Shasta River
Chinook and Coho Salmon Observations in 2016
Siskiyou County, CA

Photo by Martin Anderson

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Shasta River Fish Counting Facility, Chinook and Coho Salmon Observations in 2016 Siskiyou County, CA

ABSTRACT

A total of **2,889** fall run Chinook Salmon (Chinook, *Oncorhynchus tshawytscha*) were estimated to have entered the Shasta River during the 2016 spawning season. An underwater video camera was operated in the flume of the Shasta River Fish Counting Facility (SRFCF) twenty four hours a day, seven days a week, from September 6, 2016 until December 13, 2016. The first Chinook was observed on September 7, 2016 and the last Chinook on December 4, 2016. KRP staff also processed a total of 37 Chinook carcasses during spawning ground surveys, and 15 Chinook carcasses as wash backs against the SRFCF weir (a systematic 1:10 sample until 11/7/16, then a systematic 1:2 sample for the remainder of the season). The remaining 75 weir wash back Chinook carcasses were examined, chopped and counted but not processed unless they were AD.

Chinook carcasses sampled in the spawning ground surveys were used to describe characteristics of the run. Carcasses ranged in fork length (FL) from 60 cm. to 96 cm. and grilse were determined to be < 59 cm. in FL. Males ranged in FL from 60 cm. to 96 cm. and averaged 77.5 cm. Females ranged in FL from 60 cm. to 85 cm. and averaged 72.8 cm. The run was comprised of 135 grilse (4.7%), and 2,754 adults (95.3%). The sex composition of the run, based on 37 fish sampled, was 46% (1,329) female and 54% (1,560) male. A total of 1 AD (AD) Chinook was recovered in the weir wash back sample. The AD carcass contained a coded wire tag (CWT) which identified it as a 4 year old fish from Iron Gate Hatchery (IGH). Hatchery composition was estimated using expansion of the known CWT and carcasses handled during the spawning ground surveys and weir wash backs. In 2016, 127 carcasses were examined. Using a sample expansion (the inverse of the number of carcasses examined (127 divided by the video estimate, 2,889) yields a hatchery composition of 91 Chinook (4.4%).

A net total of 48 Coho Salmon (Coho, *Oncorhynchus kisutch*) were estimated to have entered the Shasta River prior to removal of the weir on December 13, 2016. The first Coho of the season was observed swimming upstream through the SRFCF on November 9, 2016 and the last Coho was observed swimming upstream through the SRFCF on December 13, 2016. None of the 6 Coho which were PIT tagged and released from IGH were detected at antenna arrays located at the SRFCF or other points upstream in 2016. 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 2016 Shasta River Coho run.

A net total of 33 adult steelhead trout **(***Oncorhynchus mykiss)* were observed passing through the SRFCF during the 2016 season, prior to the removal of the SRFCF on December 13, 2016. An additional net total of three adult steelhead were detecting using an ARIS sonar unit between December 19, 2016 and May 5, 2017 for a net total of 35 steelhead known to have remained in the Shasta River.

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 and Coho Salmon 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). 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 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 run into the Shasta River. In addition, the KRP has operated an ARIS sonar fish counting system at the SRFCF following the removal of the video weir and though March of 2017. This report describes the characteristics of the Chinook, Coho and steelhead salmon runs that entered the Shasta River during the 2016-2017 season.

METHODS

Monitoring of the salmon run within the Shasta River during the 2016 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 (wash backs), and completion of spawning ground surveys upstream of the weir to obtain biological data from salmon carcasses.

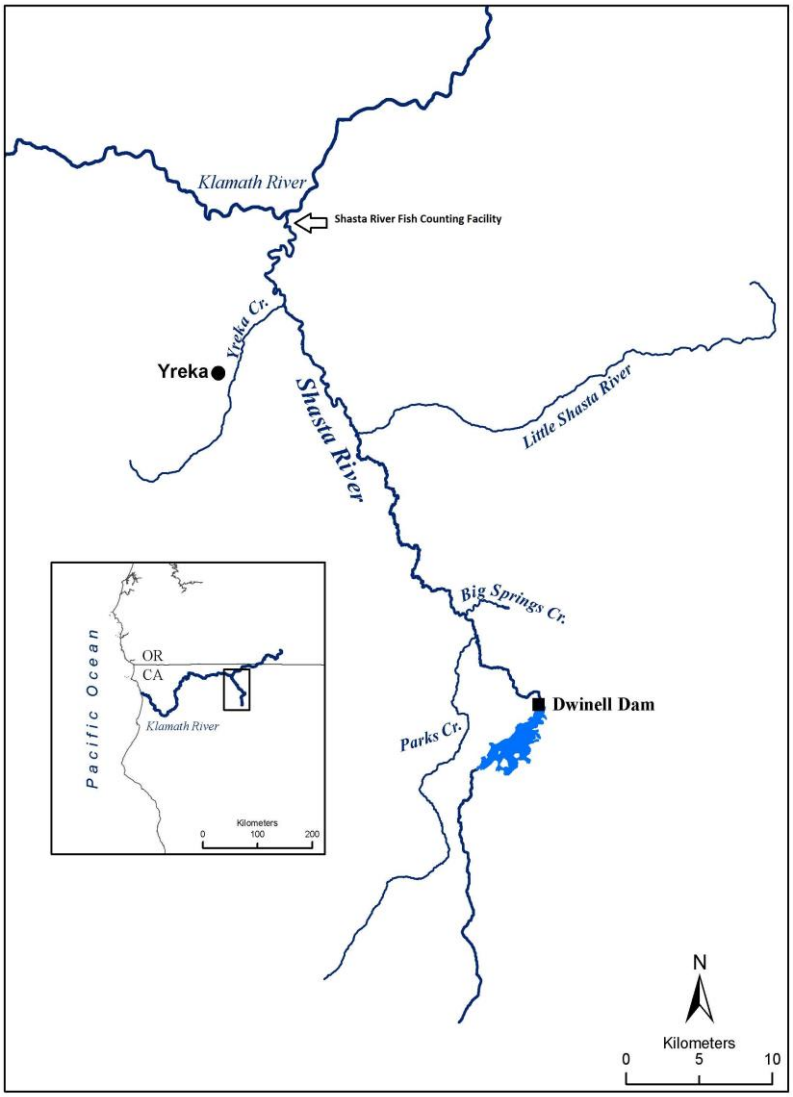

Figure 1. The Shasta River Watershed and location of Shasta River Fish Counting Facility (SRFCF).

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 2). 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 2016 for capturing images, and an ECOR 264 digital video recorder (DVR) with a swappable hard drive were used for recording[1].

Figure 2. Alaska-style panels of the Shasta River Fish Counting Facility (SRFCF)

The weir and video camera were installed and recording began on September 6, 2016. 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 wash-back 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 personal 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 6, 2016 at 11:53 hours, Pacific Standard Time (P.S.T.). The first Chinook of the season was observed on September

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

7, 2016 and the last Chinook was observed on December 4, 2016. The weir and recording equipment were removed on December 13, 2016 due to projected high flows. An ARIS sonar unit was installed at the SRFCF on December 19, 2016 and recorded, with intermittent power outages, until May 5, 2017.

WASHBACK CARCASSES

All salmon carcasses that drifted downstream and became impinged on the weir panels were recovered. A systematic sample of one in ten Chinook carcasses (from September 6 through November 7, 2016) and a one in two systematic sample (from November 7 to December 13, 2016) were processed. The sampling rate was changed due to a scarcity of wash back carcasses. Data collected on these systematically sampled wash back 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 un-spawned (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 and steelhead carcasses were processed. Heads were collected from each AD fish for later coded wire tag (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

Spawning ground surveys were conducted between October 12, 2016 and December 21, 2016. 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. 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.

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 wash backs. 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.

Table 1. Description of Shasta River Spawning Ground Survey Reaches, 2016.

	Reach Number	Downstream end	Upstream end	Approximate Length Miles	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	Shelley Bridge (canoe reach)	0.37	0.59
Shasta River	20	Confluence with Big Springs Creek	Confluence with 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 Rd. crossing	1.89	3.04

GRILSE CUT-OFF

Due to the absence of grilse and small sample size in the spawning ground survey (N=37), and a wash back sample that has consistently been biased toward males (average 81% in the past 11 seasons), the grilse cut-off and subsequent grilse/adult proportions were derived using the following equations. This method was used for the 2006 and 2010 Shasta runs, for which the wash back and SGS samples were also felt to be biased. The proportion of males among adults P(M/A) was estimated using the carcass survey data. There were 20 males out of 37 samples, (.54), and no grilse were recovered in the SGS sample. The proportion of grilse (jacks) among males, P(J/M) was derived from the wash back sample, 1 jack out of 12 males (.083333).

1. Estimate the proportion of males P(M) in the run:

$$P(M) = \frac{P(M/A)}{1-P(J/M)\ [1-P(M/A)]} = \frac{0.54}{1-0.083333\ [\ 1-\ 0.54]} = 0.5615$$

Based on the following relationship:

$$P(M/A) = \frac{P(M/A)}{P(A)} = \frac{P(M)-P(J)}{1-P(J)} = \frac{P(M)-P(J/M)P(M)}{1-P(J/M)P(M)}$$

1. Estimate the proportion of jacks in the run:

   P(J)=P(M) x P(J/M) = (0.5615)(0.083333)= 0.046792

2. Estimate the jack run (J):

   J= N x P(J)= 2,889 x .046792= 135.18

3. Estimate the adult run (A):

   A=N-J= 2,889-135= 2,754

   N=A + J= 2,754 +135= 2,889

Using this method, the Department estimates that the Chinook Salmon run in the Shasta River during 2016 was comprised of 135 (4.7%) grilse and 2,753 (95.3%) adults for a total run size of **2,889** Chinook Salmon. Estimates of the age composition of the adult component of the 2016 runt to the Shasta River were made by the Klamath River Technical Advisory Team (KRTAT,

2017) using scale age analysis conducted by the Yurok Tribe and U.S. Fish and Wildlife Service (Table 2).

Table 2. Age composition of the Chinook Salmon run to the Shasta River, 2002-2016.

	Age 2	Age 3	Age 4	Age 5	Total Adults	Total Run
2002	386	4,286	2,088	58	6,432	6,818
2003	155	2,798	1,325	11	4,134	4,289
2004	129	184	484	166	834	963
2005	37	1,361	579	79	2,018	2,055
2006	1,395	151	625	13	789	2,184
2007	27	1,855	146	8	2,009	2,036
2008	3,621	1,222	1,456	63	2,741	6,362
2009	151	5,587	315	243	6,145	6,296
2010	87	240	1,021	0	1,261	1,348
2011	11,175	23	190	0	213	11,388
2012	1,944	27,598	2	0	27,600	29,544
2013	1,096	3,896	3,029	0	6,925	8,021
2014	3,945	4,064	10,265	83	14,412	18,357
2015	133	5,752	658	202	6,612	6,745
2016	135	536	2,218	0	2,754	2,889
Average	**1,628**	**3,970**	**1,627**	**62**	**5,866**	**7,286**

RESULTS

CHINOOK SALMON

A net total of 2,889 Chinook were counted passing through the SRFCF during the 2016 season. This number was derived by subtracting the number of downstream observations (24) from the number of upstream observations (2,913). The majority of the run (54%) was observed between September 26, 2016 and October 6, 2016, and the peak day of the run was October 1, 2016 with 185 (6%) Chinook observed (Figure 3). Consistent with previous years' monitoring efforts, the majority of Chinook (92%) passed upstream through the SRFCF during daylight hours between 06:00 and 17:00 hours (Figure 4).

A total of 665 Chinook (23.0% of the run) were recorded as having one live lamprey observed attached to their bodies and 114 Chinook (3.9%) were recorded as having 2 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.

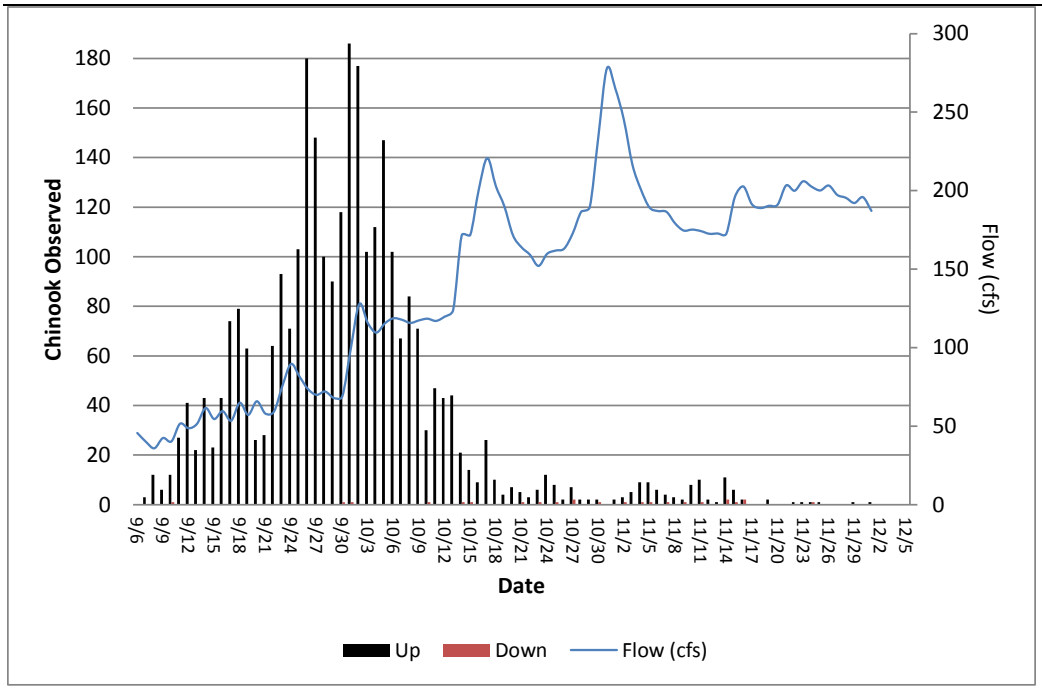

Figure 3. Chinook Salmon observed migrating through the Shasta River Fish Counting Facility, 2016 by date, and flows at nearby USGS gauge 11517500.

A net total of 6 AD Chinook 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 wash back sample and not on video observations. In 2016, the head from one AD Chinook was recovered as a wash back on the weir. The head from this one fish contained a coded wire tag (CWT) which showed it was a 4 year old fish from Iron Gate Hatchery, released as a fingerling.

An estimate of total hatchery contribution was derived based on multiplying the recovered tag by a sample expansion factor of 22.74 (video count/ number of carcasses examined in spawning ground surveys and weir wash backs). Using this method a total of 91 hatchery origin Chinook, or 3.1% of the total run, were estimated to have entered the Shasta River during the 2016 run (Table 3).

Table 3. Estimated contribution of 1 known coded wire tag (CWT) code recovered in the Shasta River during the 2016 season.

2016 Shasta River hatchery composition estimate using one weir wash back carcass with known CWT									
Coded Wire Tag	Location	Release Type a/	Brood Year	Age	Sample Number	Production Multiplier b/	Production Estimate	Sample Expansion c/	Total Estimate
068798	IGH	F	2012	4	1	4.01	4	22.74	91
				Sub Total=	1			Sub Total=	91
							Total Estimated Hatchery Contribution=		**91**
a/ Release type; F=Fall fingerling, Y=Fall Yearling									
b/ Production Multiplier value is the inverse of the proportion of effectivily tagged and total release from IGH									
c/ Sample expansion is the inverse of the number samples sampled in spawning ground surveys and weir wash backs (N=149) divided by the video estimate (N=2,889)									

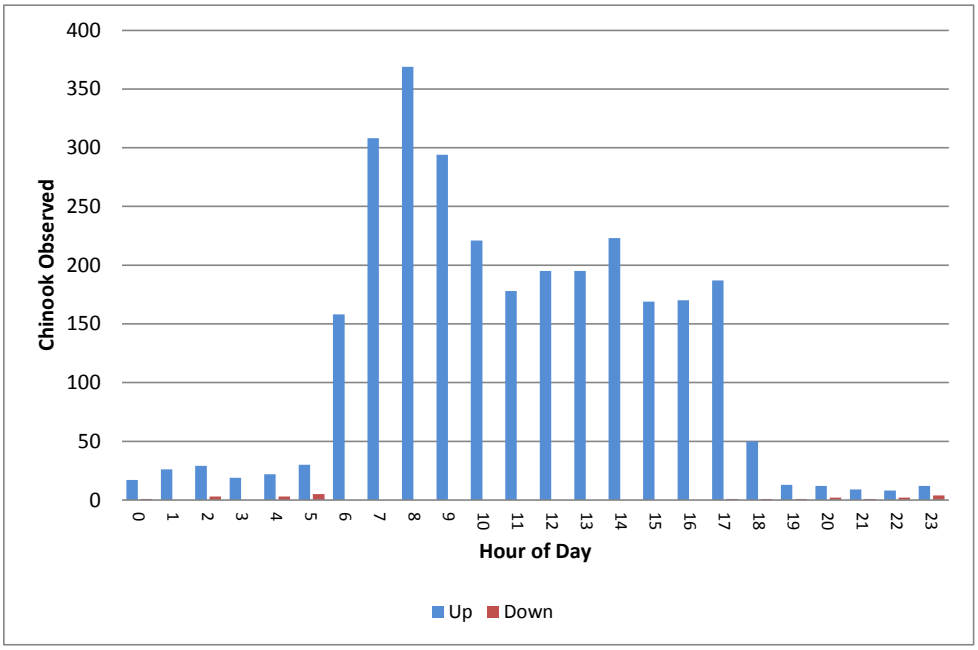

Figure 4. 2016 Shasta River Chinook observed by hour of day.

SPAWNING GROUND SURVEYS

A total of 37 Chinook carcasses were observed and sampled during spawning ground surveys, of which 17 (46%) were female and 20 (54%) were male. Of the 17 female carcasses examined, 12 (71%) were determined to have spawned successfully (zero or few eggs observed) and 5 (29%) died without having spawned successfully (many eggs observed). Fork lengths of the recovered female and male carcasses are shown in Figures 5 and 6.

A total of 181 redds were observed during spawning ground surveys in 2016. 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 181 redds observed, 124 (69%) were observed in the canyon reaches and 57 redds (31%) 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 flagged and marked with a GPS unit, and after the initial survey only new redds were identified. Species determinations of the redds were not always possible; however, one redd observed on November 29, 2016 on Parks Creek (Reach 24) was identified as a Coho redd. A live Coho was observed in the main stem Shasta River between the confluence with Parks Creek and Hole in the Ground Ranch (Reach 22) on November 29, 2016. The remaining redds and live fish were believed to be Chinook, with the exception of one fish identified as "unknown species" on Reach 22 on December 7, 2016.

WASHBACKS

A total of 90 Chinook carcasses washed back on the SRFCF weir, of which 14 were sampled systematically and one as a non-random AD fish. All 15 Chinook sampled had successful sex and fork length determinations made. Of the 15 carcasses sampled, 12 (80%) were males and 3 (20%) were females. A length frequency distribution of these samples is presented in Figure 7. As in previous years, the wash back samples collected at the SRFCF show a heavy bias toward males (Table 4).

Table 4. Sex composition of wash back carcasses sampled at Shasta River Fish Counting Facility, 2005-2016.

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
AVERAGE				81	19

HATCHERY STRAYING

Since 2002, the KRP has estimated the number of hatchery origin Chinook that may have strayed into the Shasta River. These estimates have been based on sample expansions from known tag recoveries obtained from the Shasta River, or have been based on the proportional distribution of CWT recoveries observed at IGH and applied to the number of unrecovered AD Chinook that are observed passing through the SRFCF during the season, or both. 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). The hatchery composition of the Shasta River run was 3.1% in 2016.

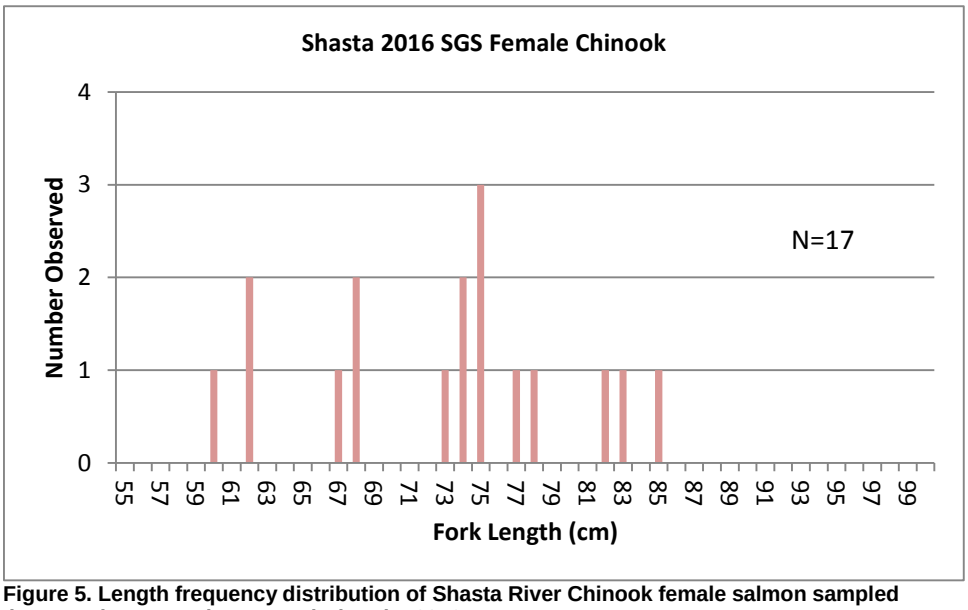

Figure 5. Length frequency distribution of Shasta River Chinook female salmon sampled in spawning ground surveys during the 2016 season.

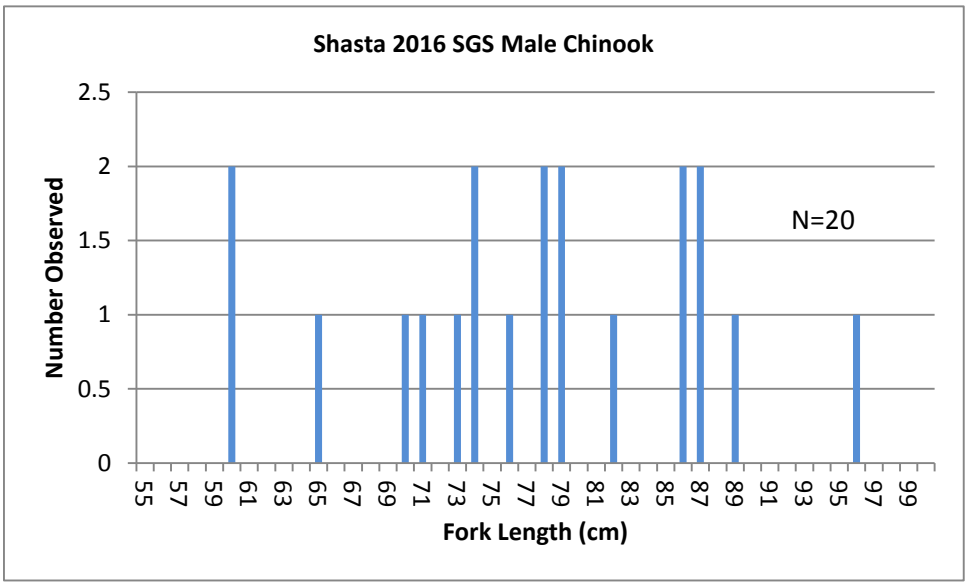

Figure 6. Length frequency distribution of Shasta River Chinook male salmon sampled in spawning ground surveys during the 2016 season.

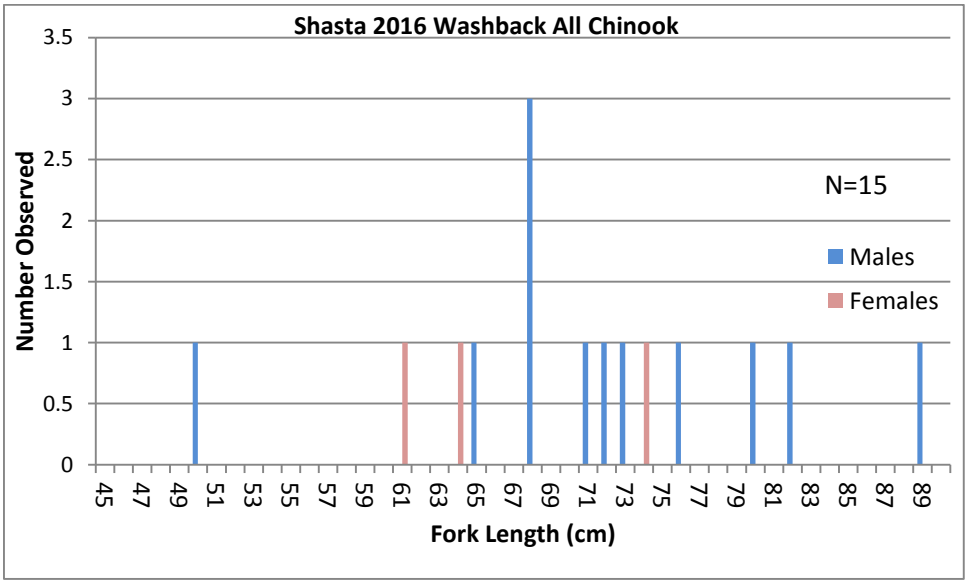

Figure 7. Length frequency distribution of Shasta River Chinook Salmon sampled as weir wash backs during the 2016 season.

Table 5. Contribution of hatchery origin Chinook straying to the Shasta River, 2002-2016.

Year	Total # Chinook	Hatchery Stray Estimate	Percent Hatchery
2002	6,818	79	1.2%
2003	4,289	436	10.2%
2004	963	372	38.6%
2005	2,055	469	22.8%
2006	2,184	105	4.8%
2007	2,036	69	3.4%
2008	6,362	56	0.9%
2009	6,296	131	2.1%
2010	1,348	157	11.6%
2011	11,388	74	0.6%
2012	29,544	126	0.4%
2013	8,021	146	1.8%
2014	18,357	735	4.0%
2015	6,745	89	1.3%
2016	2,889	91	3.1%
AVERAGE			**7.1%**

COHO SALMON

A total of 52 Coho Salmon were observed passing upstream and 4 Coho were observed passing downstream through the SRFCF from November 9, 2016 to December 13, 2016 (Figure 8). The net number of Coho known to have entered and remained in the Shasta River prior to removal of the weir was **48.** Because the weir was removed on December 13, 2016 due to a forecasted high flow event, it is likely that the video weir did not capture the entire Coho migration period.

In 2016, 6 Coho Salmon which entered IGH were tagged with Passive Integrated Transponder (PIT) tags and released from the IGH. The first fish entered the hatchery with Chinook Salmon on November 1, 2016 and was inadvertently shocked. It was deemed unlikely to survive until a spawning matrix was available, and was released. The five other fish, all males, were released on December 1, 2016 due to a lack of suitable females on the spawning matrix. None of these IGH-released Coho were detected at PIT tag antenna arrays in the Shasta River.

Historically, the proportions of hatchery-origin (HOS) and natural-origin (NOS) Coho entering the Shasta River have been estimated by applying the observed clip rates from spawning ground survey and weir wash back samples that were not PIT tagged to the unknown (video) portion of the run. However, in 2016 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 2 Coho grilse observations and 46 adult Coho observations through the video flume, which uses lines on the backdrop 56 centimeters apart to delineate grilse vs. adult salmon. Twelve observations (25%) were made of lamprey attachments on upstream migrating Coho as they passed through the SRFCF during the 2016 season.

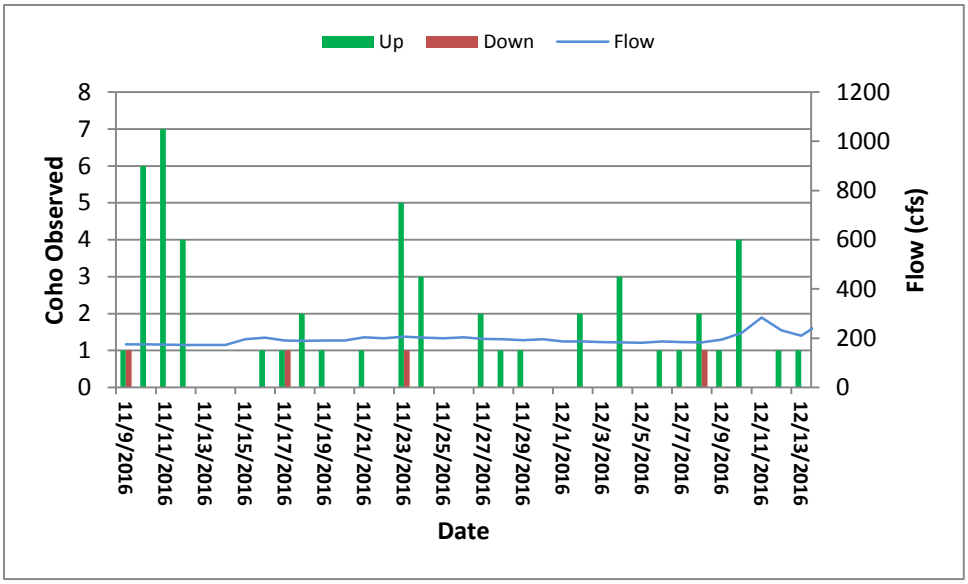

Figure 8. Coho Salmon observed by date at the Shasta River Fish Counting Facility, 2016, and flow at nearby USGS gauge 11517500.

STEELHEAD TROUT

In 2016, a net total of 33 adult steelhead were estimated to have entered and remained in the Shasta River during the video recording season from September 6, 2016 to December 13, 2016 (Figure 9). Lines on the back of the video flume were set at 16 inches (40.64 cm) apart to delineate sub-adults versus adults. An additional 3 salmonids, presumed to be adult steelhead, were detected by the ARIS sonar system on March 28, 2017, for a net total of 36 adult estimated to have entered and remained in the Shasta River during the 2016-2017 season. The ARIS sonar unit was in place until May 5, 2017

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 not counted as they passed through the video weir.

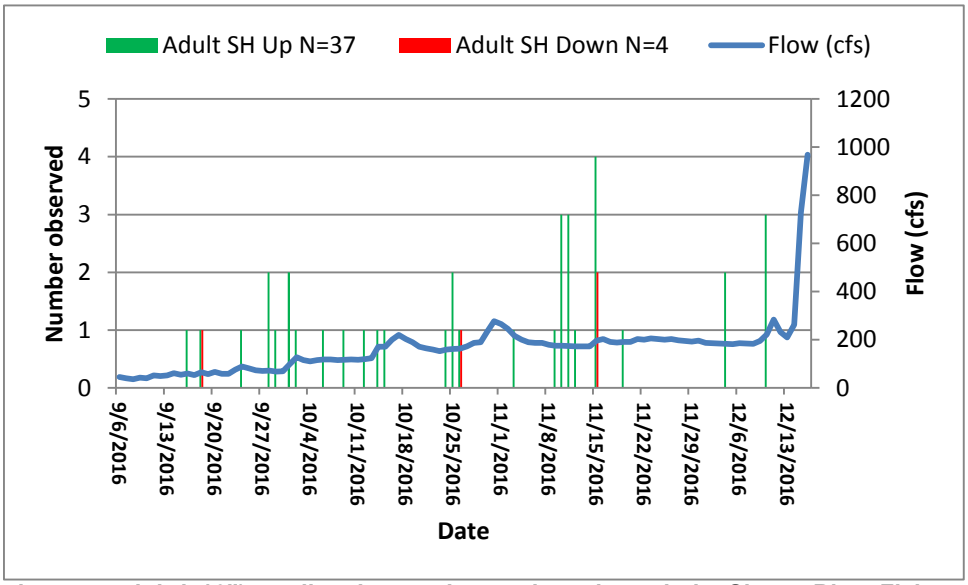

Figure 9. Adult (≥16") steelhead trout observations through the Shasta River Fish Counting Facility during the 2016 season from September 6, 2016 through December 13, 2016.

DISCUSSION

CHINOOK SALMON

The 2016 run of Chinook Salmon of 2,889 was 3,378 fish below the 39-year average of 6,267 (Figure 10). 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 46% of the 39 year average, the Shasta River exhibited a relatively stronger return of Chinook in 2016 than other upper Klamath sectors such as Bogus Creek (10.5% of average), Scott River (28.5% of average) and Iron Gate Hatchery (15.9% of average). The fall Chinook return for the entire Klamath Basin was the second lowest in 39 years of monitoring.

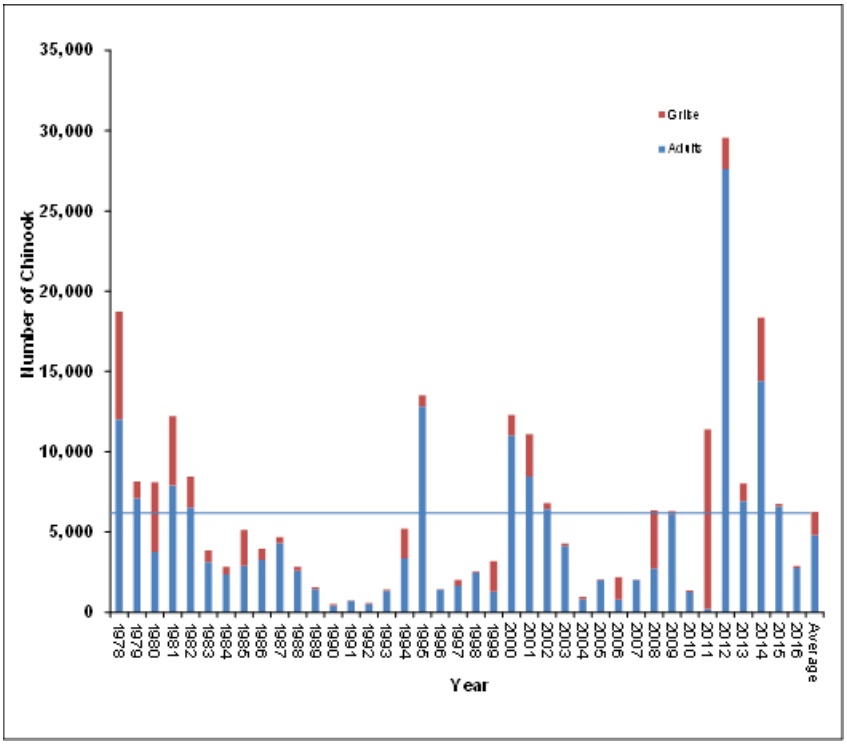

Figure 10. Adult and grilse Chinook Salmon returns to the Shasta River, 1978-2016.

The 2016-17 water year in California was one of the wettest on record, after a severe multi-year drought. Although some scouring of redds and loss of eggs may have occurred during high flows, juvenile (brood year 2016) salmonids leaving the Klamath River tributaries, including the Shasta River in 2017 will encounter flow and temperature conditions in the main stem Klamath River that are likely to minimize exposure to *Ceratonova shasta* and other pathogens. Conversely, the brood years returning to the Klamath tributaries in 2016 had been subjected to adverse river conditions during their out migration years of 2014 and 2015, critically dry years, and exposure to *Ceratonova Shasta* and *Parvicapsula minibicornis* was reported to be 81% and 91%, in sentinel fish, respectively (True et al, 2016.) Both pathogens are known sources of mortality in juvenile Chinook, Coho and Steelhead (True et al, 2016). This exposure, as well as sub-optimal ocean conditions are likely to be significant factors in the historically low returns of salmon to the Klamath basin. Returns of Chinook Salmon were lower than average along the Pacific Coast, including Alaska, indicating that warmer than average ocean conditions may be having an adverse effect on all Pacific salmon. (NOAA, 2017).

Data from brood years 2000 through 2015 indicate the Shasta river's current habitat conditions continue to produce more 0+ Chinook as more adults return, indicating that the watershed continues to have an increasing ability to produce juvenile Chinook (Figure 11) 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.

The Shasta River is an important component of the Klamath Basin Chinook run (including Trinity River) and has contributed an average of 10 percent of the basin-wide natural spawning escapement during the period from 1978 to 2016 (Table 6). 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 counted at the Shasta Racks (predecessor to the SRFCF) in 1935.

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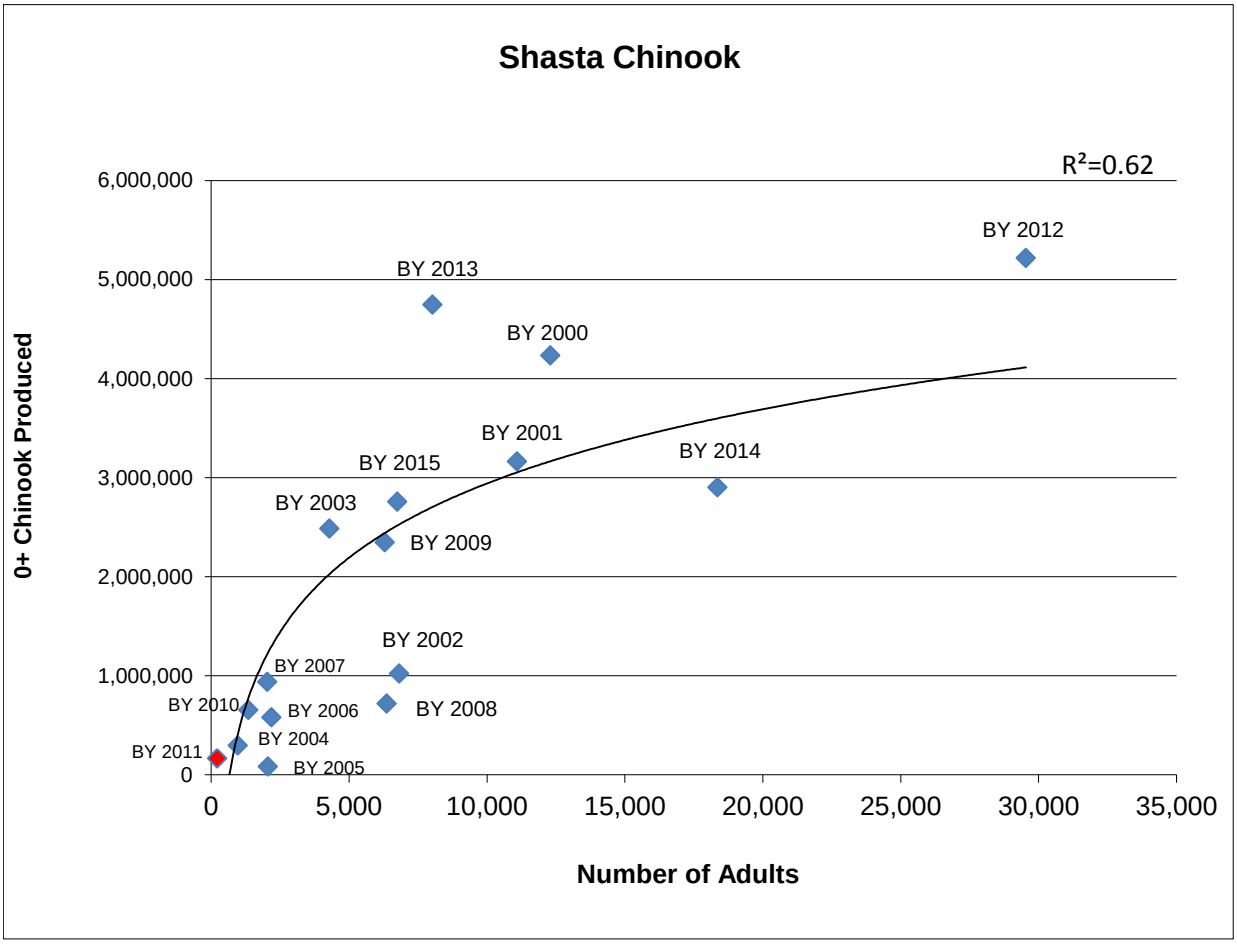

Figure 11. Number of 0+ Chinook produced per adult spawner in the Shasta River, Brood Years 2000-2016.

Because the Shasta River fall Chinook 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 1st.

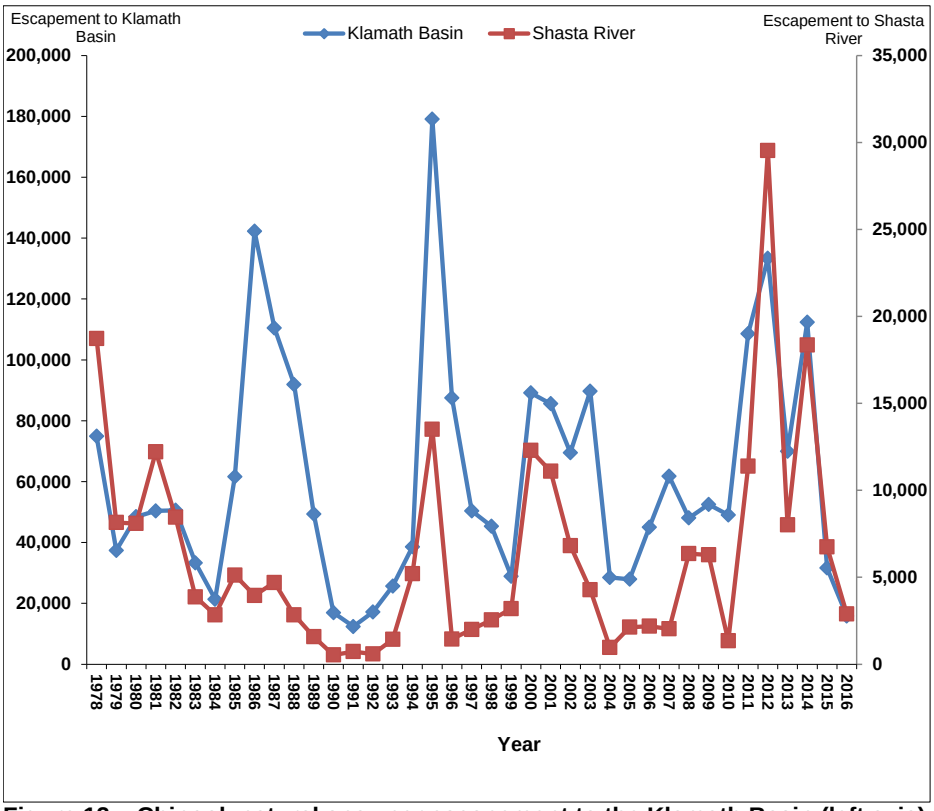

Figure 12. Chinook natural spawner escapement to the Klamath Basin (left axis) and Shasta River (right axis), 1978-2016.

Coho Salmon

Coho returns to the Shasta River from 1978 to 2016 are shown in Figure 13. Sampling from 1983 to 2000 cannot be directly compared to other years, as the weir was removed on or before November 11th during those years and sampling does not represent the entire run of Coho. Estimates of hatchery origin adult Coho Salmon entering the Shasta River from 2007-2016 are shown in Figures 14-16. In 2016, no Coho carcasses were recovered in the spawning ground survey or as weir wash backs, 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. Estimates of hatchery strays to the Shasta River from 2007 to 2014 are shown in Table 7.

Because Coho have an extended freshwater phase in their life history, the severe multi-year drought in California, with corresponding low flows and high temperatures in both

Table 6. Escapement of Chinook Salmon to the Klamath Basin and Shasta River, 1978-2016.

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%
Average	**61,347**	**6,269**	**10%**

rearing and migration habitats, undoubtedly had a devastating effect on the species in the Klamath Basin. Coho were subjected to the same exposure to pathogens in the main stem Klamath River and sub-optimal, unusually warm ocean temperatures as discussed for Chinook Salmon, and were likely to have suffered high juvenile mortality during the critically dry water years of 2014 and 2015.

The decline of Coho 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 Iron Gate Hatchery 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 during periods of extreme low abundance of Shasta River Coho the straying of IGH fish into the Shasta River will benefit the Shasta River Coho population and its recovery.

Ongoing rotary trap operations at the mouth of the Shasta River (Debrick et al, 2015) 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 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 425%. 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 (Bill Chesney, pers. comm.), only 8 Coho smolts were estimated to have left the Shasta River that year during the rotary trapping season.

Analyzing the comparisons of estimated adult Coho 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 2001-2014 (Table 9). As the number of yearlings produced per returning adult increases it can be inferred that in-river conditions for Coho Salmon are improving. Conversely, as the number of yearlings produced per returning adult decreases it can be inferred that in river conditions for Coho Salmon 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 7. Estimates of hatchery strays as percentage of Coho entering the Shasta River, 2007-2014

Year	Total # of Coho	Hatchery Stray Estimate	Percent Hatchery
2007	249	5	2%
2008	30	22	73%
2009	9	2	22%
2010*	44	11	25%
2011*	62	44	71%
2012*	115	81	70%
2013*	163	101	62%
2014*	46	37	80%
AVERAGE			**51%**

* in 2010-2016, surplus adult coho were PIT tagged and released after entering Iron Gate Hatchery. Hatchery composition was not estimated in 2015 or 2016 as no coho carcasses were recovered.

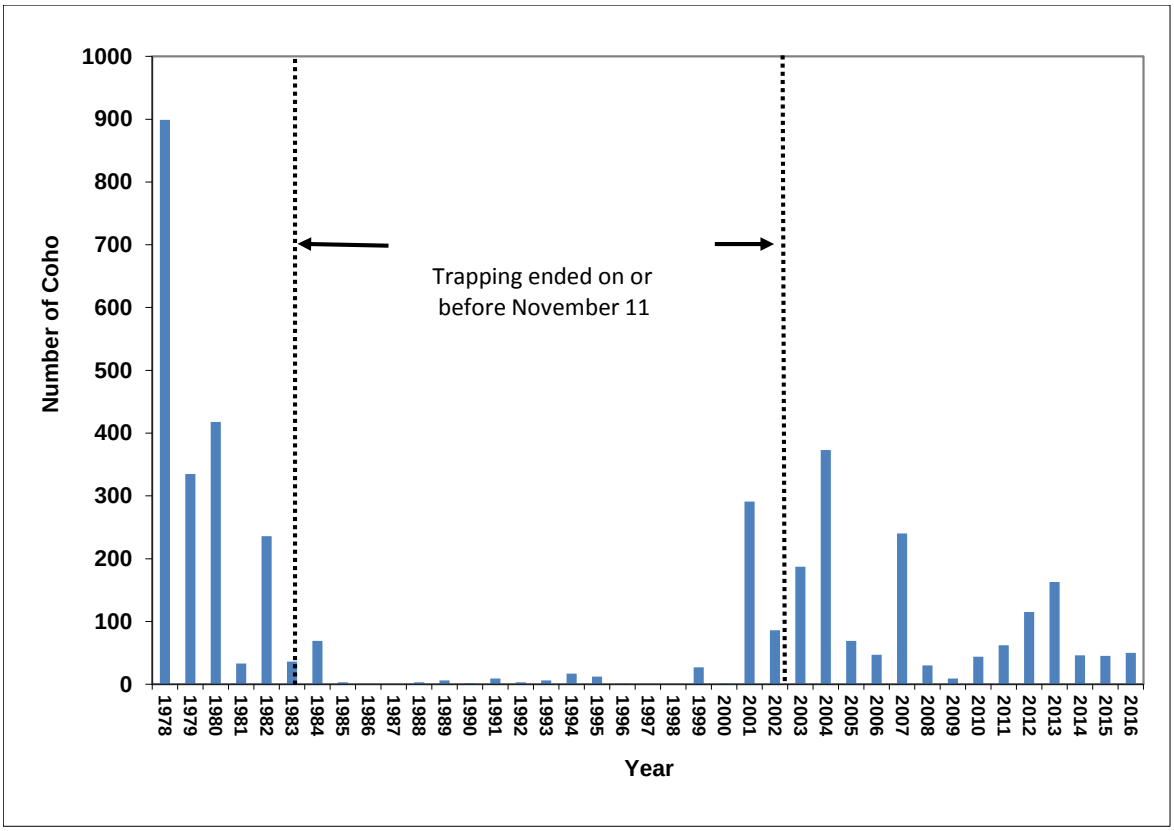

Figure 13. Returns of Coho Salmon to the Shasta River, 1978-2016. It is likely that the entire coho migration Period was not covered by the video weir, as flows often make the removal of the weir in mid to late December necessary.

Increased straying of adult IGH Coho due to releases from the IGH spawning building, 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. In 2013 through 2015, Coho tissue samples were collected at the rotary screw trap located near the SRFCF and were provided to the NOAA salmon genetics repository in Santa Cruz, Ca, where an analysis of natural versus hatchery origin composition of Shasta River Coho Salmon is currently underway.

Table 8. Coho smolt abundance point estimates, adult Coho abundance estimates, ratio of smolts to adult returns and proportion of smolts that returned as adults by brood year for the Shasta River, Brood Years 2001-2013.

Brood Year	Smolt Year	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	11052	2003	2004	*	373	373	3.37%
2002	2004	1799	2004	2005	*	69	69	3.84%
2003	2005	2054	2005	2006	*	47	47	2.29%
2004	2006	10833	2006	2007	*	244	244	2.25%
2005	2007	1178	2007	2008	*	9	9	0.76%
2006	2008	208	2008	2009	*	7	7	3.37%
2007	2009	5396	2009	2010	*	33	33	0.61%
2008	2010	169	2010	2011	6	18	24	10.65%
2009**	2011	8	2011	2012	32	34	66	425.00%
2010	2012	2049	2012	2013	1	61	62	2.98%
2011	2013	494	2013	2014	6	9	15	1.82%
2012	2014	850	2014	2015	2	37	39	4.35%
2013	2015	6279	2015	2016	2	48	50	0.76%
* grilse information not available for Return Years 2001-2010.								2.48%
** BY 2009: inherent error in this year's data may be due to underestimating juvenile fish or overestimation or age structure classification of adult Coho.								

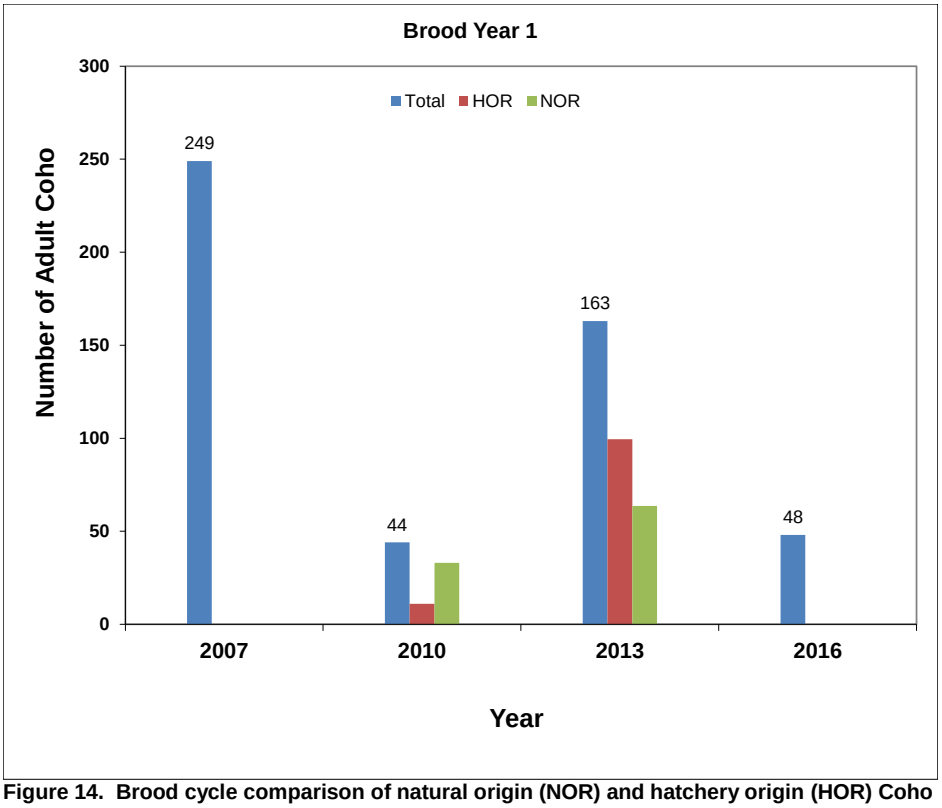

Figure 14. Brood cycle comparison of natural origin (NOR) and hatchery origin (HOR) Coho salmon returning to the Shasta River from 2007 through 2016. Due to low carcass recoveries in 2007 and 2016, hatchery contribution rates were not estimated for those years.

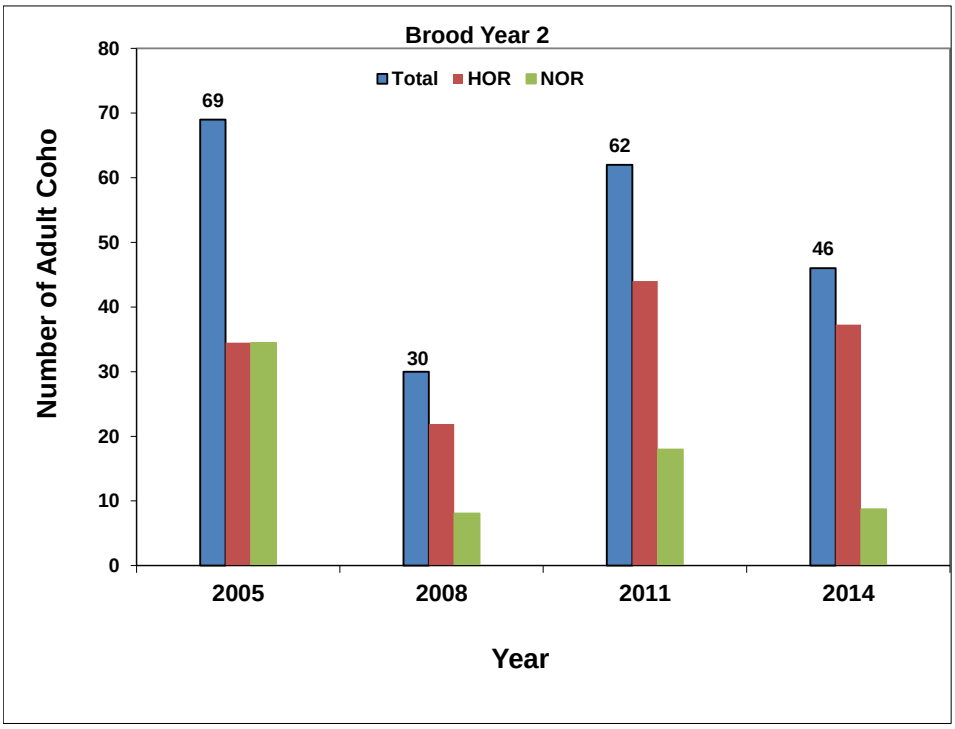

Figure 15. Brood cycle comparison of natural origin (NOR) and hatchery origin (HOR) Coho Salmon returning to the Shasta River from 2005 through 2014.

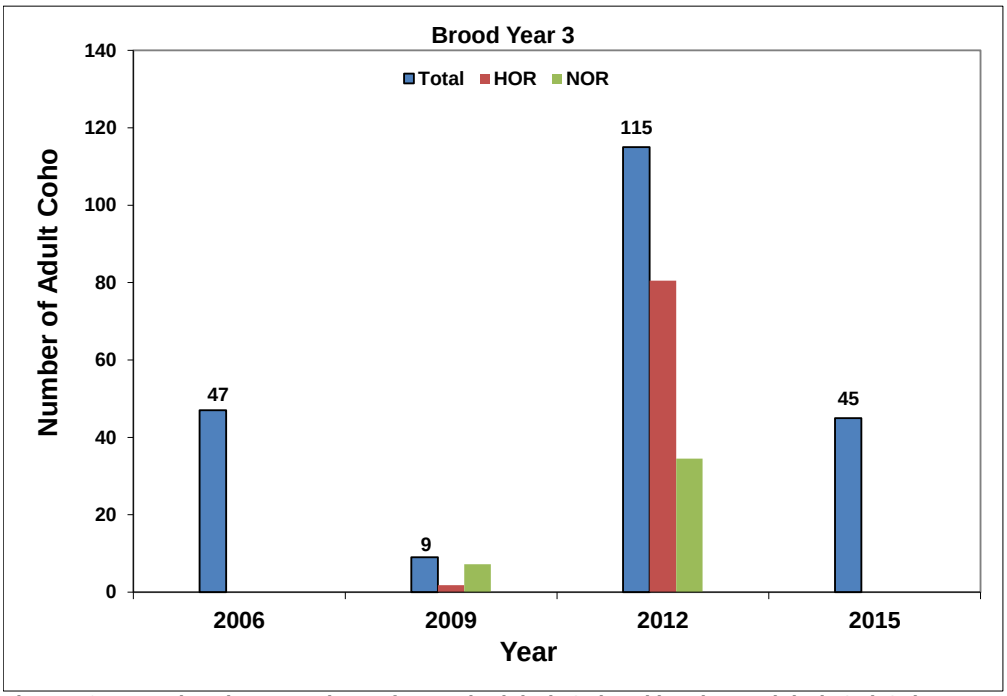

Figure 16. Brood cycle comparison of natural origin (NOR) and hatchery origin (HOR) Coho Salmon returning to the Shasta River from 2006 through 2015. Due to low carcass recovery in 2006 and 2015, hatchery contribution rate was not estimated.

Table 9. Adult Coho estimates, yearling Coho production point estimates and ratio of yearling Coho produced per adult return for the Shasta River, Brood Years 2001-2014.

Adult Year Brood Year	Adult Estimate*	Yearling year	Yearling point estimate	Yearlings produced per adult
2001	291	2003	11,052	38.0
2002	86	2004	1,799	20.9
2003	187	2005	2,054	11.0
2004	373	2006	10,833	29.0
2005	69	2007	1,178	17.1
2006	47	2008	208	4.4
2007	255	2009	5,396	21.2
2008	30	2010	169	5.6
2009	9	2011	19	2.1
2010	44	2012	2,049	46.6
2011	62	2013	494	8.0
2012	115	2014	850	7.4
2013	163	2015	6,279	38.5
2014	46	2016	229	5.0
Average				**18.2**

STEELHEAD TROUT

The objectives of the KRP have traditionally focused on monitoring the escapement of Chinook, and more recently Coho Salmon; however, the acquisition of an ARIS sonar detection system allowed the KRP to monitor the movements of salmonids entering the Shasta River beyond the removal of the weir on December 13, 2016. Estimating 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. Only 3 adult fish were observed using the ARIS unit during the 2016-17 season. Because of the low number observed, additional review of the ARIS data is underway in an effort to ascertain whether the unit functioned properly throughout the season. Returns of adult steelhead trout to the Shasta River from 2005 to 2016 are shown in Figure 17.

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.

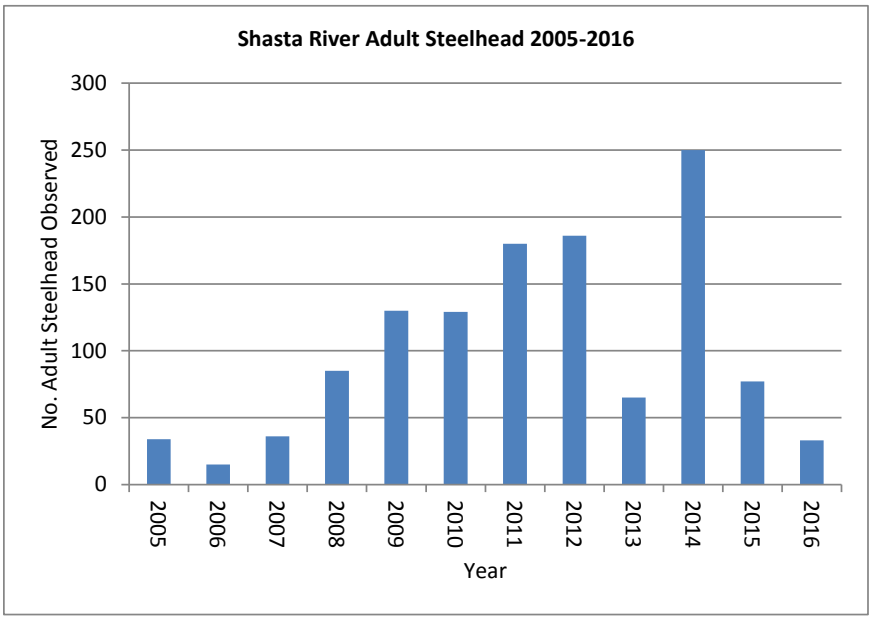

Figure 17. Returns of adult steelhead trout to the Shasta River, 2005-2016.

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 Jason Carnahan, Ken Foster, Caitlin Jetter, Barbara O'Steen, Donn Rehberg, Steel Sims, Felicia Speizer, Will Weikert and David White, as well as AmeriCorps Watershed Stewards members Martin Anderson and Leanne Cohn for their exemplary teamwork and diligence in collecting data under challenging conditions. The KRP would also like to extend their gratitude to Bill Chesney for sharing his rotary trapping data and for his unflagging dedication to the sound scientific management of California salmonids, especially in the Shasta River, throughout his 30-year career.

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