Shasta River
Salmonid Monitoring 2018
Siskiyou County, CA

Photo by Martin Anderson

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Shasta River Fish Counting Facility, Salmonid Monitoring 2018 Siskiyou County, CA

ABSTRACT

A total of **20,692** fall run Chinook Salmon (*Oncorhynchus tshawytscha*) were estimated to have entered the Shasta River during the 2018 spawning season. An underwater video camera was operated in the flume of the Shasta River Fish Counting Facility (SRFCF) 24 hours a day, seven days a week, from September 4, 2018, until January 8, 2019. The first Chinook was observed on September 4, 2018, and the last Chinook on January 6, 2019. Klamath River Project staff sampled 617 carcasses to collect biological metrics and to determine the presence of Iron Gate Hatchery (IGH) produced fish.

Chinook Salmon carcasses sampled in the spawning ground surveys were used to describe characteristics of the run. We processed 617 carcasses which ranged in fork length (FL) from 44 cm to 86 cm Grilse were determined to be < 56 cm in FL. Males ranged in FL from 46 cm to 86 cm and averaged 67.7 cm. Females ranged in FL from 44 cm to 77 cm and averaged 64.3 cm. The run was comprised of 2,017 grilse (9.75%), and 18,675 adults (90.25%). The sex composition of the run, based on 208 spawning ground survey (SGS) fish sampled, was 61.5% (12,734) female and 38.5% (7,958) male. A total of 14 adipose-clipped (AD) Chinook were recovered in the weir washback sample. All 14 AD carcasses contained a coded wire tag (CWT) from IGH, the fish were 2 and 3 years old.

Hatchery composition was estimated using expansion of the known CWT proportions and carcasses handled during the spawning ground surveys and weir washbacks. For 2018, the expanded CWT estimate was 1,883 fish or 9.1% of the run.

A net total of 39 Coho Salmon (*Oncorhynchus kisutch*) were estimated to have entered the Shasta River prior to removal of the weir on January 8, 2019. The first Coho of the season was observed swimming upstream through the SRFCF on November 7, 2018, and the last Coho was observed swimming upstream through the SRFCF on December 27, 2018. No Coho carcasses were recovered in the spawning ground surveys or washback samples. Due to the lack of Coho carcass recovery, hatchery contribution was not calculated for the 2018 Shasta River Coho run.

A net total of 392 adult steelhead trout (*Oncorhynchus mykiss)* were observed passing through the SRFCF during the 2018 season, prior to the removal of the SRFCF on January 8, 2019.

INTRODUCTION

The Klamath River Project (KRP) of the California Department of Fish and Wildlife (Department) is responsible, in cooperation with other state, federal and tribal partners, for estimating the number of Chinook Salmon (*Oncorhynchus tshawytscha*) and Coho Salmon (*Oncorhynchus kisutch*) that return to the Klamath River Basin, excluding the Trinity River Basin, each year. In addition to escapement, objectives include the determination of run timing, spawning distribution, length frequency (FL) distribution, and sex ratio for Chinook Salmon and Coho in the Shasta River. Scales and coded wire tags are collected to determine the age composition and hatchery contribution to each annual run.

To achieve these tasks the KRP employs several techniques which include a creel survey of sport fishing effort and harvest, recovery of fish returning to Iron Gate Hatchery (IGH), completion of cooperative spawning ground surveys in major tributary streams and rivers, and operation of video fish counting weirs on the Shasta River, Scott River and Bogus Creek. The Shasta River Fish Counting Facility (SRFCF) is located approximately 213 meters (700 feet) from the confluence of the Shasta and Klamath Rivers (Klamath RM 176.6, RKM 283, Figure 1 and Figure 2). Coordinates for the facility are 041º 49' 46.38" N, 122º 35' 35.38" W (WGS 84).

Video equipment was first installed at the SRFCF in 1998 and has been used to describe migration of salmonids into the Shasta River ever since. Although the primary responsibility of the KRP is to enumerate and describe Chinook Salmon and Coho Salmon populations, data are recorded for steelhead trout (*Oncorhynchus mykiss*) and other species observed at the SRFCF during its period of operation as well.

Since 2004, when the Southern Oregon/Northern California Coast ESU of Coho Salmon was listed as a Threatened Species by the California Fish and Game Commission, the KRP has operated its SRFCF video system through December, and into January when possible, in order to enumerate the Coho run as well as the Chinook Salmon run into the Shasta River. This report describes the characteristics of the Chinook, Coho, and steelhead salmon runs that entered the Shasta River during the 2018-2019 season.

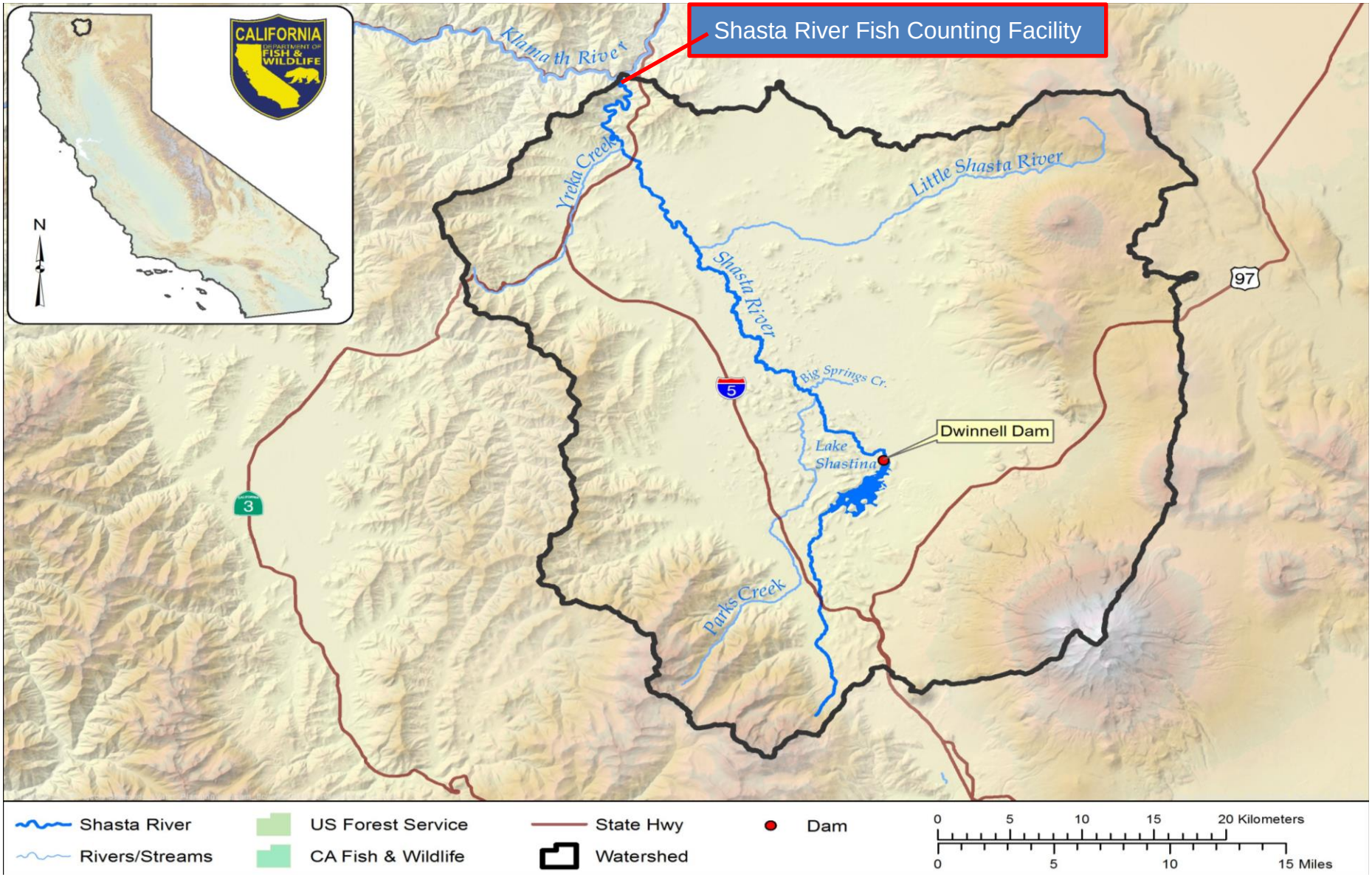

Figure 1: The Shasta River Watershed and location of the Shasta River Fish Counting Facility

Figure 2: Google Earth Image looking south at the Shasta and Klamath Confluence

METHODS

Monitoring of the salmon run within the Shasta River during the 2018 season was accomplished through three primary efforts: operation of a video weir, collection of data from salmon carcasses that become impinged on the weir panels as they float downstream (washbacks), and completion of spawning ground surveys upstream of the weir to obtain biological data from salmon carcasses.

VIDEO WEIR

The SRFCF consists of a video camera, counting flume and an Alaska-style weir strategically placed in a diagonal across the river channel (Figure 3). Fish immigrating upstream are directed through a narrow flume, which passes in front of an underwater video camera. A SplashCam Delta Vision* black and white underwater camera with a 3.6 mm wide angle lens was used in 2018 for capturing images, and an ECOR 264* digital video recorder (DVR) with a swappable hard drive were used for recording video footage.

*Use of product names in this report does not imply endorsement by the California Department of Fish and Wildlife.

Figure 3: Alaska-style panels of the Shasta River Fish Counting Facility (SRFCF)

The weir and video camera were installed and recording began on September 4, 2018. KRP staff performed routine daily maintenance of the SRFCF. This included inspecting the video system to ensure that everything was operating correctly, inspecting and cleaning weir panels and making any necessary repairs, and processing any washback carcasses present. Twice per week the hard drive was removed from the DVR and replaced with another drive. All recording equipment was secured in locked enclosures and access to the site was controlled through a locked gate located on private property.

Swappable drives with stored video data were immediately returned to the office where each was subsequently downloaded onto a shared network drive for storage and review by staff in the video lab. During each review, staff recorded the date, time (hour:min:sec), and species of each fish observed. In addition, staff noted the presence of adipose-clipped (AD) fish, and recorded the presence of lamprey or any other distinguishable marks that were visible on the footage. Fish were counted as downstream migrants if they entered the flume from the upstream end and exited at the downstream end. If fish entered the flume but backed down without exiting on the upstream end, they were not counted.

Fish for which positive identification could not be made were recorded as “unknown” species. All data were then entered into files on a computer and each data file was edited and corrections made by a second individual prior to commencement of data analysis. Operation of the SRFCF began on September 4, 2018. The first Chinook Salmon of the season was observed on September 4, 2018 and the last Chinook was observed on January 6, 2019.

WASHBACK CARCASSES

All salmon carcasses that drifted downstream and became impinged on the weir panels were recovered. A systematic sample of one in five Chinook Salmon carcasses were processed. Data collected on these systematically sampled washback carcasses included fork length (FL), gender, marks, tags and the presence of fin clips. Scales were removed from the left side of each carcass at a location posterior to the dorsal fin just above the lateral line whenever possible. Each female carcass was also examined to determine whether successful spawning had occurred. Spawning status was defined as unspawned (many eggs remaining in the body) or spawned (few or no eggs remaining). In addition to the systematically sampled Chinook carcasses, all carcasses were examined for AD clips, and all AD carcasses and Coho Salmon and steelhead carcasses were processed. Heads were collected from each AD fish for later CWT recovery and analysis. All carcasses were cut in half to prevent sample duplication and returned to the river downstream of the weir.

SPAWNING GROUND SURVEYS

Survey reaches included the lower seven miles of the Shasta River (canyon reaches), as well as five reaches of the upper Shasta River main stem and the following tributaries to the Shasta River: Yreka Creek, Big Springs Creek, Little Springs Creek and Parks Creek. Survey reaches are described in Table 1. Together, these surveys cover approximately 15 percent of the Shasta River basin, and their purpose is to gather biological data necessary to describe physical characteristics of the run, and to document spawning distribution in the reaches surveyed. Total escapement numbers are derived from the video weir. Surveys were conducted once per week, usually on Wednesdays, and were limited to areas historically used, or believed to be used, by spawning salmon.

Table 1: Description of Shasta River Spawning Ground Survey Reaches, 2018

Location	Reach Number	Downstream Point	Upstream Point	Length (miles)	Length (km)
Shasta River	1	Shasta River Fish Counting Facility	Pioneer Bridge	2.97	4.78
Shasta River	2	Pioneer Bridge	Salmon Heaven	2.47	3.98
Shasta River	3	Highway 263	Shelly Bridge (canoe reach)	0.37	0.59
Shasta River	20	Confluence w/Big Springs Creek	Confluence w/ Parks Creek	0.93	1.49
Big Springs Creek	21	Mouth of Big Springs Creek	Upper Bridge, Big Springs Creek	0.87	1.4
Shasta River	22	Mouth of Parks Creek	Hidden Valley Ranch	2.53	4.07
Parks Creek	23	Mouth of Parks Creek	2nd Fence	0.99	1.59
Parks Creek	24	Parks Creek, Dukes	Slough Road Crossing	1.89	3.04

During each survey, crews walked along the river bank or in the channel searching for salmon carcasses. As carcasses were located, crews processed each as previously described for weir washbacks. In addition to scale samples, a tissue and otolith sample was collected from the first carcass sampled from each reach on each survey day. All tissue samples were collected following protocols provided by the National Oceanic and Atmospheric Administration's (NOAA) Southwest Fisheries Science Center. Tissue samples were sent to the Salmonid Genetic Tissue Repository located at the NOAA Santa Cruz Laboratory for archiving and analysis. Otoliths were collected throughout the season and cataloged for future microchemistry analysis. Otolith samples were collected following standard protocols.

CHINOOK SALMON HATCHERY INFLUENCE

Hatchery composition was estimated using expansion of the known CWT and carcasses handled during the spawning ground surveys and weir washbacks (Table 4) and is calculated as follows:

1. The sample expansion for fish examined for adipose fin clips is calculated by dividing the total population (from video counts) by the number of carcasses that were encountered by crews and examined for an adipose fin clip (weir washback and spawning ground survey carcasses).

2. Each coded-wire tag recovered during spawning ground surveys is expanded by the hatchery production multiplier (estimated at the time of juvenile release, obtained from hatchery records) to yield a production estimate which is an estimate of the number of hatchery fish among observed carcasses.

3. The production estimates from step 2 are multiplied by the sampling fraction from step 1 and summed to estimate the total number of hatchery Chinook Salmon escaping to spawning grounds.

RESULTS

CHINOOK SALMON VIDEO DATA

A net total of 20,692 Chinook Salmon were counted passing through the SRFCF during the 2018 season. This number was derived by subtracting the number of downstream observations (142) from the number of upstream observations (20,834). The majority of the run (52%) was observed between September 4, 2018 and October 2, 2018, and the peak day of the run was October 2, 2018 with a net passage of 1,845 (8.9%) Chinook (Figure 4). Consistent with previous years' monitoring efforts, the majority of Chinook (96%) passed upstream through the SRFCF during daylight hours between 06:00 and 17:00 hours (Figure 5).

A total of 3,558 Chinook Salmon (17.2% of the run) were recorded as having one live lamprey observed attached to their bodies and 439 Chinook (2.1%) were recorded as having two or more live lamprey attached to their bodies. Since the camera captures only the left side of each fish as it migrates upstream, attached lamprey, clips, scars, or other abnormalities that may be present on the right side cannot be observed, so the incidence of lamprey attachment is probably higher.

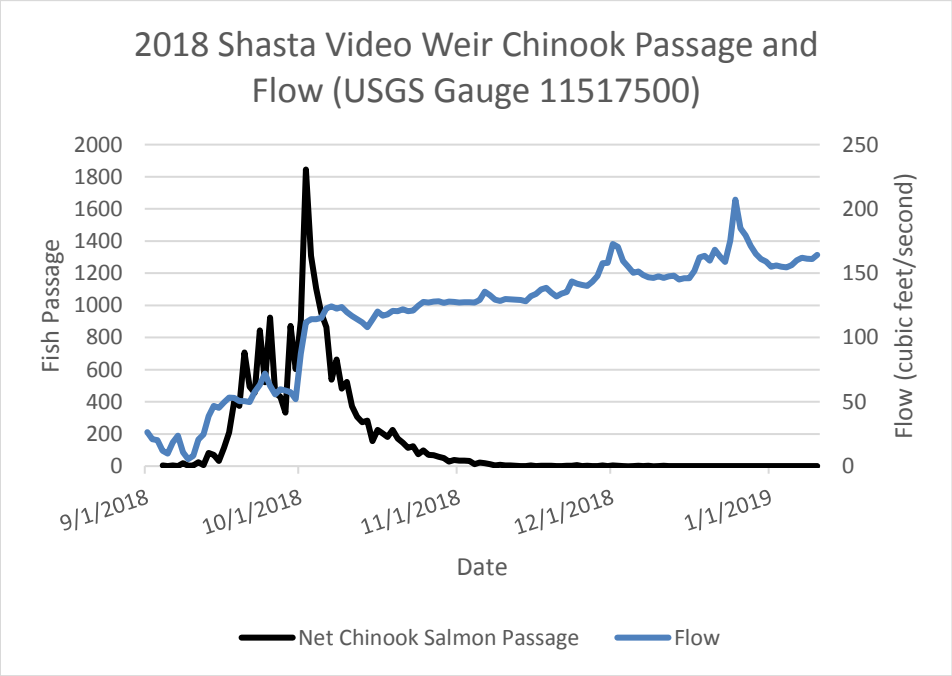

Figure 4: 2018 Shasta Chinook Salmon passage by date and flow (from Yreka gauge #11517500)

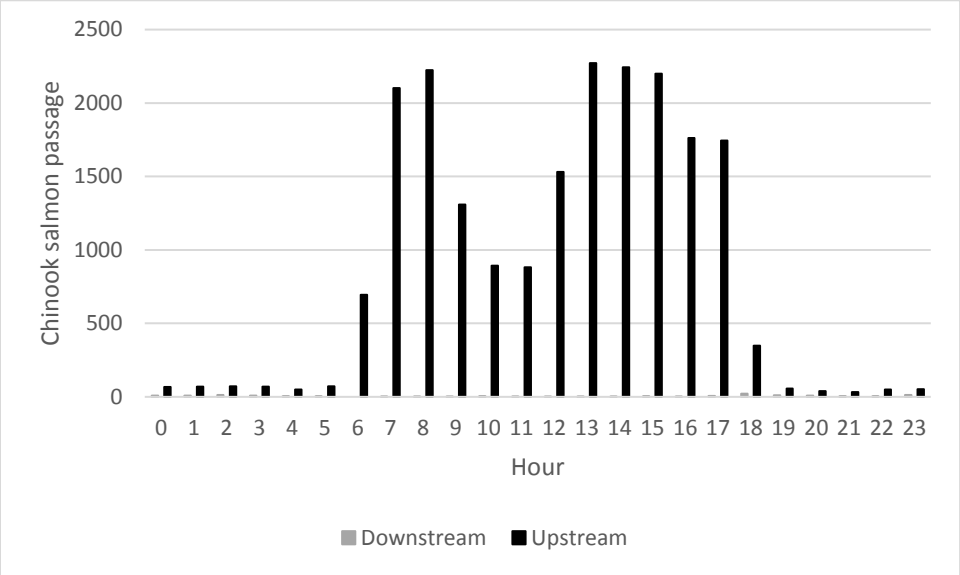

Figure 5: 2018 Shasta River Chinook Salmon observed by hour of day

CHINOOK SALMON WEIR WASHBACK CARCASSES

A total of 406 Chinook Salmon carcasses washed back on the SRFCF weir, of which 70 were sampled as part of a systematic sample (one in five, plus all AD clips) for biologic samples; however, one sample was lost so there were 69 biosamples collected. All 69 carcasses had successful sex and FL determinations made. Of the 69 carcasses sampled, 50 (72%) were males and 19 (28%) were females (Table 2). On two separate dates crews deviated from the usual sampling scheme which explains the shortage of samples (N should equal 81). As in previous years, the washback samples collected at the SRFCF show a heavy bias toward males (Table 2 and Figure 6).

Table 2: Sex composition of washbacks from Shasta River Fish Counting Facility, 2005-2018.

Year	Total Chinook	Total Wash Back	# Sampled	% Males	% Females
2005	2,129	395	395	76	24
2006	2,185	457	457	94	6
2007	2,036	228	228	71	29
2008	6,362	767	767	96	4
2009	6,287	330	327	71	29
2010	1,348	118	118	83	17
2011	11,388	1,623	1,623	99.6	0.4
2012	29,544	1,040	104	81	19
2013	8,021	643	64	81	19
2014	18,357	1,450	145	73	27
2015	6,745	82	7	71	29
2016	2,889	90	15	80	20
2017	9,905	940	174	94	6
2018	20,692	406	69	72	28
Average:				82	18

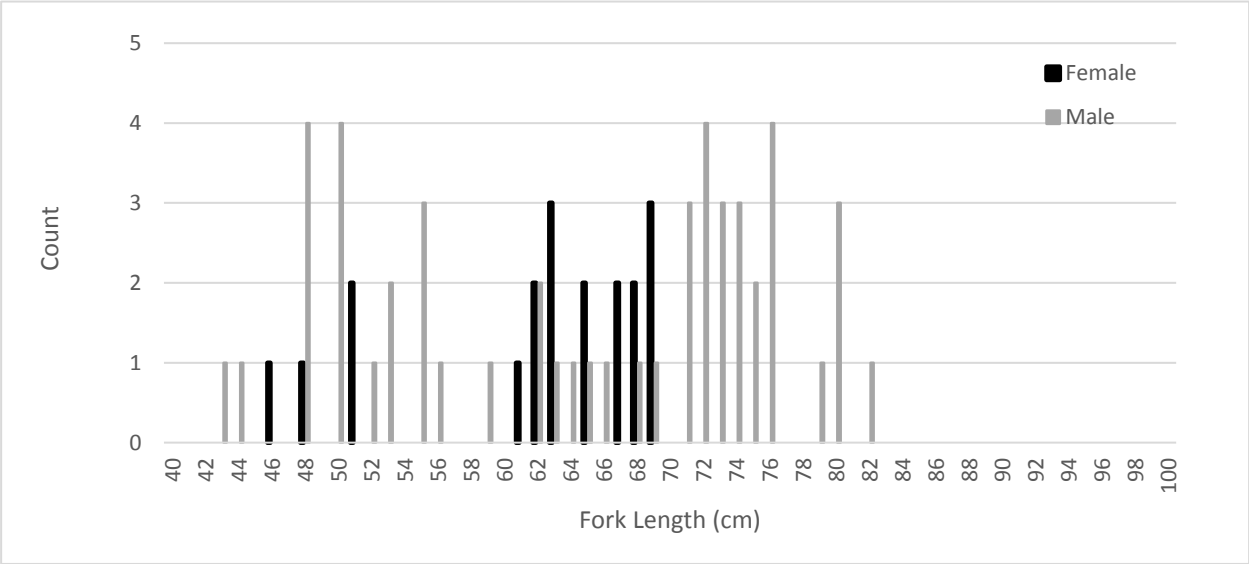

Figure 6: Length frequency of Shasta River Chinook Salmon washbacks during 2018.

CHINOOK SALMON SPAWNING GROUND SURVEYS

A total of 211 Chinook Salmon carcasses were observed and sampled during spawning ground surveys, 2 scale samples were lost and one fish did not have a recorded sex, so 208 samples were collected, 128 (62%) were female and 80 (38%) were male. Of the 128 female carcasses examined, 115 (90%) were determined to have spawned successfully (zero or few eggs observed) and 13 (10%) died without having spawned successfully (many eggs observed). Fork lengths frequencies indicate a low proportion of jacks (Figure 7 and Figure 8).

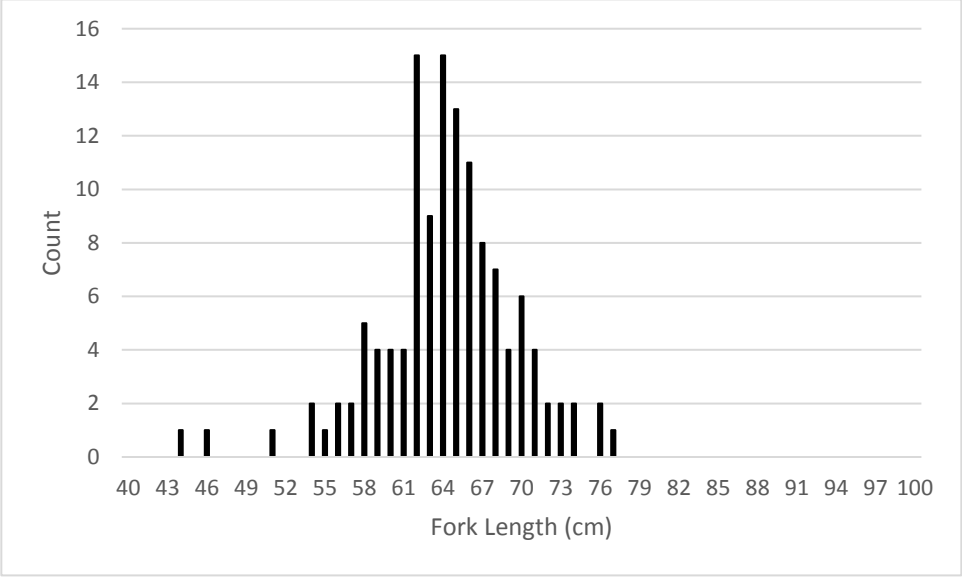

Figure 7: Length frequency of Shasta River Chinook Salmon females from 2018 spawning ground surveys

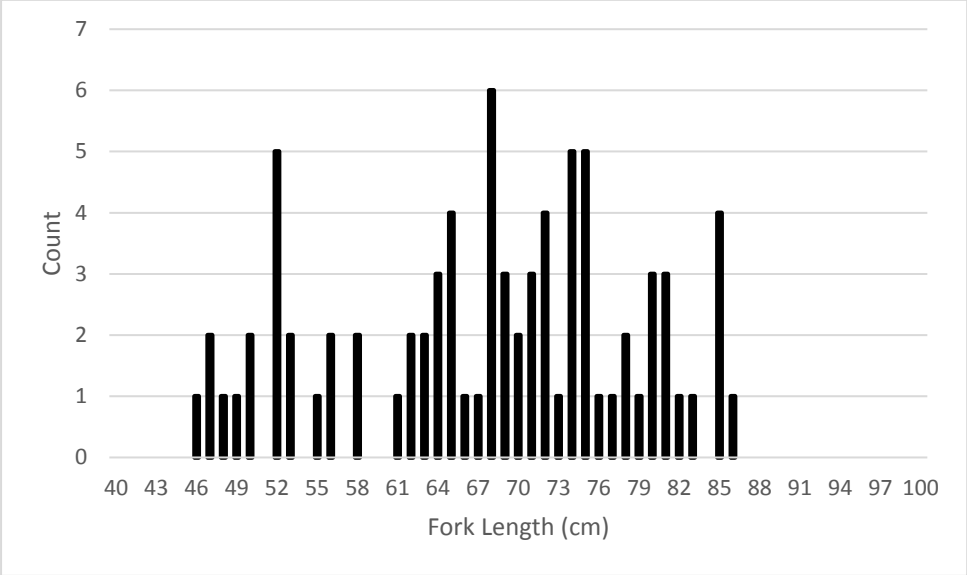

Figure 8: Length frequency of Shasta River Chinook Salmon males from 2018 spawning ground surveys

CHINOOK SALMON AGE COMPOSITION

A preliminary grilse adult cutoff length was estimated to be 57 cm, all grilse are less than 57 cm. Using the length based assessment from spawning ground data (208) grilse (n=25) were estimated to account for 12% of the run (2,487) and adults made up 88% of the run (18,205). The cutoff was based on FL data from carcasses recovered during SGS. The grilse information was updated when estimates of the age composition of the adult component of the 2018 run in the Shasta River were finalized by the Klamath River Technical Advisory Team (KRTAT, 2019) using scale age analysis conducted by the Yurok Tribe and U.S. Fish and Wildlife Service (Table 3).

Table 3: Age composition of the Chinook Salmon run to the Shasta River, 2002-2018

	Age 2	Age 3	Age 4	Age 5	Total Adults	Total Run
2002	386	4286	2088	58	6432	6818
2003	155	2798	1325	11	4134	4289
2004	129	184	484	166	834	963
2005	37	1361	579	79	2019	2056
2006	1395	151	625	13	789	2184
2007	27	1855	146	8	2009	2036
2008	3621	1222	1456	63	2741	6362
2009	151	5587	315	243	6145	6296
2010	87	240	1021	0	1261	1348
2011	11175	23	190	0	213	11388
2012	1944	27598	2	0	27600	29544
2013	1096	3896	3029	0	6925	8021
2014	3945	4064	10265	83	14412	18357
2015	133	5752	658	202	6612	6745
2016	135	536	2218	0	2754	2889
2017	6618	782	2022	483	3287	9905
2018	2016	17716	960	0	18676	20692
Average	1944.12	4591.24	1610.76	82.88	6284.88	8229.00

REDDS

A total of 440 redds were observed during spawning ground surveys in 2018. These observations were not intended to represent a comprehensive description of spawning distribution in the Shasta River or to produce an escapement estimate, as spawning ground surveys only cover approximately 15 percent of the watershed. Of the 440 redds observed, 73 (17%) were observed in the canyon reaches and 367 redds (83%) were observed in the valley reaches. Redds observed in the canyon reaches were not flagged, and the season estimate was derived from the peak daily redd count. Redds encountered in the upper Shasta River were marked with a GPS unit and flagged using bright flagging tape so each redd would only be counted and marked on the GPS once.

CHINOOK SALMON HATCHERY INFLUENCE

A net total of 43 adipose fin clipped (AD) Chinook Salmon were observed passing through the SRFCF during the season, and these fish were assumed to be of hatchery origin. Because of turbulence, the position of the fish in the flume or poor visibility due to water quality, the adipose fin is not always visible during video review, so the observed number is likely less than the number of AD Chinook that pass through the weir. For this reason, the hatchery contribution to the Shasta River is based on carcasses examined during spawning ground surveys and the weir washback sample and not on video observations. In 2018, the heads from 14 AD Chinook were recovered as washbacks on the weir. All 14 AD fish were produced at IGH: one was a 2-year-old, and 13 were 3-year-olds.

Hatchery composition was estimated using the expansion method detailed in the methods section. For 2018, the expanded CWT estimate was 1,883 fish or 9.1% of the run. Since 2001 the estimated contribution of hatchery strays to the Shasta River has ranged from a low of 0.4% in 2012 to a high of 38.6% in 2004 (Table 5).

Table 4: Estimated Hatchery Contribution in the Shasta River during the 2018 season

2018 Shasta River Hatchery Composition Estimate using 14 Adclipped Washback Samples									
Coded Wire Tag	Location	Release Type*	Brood Year	Age	Sample Number	Production Multiplier **	Production Estimate	Sample Expansion***	Total Estimate
060454	IGH	F	2015	3	1	4.023392165	4.02339216	33.53646677	134.9303576
060783	IGH	Y	2015	3	1	4.003038644	4.00303864	33.53646677	134.2477725
060786	IGH	F	2015	3	6	4.020709775	24.1242587	33.53646677	809.0423987
060787	IGH	F	2015	3	4	4.001566563	16.0062663	33.53646677	536.7936163
068045	IGH	F	2016	2	1	4.002684006	4.00268401	33.53646677	134.2358792
060994	IGH	F	2016	2	1	4.001913095	4.0019131	33.53646677	134.2100255
Estimated Hathcery Contribution									**1883.46005**
* Release type: F= fall fingerling, Y=Fall yearling									
** Production Multiplier value is the proportion of #of IGH total release for the code to the # of fish effectively tagged.									
*** Sample expansion is video total (20,692) divided by the number of fish examined for ad clips (617).									

Table 5: Contribution of hatchery origin Chinook Salmon straying to the Shasta River, 2002-2018

Year	Total # Chinook	Hatchery Stray Estimate	Percent Hatchery
2002	6,818	79	1.16%
2003	4,289	436	10.17%
2004	963	372	38.63%
2005	2,055	469	22.82%
2006	2,184	105	4.81%
2007	2,036	69	3.39%
2008	6,362	56	0.88%
2009	6,296	131	2.08%
2010	1,348	157	11.65%
2011	11,388	74	0.65%
2012	29,544	126	0.43%
2013	8,021	146	1.82%
2014	18,357	735	4.00%
2015	6,745	89	1.32%
2016	2,889	91	3.15%
2017	9,905	117	1.18%
2018	20,692	1,883	9.10%
AVERAGE			6.76%

COHO SALMON

A total of 42 Coho Salmon were observed passing upstream and three Coho were observed passing downstream through the SRFCF from November 7, 2018, through December 27, 2018 (Figure 9). The net number of Coho known to have entered and remained in the Shasta River prior to removal of the weir was **39.**

Historically, the proportions of hatchery-origin (HOR) and natural-origin (NOR) Coho Salmon entering the Shasta River have been estimated by applying the observed clip rates from spawning ground survey and weir washback samples that were not PIT tagged to the unknown (video) portion of the run. However, in 2018, no Coho carcasses were recovered, and the hatchery component was not estimated. No PIT-tagged fish were detected in the Shasta River, and it was not possible to determine with certainty whether Coho passing through the video weir had maxillary clips. There were three Coho grilse observations and 36 adult Coho observations through the video flume, which uses lines on the backdrop 56 cm apart to delineate grilse vs. adult salmon. Four Coho (10%) had at least one lamprey attached to them while passing through the video flume.

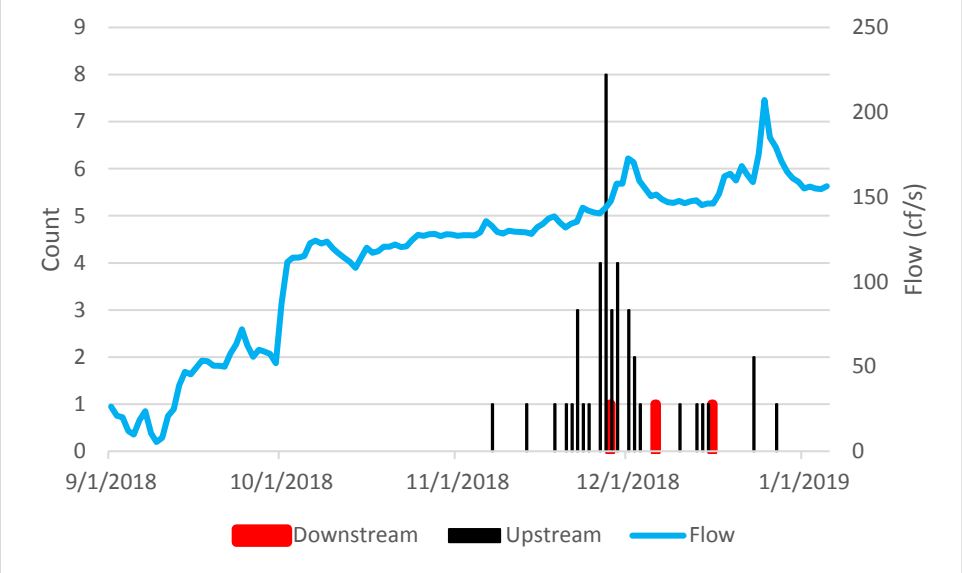

Figure 9: 2018 Shasta River Coho salmon observed by date and flow (from USGS Yreka gauge #11517500)

STEELHEAD

In 2018, a net total of 392 adult steelhead were estimated to have entered and remained in the Shasta River during the video recording season from September 8, 2018, to January 7, 2019 (Figure 10). No observations were made of steelhead with AD clips, which would indicate hatchery origin. Because the Alaskan weir is not impermeable to juvenile fish, including “half pounders,” sub-adult or juvenile steelhead were counted but excluded from this analysis, so all steelhead included in this analysis were greater than 16 inches.

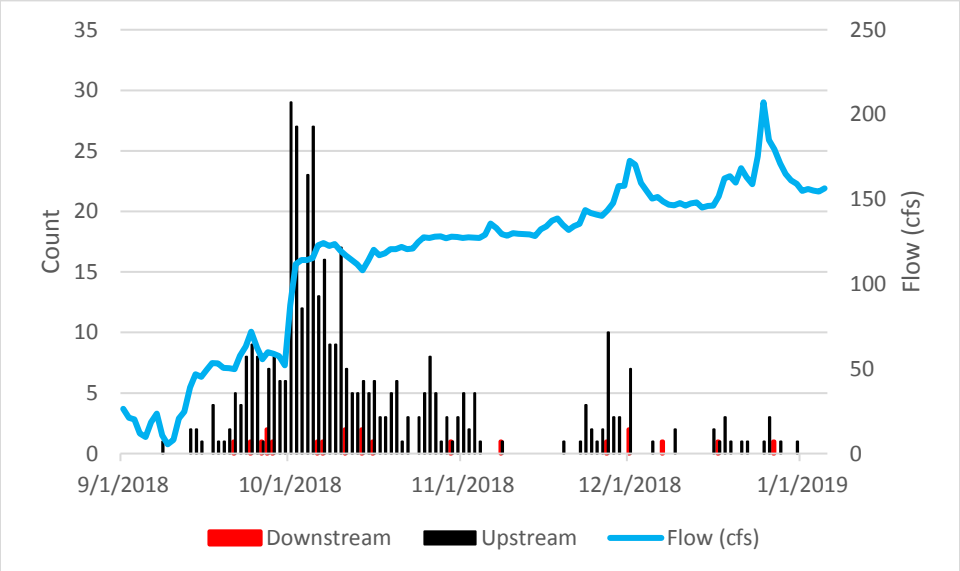

Figure 10: 2018 Shasta River Steelhead observed by date and flow (from USGS Yreka gauge #11517500)

DISCUSSION

CHINOOK SALMON

The 2018 run of Chinook Salmon of 20,692 was 13,984 fish above the 41-year average of 6,708 (Figure 11). At the current monitoring site, run sizes have ranged from a low of 533 fish in 1990 to a high of 29,544 fish in 2012. At 308% of the 41 year average, the Shasta River had a large return of Chinook in 2018 and the 2017 run had the second highest proportions of grilse (67%), which illustrates that total number of grilse can be an indicator when predicting future run sizes.

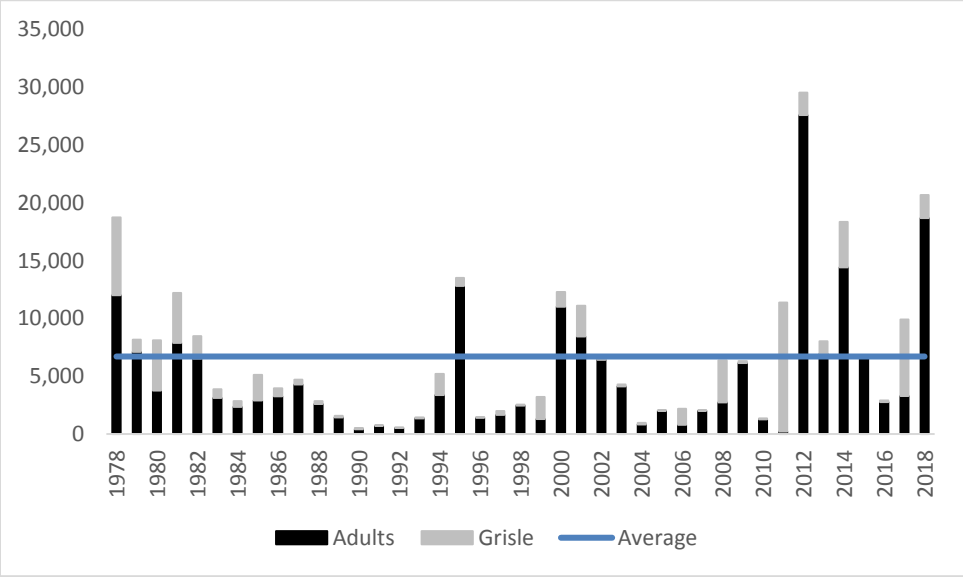

Figure 11: Shasta River Annual Adult and Grilse Chinook Salmon Populations

The 2018-2019 water year on the Shasta River was fairly stable however heavy precipitation in February and March raised the Shasta River flows. Depending on the hatch timing, redd scouring may have occurred during these high flows. Juvenile (brood year 2018) salmonids leaving the Klamath River tributaries, including the Shasta River in 2018-2019 will encounter average flow and temperature conditions in the main stem Klamath River and exposure to *Ceratonova shasta* and other pathogens is likely, although the extent of exposure is unknown at this time. This and other pathogens are known sources of mortality in juvenile Chinook Salmon, Coho Salmon, and steelhead (True et al. 2016). This exposure along with ocean conditions play a key role in adult returns.

The Shasta River is an important component of the Klamath Basin Chinook Salmon run (including Trinity River) and has contributed an average of 11 percent of the basin-wide natural spawning escapement during the period from 1978 to 2018 (Table 6).

Table 6: Escapement of Chinook Salmon to the Klamath Basin and Shasta River, 1978-2018.

Year	Chinook Natural Spawner Escapement		% Shasta
	Klamath Basin	Shasta River	
1978	74,906	18,731	25%
1979	37,398	8,151	22%
1980	48,465	8,096	17%
1981	50,364	12,220	24%
1982	50,597	8,455	17%
1983	33,310	3,872	12%
1984	21,349	2,842	13%
1985	61,628	5,124	8%
1986	142,302	3,957	3%
1987	110,489	4,697	4%
1988	91,930	2,842	3%
1989	49,377	1,577	3%
1990	16,946	533	3%
1991	12,367	726	6%
1992	17,171	586	3%
1993	25,683	1,426	6%
1994	38,578	5,203	13%
1995	179,118	13,511	8%
1996	87,500	1,450	2%
1997	50,369	2,001	4%
1998	45,343	2,542	6%
1999	28,904	3,197	11%
2000	89,122	12,296	14%
2001	85,581	11,093	13%
2002	69,502	6,818	10%
2003	89,744	4,289	5%
2004	28,516	962	3%
2005	27,931	2,129	8%
2006	45,002	2,184	5%
2007	61,741	2,036	3%
2008	48,073	6,362	13%
2009	52,499	6,287	12%
2010	49,031	1,348	3%
2011	108,612	11,388	10%
2012	133,361	29,544	22%
2013	69,986	8,021	11%
2014	112,343	18,357	16%
2015	31,596	6,745	21%
2016	15,818	2,889	18%
2017	35,036	9,905	28%
2018	61,561	20,692	34%
Average	**60,711**	**6,709**	**11%**

A comparison of Shasta River escapement to Klamath Basin escapement is shown in Figure 12. Historically, the Shasta River was documented as a highly productive salmon stream, with a run of over 75,000 Chinook Salmon counted at the Shasta Racks (predecessor to the SRFCF) in 1935. In most cases the Shasta River follows the trend of the basin indicating similar survival rates; however, in the 1980s, the Shasta River does not reflect that trend.

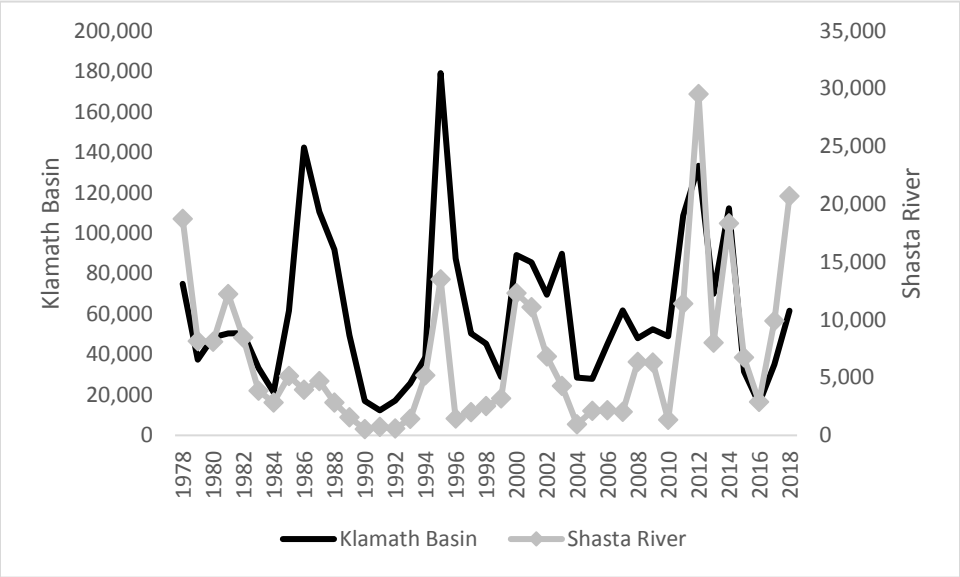

Figure 12: Chinook Salmon natural spawner escapement to the Klamath Basin and Shasta River from 1978-2018.

Because the Shasta River fall Chinook Salmon run typically enters the river in early September, earlier than runs to other upper Klamath tributaries, fishery managers have, in recent years been concerned with flow and temperature conditions in the river during the early weeks of the fall migration. Observations of fish migration through the SRFCF and real time temperature monitoring have been the basis for coordination between resource agencies and local landowners to ensure adequate flows during the critical month of September. The Nature Conservancy, the Department, the Shasta Resource Conservation District (RCD), and local landowners coordinate closely during this period to manage the timing and magnitude of irrigation diversions prior to the end of the irrigation season on October 1.

Data from brood years 2000 through 2017 indicate the Shasta river's current habitat conditions continue to produce more 0+ Chinook Salmon as more adults return, indicating the watershed continues to have an increasing ability to produce juvenile Chinook (Figure 13), although the rate at which juvenile Chinook were produced from brood year 2012 was reduced when compared to previous seasons (Debrick et al. 2015). In addition, factors such as high flow events which result in streambed mobilization and sediment transport can cause significant damage to redds and emerging fry, and the age and sex composition of the Chinook run may also affect 0+ Chinook production.

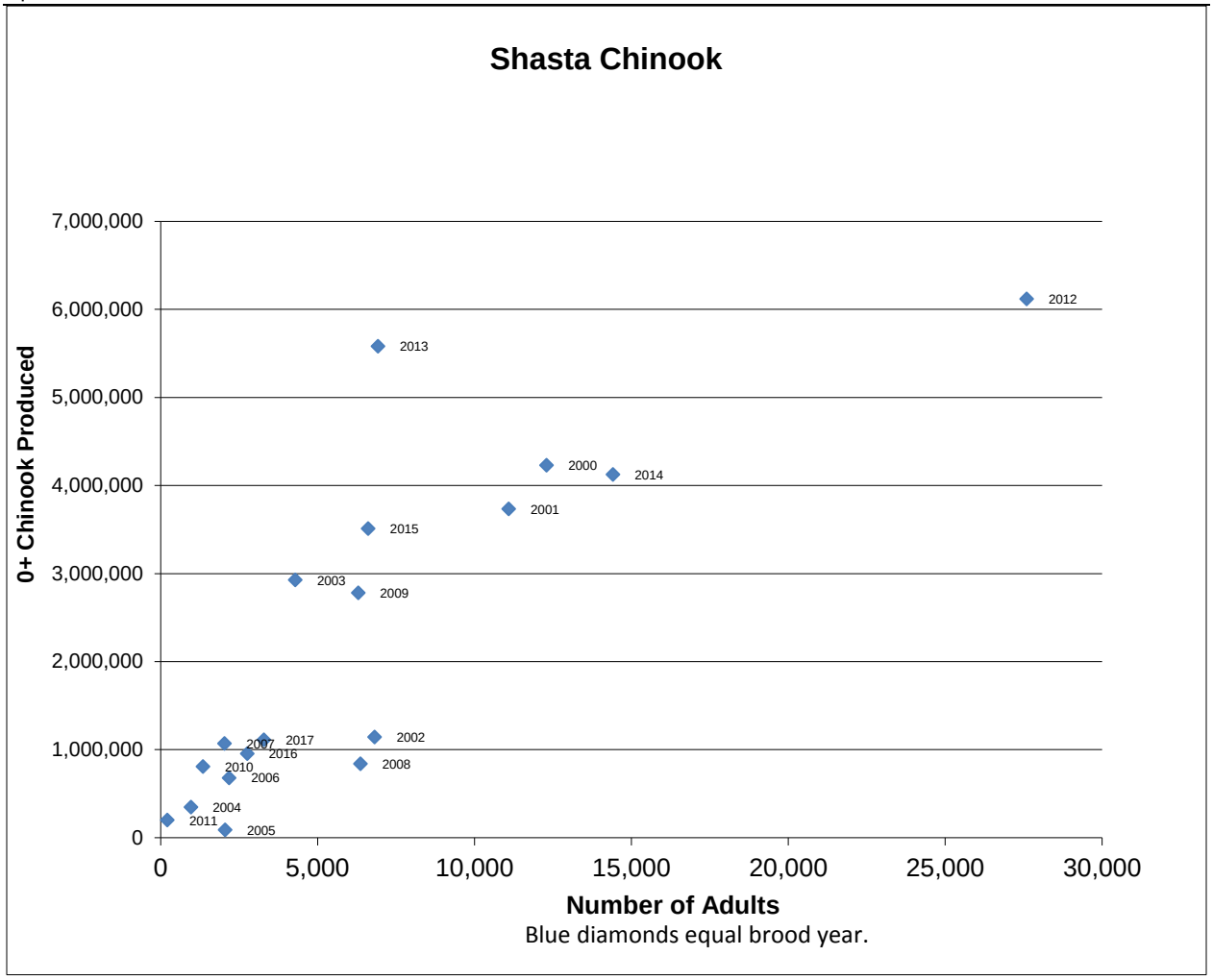

Figure 13: Number of 0+ Chinook produced per adult spawner in the Shasta River 2000-2017.

COHO SALMON

Coho Salmon returns to the Shasta River from 1978 to 2018 are shown in Figure 14. Sampling from 1983 to 2001 cannot be directly compared to other years, as the weir was removed before November 12th during those years and sampling does not represent the entire run of Coho. Estimates of hatchery-origin adult Coho entering the Shasta River from 2007-2018 are shown in Figures 15-17.

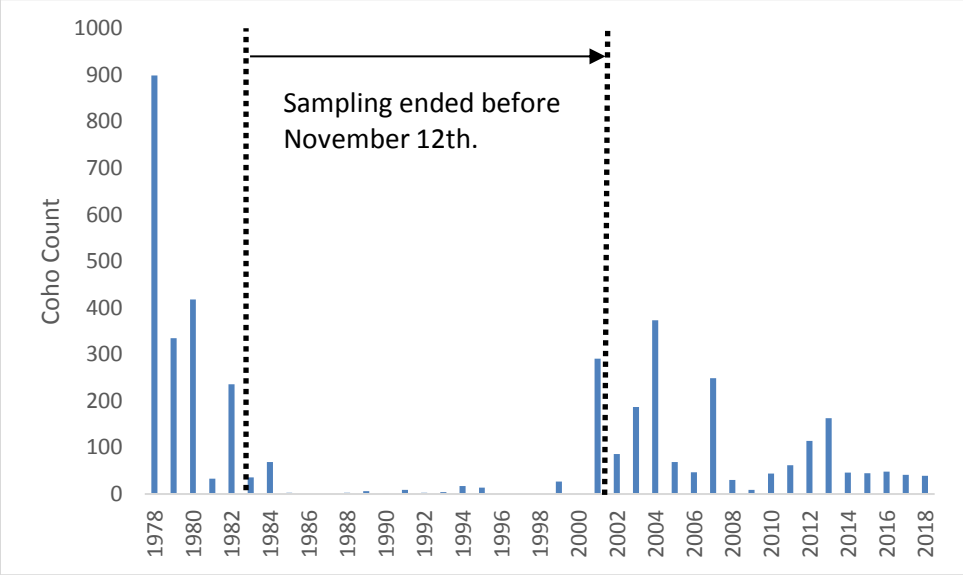

Figure 14: Shasta River Coho counts by year. In the years 1982-2001 sampling ended before November 12th and likely missed the bulk of the Coho population.

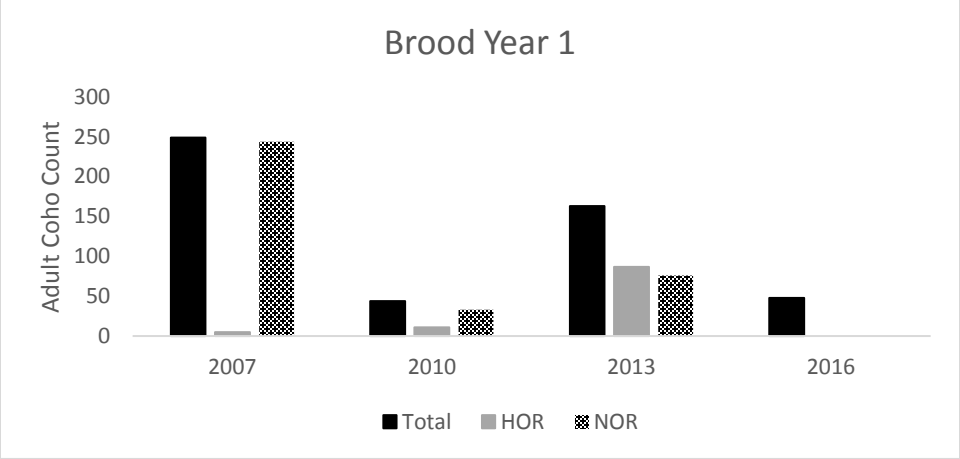

Figure 15: Brood cycle 1 comparison of natural origin (NOR) and hatchery origin (HOR) adult Coho returning to the Shasta River. Hatchery contribution not calculated for 2016 due to no carcass recoveries.

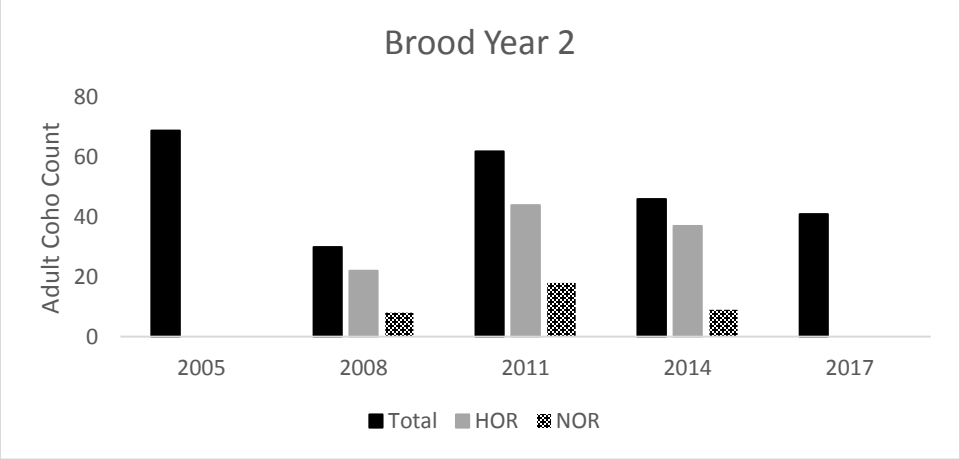

Figure 16: Brood cycle 2 comparison of natural origin (NOR) and hatchery origin (HOR) adult Coho returning to the Shasta River. Hatchery contribution not calculated for 2005 because there is no data available on hatchery composition and for 2017 due to no carcass recoveries.

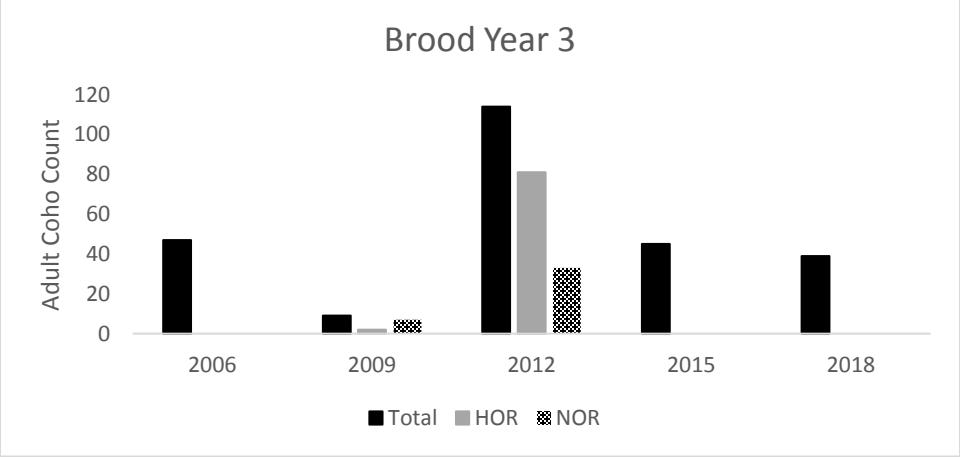

Figure 17: Brood cycle 3 comparison of natural origin (NOR) and hatchery origin (HOR) adult Coho returning to the Shasta River. Hatchery contribution not calculated for 2006 because there is no data available on hatchery composition and for 2015 and 2018 due to no carcass recoveries.

The decline of Coho Salmon populations in the Klamath Basin, and the Shasta River in particular, has led to much discussion on the cost and benefits of different recovery strategies. The Hatchery Genetic Management Plan (HGMP) recently adopted for IGH identifies the IGH Coho program as an integrated recovery program. This type of program is designed to aid in the recovery and conservation of a natural population, and the fish produced are intended to spawn in the wild or be genetically integrated with the targeted natural population (HGMP, 2013). The consensus among salmon geneticists involved in Shasta River Coho management is that risk of extinction (due to inbreeding and difficulty finding mates) outweigh any negative effects of IGH fish straying and spawning in the Shasta River. Research by Galbreath et al. (2014) indicates that domestication effects carried by hatchery-origin Coho that spawn in natural areas are moderated within as few as two generations by selection pressures encountered in the natural environment. Improved, genetically-based brood stock management practices at IGH are intended to increase the genetic diversity and fitness of IGH Coho and their progeny, so that when IGH fish stray into the Shasta River, it will benefit the Shasta River Coho population and its recovery.

In 2015-2018, no Coho Salmon carcasses were recovered in the spawning ground survey or as weir washbacks, and definitive presence or absence of a left maxillary clip could not be determined from video footage, so estimates of hatchery origin and natural origin Coho were not made (Table 7). Increased straying of adult IGH Coho due to releases from IGH, as well as hatchery juveniles entering the Shasta River during their downstream migration (Bill Chesney, pers comm) and possibly imprinting on Shasta River water, have been observed in recent years.

Table 7: Estimates of hatchery strays as percentage of Coho entering the Shasta River, 2007-2018

Year	Total # of Coho	Hatchery Stray Estimate	% Hatchery
2007	249	5	2%
2008	30	22	73%
2009	9	2	22%
2010*	44	11	25%
2011*	62	44	71%
2012*	114	81	71%
2013*	163	87	53%
2014*	46	37	80%
2015*	45	NA	NA
2016*	48	NA	NA
2017*	41	NA	NA
2018*	39	NA	NA
Average			50%
* in 2010-2018, surplus adult Coho were PIT tagged and released after entering Iron Gate Hatchery.			
Hatchery composition was not estimated for 2015-2018 as no Coho carcasses were recovered.			

Ongoing rotary trap operations at the mouth of the Shasta River (Massie et al. 2018) have resulted in reports documenting annual smolt point estimates, which, along with annual adult escapement estimates, can provide a means of estimating the survival of Shasta River Coho Salmon from outmigration to adult escapement (Table 8). These relationships are complicated by the difficulty of adequately estimating the contribution of hatchery-origin spawners, estimating age structure, as well as the challenges of producing population estimates at extreme low abundance. The brood year 2009 group shows a percent smolt survival of 287.5%. It may be that the 2012 adult return of Coho included fish that were not of Shasta River origin yet were not identified as strays. The smolts observed in 2011 were the product of a very low adult return of 9 Coho (7 after adjusted for hatchery contribution) in 2009, and although trapping effort and efficiency were normal in 2011 only 8 Coho smolts were estimated to have left the Shasta River that year during the rotary trapping season (Debrick et al. 2015).

Analyzing the comparisons of estimated adult Coho Salmon returns to yearling Coho production estimates (Debrick et al. 2015) also produces freshwater survival estimates in the form of yearling Coho produced per adult return. The number of yearling Coho produced per returning adult has averaged 18.2 and ranged from a low of 2.1 to a high of 46.6 for brood years 2001-2016 (Table 9). As the number of yearlings produced per returning adult increases, it can be inferred that in-river conditions for Coho are improving. Conversely, as the number of yearlings produced per returning adult decreases it can be inferred that in river conditions for Coho are getting worse. Production is subject to variability in sex ratios of returning adults, as well as depensation effects that can occur at low population sizes. Refinements to these estimates will continue to be made in future years.

Table 8: Shasta River natural origin Coho smolt and adult abundance, production and survival.

Brood Year	Smolt Year	NOR Smolt Point Estimate	Age 2 Return Year	Age 3 Return Year	Age 2 return	Age 3 return	Age 2&3 return	Percent smolt survival
2001	2003	12735	2003	2004		373	373	2.93%
2002	2004	2090	2004	2005		69	69	3.30%
2003	2005	2554	2005	2006		47	47	1.84%
2004	2006	11077	2006	2007		244	244	2.20%
2005	2007	1374	2007	2008		8	8	0.58%
2006	2008	208	2008	2009		7	7	3.37%
2007	2009	6295	2009	2010		33	33	0.52%
2008	2010	215	2010	2011		17	17	7.91%
2009**	2011	9	2011	2012	1	22	23	255.56%
2010	2012	2049	2012	2013	11	61	72	3.51%
2011	2013	586	2013	2014	1	1	2	0.34%
2012	2014	991	2014	2015	8	37	45	4.54%
2013	2015	7326	2015	2016	2	46	48	0.66%
2014	2016	268	2016	2017	2	38	40	14.93%
2015**	2017	33	2017	2018	3	36	39	118.18%
2016	2018	4236	2018	2019	3		3	0.07%
2017	2019		2019	2020			0	NA

* Grilse information not available for 2001-2010

** BY 2009 & 2015: Inherent error in this years data may be due to underestimating juvenile fish or overestimation or age structure classification of adult coho.

Table 9: Adult Coho estimates, yearling Coho production point estimates and ratio of yearling Coho produced per adult from 2001-2018

Adult Brood Year	Adult Estimate	Yearling Year	NOR Yearling Point Estimate	Yearlings Produced Per Adult
2001	291	2003	11052	38.0
2002	86	2004	1799	20.9
2003	187	2005	2054	11.0
2004	373	2006	10833	29.0
2005	69	2007	1178	17.1
2006	47	2008	208	4.4
2007	249	2009	5396	21.7
2008	30	2010	169	5.6
2009	9	2011	19	2.1
2010	44	2012	2049	46.6
2011	62	2013	494	8.0
2012	114	2014	850	7.5
2013	163	2015	6279	38.5
2014	46	2016	229	5.0
2015	45	2017	28	0.6
2016	48	2018	3697	77.0
2017	41	2019	NA	NA
2018	39	2020	NA	NA
Average				20.8

STEELHEAD TROUT

The objectives of the KRP have traditionally focused on monitoring the escapement of Chinook Salmon, and more recently Coho Salmon. In recent years, efforts have been made to extend the monitoring time frame to generate an estimate of adult steelhead returning to the Shasta River. In 2018 the video monitoring station was run until January 8 2019. Steelhead trout escapement has proven challenging due to run timing (steelhead migration is usually underway when flow conditions make weir removal necessary) and life history, as individual steelhead are often observed to move repeatedly through the video flume in upstream and downstream directions. A net total of 392 steelhead swam upstream past the Shasta video site. Returns of adult steelhead trout to the Shasta River from 2005 to 2018 are shown in Figure 18.

Declines of steelhead trout throughout California have been documented in recent decades and have been mainly attributed to habitat degradation. In the Shasta River, construction of the Dwinnell Dam in 1928 at River Mile 40 has blocked access to over 18 miles of high quality steelhead habitat since that time. The dam, along with other downstream diversions, has changed the Shasta River hydrograph and has contributed to an increase in summer water temperatures, limiting the availability of high quality habitat for steelhead (Moyle et al. 2008). As with Coho Salmon, another species with an extended fresh water period in its life history, steelhead have been impacted by the recent, severe California multi-year drought. Ongoing land and water management projects in the upper Shasta River, targeted for the recovery of Coho Salmon, will undoubtedly benefit steelhead as well.

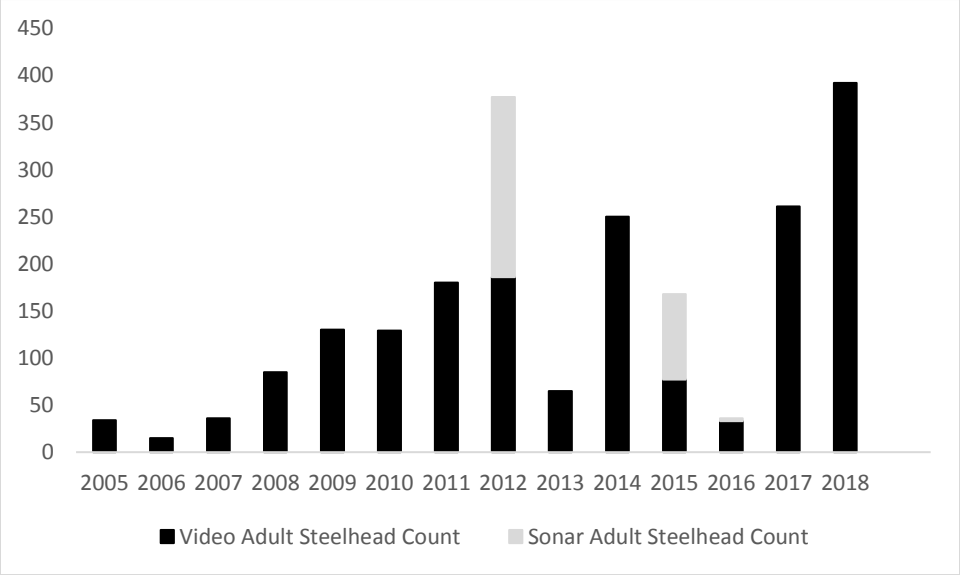

Figure 18: Adult Steelhead Returning to the Shasta River, 2005-2018

ACKNOWLEDGMENTS

KRP staff would like to thank Shasta River landowners for their cooperation in granting access to their properties. We would also like to thank KRP crew members as well as AmeriCorps Watershed Stewards members for their exemplary teamwork and diligence in collecting data under challenging conditions. The KRP would also like to extend their gratitude to the Yreka Fisheries Program for sharing the rotary trapping data.

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