California Department of Fish and Wildlife

Klamath River Project

Recovery of Fall-run Chinook and Coho Salmon at Iron Gate Hatchery

October 10, 2016 to December 1, 2016

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ABSTRACT

A total of 2,587 fall-run Chinook Salmon, (Chinook, *Oncorhynchus tshawytscha),* entered Iron Gate Hatchery (IGH) during the fall 2016 spawning season from October 10, 2016 through November 21, 2016. Klamath River Project (KRP) staff systematically sampled 1 in every 10 Chinook, as well as all adipose-clipped (AD) Chinook during recovery efforts, for a sample size of 749. Scale samples and sex and fork length data were collected from systematically sampled Chinook. Analysis of the length-frequency distribution for systematically sampled Chinook males indicates that the cutoff point between grilse and adults occurred at <55 cm fork length (FL). Systematically sampled male Chinook ranged in size from 44 to 96 cm FL, and systematically sampled female Chinook ranged from 52 to 87 cm FL. Based on scale age analysis, the Klamath River Technical Team (KRTT) estimated that 5.8% (151) of the run were grilse. Females accounted for 47.9% (1,239) of the run while males accounted for 52.1% (1348). The 2016 Chinook return to IGH contributed roughly 9.5% to the total (Klamath basin) in-river run of 27,353 and 12.9% to the total spawner escapement of 19,948. Based on coded wire tag expansion, KRP staff estimated that 82% (2,129) of the Chinook entering IGH during the 2016 season were of hatchery origin.

A total of 86 Coho Salmon (Coho, *Oncorhynchus kisutch*) entered IGH during the 2016 spawning season. The recorded dates for the Coho run were from November 1, 2016 to December 1, 2016. KRP staff collected biological data (sex, fork length, presence of marks or clips, scale samples, and tissue samples) on every Coho that entered the hatchery as well as scales from mortalities and Coho used in spawning. Otoliths were collected from the first left maxillary-clipped Coho used in spawning or recovered as amortality on each processing day. Otoliths were collected from all unmarked Coho used for spawning or recovered as mortalities. Males ranged in size from 31 to 70 cm FL (mean FL 55 cm) and represented 70% (60) of the run, while females ranged in size from 58 to 71 cm fork length (mean FL 64 cm) and represented 30% (26) of the run. Based on the length frequency distribution of 60 male Coho, grilse were estimated to be <52 cm FL. Using this grilse cutoff, the age composition of the 2016 IGH Coho run was 35% (30) grilse and 65% (56) adult Coho. The proportion of grilse among males was 50%. Of the Coho that entered IGH during 2016, 77% (66) had left maxillary clips and 23% (20) had no clips. No AD or right maxillary clipped Coho were recovered at IGH in 2016. The 2016 Coho spawning season was the seventh in which Coho were spawned at IGH using a spawning matrix provided weekly by the National Oceanic and Atmospheric Administration.

INTRODUCTION

Iron Gate Hatchery

The Iron Gate Hatchery (IGH) is located adjacent to the Klamath River at river kilometer 306 (River Mile 190) in Siskiyou County, California, approximately 193 kilometers (120 miles) north of Redding, near the Oregon border (Figure 1). This hatchery was established in 1963 to mitigate for loss of habitat between Iron Gate Dam and Copco Dam. The production goals for the hatchery are listed in Table 1 (CDFG and PP&L IGH Goals and Constraints, 1996).

Klamath River Project

The California Department of Fish and Wildlife's (CDFW) Klamath River Project (KRP) conducts systematic sampling of fall-run Chinook Salmon (Chinook) annually during the spawning season at IGH. The purpose of the sampling is to characterize Chinook entering IGH in terms of timing, age and sex composition, and to recover data from all coded wire tags (CWT) recovered from the heads of adipose fin clipped (AD) Chinook. Approximately 25% of all Chinook at IGH are adipose fin-clipped and implanted with CWT's so they can be identified when they return to the hatchery or other locations during subsequent spawning seasons. Data from CWT fish provide a reference of known-age fish which is used, along with scale samples and analysis of length frequency distribution, to determine the age composition of the run. The CWT data are also used to evaluate Chinook release strategies, survival rates, ocean distribution and harvest as well as in-river migration timing, straying and harvest. KRP staff also sample Coho Salmon (Coho, *Oncorhynchus kisutch*) that enter IGH, typically from mid-October through December. All Coho entering IGH are sampled, and spawning protocols are employed that are in accordance with the recommendations of the Hatchery and Genetic Management Plan (HGMP) for Iron Gate Hatchery.

Coded Wire Tagging

In 2016, 25% of the brood year 2015 Chinook smolt and yearling groups were adipose-clipped and coded wire tagged prior to release. Tagging operations at IGH were conducted by staff of the Pacific States Marine Fisheries Commission with assistance from the IGH staff (Buttars, 2017).

Table 1. Production goals for anadromous salmonid releases from Iron Gate Hatchery, Klamath River.

Species	Number released	Released	Adult return timing
Chinook Salmon	5,100,000 smolts	May-June	mid-September to early November
	900,000 yearlings	November	
Coho Salmon	75,000 yearlings	March	late October to early January
Steelhead	200,000 yearlings	March-May	November to March

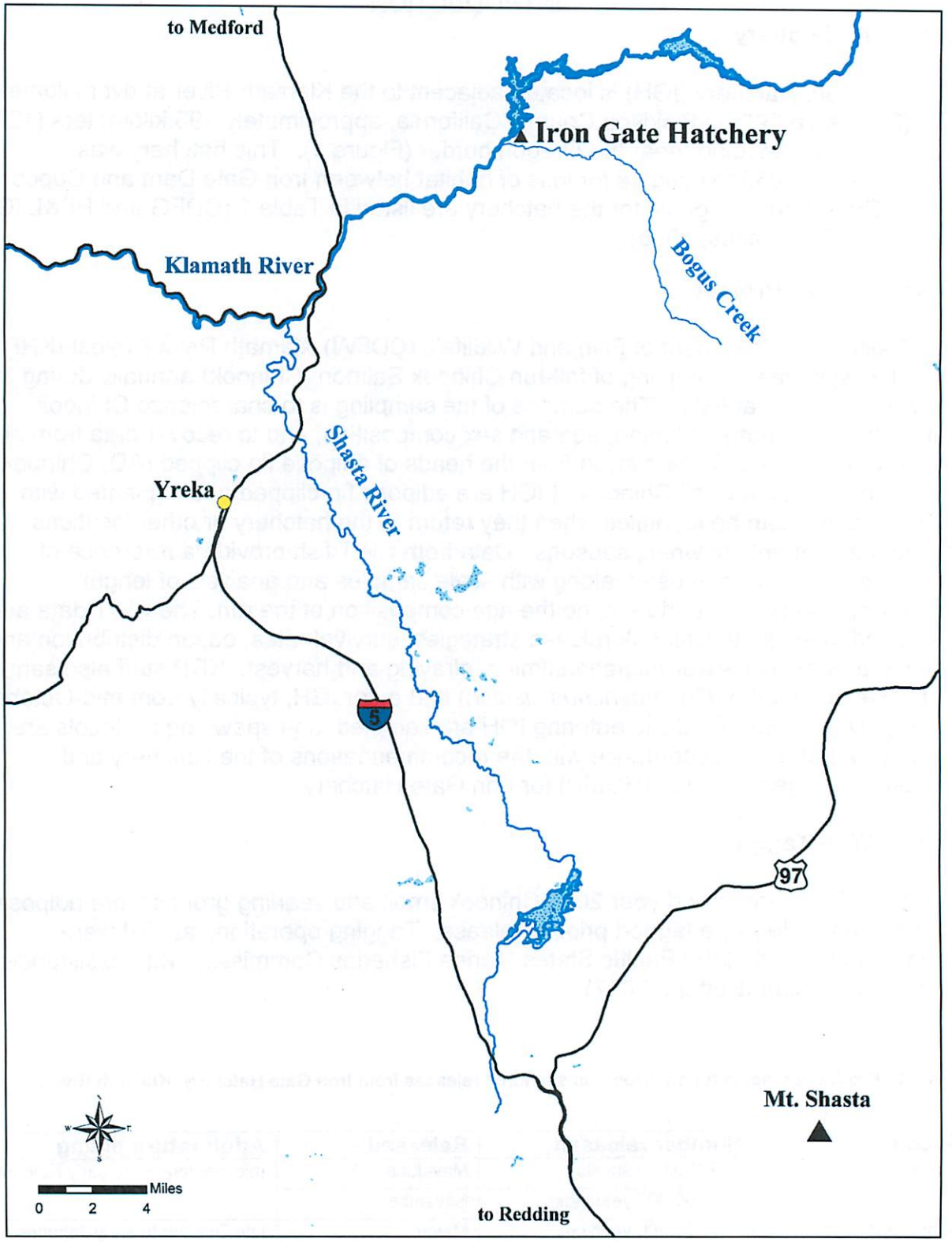

Figure 1. Location of Iron Gate Hatchery, Siskiyou County, California.

MATERIALS AND METHODS

Chinook Salmon

Starting in 1997, all Chinook entering the fish ladders have been allowed to enter IGH. Upon entering the hatchery, Chinook are sorted by IGH staff. Those selected as brood stock are spawned (if ready) or held in round tanks until they are ready to spawn. Readiness to spawn is determined by hatchery staff and based on timing, firmness of the ovaries, and ease of stripping eggs when handled. Once daily or weekly egg goals are met, extra Chinook are sacrificed and collected for off-site processing by American-Canadian fisheries for later distribution to interested individuals and organizations.

In 2016, KRP staff conducted a systematic sample of every 10th Chinook along the process line, as well as all AD Chinook. These systematic and non-systematic fish were set aside for sampling. Sampling included collection of data on fork length, sex, scale samples, presence or absence of clips and/or marks, and spawning disposition. Heads were taken from all AD Chinook (systematic and non-systematic fish). All heads were transported to the KRP's Yreka laboratory for tag extraction and reading.

Since 2015, Chinook at IGH have been spawned using a 1:1 male to female ratio. In this method, the eggs of one female Chinook and milt of one male Chinook are mixed in a pan. After fertilization, the eggs are combined with eggs of other pairs in a 5 gallon bucket along with PVP Iodophor solution for disinfection. The eggs are water hardened prior to transport to the hatchery building. The egg lots are labeled by date, and individual pairings are not tracked when measured into Heath stack incubators.

Another methodology implemented in 2015 and continued in 2016 is the air spawning of Chinook and Coho. In this method a euthanized female fish is hung from a hook and a hypodermic needle inserted into the body ½ to 1 inch deep, usually in the hollow area below a pelvic fin. Air pressure applied at 2-3 psi forces the eggs to be expelled from the body cavity through the vent. This method replaces the technique of evisceration, in which an incision is made along the ventral surface of the female salmon and the eggs manually stripped from the ovaries.

Grilse/adult and age composition determinations were made by the Klamath River Technical Team (KRTT 2017) using scale age proportions.

Systematic sampling for the presence of Ich *(Ichtyophthirius multifillis)* in IGH Chinook was conducted by KRP staff throughout the 2016 spawning season. A target of 20 adult Chinook were sampled weekly. The first gill arch from the left and right gills of systematically sampled, recently euthanized fish were removed with scissors immediately post-mortem and placed in a sealable plastic bag with a sample number. The samples were cross-referenced with data on sex, fork length, left or right gill, clip information, and general appearance of gills. Samples were then placed on ice in insulated containers and were evaluated with a stereo (dissecting) microscope upon

return to the Yreka laboratory. In addition to Ich, gills were inspected for columnaris (*Flavobacter columnare)* and copepods *(Salmincola californensis*) as well as other observed abnormalities.

Coho Salmon

As Coho entered IGH during the 2016 season, hatchery personnel netted each fish and placed it in a flume, then a processing tank, where KRP staff collected biological data including tissue samples, fork length, sex, and clip/tag information. Tissue samples were sent via overnight mail to the National Oceanic and Atmospheric Administration (NOAA) for genetic analysis and the creation of a weekly spawning matrix designed to avoid the mating of closely related fish. Coho were not anaesthetized, but kept in water throughout processing. In 2016, due to a small return, all Coho that entered IGH were retained as potential brood stock with the exception of one fish that was deemed to be in poor condition and 5 which did not have suitable mates on the spawning matrix on the final spawning day of the season. These 6 fish were PIT-tagged and released into the Klamath River at the IGH spawning building.

Those Coho retained as potential brood stock were assigned a unique number, placed in individual PVC tubes, and placed in a round tank (Figure 2) with heads oriented into the flow. As genetic information was received in the form of a spawning matrix from NOAA, fish were either used as brood stock (if suitable mates were available), held for future spawning or PIT-tagged and released. Scale samples were collected from spawned fish as well as fish that experienced pre-spawn mortality, and otoliths were collected from all unmarked Coho (spawned or pre-spawn mortalities) and also from the first left-maxillary clipped spawned Coho on each spawning day.

On subsequent spawning days, those Coho that were included in the spawning matrix were checked in their tubes for spawning readiness, and were either left in the tubes if not ready to spawn (or did not have suitable mates available), or brought into the spawning building from the round tanks, euthanized and spawned with fish chosen from the matrix. In 2016, Coho crosses consisted of two males to one female when possible, with half of each female's eggs placed in labeled containers (Figure 2) and fertilized by one male for each container and the egg lots kept separate. IGH and KRP personnel tracked the use of marked vs. unmarked individuals and the use of grilse for spawning.

Photo by Rosa Albanese
Figure 2. Coho brood stock held in individually numbered tubes pending spawning readiness and arrival of spawning matrix.

Figure 3. Eggs from one female Coho are divided in half and each half placed in its own pan. Each pan will receive milt from a different male Coho.

NOAA laboratory staff developed a spawning matrix designed to avoid the spawning of closely related individuals. The weekly matrix, sent via e-mail to the KRP and IGH, displayed a series of columns with the brood stock ID number of each female Coho at the top of a column, and beneath it, brood stock ID numbers of males in descending order of spawning suitability for that female (Table 2).

Table 2. Spawning matrix created by NOAA Salmon Genetics Repository. The suffix M refers to an adult, left maxillary clipped male, MJ a grilse, maxillary clipped male, MN an unmarked male, and MJN a grilse unmarked male. F refers to an adult, left maxillary clipped female, and FN an unmarked female. Males noted in red ink with a double asterisk denote a male which falls below the suitability threshold and is too closely related to that female to be used for spawning.

F_24FN	F_32F	F_34F	F_35F	F_38F
M_62MJ	M_68MN	M_68MN	M_71M	M_59MJ
M_59MJ	M_59MJ	M_59MJ	M_62MJ	M_73MN
M_72M	M_57MJ	M_73MN	M_63MJ	M_68MN
M_68MN	M_58MJ	M_57MJ	M_68MN	M_65MN
M_63MJ	M_67MJ	M_60MN	M_72M	M_62MJ
M_57MJ	M_62MJ	M_65MN	M_67MJ	M_72M**
M_58MJ	M_65MN	M_70M	M_73MN	M_60MN**
M_67MJ	M_73MN	M_67MJ	M_57MJ	M_63MJ**
M_65MN**	M_63MJ	M_62MJ	M_60MN	M_70M**
M_71M**	M_60MN	M_58MJ**	M_70M	M_67MJ**
M_73MN**	M_72M**	M_72M**	M_59MJ	M_58MJ**
M_60MN**	M_71M**	M_63MJ**	M_58MJ	M_71M**
M_70M**	M_70M**	M_71M**	M_65MN**	M_57MJ**

RESULTS

Chinook Salmon

Chinook began entering IGH on October 10, 2016. A total of 2,587 Chinook returned to IGH during the fall 2016 spawning season. Of these, KRP staff collected biological data including sex, fork length, clip information, and spawning disposition for 749 Chinook, which included 261 systematically (1:10) sampled "random" fish and 488 AD fish which were not part of the 1:10 sampling (non-random AD fish). Scale samples were collected from all random fish, and an additional 21 non-random scale samples were collected from Chinook less than 54 cm in fork length, for use in scale reading validation. Tissue and otolith samples were collected from every 100th Chinook. Systematically sampled male Chinook ranged in size from 44 to 96 cm fork length (FL) and averaged 70 cm (Figure 4). Systematically sampled female Chinook ranged from 52 to 87 cm FL and averaged 65 cm (Figure 5). The grilse and adult components of the 2016 run were estimated using scale age analysis (KRTAT, 2017), yielding approximately 151 grilse (5.8%) and 2,436 adults (94.2%) for a total run size of 2,587. Females accounted for 48% of the systematically sampled fish (125) and males accounted for 52% (136). The last Chinook of the season entered IGH on November 21, 2016.

Heads from 543 AD Chinook (random and non-random fish) were collected for CWT recovery, from which positive reads were obtained for 506 (Table 3). The remainder were either lost during extraction (13), had shed their tags (13) or the tags were unreadable (11). The contribution of lost or unreadable CWTs was estimated by applying the proportions of known CWTs (506) to the 24 lost or unreadable CWTs (Table 4).

The estimated contribution of unknown CWTs was then added to the contribution of known CWTs to determine the total contribution of hatchery-origin Chinook entering IGH. Of the 506 CWTs recovered (and successfully read), 505 originated from IGH and

one from Trinity River Hatchery. Based on the expansion of CWTs, KRP staff estimated that 82% of the Chinook entering IGH during the 2016 season were of hatchery origin. Proportions of hatchery-origin Chinook returning to IGH from 2002-2016 are shown in Figure 6. Of the expanded CWT returns (positive reads) in 2016, 926 (46%) were from yearling release groups and 1,107 (54%) were from smolt release groups.

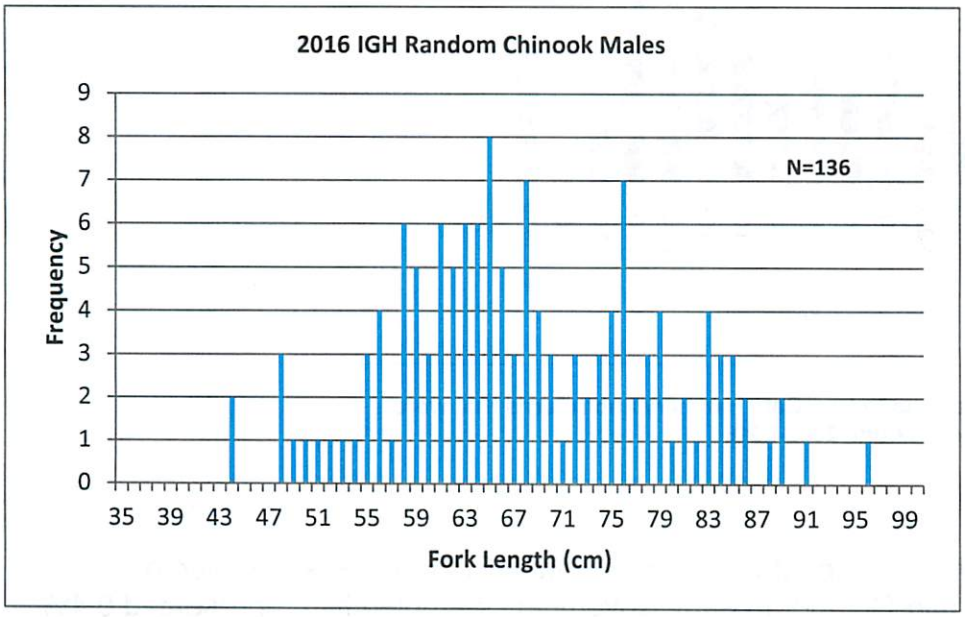

Figure 4. Length frequency distribution for systematic sample of male Chinook salmon recovered at IGH during the 2016 spawning season.

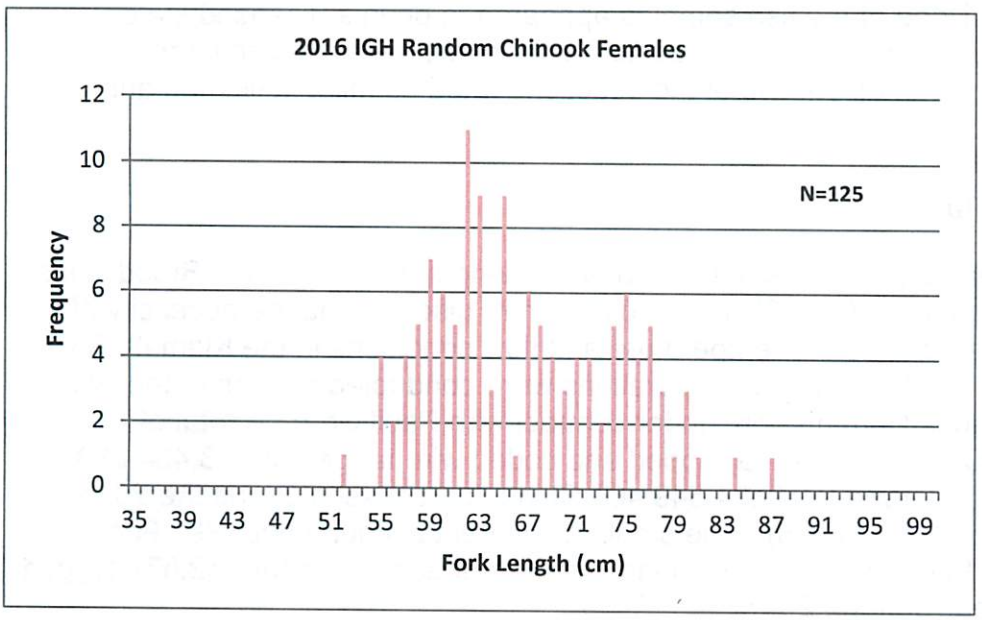

Figure 5. Length frequency distribution for systematic sample of female Chinook salmon recovered at IGH during the 2016 spawning season.

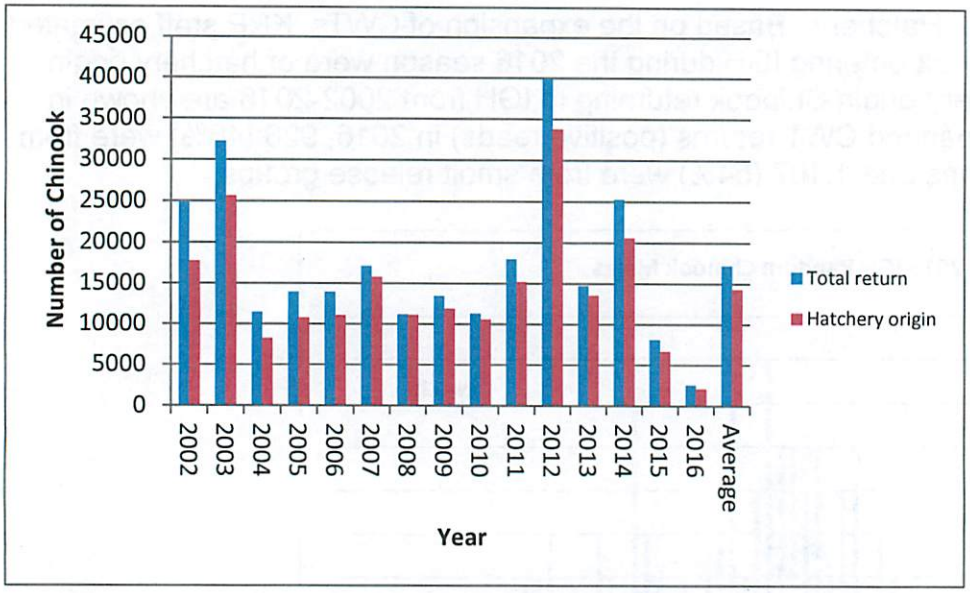

Figure 6. Total Chinook returns to Iron Gate Hatchery and returns that were determined to be of hatchery origin, 2002-2016.

Ich Sampling

During the 2016 Ich monitoring effort at IGH, 79 adult Chinook were sampled over 10 sampling dates from mid-October to early November. Sampled fish represented 6.4% of the Chinook that entered the hatchery during the sampling dates. Of the 79 Chinook, 15 were positive for Ich trophonts (19%), but at a very low level of infection. Two of the 15 positive fish had 2 single trophonts observed, and the remaining 13 fish had 1 trophont observed. None of the fish sampled appeared to be in a diseased state. Seventeen of the 79 Chinook (21%) were positive for columnaris (*Flavobacter columnare*) infection, with all but two of the infections rated as mild. (Hileman and Chesney, 2017).

Coded Wire Tagging

2016 was the 8th year of 25% constant fractional marking at IGH, although Brood Year 2010 was tagged at a rate of 17.2% due to losses from disease and the necessity of releasing surviving smolts before temperature and flow conditions in the Klamath River became detrimental. In 2016, tagging operations were conducted by staff of the Pacific States Marine Fisheries Commission, under contract with PacifiCorp. A total of 1,144,581 juvenile Chinook were AD clipped and coded wire tagged, and 3,404,883 counted but not tagged, for a total of 4,549,464 Chinook processed during the 2016 tagging season (Brood Year 2015). The smolt component accounted for 891,904 tagged and 2,646,210 counted. The yearling component accounted for 252,677 tagged and 758,673 counted (Buttars, 2017).

Table 3. Estimated contribution of Chinook from Iron Gate Hatchery (IGH) to total run at IGH, based on coded-wire tags (CWT) recovered from fall-run Chinook salmon at IGH during the 2016 spawning season.

CWT	Release Location	Brood Year	Age	Release Type	Number Recovered	Production Multiplier	Expanded Estimate	Proportion of Expanded Estimate by Age
Estimated contribution of known CWTs:								
60419	IGH	2011	5	F	1	4.01	4	
60420	IGH	2011	5	F	1	4.01	4	Age 5
60421	IGH	2011	5	F	1	4.00	4	N=28
60422	IGH	2011	5	Y	4	4.00	16	0.0138
55660	IGH	2012	4	F	1	4.08	4	
68796	IGH	2012	4	F	16	4.01	64	
68797	IGH	2012	4	F	32	4.00	128	
68798	IGH	2012	4	F	41	4.01	164	
60375	IGH	2012	4	F	17	4.02	68	
60385	IGH	2012	4	F	2	4.02	8	Age 4
60501	IGH	2012	4	F	35	4.02	141	N=602
60507	IGH	2012	4	Y	6	4.02	24	0.2961
60417	IGH	2013	3	F	9	4.01	36	
60597	IGH	2013	3	F	50	4.05	203	
60601	IGH	2013	3	F	40	4.04	162	
60602	IGH	2013	3	F	15	4.02	60	
60603	IGH	2013	3	F	4	4.00	16	Age 3
60604	IGH	2013	3	Y	213	4.01	854	N=1,335
60608	TRH	2013	3	F	1	4.10	4	0.6567
60684	IGH	2014	2	F	6	4.04	24	
60685	IGH	2014	2	F	1	4.00	4	
60686	IGH	2014	2	F	1	4.02	4	Age 2
60687	IGH	2014	2	F	1	4.03	4	N=68
60688	IGH	2014	2	Y	8	4.02	32	0.0084
				Subtotal	**506**		**2,033**	
Estimated contribution of unknown CWTs								
200000					13			
400000					11			
				Subtotal	**24**		**96**	
	Total Estimated Hatchery Contribution =						**2,129**	
Unreadable CWTs: 200000=CWT lost, 400000=CWT unreadable, 300000=Head lost								

Table 4. Estimated contribution of 24 AD Chinook with unknown CWT codes (lost or unreadable) that were recovered at IGH based on the proportional distribution of known CWTs recovered at IGH during the 2016 season.

CWT	BY	# CWTs Recovered	Proportion of CWTs recovered	Estimated Number	Production Multiplier	Expanded Estimate
60419	2011	1	0.0019763	0.05	4.01	0.190
60420	2011	1	0.0019763	0.05	4.01	0.190
60421	2011	1	0.0019763	0.05	4.02	0.191
60422	2011	4	0.0079051	0.19	4.00	0.759
55660	2012	1	0.0019763	0.05	4.08	0.194
68796	2012	16	0.0316206	1	4.01	3.043
68797	2012	32	0.0632411	2	4.01	6.086
68798	2012	41	0.0810277	2	4.01	7.798
60375	2012	17	0.0335968	1	4.02	3.241
60385	2012	2	0.0039526	0.09	4.02	0.381
60501	2012	35	0.0691700	2	4.00	6.640
60507	2012	6	0.0118577	0.28	4.00	1.138
60417	2013	9	0.0177866	0.43	4.01	1.712
60597	2013	50	0.0988142	2	4.05	9.605
60601	2013	40	0.0790514	2	4.04	7.665
60602	2013	15	0.0296443	1	4.02	2.860
60603	2013	4	0.0079051	0.19	4.00	0.759
60604	2013	213	0.4209486	10	4.01	40.512
60608	2013	1	0.0019763	0.05	4.02	0.191
60684	2014	6	0.0118577	0.28	4.04	1.150
60685	2014	1	0.0019763	0.05	4.00	0.190
60686	2014	1	0.0019763	0.05	4.02	0.191
60687	2014	1	0.0019763	0.05	4.03	0.191
60688	2014	8	0.0158103	0.38	4.01	1.522
		506	1	24		**96**

Coho Salmon

Eighty-six (86) Coho entered IGH during the 2016 season, from November 1, 2016 to December 1, 2016. The Coho run consisted of 60 males (69.8%) and 26 females (30.2%). Male Coho ranged in size from 31 to 70 cm in FL and averaged 55 cm (Figure 7), and female Coho ranged in size from 58 to 71cm in FL and averaged 64 cm (Figure 8). Based on the length frequency distribution of 86 Coho, grilse were estimated to be <52 cm FL, yielding a grilse component of 35% (30) and an adult component of 65% (56). The proportion of grilse among male Coho was 50%. The mean FL for grilse was 47 cm, and the mean FL for adult male Coho was 64 cm.

Of the 86 Coho that entered IGH, 66 (77%) had left maxillary clips, indicating IGH origin, and 20 (23%) were unmarked. No right maxillary or AD clipped Coho were observed during the 2016 season (Table 5).

Table 5. Proportions of marked and unmarked Coho that entered IGH from 1997 to 2016.

Year	# Sampled	LM	RM	AD	OTHER	MARKED	UNMARKED	% MARKED
1997	2174	1970	5	28	6	2009	165	92%
1998	669	378	0	2	0	380	289	57%
1999	169	153	0	1	0	154	15	91%
2000	1354	1067	4	58	4	1133	262	84%
2001	2573	2130	138	51	8	2327	246	90%
2002	1301	1006	25	38	7	1076	225	83%
2003	1558	838	69	58	4	969	589	62%
2004	1734	1203	32	69	1	1305	424	75%
2005	1425	1282	2	1	0	1285	140	90%
2006	301	204	2	16	0	222	80	74%
2007	779	643	6	2	1	652	127	84%
2008	1296	1268	2	0	1	1271	25	98%
2009	45	29	7	0	0	36	9	80%
2010	258	222	1	0	0	223	36	86%
2011	586	522	0	2	1	525	63	90%
2012	644	609	4	1	1	615	29	95%
2013	1268	1158	2	1	2	1163	105	92%
2014	384	346	0	5	0	351	33	91%
2015	72	59	0	2	0	61	11	85%
2016	86	66	0	0	0	66	20	77%

A total of 5 male Coho which were held as potential brood stock and did not have suitable mates on the matrix were PIT-tagged and released back to the Klamath River on December 1, 2016, and 1 adult male which entered on November 1 was inadvertently shocked with Chinook and was revived in the flume, PIT-tagged and released that day. Four (4) of the released Coho had left maxillary clips, and 2 were unmarked. Twenty-four (24) female Coho were used for spawning in 2016, although one was found to have eggs that adhered to the skein and were not viable. Forty-seven (47) male Coho were used for spawning during the 2016 season, and 9 died prior to spawning.

Three (3) of the 6 IGH-released PIT-tagged Coho were detected at antenna arrays located at the confluence of Bogus Creek and the Klamath River and less than 0.5 river kilometers downstream of the release site at IGH (Table 6). No detections of IGH PIT-tagged and released Coho occurred in the Shasta River in 2016.

Table 6. Detections of 3 PIT-tagged male Coho released from IGH on December 1, 2016. An additional 3 male Coho were PIT-tagged and released, but no subsequent detections were made.

PIT number	Date Released	Sex	FL	Marks	1st detection	2nd detection	3rd detection
989002001131767	12/1/2016	M	48	LM	12/1/2016	12/2/2016	12/9/2016
989002002186323	12/1/2016	M	44	LM	12/1/2016	12/2/2016	12/10/2016
989002000480165	12/1/2016	M	70	NONE	12/1/2016	n/a	n/a

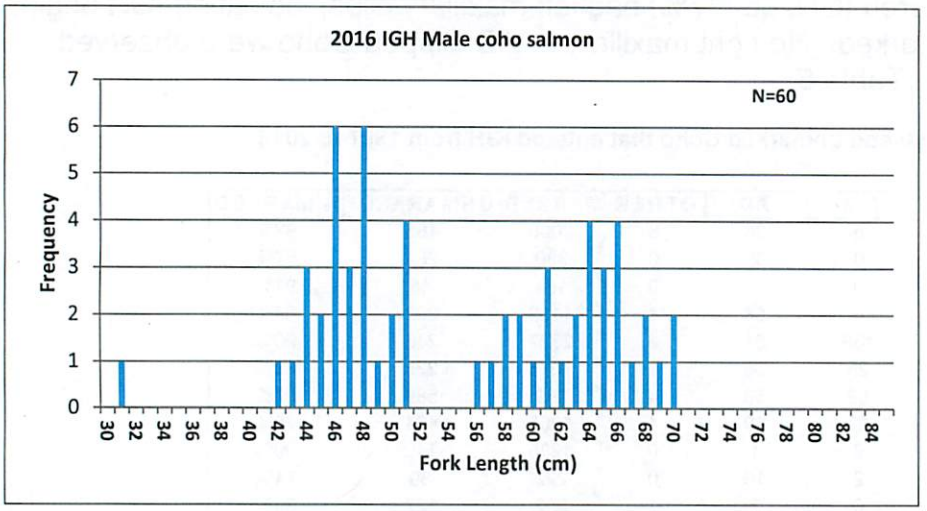

Figure 7. Length frequency distribution for male Coho salmon recovered at Iron Gate Hatchery during the 2016 spawning season.

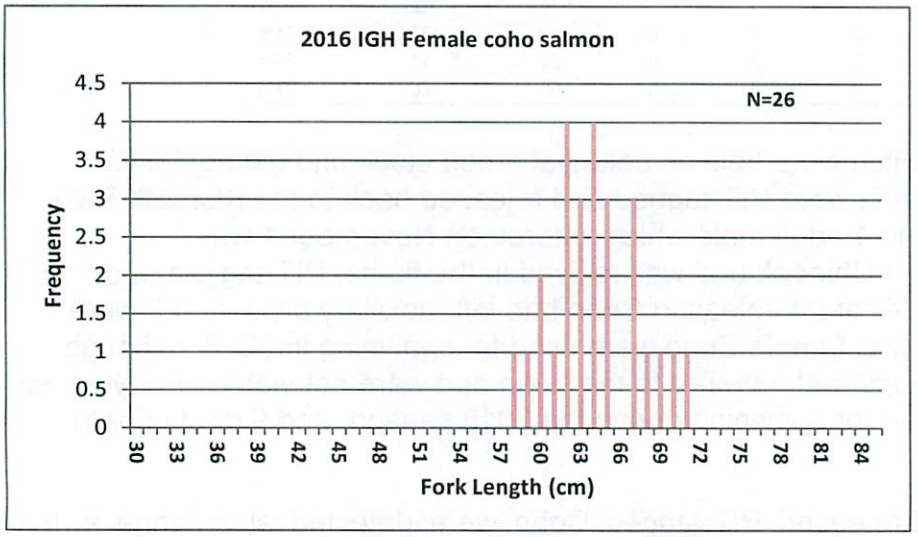

Figure 8. Length frequency distribution for female Coho salmon recovered at Iron Gate Hatchery during the 2016 spawning season.

DISCUSSION

Chinook Salmon

The 2016 run of Chinook to IGH (2,587) was 13,619 fish less than the 39-year average of 16,206 (Figure 9). It was the second lowest recorded during that period. Returns of Chinook to the Klamath Basin as a whole were also at a historic low, with the lowest return of adult Klamath River Fall Chinook since 1978 (Figure 10). Escapement to IGH was 9.5% of basin spawner escapement in 2016. Klamath Basin returns of adult Chinook were only 47% of the projected forecast, with 24,600 adults returning vs. the projected forecast of 52,100.

The brood years returning to the Klamath River in 2016 were subjected to adverse river conditions during their outmigration as juveniles, and in the marine environment. Unusually warm sea surface temperatures in the northeast Pacific (El Niño) have persisted during the recent three drought years and have had a negative effect on the abundance of forage fishes and copepods (PFMC, 2016) that are important sources of food for salmon. Both 2014 and 2015 were critically dry water years in California in general and the Klamath River in particular. Ongoing research on *Ceratonova shasta and Parvicapsula minibicornis* in the mainstem Klamath River, using sentinel fish during the peak migration period of May to the end of July indicate that in 2014 and 2015, juvenile Chinook experienced infection rates of 81% and 91%, compared to the 10 year mean of 44% (True et al, 2016).

Both *C. shasta and P. minibicornis* are myxosporean parasites that are known to be significant contributors to mortality in juvenile fish exposed to the parasites as they migrate downstream (Ray et al., 2013). Higher flows are believed to not only dilute the infectious spore stages, but also dislodge the intermediate *C. shasta* host polychaete worms, *Manayunkia speciosa,* and decrease the rate of infection and mortality associated with infection. (Hallett et al., 2012; True et al., 2016).

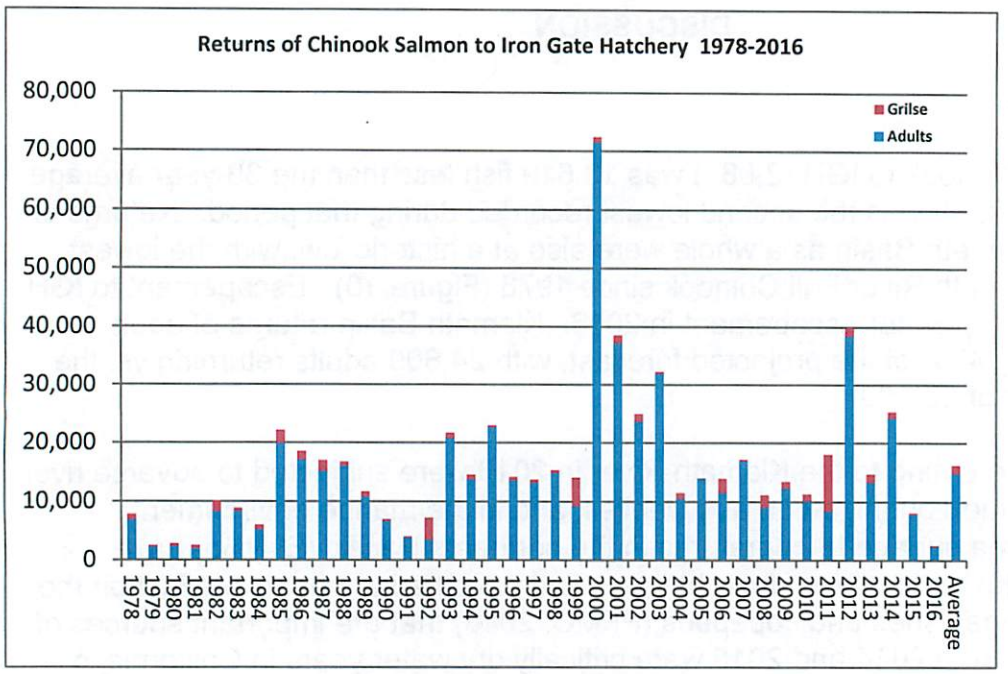

Figure 9. Chinook salmon escapement to Iron Gate Hatchery, from 1978 to 2016.

California's water year 2016-2017 (October-September) is one of the wettest on record, especially for northern California. This welcome relief from the multi-year drought is likely to be beneficial to the fresh water life stages of Klamath Basin salmonids. In February of 2017, a U.S. District Judge ordered the Bureau of Reclamation (BOR) to implement winter-spring flushing flows designed to dislodge and flush out polychaete worms which are the intermediate host in the life cycle of *C. Shasta*. This ruling was in response to lawsuits filed by area Tribes, fishermen's associations and environmental groups. Due to high flows into Klamath Lake from winter storms, the BOR implemented the increased flow events in February to coincide with the need for releases from the Link River Dam for flood control purposes (usbr.gov, 2017). During the months of March and early April, when many young-of-the year salmon begin their downstream migration, flood control flows below Iron Gate Dam in the main stem Klamath River have reached and exceeded 10,000 cfs, more than twice the historical mean of 3,480 cfs (USGS Gauge 11516530) (Figure 11).

In 2015, the Iron Gate Hatchery Coordination Team (HCT) made a recommendation to the Statewide Policy Team to implement the use of one-on-one (1:1) spawning of Chinook. This method was first used in 2015 and again in 2016. One-on-one spawning has been shown to increase the overall number of parents contributing to a population, and to reduce the effects of sperm competition. Due to the small runs of Chinook in 2015 and 2016, it was sometimes necessary to use a male Chinook with more than one female, but no more than one male and one female were spawned per pan.

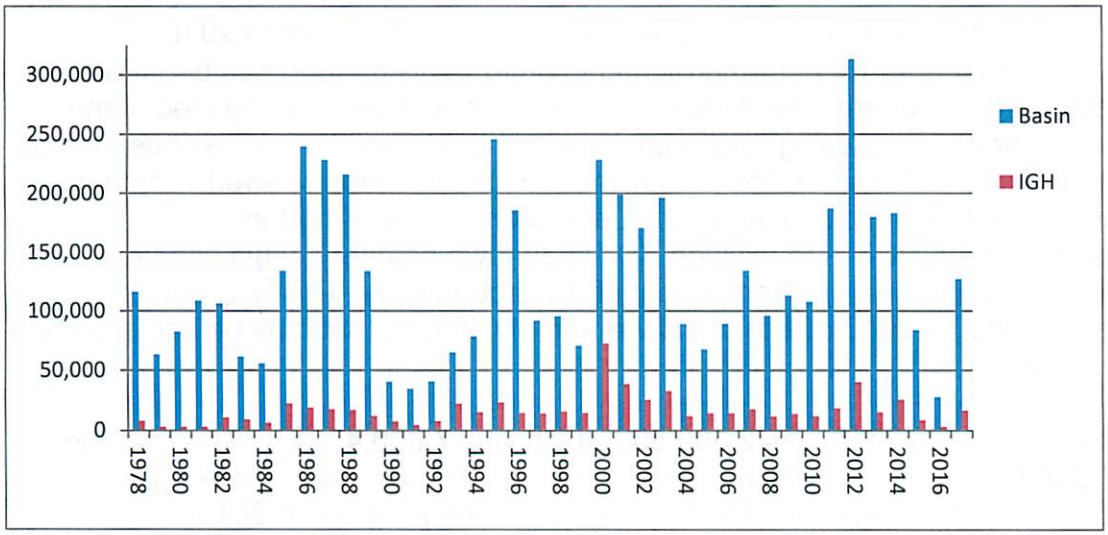

Figure 10. Chinook salmon escapement to the Klamath Basin and Iron Gate Hatchery, 1978-2016.

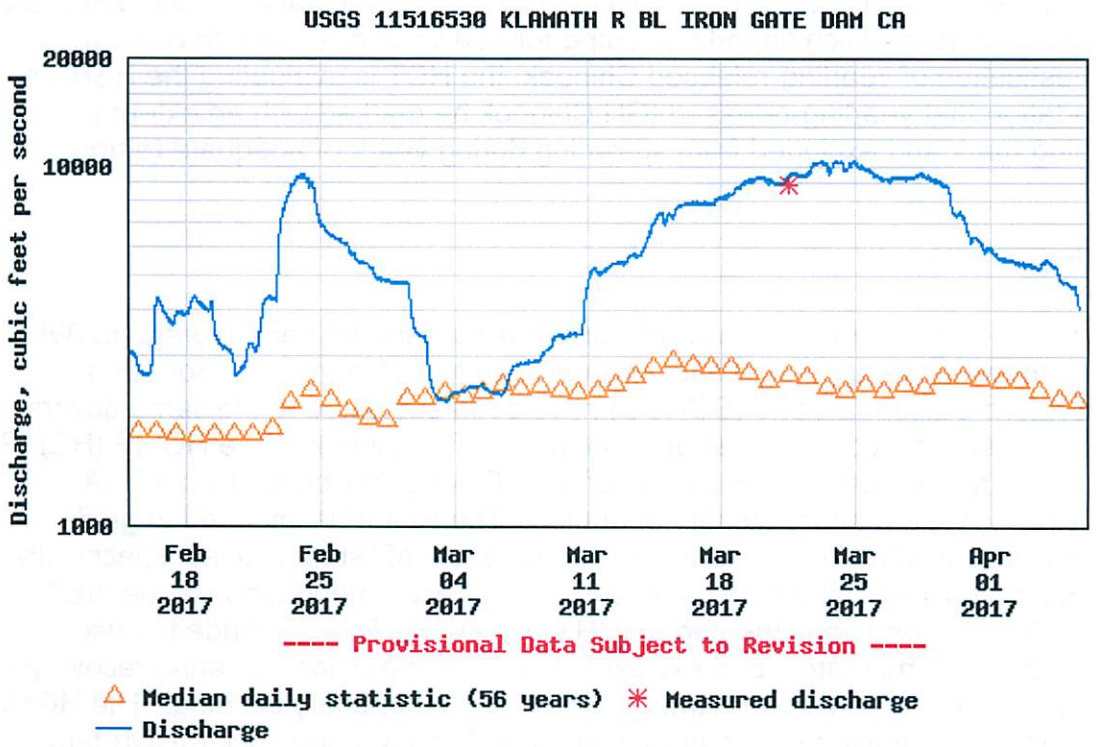

Figure 11. Flows at USGS Gauge 11516530 below Iron Gate Dam, February 15- April 5, 2017.

Air spawning is another method implemented in 2015 and used again in 2016. According to IGH manager Keith Pomeroy (pers.comm.), this method has been found to result in cleaner eggs that are less likely to be broken or contaminated by blood, and also results in a cleaner spawning house environment compared to the previous method of evisceration. Internal examination of spawned female Chinook showed very few residual eggs when the air spawning technique was employed. Another recommendation of the HCT is to exclude AD fish (known hatchery origin fish) from spawning to increase the natural component of the brood stock. This was not implemented in 2015 or 2016 due to the low return of Chinook, but may be implemented in future seasons.

The Chinook egg take in 2016 was 2,309,550 which was 7,890,450 eggs short of the target of 10,200,000 eggs. Due to the small return of Chinook, no Chinook eggs underwent the triploid process for CDFW's inland Chinook program in 2016.

The Chinook releases from IGH include both smolt and yearling releases. The current production goals include releases of 5,100,000 Chinook smolts in May and June and 900,000 yearlings the following November. Table 7 compares return rates of smolt and yearling releases from 1990 to 2014. Between 1990 and 2010, data on 19 brood years show only four years in which fingerlings outperformed yearlings. Due to concerns about domestication of yearling-released Chinook, the HCT is evaluating the HSRG's recommendation that yearling-released IGH Chinook be marked with an external, distinguishing mark and excluded from spawning during years of adequate returns.

Coho Salmon

The 2016 run of Coho to IGH (86) was 912 fish less than the 55-year average of 998 and the eighth lowest return in 55 years of record keeping (Figure 12). Southern Oregon Northern California Coho (SONCC) have been subjected to the same adverse ocean and in-river conditions as previously described for Chinook. The HGMP (HGMP, v.10, 2013) was developed for IGH as part of the CDFW's application for an ESA section 10(a) (1)(A) permit for hatchery operation. The HGMP is intended to guide hatchery practices toward the conservation and recovery of listed species, specifically, the upper Klamath River Coho population unit. Many recommendations of the draft HGMP (2009) have been implemented at IGH since 2010. These include the use of NOAA's Coho spawning matrix, bird exclusion netting in the outdoor rearing raceways, and the installation of a new water filtration system in the hatchery building. The HGMP also recommends increasing the proportion of natural origin broodstock (pNOB target 20-50%) and the proportion of jacks (pJacks) included in the broodstock (Table 7).

Table 7. Return rates of IGH Chinook smolt and yearling CWT releases for brood years1990-1996, and 1999-2014.

Return rates of IGH smolt and yearling CWT releases for brood years 1990 to 1996, 1999-2014							
Brood Year	IGH Smolt Releases			IGH Yearling Releases			Ratio of yearling/smolt return rates
	# CWTs Released	# CWTs	% Return	# CWTs Released	# CWTs Returne	% Return	
1990	188,595	713	0.378%	95,880	740	0.772%	2.04
1991	191,200	96	0.050%	90,982	167	0.184%	3.66
1992	185,464	1,015	0.547%	74,024	269	0.363%	0.66
1993	188,562	40	0.021%	98,099	196	0.200%	9.42
1994	194,644	94	0.048%	86,564	453	0.523%	10.84
1995	191,799	85	0.044%	90,172	954	1.058%	23.87
1996	196,648	162	0.082%	95,396	581	0.609%	7.39
1999	182,131	686	0.377%	91,220	514	0.563%	1.50
2000	187,417	277	0.148%	100,702	707	0.702%	4.75
2001\[a]	198,311	11	0.006%	110,167	764	0.693%	125.02
2002	210,114	367	0.175%	109,711	295	0.269%	1.54
2003	261,888	70	0.027%	48,592	60	0.123%	4.62
2004	205,950	691	0.336%	98,752	215	0.218%	0.65
2005	209,754	194	0.092%	103,157	445	0.431%	4.66
2006	309,671	224	0.072%	103,361	230	0.223%	3.08
2007	307,204	340	0.111%	103,876	300	0.289%	2.61
2008\[b]	986,141	269	0.027%	192,339	197	0.102%	3.75
2009	1,119,054	10,224	0.914%	264,253	581	0.220%	0.24
2010\[c]	671,755	2,473	0.368%	261,332	278	0.106%	0.29
2011	1,158,028	2,694	0.233%	286,947	843	0.294%	1.26
2012\[d]	1,040,836	1,108	0.106%	263,614	22	0.008%	0.08
2013\[d]	1,117,134	146	0.013%	263,836	217	0.0822%	6.29
2014\[d]	965,584	9	0.001%	263,272	8	0.0030%	3.26
AVERAGE			0.182%			0.349%	9.63
\[a]BY 2001 smolt releases subject to critically dry conditions at release, record low return rates observed							
\[b] BY 2008 was the first to receive 25% constant fractional mark							
\[c] BY 2010 smolt release tagged at 17.16% due to disease and river conditions							
\[d] Incomplete returns for BY 2012-2014							

Unmarked Coho are presumed to be of non-hatchery origin, and are incorporated into spawning as close to the target as possible, if the NOAA matrix shows they are suitable as brood stock. Proportions of marked and unmarked Coho that entered IGH from 1997 to 2016 are shown in Table 8.

The relatedness coefficient (Rxy) of pairs of Coho spawned at IGH during the 2016 season with the use of the NOAA spawning matrix is shown in Figure 14. This was the seventh season for which the matrix was used. The green bars represent the optimal pairings of males and females that could be achieved if the most unrelated male was spawned with its most unrelated female for each mating. In the absence of the spawning matrix and if pairs were selected purely at random the resulting Rxy values are represented by blue bars, and the yellow bars represent actual crosses. Highly inbred pairings result in Rxy values > 0.10. During the 2016 spawning season, all of the actual crosses were below the inbreeding threshold (Gilbert-Horvath, 2017). Fourteen (14) inbred crosses were prevented in 2016 with the use of the spawning matrix.

During the 2016 season, Coho that entered IGH during October and early November, while the Chinook spawning season was still underway, were not released as in prior years unless they were deemed to be in poor condition and unlikely to survive until

spawning. Despite infrastructure challenges, early holding of Coho and more frequent spawnings may be necessary during years of small Coho returns. More frequent spawning also minimizes pre-spawning (tube) mortality. Proportions of Coho retained at IGH and released into the Klamath River between 2004 and 2016 are shown in Figure 13.

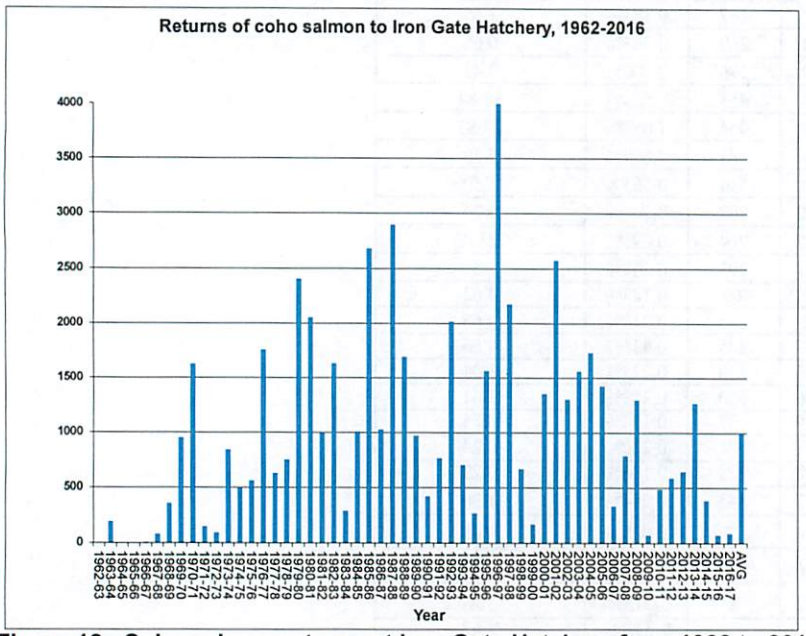

Figure 12. Coho salmon returns at Iron Gate Hatchery from 1962 to 2016.

Table 7. Coho male, female and jack returns, number of females spawned, proportion of natural origin broodstock (pNOB) and jacks (pJacks) used in spawning, egg take, fecundity and yearlings released by brood year at IGH from 1993-2016.

Year	Total run of coho to IGH	Adult Males	Adult Females	Jacks	HOR Females Spawned	NOR Females Spawned	Natural Origin Broodstock	pNOB*	pJacks*	# Eggs	Fecundity	Yearlings released	Egg to Smolt Survival	Date released
1993	704	361	314	29	219	?	?	~15	~1	503,326	2,298	79,506	16%	1995
1994	269	100	72	97	57	?	?	~15	~1	141,397	2,481	74,250	53%	1996
1995	1,560	708	793	59	294	?	?	~15	~1	782,170	2,660	81,489	10%	1997
1996	4,097	1,715	1,831	551	200	?	?	~15	~1	547,255	2,736	79,607	15%	1998
1997	2,174	825	1,047	302	126	?	16	6.3	~1	304,728	2,418	75,156	25%	1999
1998	669	243	268	158	122	?	75	30.7	~1	298,357	2,446	77,147	26%	2000
1999	169	90	61	18	35	?	5	7.1	~1	86,519	2,472	46,250	53%	3/29/2001
2000	1,354	295	428	631	95	?	52	27.4	~1	270,151	2,844	67,933	25%	3/27/2002
2001	2,573	972	1,494	107	126	?	22	8.7	~1	404,370	3,209	74,271	18%	3/27/2003
2002	1,301	566	627	108	187	?	68	18.2	~1	609,193	3,258	109,374	18%	3/29/2004
2003	1558	609	708	241	197	?	172	43.7	~1	502,048	2,548	74,716	15%	4/13/2005
2004	1734	630	865	239	276	?	10	1.8	~1	799,623	2,897	89,482	11%	4/17/2006
2005	1425	596	799	30	62	4	10	8.1	~1	295,101	4,760	118,487	40%	4/25/2007
2006	332	112	151	69	82	3	10	6.1	~1	236,406	2,883	53,950	23%	4/9/2008
2007	779	300	325	154	125	4	10	4.0	~1	316,155	2,529	117,832	37%	4/17/2009
2008	1296	508	770	18	145	3	9	3.1	~1	455,480	3,141	121,000	27%	4/8/2010
2009	70	21	25	24	13	5	6	30.0	40	53,435	4,110	22,236	42%	4/14/2011
2010	485	193	235	57	86	5	21	26	18	259,490	3,017	155,840	60%	3/29/2012
2011	586	248	204	134	52	4	26	23	11	151,241	2,908	39,250	26%	3/18/2013
2012	644	98	203	343	51	3	12	12	64	158,651	3,111	78,000	49%	3/17/2014
2013	1268	552	653	63	69	12	37	23	17	224,071	3,247	89,500	40%	3/17/2015
2014*	384	39	95	250	51	12	26	31	51	121,421	1,958	27,568	23%	4/5/2016
2014 post egg loss	384	39	95	250	17	3	3	12	52	37,350	1,500	27,568	74%	4/5/2016
2015	72	13	21	38	9	4	9	52	40	22,240	2,471	17,232	77%	3/24/2017
2016	86	30	26	30	18	6	22	47	49	43,705	2,428	N/A	N/A	N/A
Average	**1039**	**395**	**484**	**160**	**109**	**5**	**30**	**20**	**38**	**304,955**	**2,813**	**79,675**	**26%**	

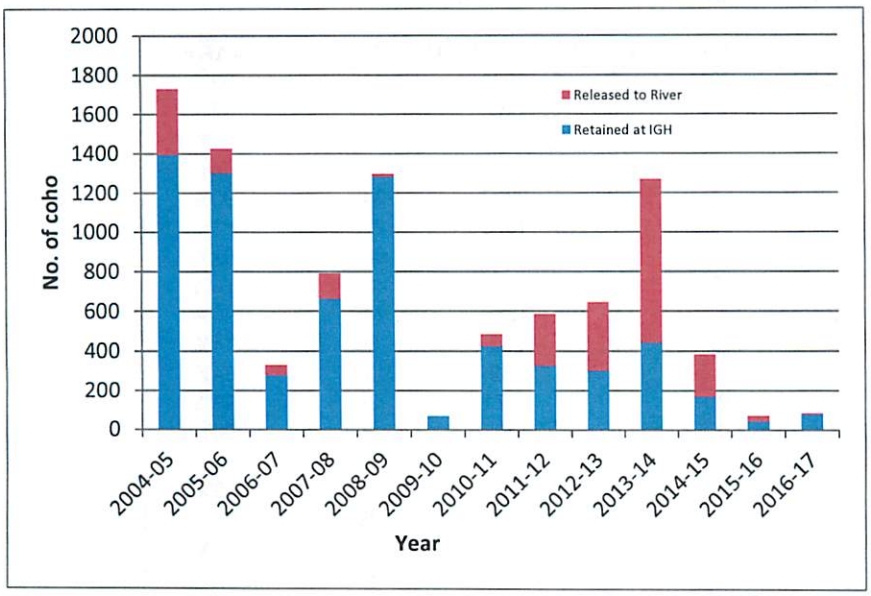

Figure 13. Coho retained at IGH and Coho released alive into Klamath River at IGH from 2004 to 2016.

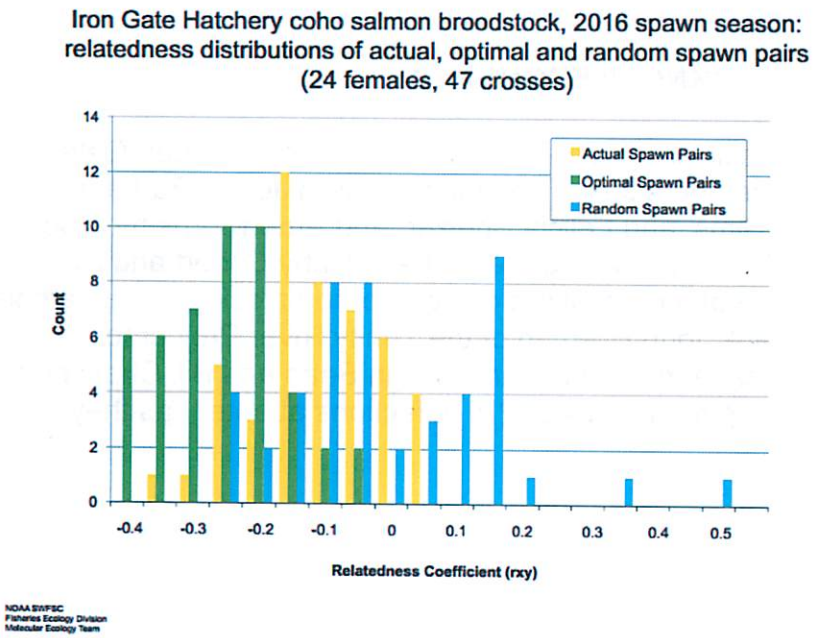

Figure 14. Observed relatedness coefficients of actual spawned pairs, optimally spawned pairs and randomly chosen pairs for IGH Coho during the 2016 season. (Figure provided by NOAA SW Fisheries Science Center Salmonid Genetic Laboratory.)

Table 8. Marked and unmarked Coho Salmon that returned to IGH, 1997-2016.

Year	# Sampled	LM	RM	AD	OTHER	MARKED	UNMARKED	% MARKED
1997	2174	1970	5	28	6	2009	165	92%
1998	669	378	0	2	0	380	289	57%
1999	169	153	0	1	0	154	15	91%
2000	1354	1067	4	58	4	1133	262	84%
2001	2573	2130	138	51	8	2327	246	90%
2002	1301	1006	25	38	7	1076	225	83%
2003	1558	838	69	58	4	969	589	62%
2004	1734	1203	32	69	1	1305	424	75%
2005	1425	1282	2	1	0	1285	140	90%
2006	301	204	2	16	0	222	80	74%
2007	779	643	6	2	1	652	127	84%
2008	1296	1268	2	0	1	1271	25	98%
2009	45	29	7	0	0	36	9	80%
2010	258	222	1	0	0	223	36	86%
2011	586	522	0	2	1	525	63	90%
2012	644	609	4	1	1	615	29	95%
2013	1268	1158	2	1	2	1163	105	92%
2014	384	346	0	5	0	351	33	91%
2015	72	59	0	2	0	61	11	85%
2016	86	66	0	0	0	66	20	77%

LM=Iron Gate Hatchery (left maxillary clip)
RM= Trinity River Hatchery (right maxillary clip)
AD= (adipose clip) several Oregon projects, may or may not have CWT
Other= unknown origin, or result of tag error or injury

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REFERENCES

Buttars, Braden. 2017. Constant Fractional Marking/Tagging Program for Iron Gate Hatchery Fall-run Chinook Salmon, 2016 Marking Season. Pacific States Marine Fisheries Commission: bbuttars@psmfc.org

California Department of Fish and Game, National Marine Fisheries Service Southwest Region Joint Hatchery Review Committee. 2001. Final Report on Anadromous Salmonid Fish Hatcheries in California. Review Draft June 27, 2001. 79pp.

California Department of Fish and Game, Pacific Power and Light Company. 1996. Iron Gate Hatchery Production Goals and Constraints. 3pp.

California Department of Fish and Wildlife. 2013. Hatchery and Genetic Management Plan for Iron Gate Hatchery.Coho Salmon V 10. Prepared for National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

California Hatchery Scientific Review Group. 2012. California Hatchery Review: Statewide Report. 100 pp.

Garza, John Carlos, and Molecular Ecology & Genetic Analysis Team, 2012. Population Genetic Structure of Coho Salmon in the Klamath River. Southwest Fisheries Science Center.

Gilbert-Horvath, Libby. 2017. Observed relatedness coefficients of actual spawned pairs, optimally spawned pairs and randomly chosen pairs for IGH Coho during the 2016 season. NOAA Southwest Fisheries Science Center Salmonid Genetic Laboratory.

Hallett, S., R. Ray, C. Hurst, R. Holt, G. Buckles, S. Atkinson, J. Bartholomew. 2012. Density of the Waterborne Parasite *Ceratomyxa shasta* and Its Biological Effects on Salmon. *Applied and Environmental Microbiology, 78*(10), 3724-3731.

Hileman, J. and D. Chesney. 2017. 2016 Ich Trophont Monitoring of Adult Chinook at Trinity River Hatchery and Iron Gate Hatchery. CDFW Klamath/Trinity Program.

KRTT (Klamath River Technical Team). 2017. Klamath River Fall Chinook Age-Specific Escapement, River Harvest, and Run Size Estimates, 2016 Run.

Pacific Fishery Management Council. 2016. *Preseason Report I: Stock Abundance Analysis and Environmental Assessment Part 1 for 2016 Ocean Salmon Fishery Regulations.* (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Ray, A., and J. Bartholomew. (2013). Estimation of transmission dynamics of the *Ceratomyxa shasta* actinospore to the salmonid host. *Journal of Parasitology, 140*, 907-916.

True, Kimberly, A. Voss, and J. Scott Foote. 2016. Myxosporean Parasite (Ceratonovashasta and Parvicapsula minibicornis) Prevalence of Infection in Klamath River Basin Juvenile Chinook Salmon, California-Nevada Fish Health Center FY 2016 Investigational Report: March-August 2016.