schooling behavior through the sonar field also supports this assertion.

Run-Timing (Temporal Migration Patterns)

We investigated monthly diel migration patterns (diurnal and nocturnal) by pooling total net passage (TL > 41 cm; un-speciated) for each hour stratum (expressed as a percentage of a given month's total count) to see if hourly migration patterns varied by month. *A priori*, we hypothesized that upstream migration during months of low flow/clear water periods (e.g. September and October) would be biased towards time of low light, and in higher flow periods (e.g. November and December) migration across hours would be more equal. Monthly counts for a given species and run type across time were used for describing the general temporal trend in migration. Daily counts were used to specifically define run timing in relation to average stream discharge measured at the USGS and CDWR gaging station (#11481000).

RESULTS

Sonar Deployment and Missing Data

We did not experience any sonar down time during the deployment period of August 28, 2017 – January 2, 2018. The sonar operated a total of 3,072 hrs during this time period.

Total Abundance Estimate (all species combined)

We estimate a total of 18,153 anadromous salmonids (TL > 41 cm) (95% CI = 17,691 – 19,335; CV = 2.2%) migrated upstream of the sonar site from August 28, 2017 – January 2, 2018. The number of small adults (TL 42 – 54 cm) equaled 6,159 (95% CI = 5,801 – 6,517; CV = 2.9%), and for larger adults (TL > 54 cm) equaled 12,354 (95% CI = 11,768 – 12,940; CV = 2.4%).

Monthly Abundance Estimates (all species combined)

The months of October (N = 7,221) and November (N = 7,581) accounted for 80% of total abundance (N = 18,153) (Fig. 2).

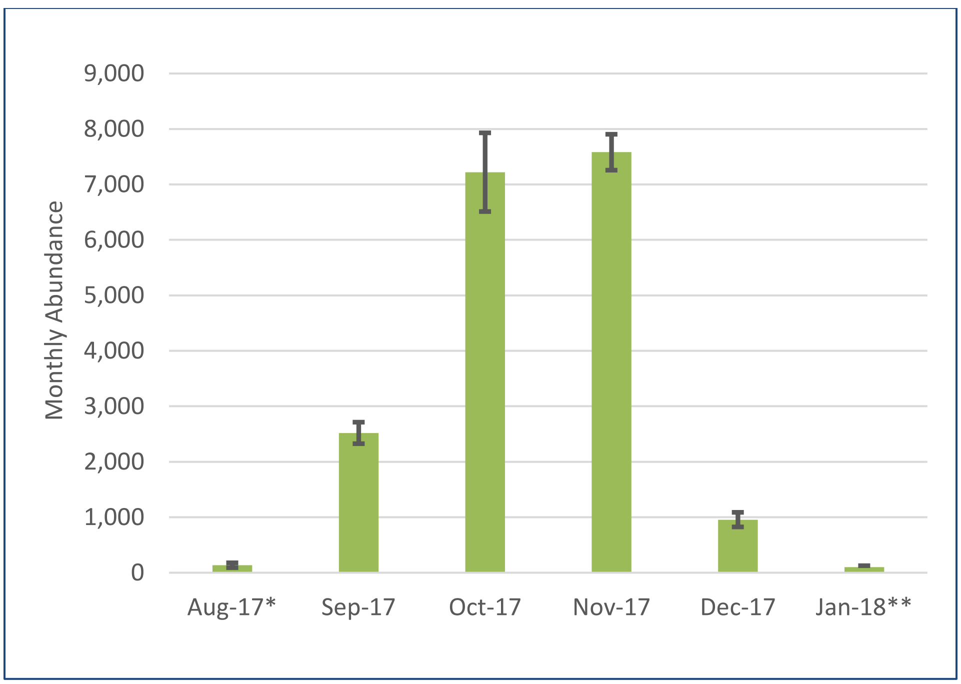

Figure 2. Monthly abundance estimates (for all species and size categories combined) from August 28, 2017 – January 2 2018, Mad River, Humboldt County, CA. Error bars represent 95% Confidence Intervals. * Denotes estimate for August 28 – 31, 2017. ** Denotes estimate for January 1 – 2, 2018.

Monthly abundances for larger adults (TL > 54 cm) ranged from 54 – 6,021 and for smaller adults (TL 42 – 54) ranged from 42 – 2,670 (Table 1).

Table 1. Monthly abundance estimates for all species combined per two size categories, 95% confidence intervals (95% CI), and coefficient of variation (CV), Mad River, Humboldt County, CA., August 28, 2017 – January 2, 2018.

	TL > 54 cm				TL 42 – 54 cm		
	N	95% CI	CV (%)		N	95% CI	CV (%)
August*	54	34 – 74	18.6		81	48 – 114	20.4
September	1,023	891 – 1,115	6.5		1,497	1,360 – 1,634	4.6
October	4,551	4,077 – 5,025	5.2		2,670	2,384 – 2,956	5.4
November	6,021	5,724 – 6,318	2.5		1,560	1,428 – 1,692	4.2
December	648	552 - 744	7.4		309	236 - 382	11.8
January**	57	36 - 78	18.1		42	23 - 61	22.4
Total:	12,354	11,768 – 12,940	2.4		6,159	5,801 – 6,517	2.9
Grand Total:	18,513	17,691 – 19,335	2.2				

*Encompasses August 28-31. **Encompasses January 1-2.

Daily Abundances (all species and size classes combined)

Daily passage rates for all species and sizes combined ranged from -3 to 1,707 and averaged 145 fish/day (SEM = 18). The peak in abundance (N = 1,707) occurred on 10/20/17, when average daily streamflow increased from 89 to 140 cfs (Fig. 3). A total of 11,517 fish (or 62% of total) migrated past the sonar site during the low flow fishing closure (September 1 – November 8).

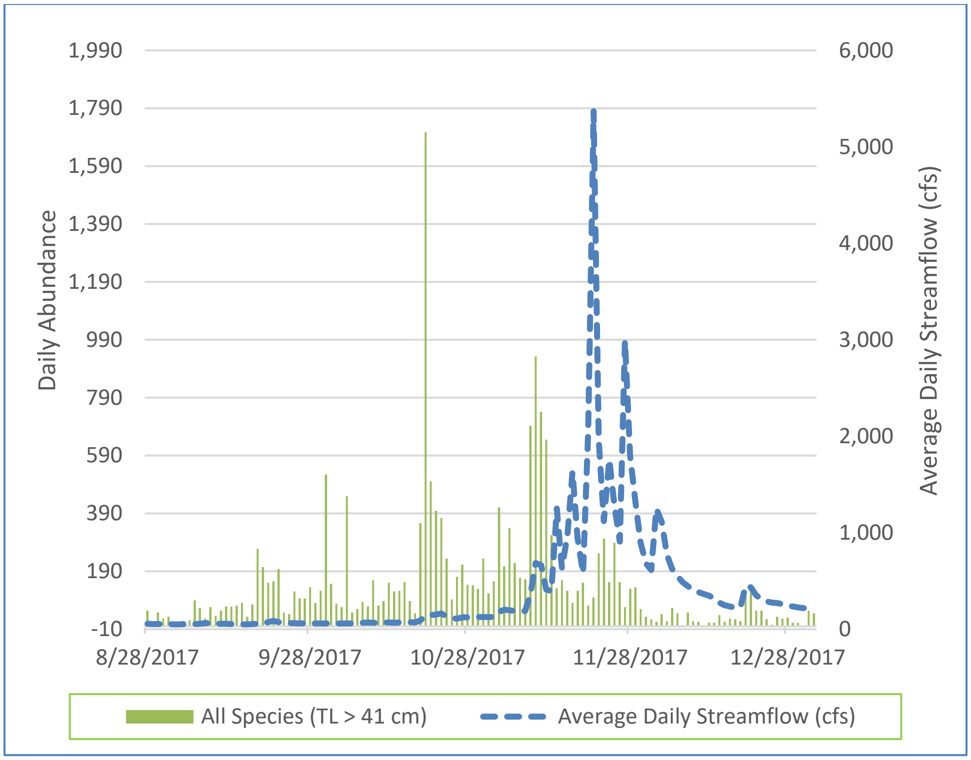

Figure 3. Daily passage estimates of all anadromous species combined (TL > 41 cm) in relation to average daily streamflow (cfs) (USGS ARC Station, #11481000) during the deployment period August 28, 2017 – January 2, 2018, Mad River, Humboldt County, CA.

A total of 16,746 anadromous salmonids (or 90% of total) migrated upstream at average daily streamflows less than 1,000 cfs (Fig. 4). Fish passage at streamflows greater than 2,900 cfs accounted for 0.89% of the total, and passage at 5,370 cfs accounted for 0.53% of the total.

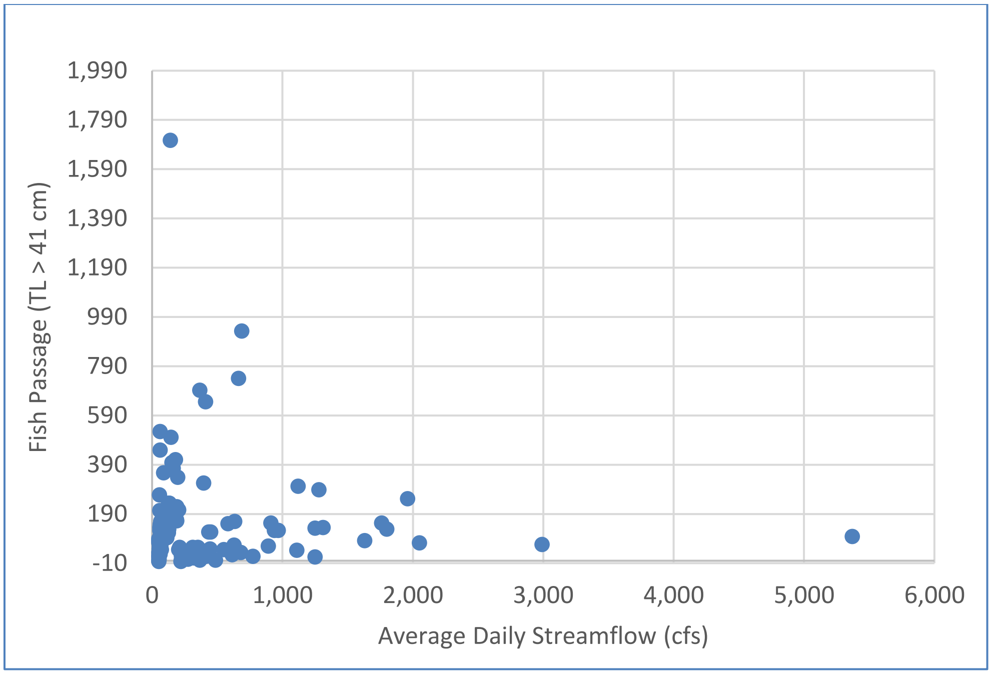

Figure 4. Relationship of daily fish (TL > 41 cm) passage estimates and average daily streamflow (cfs) (n = 128 data points) during the sonar deployment period, Mad River, Humboldt County, CA.

Diurnal and Nocturnal Passage (all species and size classes combined)

The net upstream migration of anadromous salmonids (TL > 41 cm) during periods of low flows and clear (stream) visibility primarily occurred during periods of darkness and low light levels for the September and October runs (Figure 5). Migration from 0000 – 0800 and 2000 – 2400 accounted for 89% of the total run in September (N = 2,520), and 82% of the total run in October (N = 7,221) (Figure 5). In contrast, migration during these same hourly time periods accounted for 56% of the total run in November (N = 7,581), and 61% of the total run in December (N = 957) (Figure 6). Streamflows in November and December were much greater than streamflows in September and October.

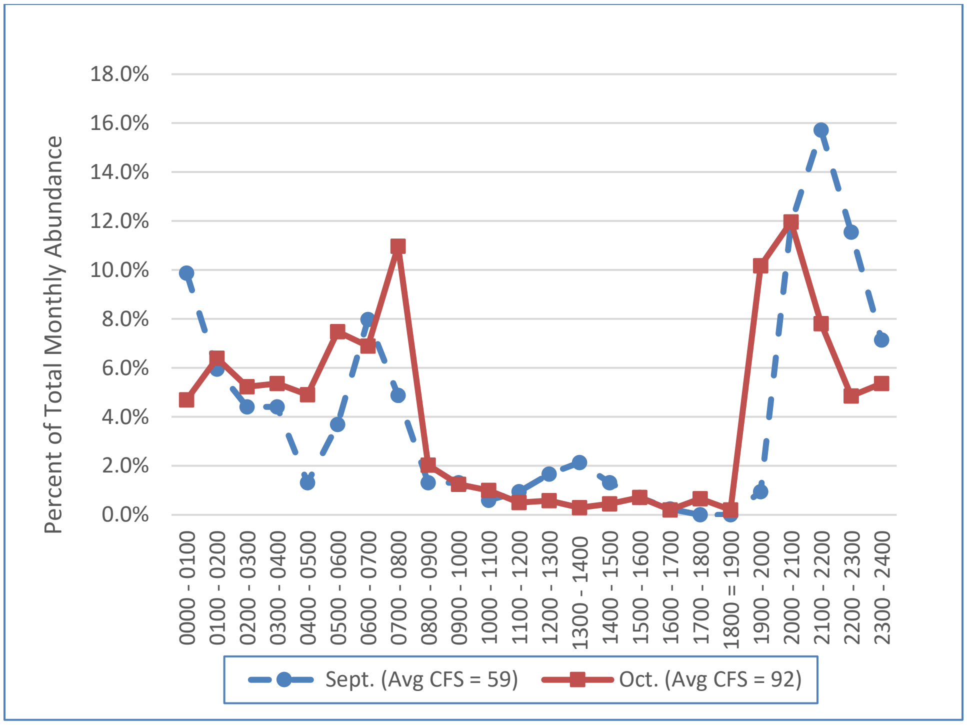

Figure 5. Diel migration patterns for all species and size classes combined in September (N = 2,520) and October (N = 7,221), 2017, Mad River, Humboldt County, CA.

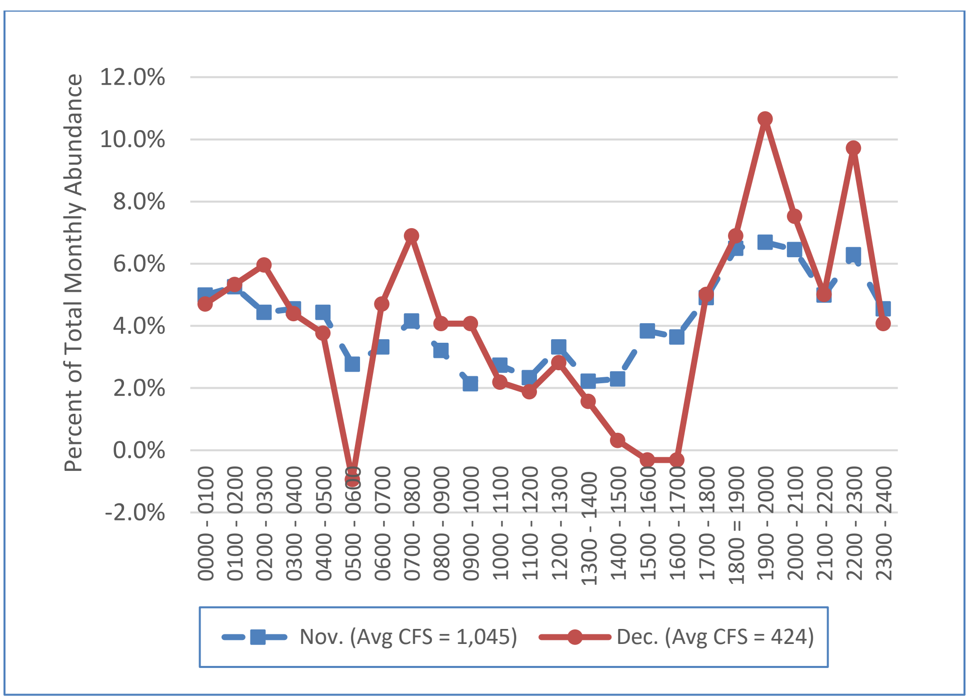

Figure 6. Diel migration patterns for all species and size classes combined in November (N = 7,581) and December (N = 957), 2017, Mad River, Humboldt County, CA.

Species Apportionment Data (Snorkeling)

We observed a total of 2,568 anadromous salmonids (TL > 41 cm) during the deployment period, which consisted of 188 dives (Table 2). We observed more larger adults (TL > 54 cm, n = 1,407) than smaller adults (TL 42 – 54 cm, n = 1,161). Chinook Salmon were the most numerous fish observed in each size category (Table 2). We also observed three adult Chum Salmon *(Oncorhynchus keta*) and two Striped Bass (*Morone saxatilis*), however we did not attempt to produce abundance estimates due to low observations.

Table 2. Snorkel survey dive results (n = 188 dives) from August 28, 2017 - January 2, 2018, Mad River, Humboldt County, CA.

	Larger Adults (TL > 54 cm)			Smaller Adults (TL 42 – 54 cm)	
Species	No. Observed	% of Total		No. Observed	% of Total
Chinook Salmon	1,085	77.1		689	59.2
Steelhead Trout*	130	9.2		284	24.5
Coho Salmon	68	4.8		96	8.3
Pink Salmon	95	6.8		89	7.7
Winter-Run Steelhead	29	2.1		3	0.3
Total:	1,407			1,161	
Grand Total:	2,568				

* Denotes late summer/fall-run.

Species Run Timing

The run timing of anadromous species during sonar deployment varied by species (and run-type) (Table 3). Pink salmon exhibited the shortest run timing (49 d) and Chinook Salmon exhibited the longest run timing (124 d).

Table 3. Run timing of various anadromous species from August 28, 2017 - January 2, 2018, Mad River, Humboldt County, CA.

Run Type/Species	Period of Run Timing in 2017/18	Number of Days	Percentage of Time Sonar in Use
Late Summer/Fall-Run steelhead	August 28, 2017 – November 30, 2017	95	100
Chinook Salmon*	August 28, 2017 – December 29, 2017	124	100
Pink Salmon	September 13, 2017 – October 31, 2017	49	100
Coho Salmon	September 26, 2017 - January 2, 2018	99	100
Winter-Run steelhead**	December 1, 2016 – January 2, 2017	33	100

*Late summer/fall/early winter run types. ** Report covers December 2017 and January 1-2, 2018, actual run timing ends March 31, 2018, a total of 121 days.

CC Chinook Salmon Abundance Estimate

The estimated abundance of Chinook Salmon (TL > 41 cm) returns from August 28, 2017 to December 29, 2017 equaled 12,667 (95% CI = 12,010 – 13,324; CV = 2.6%). The number of Chinook Salmon adults (TL > 54 cm) equaled 9,906 (95 % CI = 9,390 – 10,423; CV = 2.6%), and for Chinook Salmon jacks (TL 42 – 54 cm) equaled 2,761 (95% CI = 2,551 – 2,966; CV = 3.7%).

Monthly Abundances

Monthly abundances of Chinook Salmon (TL > 41 cm) ranged from 32 – 5,546 (Fig. 7). October and November (N = 10,965) accounted for 87% of the total run (N = 12,667).

Chinook Salmon adult (TL > 54 cm) abundances peaked in October and November, compared to September and October for Chinook Salmon jacks (TL 42 – 54 cm) (Fig. 8).

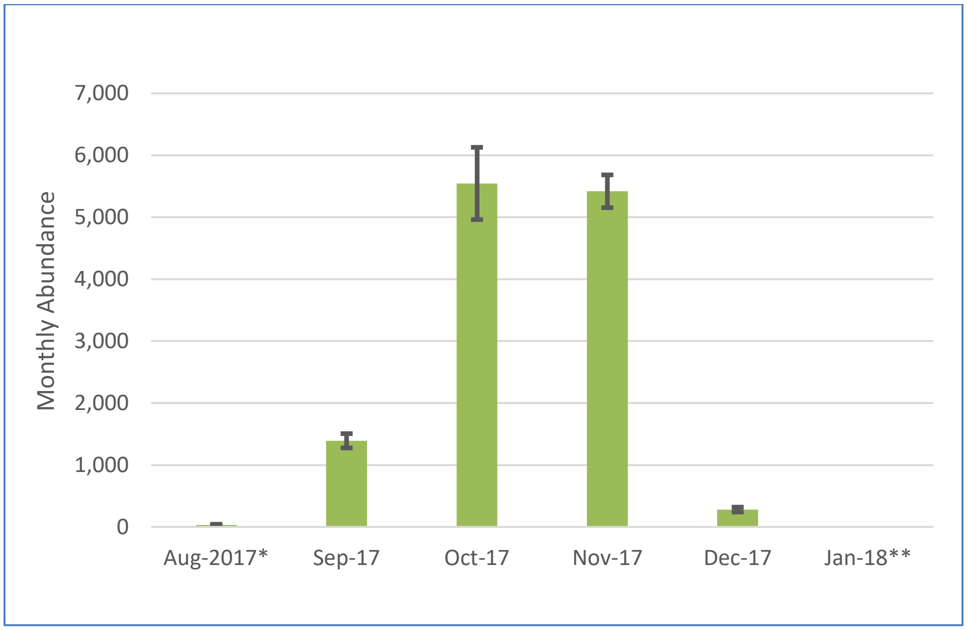

Figure 7. Chinook Salmon (TL > 41 cm) monthly passage in 2017, Mad River, Humboldt County, CA. Error bars represent 95% Confidence Intervals. * Denotes estimate for August 28 - 31. ** Denotes estimate for January 1 - 2, 2018 (N = 0).

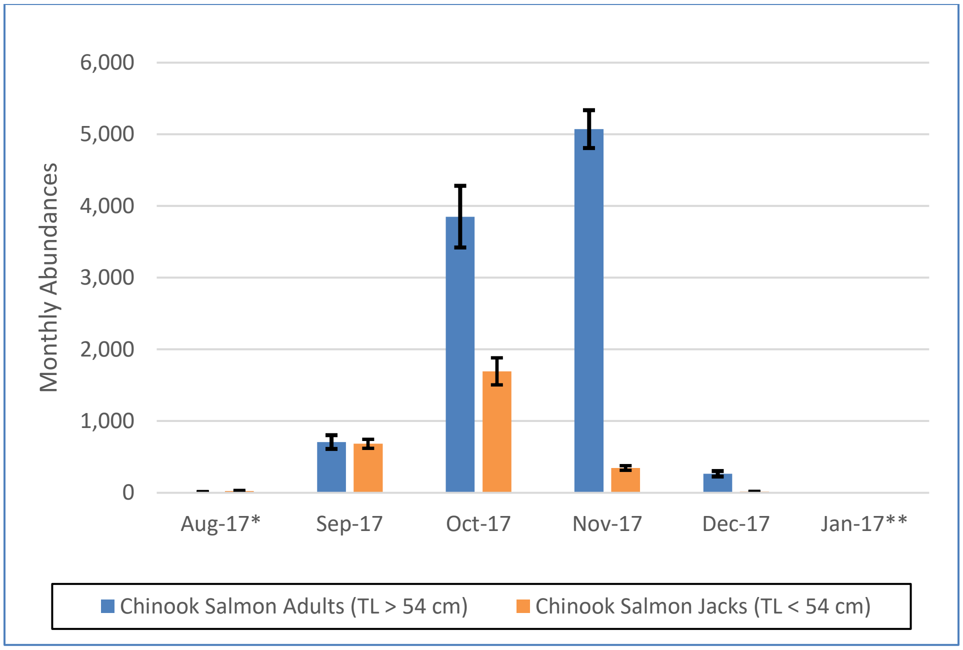

Figure 8. Chinook Salmon adults (TL > 54 cm) and Chinook Salmon jacks (TL 42 - 54 cm) monthly passage in 2017, Mad River, Humboldt County, CA. Error bars represent 95% Confidence Intervals. * Denotes estimate for August 28-31. ** Denotes estimate for January 1 – 2, 2018 (N = 0).

Daily Abundances

Daily passage rates in 2017 ranged from -9 to 1,507 and averaged 102 fish/d (SE = 16.4) (Fig 9). Peaks in daily migration occurred in October and November. The peaks on 10/01/17 (N = 408) and 10/05/17 (N = 334) occurred during a stable hydrograph. The largest peak occurred on 10/20/17 (N = 1,507), when average daily streamflow increased from 89 cfs to 140 cfs. The second largest peak occurred on 11/10/17 (N = 794), when average daily streamflow increased from 367 cfs to 688 cfs.

A total of 7,182 Chinook Salmon (or 62% of total) migrated upstream past the sonar site during the low flow fishing closure (cfs < 200; 9/1/17 – 11/8/17).

Comparison of Total Abundances in YRS 2014 – 2017

Chinook Salmon (TL > 41 cm) population abundances in 2014 – 2017 ranged from 5,645 – 12,667 and averaged 8,247 (SEM = 1,527) (Fig. 10). The highest abundance occurred in 2017 (N = 12,667).

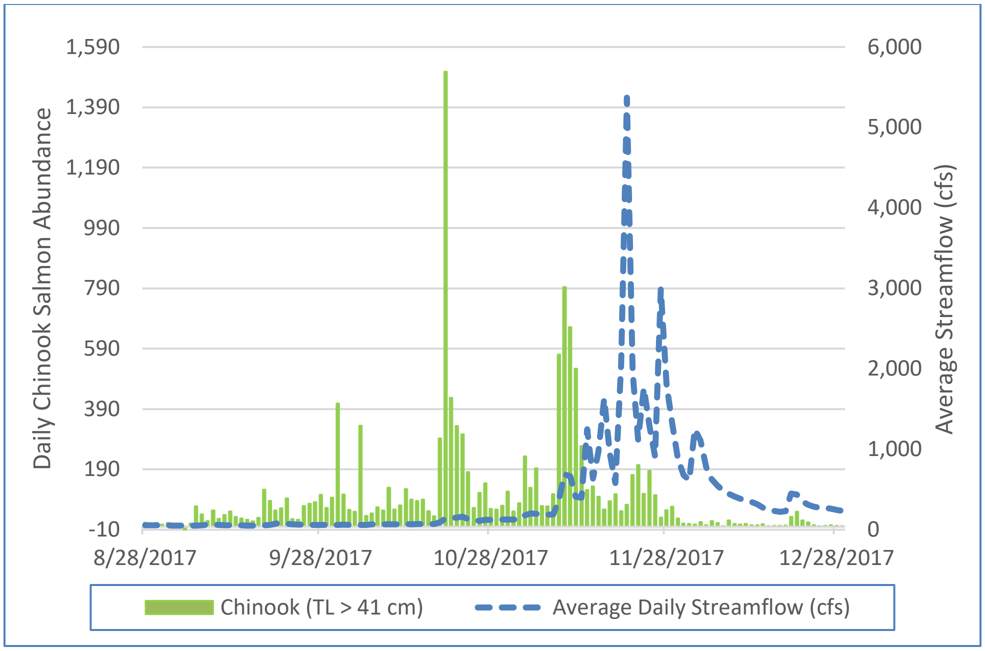

Figure 9 . Daily passage estimates for Chinook Salmon (TL > 41) returns in relation to average daily streamflow (cfs) (USGS/CDWR Arcata Gaging Station, #11481000) in 2017, Mad River, Humboldt County, CA.

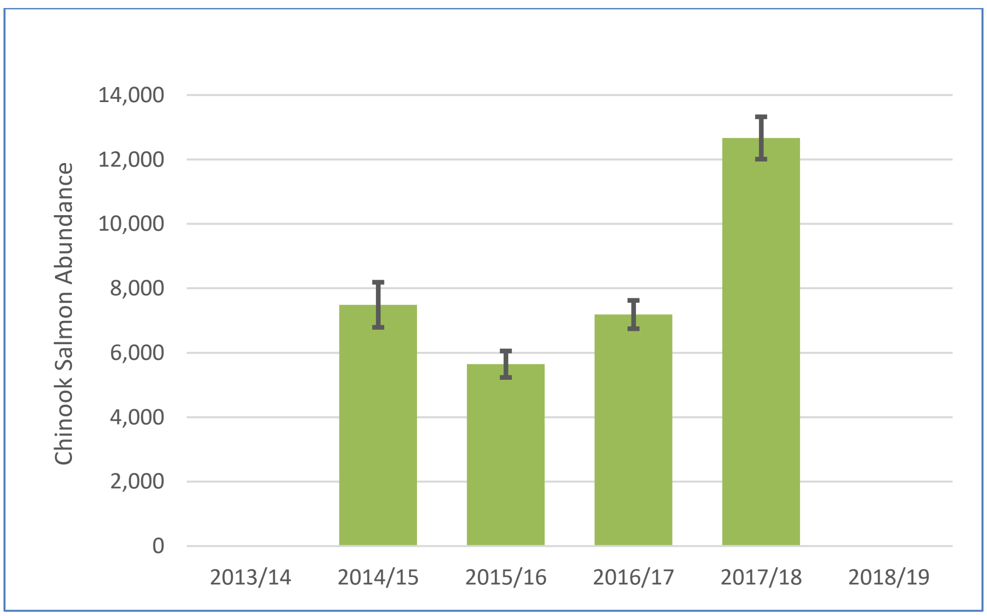

Figure 10. Chinook Salmon (TL > 41 cm) abundance estimates in 2014 – 2017, Mad River, Humboldt County, CA. Error bars represent 95% Confidence Intervals.

NC Late Summer/Fall-Run Steelhead Trout Abundance Estimate

The estimated abundance of steelhead (TL > 41 cm) returns from August 28, 2017 – November 30, 2017 equaled 2,808 (95% CI = 2,684 – 2,932; CV = 2.2%), and was the highest of record.

Monthly Abundances

Monthly abundances ranged from 103 - 1,063 and peaked in November (Figure 11).

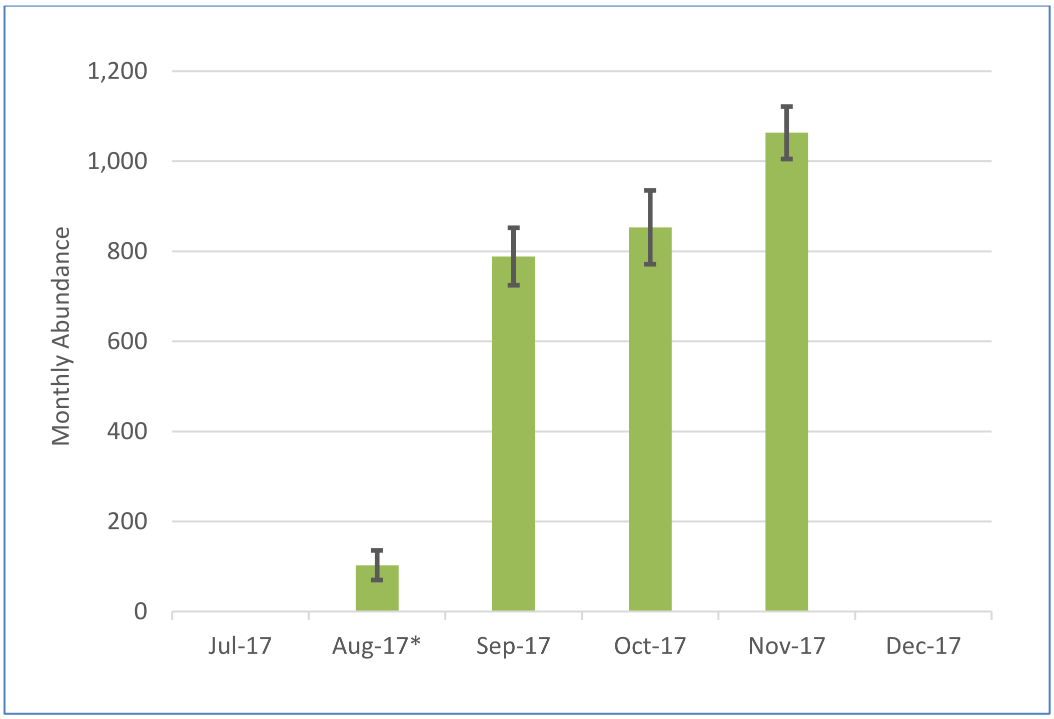

Figure 11. Late summer/fall-run steelhead (TL > 41 cm) monthly passage in 2017, Mad River, Humboldt County, CA. Error bars represent 95% Confidence Intervals. * Denotes estimate for August 28-31.

Daily Abundances

Late summer/fall-run steelhead passage rates ranged from 3 – 125 per day, and averaged 30 fish/day (SEM = 2.3). The peak in abundance (N = 125) occurred during a slight rise in the hydrograph on 10/20/17 (Fig. 12). A total of 1,851 steelhead (or 66% of total) migrated upstream past the sonar site during the low flow fishing closure (9/1/17 – 11/8/17).

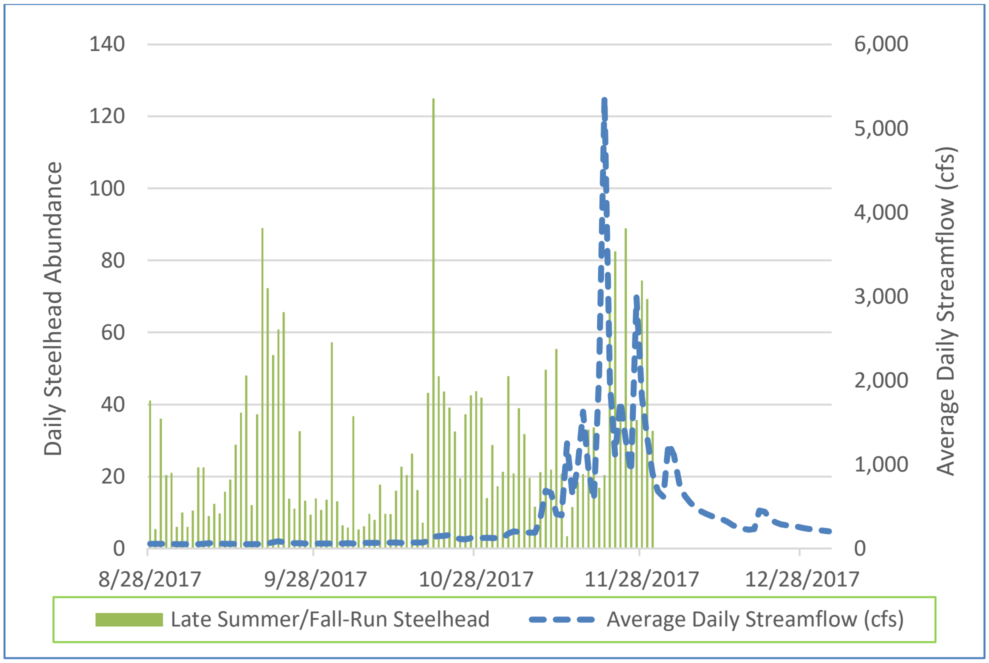

Figure 12. Daily passage estimates for late summer/fall-run steelhead (TL > 41) returns in relation to average daily stream flow (cfs) (USGS/CDWR Arcata Gaging Station, #11481000) in 2017, Mad River, Humboldt County, CA.

Comparison of Total Abundances in YRS 2014 – 2017

Population abundances in 2014 – 2017 ranged from 425 – 2,808 and averaged 1,221 (SEM = 539) (Fig. 13). The highest abundance occurred in 2017 (N = 2,808).

Natural-Origin and Hatchery-Origin Composition (YRS 2014 – 2017)

The late summer/fall-run steelhead in the Mad River are mostly natural-origin. The abundance of natural-origin steelhead ranged from 300 – 2,152 and averaged 941 (SEM = 413), and for hatchery-origin steelhead ranged from 125 – 656 and averaged 280 (SEM = 127) (Fig. 14). The peak in natural-origin and hatchery-origin steelhead abundances occurred in 2017 (Fig. 14). Natural-origin steelhead comprised 71 – 82% of annual abundances.

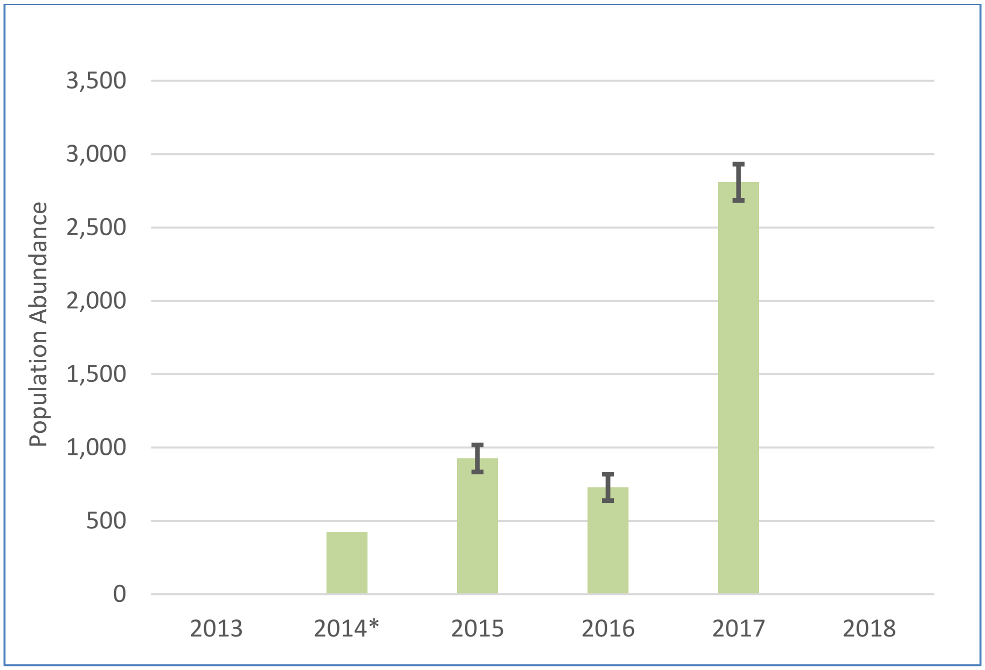

Figure 13. Late summer/fall-run steelhead abundance estimates in 2014 – 2017, Mad River, Humboldt County, CA. Error bars represent 95% Confidence Intervals. * Denotes 95% CI not determined.

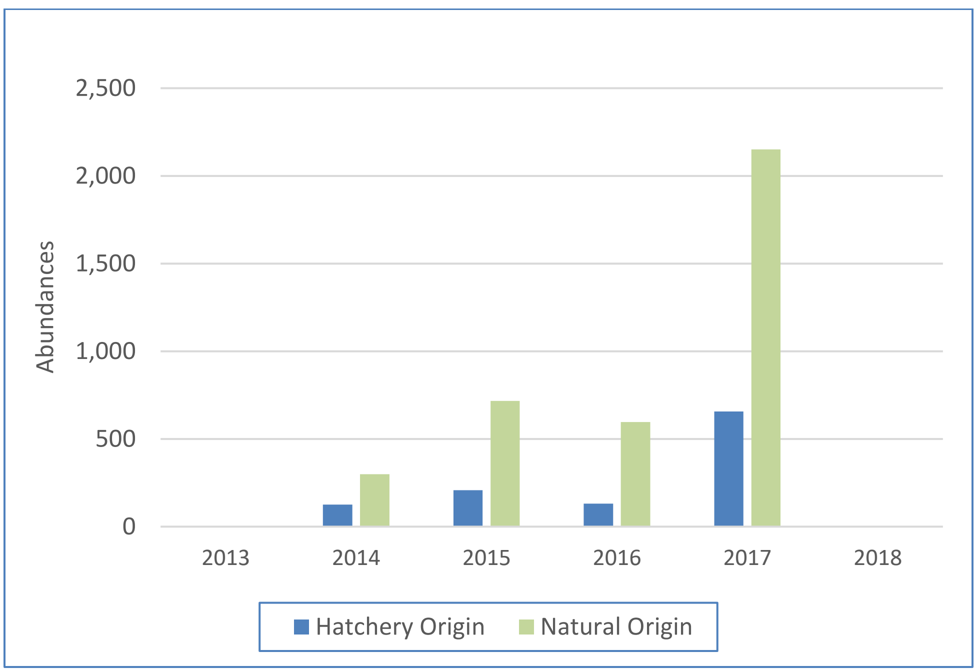

Figure 14. Annual abundances of natural and hatchery-origin late summer/fall-run steelhead in 2014 – 2017, Mad River, Humboldt County, CA.

SONCC Coho Salmon Abundance Estimate

The estimated abundance of Coho Salmon (TL > 41 cm) returns from September 26, 2017 – January 2, 2018 equaled 1,575 (95% CI = 1,482 – 1,668; CV = 3.0%).

Monthly Abundances

Monthly abundances ranged from 2 - 1,099 and peaked in November (Fig 15). The run in November accounted for 70% of total abundance (Fig. 15).

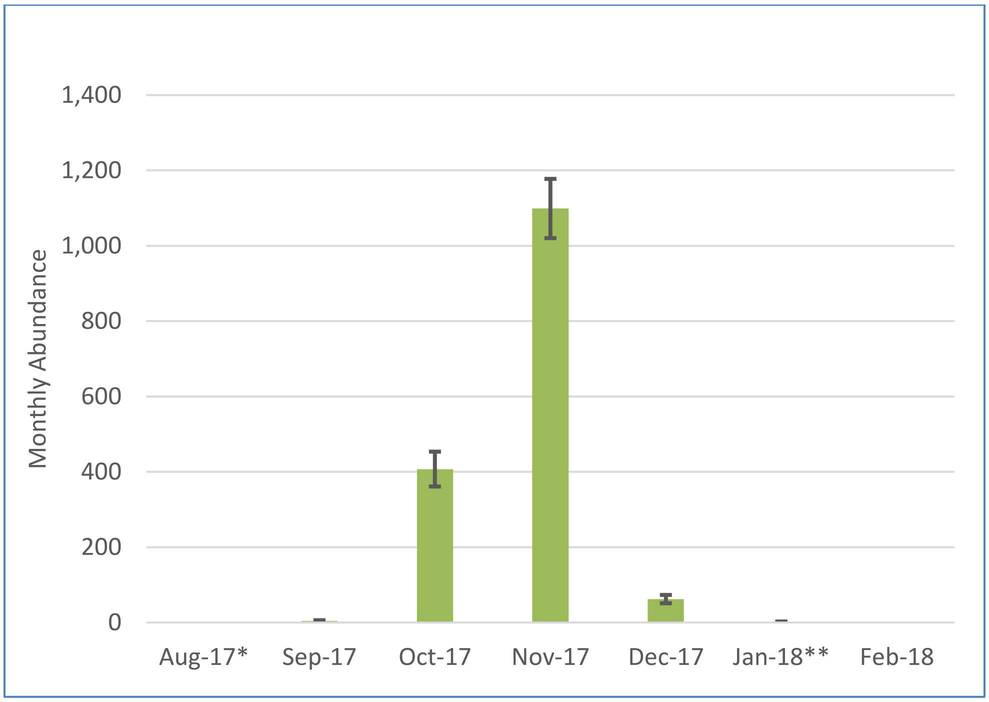

Figure 15. Coho Salmon (TL > 41 cm) monthly passage in 2017, Mad River, Humboldt County, CA. Error bars represent 95% Confidence Intervals. * Denotes estimate for August 28-31. ** Denotes estimate for January 1 – 2, 2018.

Daily Abundances

Coho Salmon passage rates ranged from 0 – 130 per day, and averaged 16 fish/day (SEM = 2.9). The peak in abundance (N = 130) on 11/03/17 occurred during a slight rise in the hydrograph when average daily streamflow rose from 127 cfs to 178 cfs (Fig. 16). A total of 1,054 Coho Salmon (or 67% of total) migrated upstream past the sonar site during the low flow fishing closure (9/1/17 – 11/8/17).

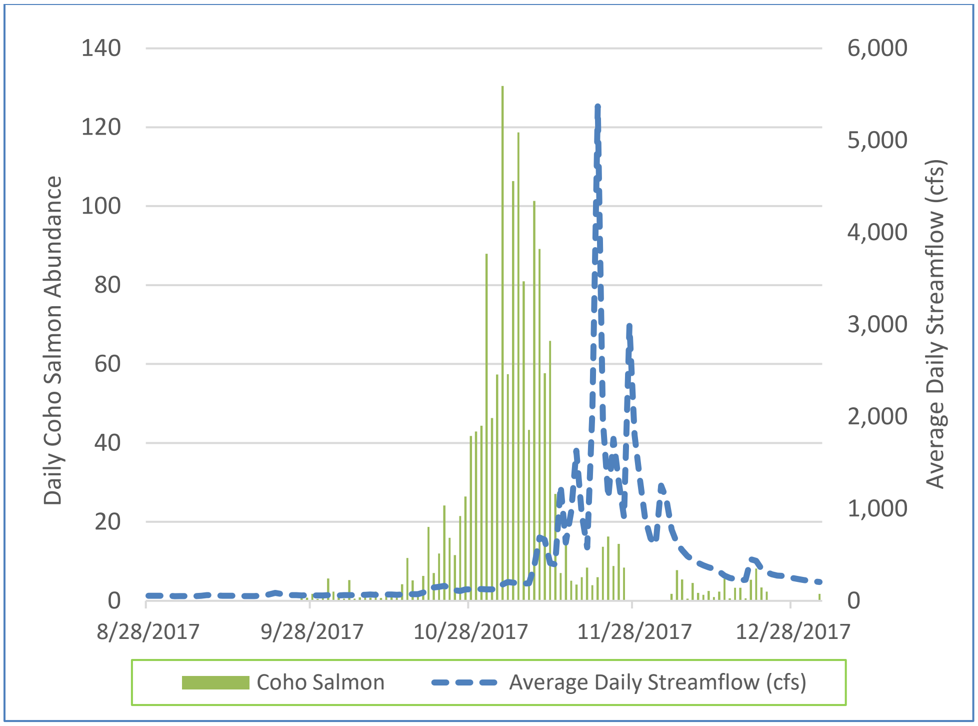

Figure 16. Daily passage estimates for Coho Salmon (TL > 41) returns in relation to average daily stream flow (cfs) (USGS/CDWR Arcata Gaging Station, #11481000) in 2017, Mad River, Humboldt County, CA.

Pink Salmon Abundance Estimate

The estimated abundance of Pink Salmon (TL > 41 cm) returns from September 13, 2017 – October 31, 2017 equaled 750 (95% CI = 694 – 807; CV = 3.8%).

Monthly Abundances

Pink Salmon returned in September and October 2017, with October accounting for slightly more returns than September (Figure 17).

Daily Abundances

Pink Salmon passage rates ranged from 0 – 74 per day, and averaged 15 fish/day (SEM = 2.5). The peak in abundance (N = 75) occurred on 10/05/17 during a stable hydrograph (Fig. 18). All of the Pink Salmon (N = 750) migrated upstream past the sonar site during the low flow fishing closure (9/1/17 – 11/8/17).

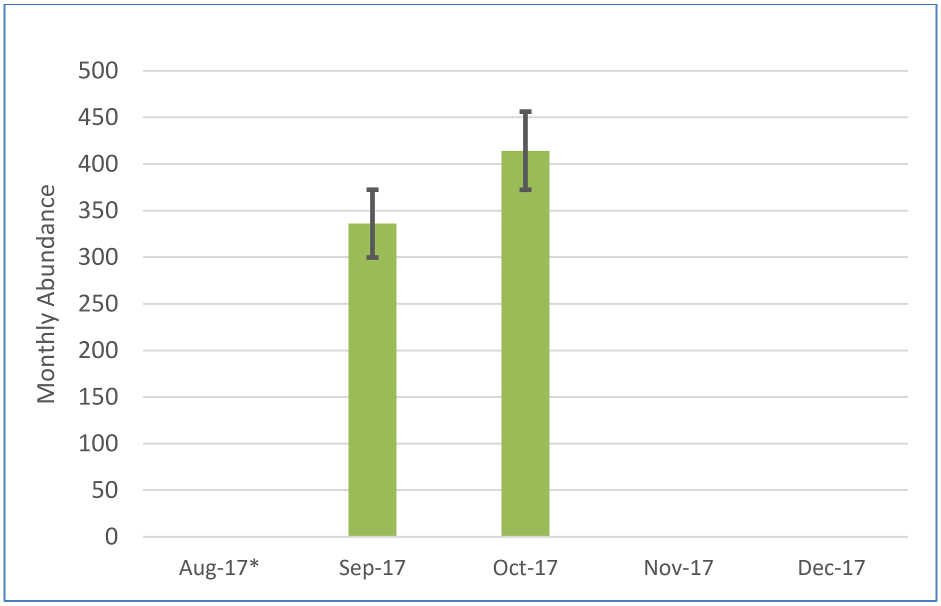

Figure 17. Pink Salmon (TL > 41 cm) monthly passage in the Mad River, Humboldt County, CA. Error bars represent 95% Confidence Intervals. * Denotes estimate for August 28-31.

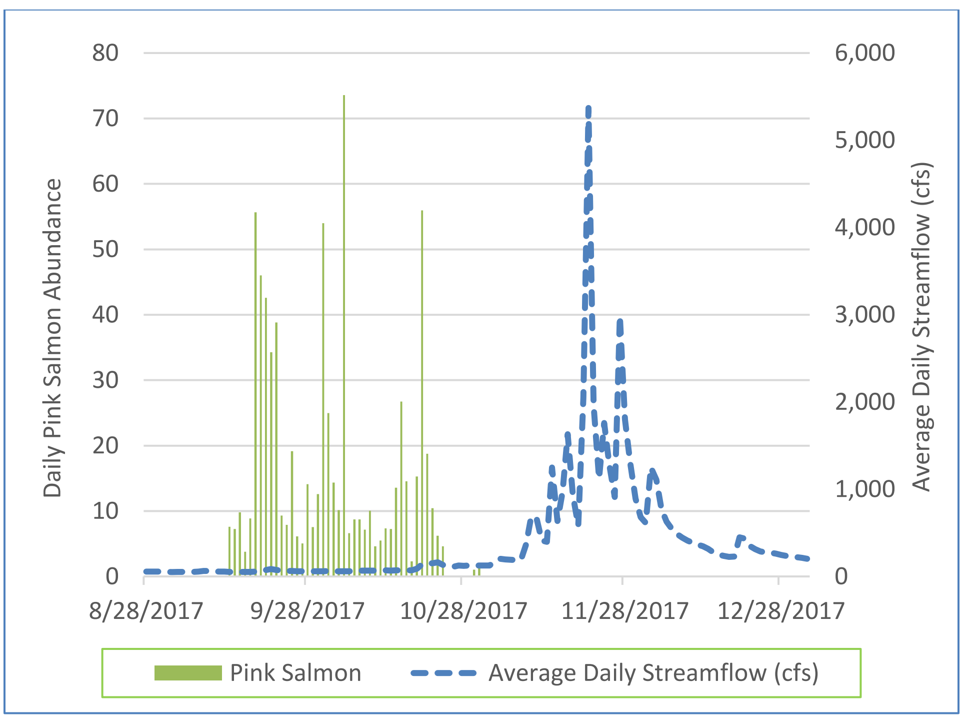

Figure 18. Daily passage estimates for Pink Salmon (TL > 41) returns in relation to average daily stream flow (cfs) (USGS/CDWR Arcata Gaging Station, #11481000) in 2017, Mad River, Humboldt County, CA.

DISCUSSION

Mad River makes important contributions to the CC Chinook Salmon ESU, NC steelhead DPS, and the SONCC Coho Salmon ESU as evidenced by the large combined runs of these species (N = 17,763) in 2017. Mad River is considered essential and important for the recovery of the CC Chinook Salmon, NC Steelhead Trout, and SONCC Coho Salmon (NMFS, 2014; NMFS 2016); and in 2005 was designated as 'critical' habitat for these species (50 CFR Part 226). Mad River is a medium sized stream in Humboldt County, known for limited access, high streamflows and turbid stream conditions during winter and spring months. Recent advances in hydroacoustic (sonar) technology (DIDSON, ARIS) have provided a much needed tool for enumerating adult salmonid returns to various streams and rivers (Holmes et al., 2006; Maxwell, 2007), and with less difficulty and more accuracy compared to past sonar applications (Maxwell and Gove, 2004; Maxwell, 2007; Maxwell et al., 2011). ADFG uses DIDSON and ARIS sonars to assist with managing economically important salmon runs in several rivers (e.g. Copper River, Kenai River, Kasilof River, Russian River, among others) that have commercial, subsistence, tribal, and recreational harvests.

The ARIS sonar, along with species apportionment methods, provides data for Mad River that was previously unattainable. Our study design and population estimates have been accepted by NMFS (2017) to fulfill several annual reporting requirements for Mad River Hatchery's HGMP and Mad Rivers' FMEP (in draft). Our sonar project should continue to provide quality, long term data that is necessary for assisting in the management of federally and state listed species.

CC Chinook Salmon

Abundance

The Chinook Salmon abundance in 2017 equaled 12,667 and was much greater than abundances in 2014 – 2016 (ranged from 5,645 – 7,489). Abundance in 2017 was 76% greater than abundance in 2016. There could be several, plausible explanations for the observed increase in 2017, including: 1) There was no ocean harvest of Chinook Salmon in 2017 from southern Oregon to Horse Mountain, Northern California (PFMC, 2017), 2) survival from smolt to adult was above average, 3) change in age class structure for returning adults in 2017, or 4) some combination of the above factors.

1) The ocean fishery (both sport and commercial) was closed in 2017 because of expected, depressed runs for Klamath River stocks returning in 2017 (PFMC, 2017). Thus, the large increase we detected in 2017 could simply be due to a lack of harvest in the ocean fishery, where CC Chinook Salmon and Klamath stocks mix. Sonar based CC Chinook Salmon returns to

nearby Redwood Creek in 2017 were also above the multiple year average (Diebner-Hanson and Henderson, 2019), and 42% greater than abundance determined in 2016 (Sparkman et al., 2017b). Managing specific stocks or ESU's in a mixed stock fishery is problematic in California (and other states) because hatchery Chinook Salmon are not universally marked. Thus, when local fisheries target hatchery or non-listed Chinook Salmon, a given percentage of wild and federally threatened CC Chinook Salmon will also be harvested (Satterthwaite et al., 2014). Universally marking hatchery Chinook Salmon is difficult and expensive when using coded wire tags as the mark. However, the use of genetic stock identification techniques to enumerate or assign ocean harvested fish to specific rivers or ESU's shows promise (Satterthwaite et al., 2014). This information could then be used to assess ocean harvest impacts upon the CC Chinook Salmon ESU and allow for taking appropriate management action(s) if deemed necessary (Satterthwaite et al., 2014).

2) There is the possibility that Mad River Chinook Salmon smolts experienced increased survival to adulthood relative to other years, which could result in more returning adults. There is also a possibility that the cohorts returning in 2017 (as adults) were from years of higher smolt production. We currently do not enumerate smolts in the Mad River, therefore we cannot support or deny this possibility.

3) The increase we detected in 2017 could have happened because salmon that would normally return in 2016 waited another year to return in 2017. However, we did not see a dip in abundance in 2016, rather we saw an increase relative to numbers in 2015. Had a substantial number of salmon stayed in the ocean to return in 2017, the numbers in 2016 should have dropped. There is also the possibility Chinook Salmon that would have returned in 2018 may have returned in 2017 due to favorable ocean conditions which allowed for faster growth. Currently we are collecting data on the age class structure of annual runs, which should provide relevant information useful for assessing any changes in the age class structure of returning adults. We currently know that the Chinook Salmon run in any given year consists of ages 2 – 5 based upon analyzing scale samples. We need to collect more data each year to determine the percent composition of age classes per season.

The abundance of CC Chinook Salmon returns to the Mad River from 2014 – 2017 ranged from 5,645 – 12,667 and averaged 8,247 (SEM = 1,528). Although we report only four years of data, we suspect the Mad River may be the second largest producer of CC Chinook Salmon within their range. The Eel River, with a much larger watershed area and historically large numbers of Chinook Salmon, is considered first.

Run Timing

The Chinook Salmon run in 2017 started in late August and ended in late December, a period of 124 days. Daily passage rates in 2017 ranged from -9 to 1,507 and averaged 102 fish/day. For descriptive purposes, the run can be classified as the following: early (September), mid (October/November), and late (December). The extended run timing in the Mad River is unlike the CC Chinook Salmon runs in nearby Redwood Creek and Eel River (Sparkman et al., 2017b; Diebner-Hanson and Henderson, 2019; Kajtaniak and Easterbrook, 2019), where the runs are much shorter in duration. The Chinook Salmon run in Redwood Creek is delayed until increases in streamflow push through the sand bar to open Redwood Creek to the ocean, which can occur as late as October or November. For example, Sparkman et al. (2017b) report that Chinook Salmon first started entering lower Redwood Creek on October 14, 2016 and the run ended on December 3, 2016 (a period of 51 days). A total of 1,539 (or 48% of total abundance) Chinook Salmon passed the sonar site (Rm 3) within one week after Redwood Creek breached to the ocean (Sparkman et al., 2017b). Chinook Salmon in the Eel River have a shorter run timing than Chinook Salmon in the Mad River as well, however, sonar locations greatly vary among studies. Numerous Chinook Salmon will stage in the lower Eel river and wait for streamflows to increase to levels suitable for upstream migration (Kajtaniak and Easterbrook, 2019). For example, Kajtaniak and Easterbrook (2019) used DIDSON sonar on the mainstem Eel (Rm 44) and reported the run-timing of Chinook Salmon occurred between November 15, 2108 – December 31 ,2018 (a period of 47 days). The increase in the period of run-timing for Chinook Salmon in the Mad River is most likely due to relatively higher streamflow during frequent dry periods (September and October). Humboldt Bay Municipal Water District releases flows from Robert Matthews Dam (Rm 77), which provide adequate streamflow for Chinook Salmon passage at least past the sonar site. We speculate that these enhanced flows also prevent the occasional formation of sand bars where Mad River enters the ocean (Van Kirk, 2004).

Late Summer/Fall-Run NC Steelhead

The late summer/fall-run steelhead is a unique life history form of the NC steelhead ESU. Although some prefer to ‘lump’ this run type with the winter-run steelhead, we believe it’s more appropriate to determine their abundance independent of winter-run steelhead. Unlike winter-run steelhead, the late summer/fall-run steelhead enter the Mad River much earlier and is more of a “stream maturing” fish than the “ocean maturing” winter-run steelhead. The late summer/fall-run steelhead spawns after summer-run steelhead, and before most of the winter-run steelhead spawn in the Mad River (CDFW, in house data).

Abundance

The late summer/fall-run steelhead abundance in 2017 equaled 2,808 and was considerably greater than abundances in 2014 – 2016 (ranged from 425 – 925). Abundance in 2017 was 286% greater than abundance in 2016. We can only speculate a few plausible explanations for this observed increase: 1) a greater number of smolts entered the ocean for returning brood years in 2017, 2) ocean conditions were not unfavorable for survival, 3) change in age class structure for returning adults, or 4) some combination of the above factors. Unlike the CC Chinook Salmon, there is little impact on adult steelhead in the ocean fisheries because few steelhead are ever caught.

Run Timing

Late summer/fall-run steelhead are usually the first anadromous salmonid to stage in lower Mad River and migrate upstream during sonar deployment. We used a meteorological endpoint of November 30 to distinguish between fall and winter-run steelhead. The run-timing for late summer/fall-run steelhead began on August 28, 2017 and ended on November 30, 2017 to total 95 days. Daily passage rates ranged from 3 – 125 and averaged 30 fish/day. The largest peak in abundance occurred on October 20, 2017 when average daily discharge increased from 89 cfs to 149 cfs.

Natural-Origin and Hatchery-Origin Compositions

The late summer/fall-run steelhead in the Mad River are mostly natural-origin, with percentages ranging from 71 – 82% of the total run. The abundance of natural-origin steelhead from 2014 - 2017 ranged from 300 – 2,152, and for hatchery-origin steelhead ranged from 125 – 656. For both origin types, peaks in annual abundances occurred in 2017. We were originally surprised to find hatchery-origin steelhead in this run type since Mad River Hatchery spawns winter-run steelhead. Additionally, we are involved in the spawning process for MRH (brood stock collection, sampling genetics of all breeders, etc.) and have only seen a few late summer/fall-run steelhead bred with a winter-run steelhead. Rather, we primarily see fresh (silvery and gravid) winter-run bred with fresh-winter run. Perhaps the presence of hatchery-origin late summer/fall-run steelhead from a winter-run steelhead program also illustrates genetic diversity and plasticity of steelhead life histories.

SONCC Coho Salmon

We observe Coho Salmon every year in the lower Mad River during species apportionment sampling. However, the number of observations over time were few and the total numbers we observed were less than 20 in any given year. Therefore, we couldn't produce a reliable estimate that wasn't negatively biased. *A priori*, and based upon professional judgement, we speculate there are at least 200 - 300 adults returning each year to the Mad River.

Abundance

We observed a total of 164 Coho Salmon (TL > 41 cm) from September 26, 2017 – January 2, 2018 using snorkel surveys. We estimate a total of 1,575 returned to the Mad River in 2017. Similar to the CC Chinook Salmon, we can only offer plausible reasons for the dramatic increase in returns: 1) No catch-release mortality on Coho Salmon adults in 2017 since the ocean fishery was closed, and 2) survival from smolt to adult was above average. There was most likely not a change in the age class distribution of returning adult Coho Salmon in 2017, since most runs in California consist of two and three-year-old fish.

Run Timing

The Coho Salmon run in 2017 started in late September and ended in early January 2018, a period of 99 days. We feel confident our species apportionment methods encompassed the majority of the run, if not the entire run because after January 2, 2018 we conducted numerous angler interviews nearby the sonar site with no additional Coho Salmon sightings. There was heavy angling pressure just downstream of the sonar site because streamflows were 'perfect' for angling, and the winter-run steelhead were very numerous. Daily passage rates for Coho Salmon in 2017 ranged from 0 – 130 and averaged 16 fish/day. The peak in passage occurred on 11/03/17, when average daily streamflow increased from 127 to 178 cfs.

Pink Salmon

Pink Salmon in California are recognized as a "Species of Special Concern" by CDFW, and California is recognized as the most southern border for the species (CDFG, 1995; Heard, 1991; Skiles et al., 2013; Moyle et al., 2017). Skiles et al. (2013) and Moyle et al. (2017) provide comprehensive and detailed information about Pink Salmon life histories and occurrences in California. Although we observed small numbers of Pink Salmon (n < 6) in the Mad River in 2015 and 2016, we visually (snorkeling) counted 184 adults in 2017. Furthermore, Thomas Dunklin (pers. comm. 2017) observed Pink Salmon spawning in the Mad River during the fall of 2017 and used video for documentation.

Abundance

We estimate a total of 750 Pink Salmon returned (or strayed) to the Mad River in 2017, which is the first documentation of relatively large numbers present. These Pink Salmon must have been strays since there is no evidence of a bi-annual run in recent years, with exception to observing a few individuals each year.

Run Timing

The run-timing for Pink Salmon began on September 13, 2017 and ended on October 31, 2017 for a total of 49 days. Daily passage rates ranged from 0 – 74 and averaged 15 fish/day. All of the Pink Salmon migrated past the sonar site during a stable hydrograph, and the peak in passage occurred on 10/05/17.

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