California Department of Fish and Wildlife

Klamath River Project

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

October 8, 2018 to December 18, 2018

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ABSTRACT

A total of 11,860 fall-run Chinook Salmon (*Oncorhynchus tshawytscha)* entered Iron Gate Hatchery (IGH) during the fall 2018 spawning season from October 8, 2018 through November 30, 2018. 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 1,154, two scale samples were lost so 1,152 scale samples were collected. Scale samples, sex and fork length (FL) 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 <53 cm FL. Systematically sampled male Chinook ranged in size from 40 to 90 cm FL, and systematically sampled female Chinook ranged from 50 to 80 cm FL. Based on scale age analysis, the Klamath River Technical Team (KRTT) estimated that 3.67% (435) of the run were grilse. Females accounted for 56% (6,588) of the run while males accounted for 44% (3,192). Based on coded wire tag expansion, KRP staff estimated that 81% (9,582) of the Chinook entering (IGH) during the 2018 season were of hatchery origin.

In 2018, 202 Coho Salmon (*Oncorhynchus kisutch*) entered IGH during the spawning season. Three right maxillary clipped Coho (Trinity River Hatchery origin) were trapped, marked with an opercle punch and released, this fish returned two more times throughout the trapping season. Taking out the multiple captures of this fish, 200 unique Coho salmon were trapped at IGH. The recorded dates for the Coho run were from October 18, 2018 to December 13, 2018. KRP staff collected biological data (sex, fork length, presence of marks or clips, 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 all unmarked Coho used for spawning or recovered as mortalities. Males ranged in size from 34 to 73 cm FL, and the average FL was 53 cm. Males represented 63% (126) of the run. Females ranged in size from 37 to 74 cm FL and the average FL was 64 cm. Females represented 37% (74) of the run. Based on the length frequency distribution of 62 male Coho, grilse were estimated to be <53 cm FL. Using this grilse cutoff, the age composition of the 2018 IGH male Coho run was 48% (61) grilse and 52% (65) adults. Of the Coho that entered IGH during 2018, 85% (170) had left maxillary clips, 1.5% (3) had right maxillary clips, and 13.5% (27) had no clips. The 2018 Coho spawning season was the ninth in which Coho were spawned at IGH using a spawning matrix provided by the National Oceanic and Atmospheric Administration. The purpose of the matrix is to estimate relatedness indices so that closely related individuals are not paired for spawning.

INTRODUCTION

Iron Gate Hatchery

The Iron Gate Hatchery (IGH) is located adjacent to the Klamath River at river kilometer 306 (River Mile 190) just upstream of where Bogus Creek flows into the Klamath River 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 (*Oncorhynchus tshawytscha*) 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 AD 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 (*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 2019, 25% of the brood year 2018 Chinook Salmon smolt and yearling groups were AD 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. All IGH produced Coho Salmon were marked with a left maxillary clip (LM) before release.

Table 1: Iron Gate Hatchery Production Goals

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

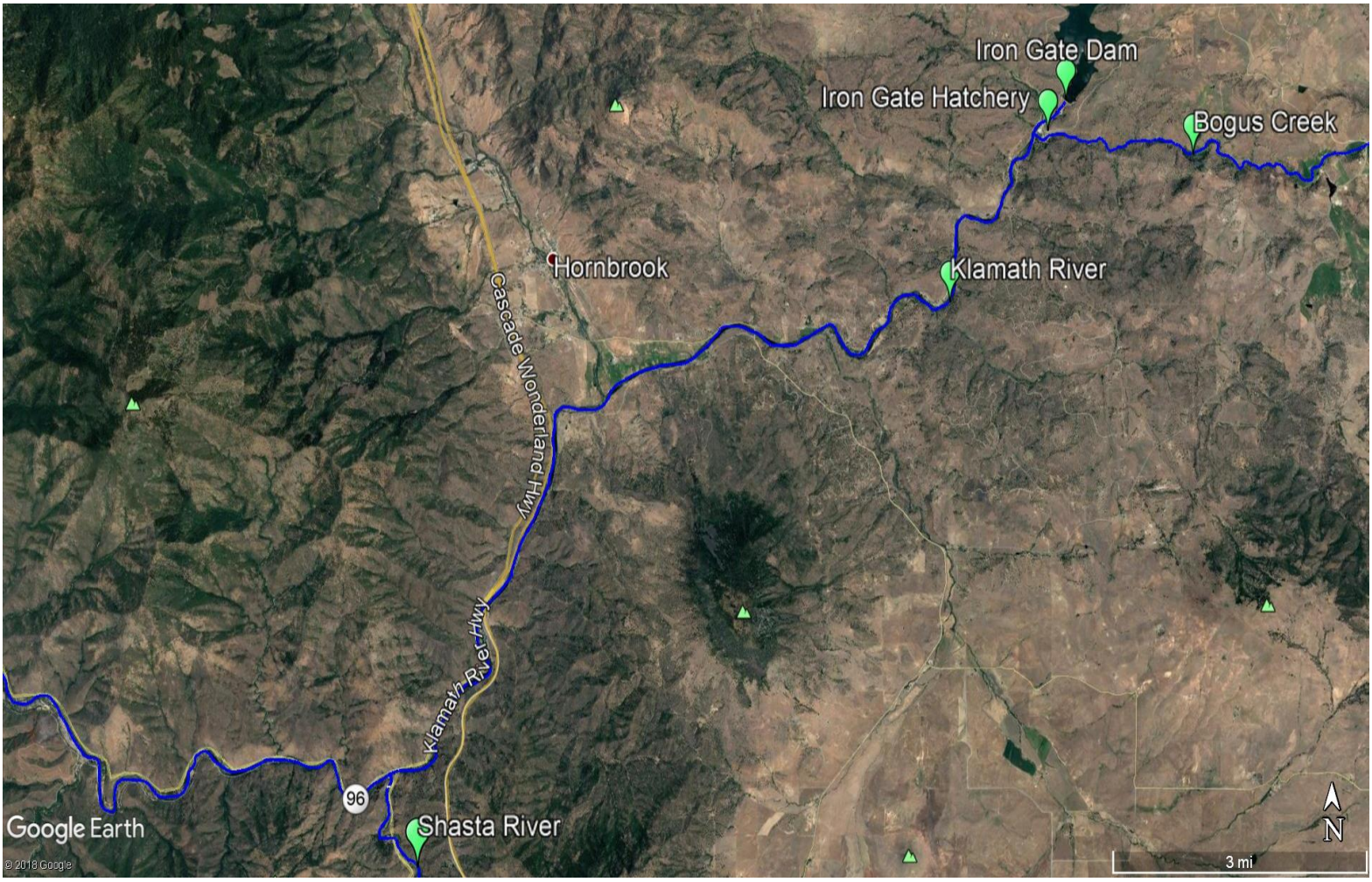

Figure 1: A Map of Iron Gate Hatchery and surrounding area, Siskiyou County, CA.

MATERIALS AND METHODS

Chinook Salmon

Starting in 1997, all Chinook Salmon 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 charitable organizations.

In 2018, KRP staff conducted a systematic sample of every 10th Chinook Salmon 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, and sex, as well as 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 Salmon 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. 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 2018 is the air spawning of Chinook Salmon and Coho Salmon. 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 pounds per square inch 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 2019) using scale age proportions.

Systematic sampling for the presence of Ich *(Ichtyophthirius multifillis)* in IGH Chinook Salmon was conducted by KRP staff throughout the 2018 spawning season. 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 Salmon entered IGH during the 2018 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 2018, eight Coho were trapped between October 18, 2018 and November 1, 2018, it was deemed too early to spawn Coho, so they were released. Additionally, three female Coho were PIT tagged and released in December 2018 because there were no more males remaining and no fish had entered the trap in over a week.

Those Coho Salmon 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 Salmon 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 2018, Coho crosses consisted of two males to one female when possible, with half of each female’s eggs placed in labeled containers (Figure 3) 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.

Figure 2: Coho Salmon brood stock in PVC tubes in a round tank. Photo by Rosa Albanese

Figure 3: Coho Salmon eggs from one female being split into two lots.

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 Salmon 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 Example

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 Salmon began entering IGH on October 8, 2018. A total of 11,860 Chinook returned to IGH during the fall 2018 spawning season. Of these, KRP staff collected biological data including sex, fork length, clip information, and spawning disposition for 3,344 Chinook, which included 1,154 systematically (1:10) sampled “random” fish and 2,190 AD fish which were not part of the 1:10 sampling (non-random AD fish). Scale samples were collected from all but two random fish, data was recorded for both fish but the scale samples were not collected or lost. Tissue and otolith samples were collected from every 100th Chinook. The grilse and adult components of the 2018 run were estimated using scale age analysis (KRTAT, 2019), yielding approximately 435 grilse (3.7%) and 11,425 adults (96.3%) for a total run size of 11,860 (Figure 4). Females accounted for 56% of the systematically sampled fish (641) and males accounted for 44% (513). The last Chinook of the season entered IGH on November 30, 2018. Systematically sampled male Chinook ranged in size from 40 to 90 cm FL and averaged 67 cm (Figure 5). Systematically sampled female Chinook ranged from 50 to 80 cm FL and averaged 64 cm (Figure 6).

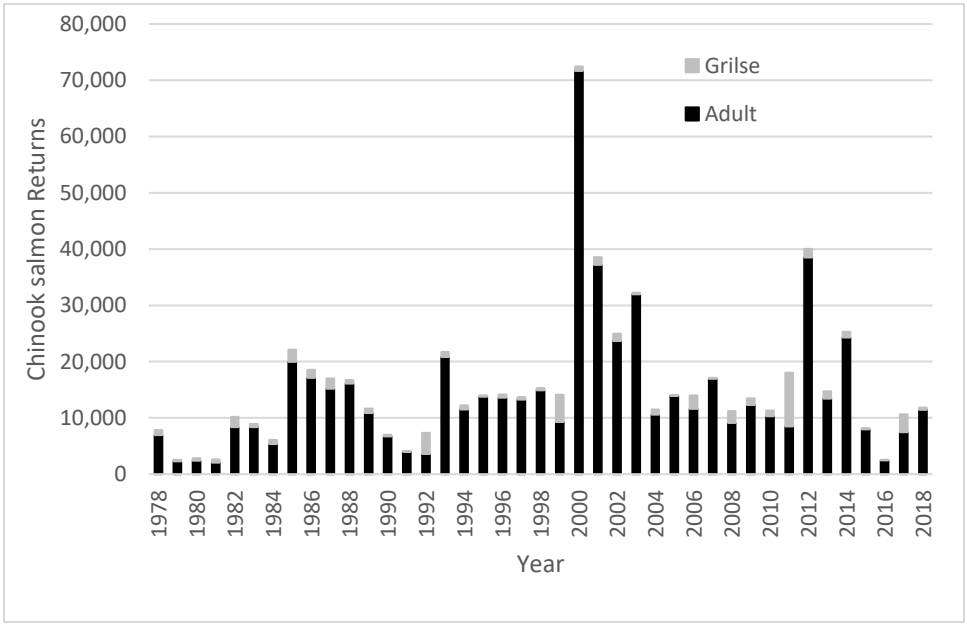

Figure 4: IGH annual Chinook Salmon returns

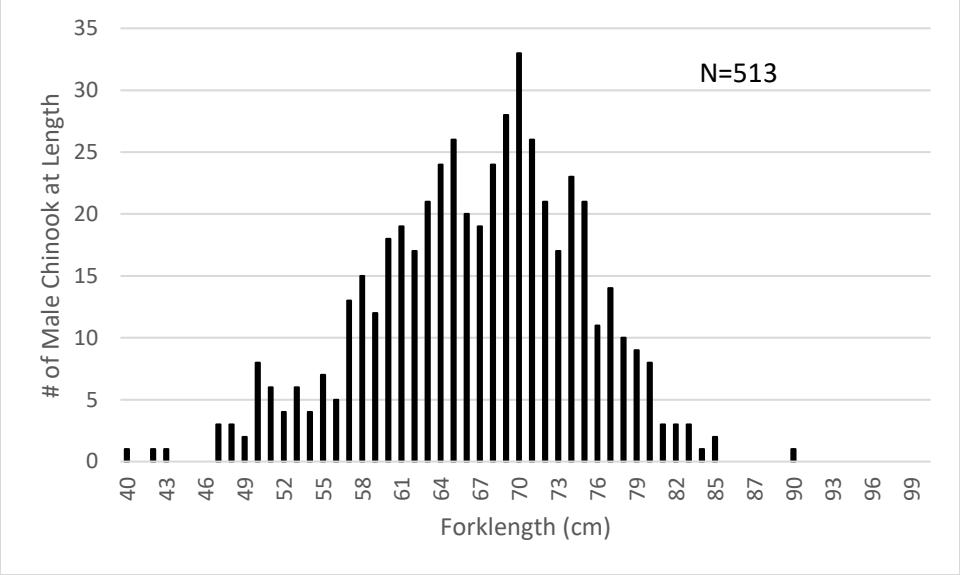

Figure 5: 2018 IGH male Chinook Salmon fork length histogram

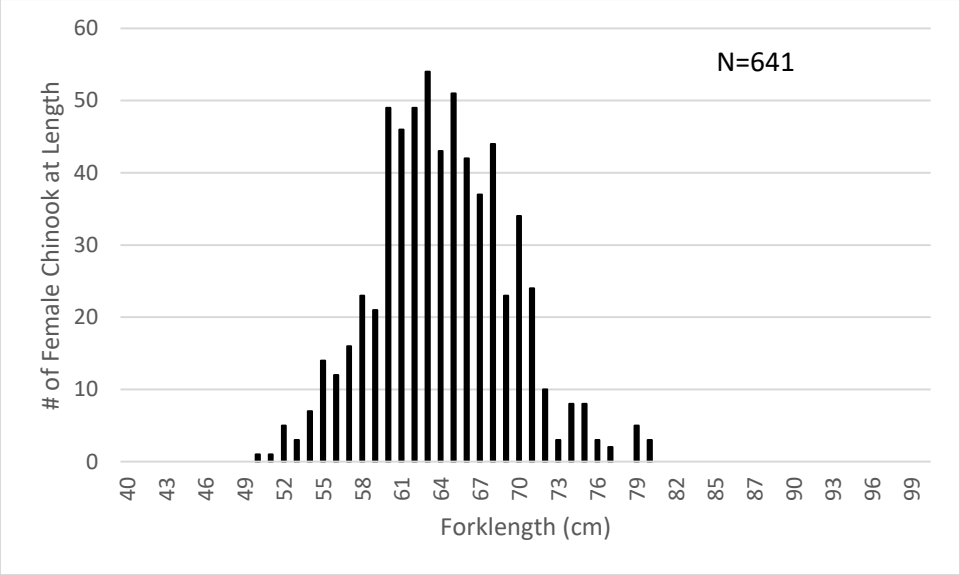

Figure 6: 2018 IGH female Chinook Salmon fork length histogram

Heads from 2,436 AD Chinook Salmon (random and non-random fish) were collected for CWT recovery, from which positive reads were obtained for 2,187 (Table 3). The remainder were either lost prior to or during extraction (54), did not have a tag (47) or the tags were unreadable (148). The contribution of lost or unreadable CWTs was estimated by applying the proportions of known CWTs (2,187) to the 202 lost or unreadable CWTs (Table 4). The contribution of 47 AD clipped fish that did not have CWTs is calculated during the tagging and releasing process and is factored in to calculating the production multiplier for each tag code.

Table 3: 2018 IGH Chinook Salmon CWT data and estimates

Estimated Contribution of Fall Run Chinook Produced at IGH to Total Run at IGH based on CWTs recovered in 2018									
CWT	**Release Location**	**Brood Year**	**AGE**	**Release Type**	**Number Recovered**	**Production Multiplier**	**Expanded Estimate**	**Estimate by age**	**Percent by age**
60685	IGH	2014	4	F	1	4.00230816	4.00		
68657	IGH	2014	4	F	1	4.011392935	4.01		
60687	IGH	2014	4	F	2	4.026980448	8.05		
60686	IGH	2014	4	F	5	4.019084622	20.10		
60684	IGH	2014	4	F	11	4.043077968	44.47		
60688	IGH	2014	4	Y	149	4.01821527	598.71	679.35	7.74
60712	IGH	2015	3	F	23	4.167898062	95.86		
60454	IGH	2015	3	F	49	4.023392165	197.15		
68703	IGH	2015	3	Y	59	4.002682071	236.16		
60787	IGH	2015	3	F	264	4.001566563	1,056.41		
60786	IGH	2015	3	F	284	4.020709775	1,141.88		
60785	IGH	2015	3	F	346	4.01106865	1,387.83		
60783	IGH	2015	3	Y	354	4.003038644	1,417.08		
60784	IGH	2015	3	F	571	4.007521218	2,288.29	7,820.66	89.15
61429	IGH	2016	2	F	1	4.080405405	4.08		
60683	IGH	2016	2	Y	5	4.00742145	20.04		
68784	IGH	2016	2	F	7	3.99815965	27.99		
68045	IGH	2016	2	F	14	4.002684006	56.04		
60994	IGH	2016	2	F	41	4.001913095	164.08	272.22	3.10
Total Run	**11,860**			**Number Recovered Subtotal**	**2,187**	**Expanded Estimate Subtotal**	**8,772.23**		
Estimated Contribution of Unknown CWTs									
200000	**CWT Lost**				**54**				
300000	**Head Lost**				**0**				
400000	**CWT Unreadable**				**148**				
Subtotal					**202**	**Unknown Estimate:**	**810.24**		
Total Estimated Hatchery Contribution							**9,582.47**	**Hatchery Proportion:**	**0.81**

The estimated contribution of unknown CWTs was then added to the contribution of known CWTs to determine the total contribution of hatchery-origin Chinook Salmon entering IGH. Of the 2,187 CWTs recovered (and successfully read), all originated from IGH. Based on the expansion of CWTs, KRP staff estimated that 81% of the Chinook entering IGH during the 2018 season were of hatchery origin (Table 3). Of the CWT returns (positive reads) in 2018, 567 (26%) were from yearling release groups and 1,620 (74%) were from fingerling release groups (Table 3). An additional 202 tag codes were apportioned for lost or unreadable tags (Table 4) and a final estimate of 9,582 (81%) Chinook Salmon were of hatchery origin during the 2018 run (Table 3).

Table 4: IGH 2018 Unknown CWT Expansion

2018 IGH Estimated Contribution of the 202 Ad Clipped Chinook with Unknown CWT Codes Based on Proportional Distribution of Known CWTs						
CWT	Brood Year	# of CWTs recovered	Proportion of CWT's Recovered	Estimated Number	Production Multiplier	Expanded Estimate
60685	2014	1	0.000457247	0.092363969	4.00230816	0.369669066
68657	2014	1	0.000457247	0.092363969	4.011392935	0.370508172
60687	2014	2	0.000914495	0.184727938	4.026980448	0.743895794
60686	2014	5	0.002286237	0.461819845	4.019084622	1.856093035
60684	2014	11	0.005029721	1.016003658	4.043077968	4.107782005
60688	2014	149	0.068129858	13.76223137	4.01821527	55.29960823
60712	2015	23	0.01051669	2.124371285	4.167898062	8.854162961
60454	2015	49	0.022405121	4.525834476	4.023392165	18.20920697
68703	2015	59	0.026977595	5.449474166	4.002682071	21.81251254
60787	2015	264	0.120713306	24.38408779	4.001566563	97.57455038
60786	2015	284	0.129858253	26.23136717	4.020709775	105.4687144
60785	2015	346	0.15820759	31.95793324	4.01106865	128.1854642
60783	2015	354	0.161865569	32.69684499	4.003038644	130.886734
60784	2015	571	0.261088249	52.73982625	4.007521218	211.3559727
61429	2016	1	0.000457247	0.092363969	4.080405405	0.376882438
60683	2016	5	0.002286237	0.461819845	4.00742145	1.850706751
68784	2016	7	0.003200732	0.646547782	3.99815965	2.585001255
68045	2016	14	0.006401463	1.293095565	4.002684006	5.175852935
60994	2016	41	0.018747142	3.786922725	4.001913095	15.15493564
Totals:		**2187**	**1**	**202**		**810.2382535**

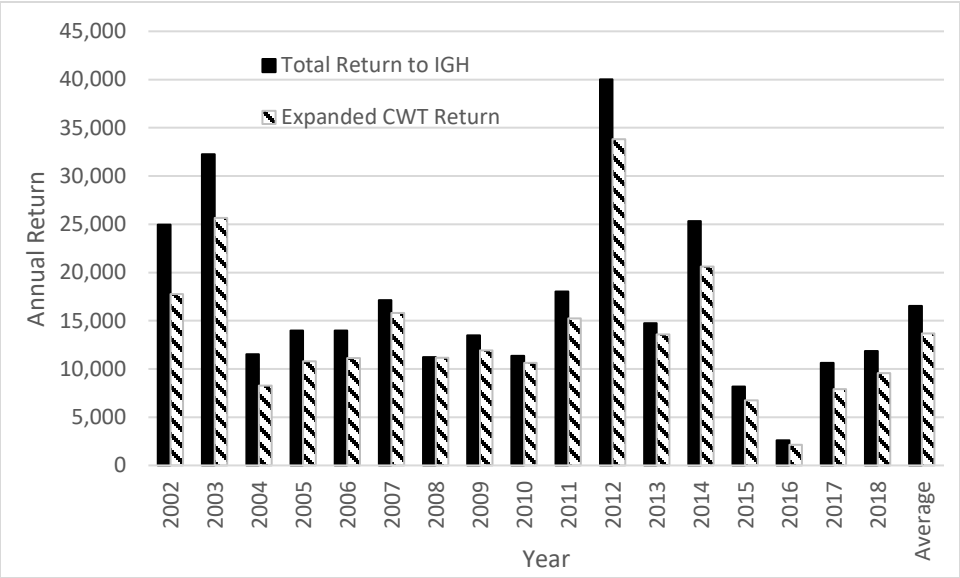

Table 7: IGH Chinook Salmon return and hatchery influence

Coded Wire Tagging

2018 was the 10th 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 2018, tagging operations were conducted by staff of the Pacific States Marine Fisheries Commission, under contract with PacifiCorp. A total of 1,327,199 juvenile Chinook Salmon were AD clipped and coded wire tagged, and 3,947,514 counted but not tagged, for a total of 5,274,713 Chinook processed during the 2018 tagging season (brood year 2017). The smolt component accounted for 1,063,044 tagged and 3,154,410 counted. The yearling component accounted for 264,155 tagged and 793,104 counted (Buttars, 2018).

Table 5: IGH CWT and mark and recovery ratios

Brood Year	IGH Smolt Releases			IGH Yearling Releases			Ratio of yearling/smolt return rates
	# CWTs Released	# CWTs Returned	% Return	# CWTs Released	# CWTs Returned	% Return	
1990	188,595	713	0.38	95,880	740	0.77	2.04
1991	191,200	96	0.05	90,982	167	0.18	3.66
1992	185,464	1,015	0.55	74,024	269	0.36	0.66
1993	188,562	40	0.02	98,099	196	0.20	9.42
1994	194,644	94	0.05	86,564	453	0.52	10.84
1995	191,799	85	0.04	90,172	954	1.06	23.87
1996	196,648	162	0.08	95,396	581	0.61	7.39
1999	182,131	686	0.38	91,220	514	0.56	1.50
2000	187,417	277	0.15	100,702	707	0.70	4.75
2001\[a]	198,311	11	0.01	110,167	764	0.69	125.02
2002	210,114	367	0.17	109,711	295	0.27	1.54
2003	261,888	70	0.03	48,592	60	0.12	4.62
2004	205,950	691	0.34	98,752	215	0.22	0.65
2005	209,754	194	0.09	103,157	445	0.43	4.66
2006	309,671	224	0.07	103,361	230	0.22	3.08
2007	307,204	340	0.11	103,876	300	0.29	2.61
2008\[b]	986,141	269	0.03	192,339	197	0.10	3.75
2009	1,119,054	10,224	0.91	264,253	581	0.22	0.24
2010\[c]	671,755	2,473	0.37	261,332	278	0.11	0.29
2011	1,158,028	2,694	0.23	286,947	844	0.29	1.26
2012	1,040,836	1,112	0.11	263,614	25	0.01	0.09
2013	1,117,134	233	0.02	263,836	462	0.18	8.40
2014*	965,584	337	0.03	263,272	969	0.37	10.55
2015*	911,162	1975	0.22	241,678	439	0.18	0.84
2016*	107,045	63	0.06	262,946	5	0.00	0.03
2017*	1,063,044			264,155			
AVERAGE			**0.18**			**0.35**	**9.27**

* Incomplete returns for BY 2014-2017

\[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

Ich Sampling

During the 2018 Ich monitoring effort at IGH, 30 adult Chinook Salmon were sampled over 4 sampling dates from mid-October to early November. Sampled fish represented 3.8% of the Chinook that entered the hatchery during the sampling dates. Of the 30 Chinook, 8 were positive for Ich trophonts (26.6%), but at a very low level of infection. None of the fish sampled appeared to be in a diseased state. None of the 30 Chinook showed signs of columnaris infection (Hileman et al 2019).

Coho Salmon

During the 2018 season 202 Coho Salmon entered IGH with the first Coho being trapped on October 18, 2018 and the last on December 13, 2018. One fish that returned on November 13, 2018 had a right maxillary clip (indicating Trinity River Hatchery origin) the fish was opercle punched and released, that fish returned to the hatchery on November 15, 2018 it was released and returned again on November 19, 2018 and it was released one final time. Since this fish returned 3 times, 2 of those returns were removed from the data analysis, for a grand total of 200 Coho returning to IGH in 2018. The Coho run consisted of 126 males (63%) and 74 females (37%). Male Coho ranged in size from 34 to 73 cm FL and averaged 53 cm (Figure 8), and female Coho ranged in size from 37 to 74 cm FL and averaged 64 cm (Figure 9). Grilse were estimated to be <53 cm FL, yielding a grilse component of 30.5% (61) and an adult component of 69.5% (139). The proportion of grilse among male Coho was 48%. The mean FL for grilse was 40 cm, and the mean FL for adult male Coho was 64 cm.

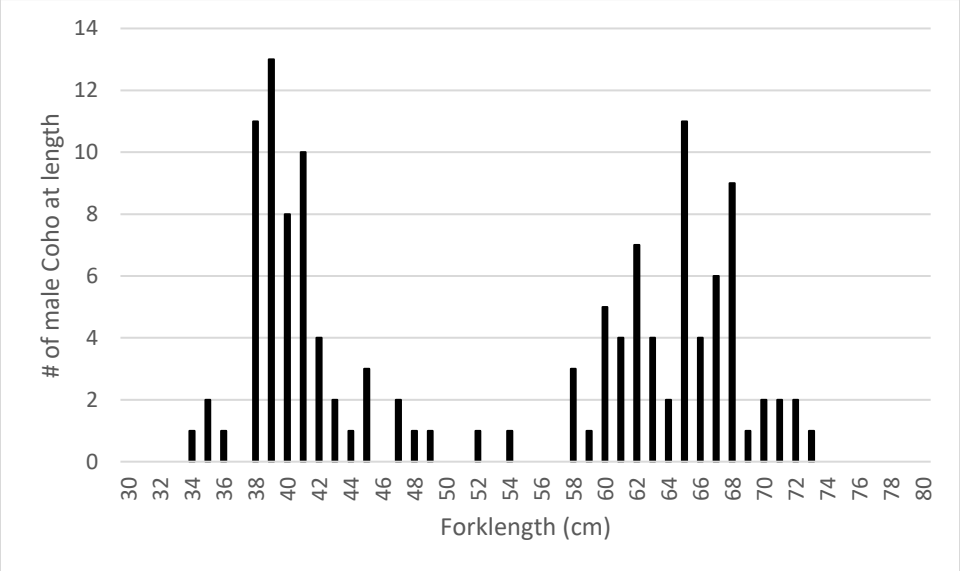

Figure 8: IGH Coho Salmon male fork length frequency histogram

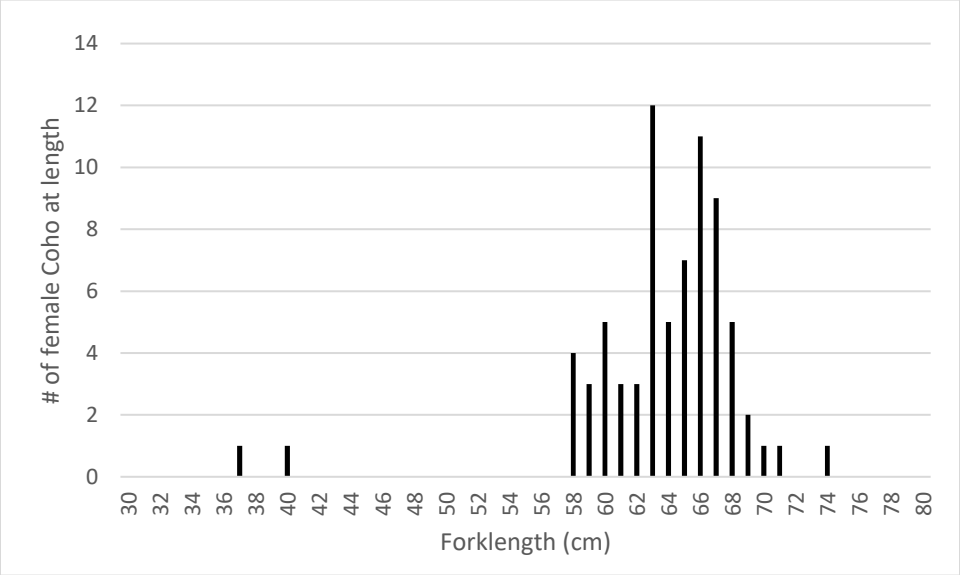

Figure 9: IGH Coho Salmon female fork length frequency histogram

Of the 200 Coho Salmon trapped, 170 (85%) had left maxillary clips (indicating IGH origin), 3 (1.5%) had right maxillary clips (indicating Trinity River Hatchery origin), and 27 (13.5%) were unmarked (Table 6).

Table 6: 1997-2018 IGH Coho Salmon marked percentage

Year	# Sampled	LM	RM	AD	OTHER	MARKED	UNMARKED	% MARKED
1997	2174	1970	5	28	6	2009	165	92.41
1998	669	378	0	2	0	380	289	56.80
1999	169	153	0	1	0	154	15	91.12
2000	1395	1067	4	58	4	1133	262	81.22
2001	2573	2130	138	51	8	2327	246	90.44
2002	1301	1006	25	38	7	1076	225	82.71
2003	1558	838	69	58	4	969	589	62.20
2004	1729	1203	32	69	1	1305	424	75.48
2005	1425	1282	2	1	0	1285	140	90.18
2006	301	204	2	16	0	222	80	73.75
2007	779	643	6	2	1	652	127	83.70
2008	1296	1268	2	0	1	1271	25	98.07
2009	45	29	7	0	0	36	9	80.00
2010	258	222	1	0	0	223	36	86.43
2011	586	522	0	2	1	525	63	89.59
2012	644	609	4	1	1	615	29	95.50
2013	1268	1158	2	1	2	1163	105	91.72
2014	384	346	0	5	0	351	33	91.41
2015	72	59	0	2	0	61	11	84.72
2016	86	66	0	0	0	66	20	76.74
2017	122	98	0	0	0	98	24	80.33
2018	200	170	3	0	0	173	27	86.50

8 Coho Salmon were trapped between October 18, 2018 and October 30, 2018 and it was deemed too early to spawn Coho, so they were released back into the Klamath River. On December 22, 2018 3 female Coho were PIT tagged and released from brood stock because there were no more males available to spawn and no males had been trapped in a week. Of the 3 released females, 2 had left maxillary clips and 1 had no mark.

DISCUSSION

Chinook Salmon

The 2018 run of Chinook Salmon to IGH (11,860) was 4,104 fish less than the 41-year average of 15,964 (Figure 10). Escapement to IGH was 11.5% of the Klamath basin escapement in 2018 (Figure 10). Klamath Basin returns of adult Chinook were 100.4% of the projected forecast, with 92,300 adults returning vs. the projected forecast of 91,900.

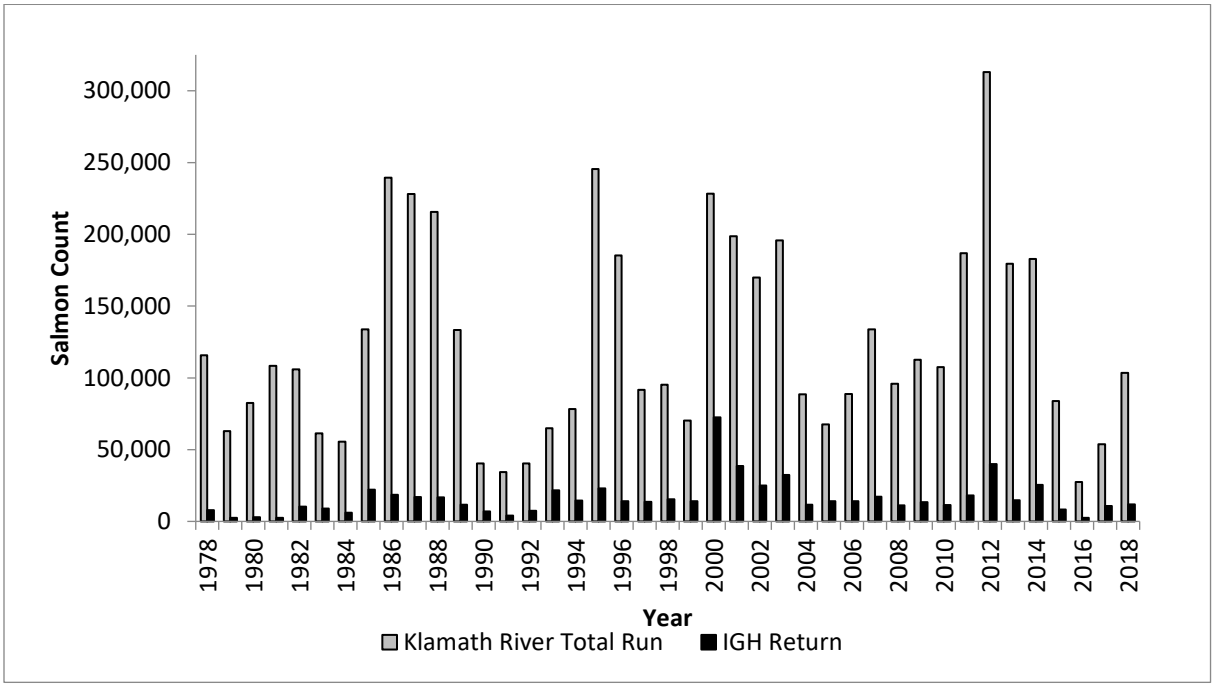

Figure 10: Chinook Salmon escapement to the Klamath Basin and Iron Gate Hatchery 1978-2018

The brood years returning to the Klamath River in 2018 were subjected to adverse river conditions during their outmigration as juveniles, and in the marine environment. 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 Salmon 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).

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 Salmon. This method was first used in 2015. 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. Sometimes male Chinook are spawned with more than one female, but no more than one male and one female were spawned per pan.

Air spawning is another method implemented in 2015 and has been used since implementation. 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 Salmon 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 2018 but may be implemented in future seasons.

The Chinook Salmon egg take in 2018 was 9,162,980 which was 1,037,020 eggs short of the target of 10,200,000 eggs.

The Chinook Salmon 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. 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 2018 run of Coho Salmon to IGH (200) was 769 fish less than the 57-year average of 969 (Figure 11). Southern Oregon Northern California Coho (SONCC) have been subjected to the same adverse ocean and in-river conditions as previously described for Chinook Salmon. 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).

Unmarked Coho Salmon are presumed to be of non-hatchery origin and are incorporated into spawning as close to the wild broodstock 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 2018 are shown in Table 7.

The relatedness coefficient (Rxy) of pairs of Coho Salmon spawned at IGH during the 2018 season with the use of the NOAA spawning matrix is shown in Figure 13. This was the ninth 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 > 0.25.

During the 2018 season, Coho Salmon that entered IGH during October while the Chinook Salmon spawning season was still underway, were released. 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 2018 are shown in Figure 12.

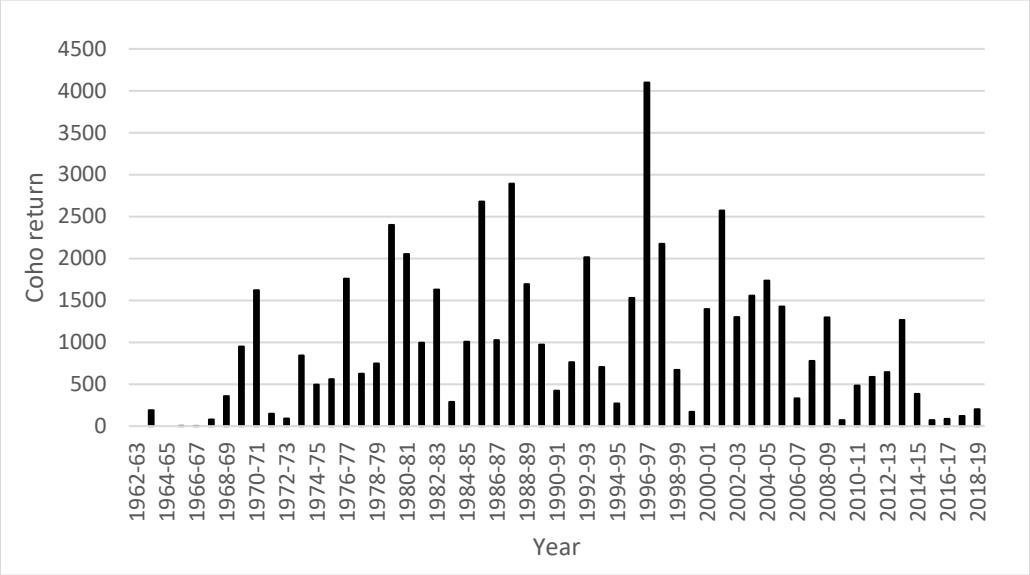

Figure 11: IGH Coho Salmon returns 1962-2018

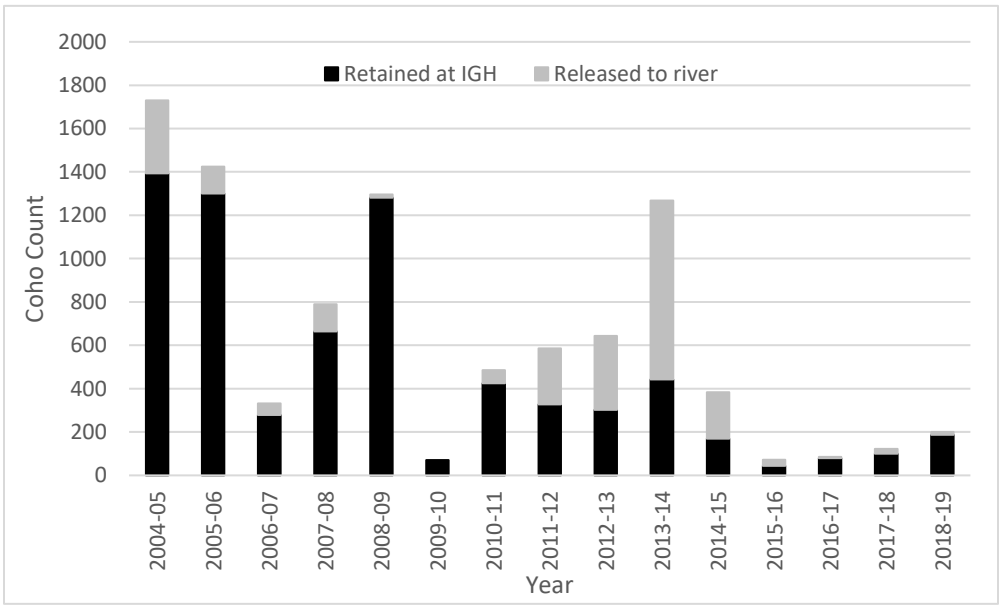

Figure 12: 2018 IGH Coho Salmon broodstock kept and released

Table 7: IGH Coho broodstock mark and spawn data. 2014 is marked because all eggs listed in the first line were lost due to equipment failure*

Year	Adult Males	Females	Total Adults	Jacks	Total Run	Females Spawned	Natural Origin Broodstock	pNOB	pJacks	# Eggs	Fecundity	Yearlings released	Egg to Smolt Survival	Date released
1993	361	314	675	29	704	219	?	~15	~1	503,326	2,298	79,506	16%	1995
1994	100	72	172	97	269	57	?	~15	~1	141,397	2,481	74,250	53%	1996
1995	708	793	1501	29	1530	294	?	~15	~1	782,170	2,660	81,489	10%	1997
1996	1,715	1,831	3546	551	4097	200	?	~15	~1	547,255	2,736	79,607	15%	1998
1997	825	1,047	1872	302	2174	126	16	6.3	~1	304,728	2,418	75,156	25%	1999
1998	243	268	511	158	669	122	75	30.7	~1	298,357	2,446	77,147	26%	2000
1999	90	61	151	18	169	35	5	7.1	~1	86,519	2,472	46,250	53%	3/29/2001
2000	304	441	745	650	1395	95	52	27.4	~1	270,151	2,844	67,933	25%	3/27/2002
2001	972	1,494	2466	107	2573	126	22	8.7	~1	404,370	3,209	74,271	18%	3/27/2003
2002	566	627	1193	108	1301	187	68	18.2	~1	609,193	3,258	109,374	18%	3/29/2004
2003	609	708	1317	241	1558	197	172	43.7	~1	502,048	2,548	74,716	15%	4/13/2005
2004	630	865	1495	239	1734	276	10	1.8	~1	799,623	2,897	89,482	11%	4/17/2006
2005	596	799	1395	30	1425	103	10	4.9	~1	295,101	2,865	118,487	40%	4/25/2007
2006	112	151	263	69	332	85	10	5.9	~1	236,406	2,781	53,950	23%	4/9/2008
2007	300	325	625	154	779	124	10	4.0	~1	316,155	2,550	117,832	37%	4/17/2009
2008	508	770	1278	18	1296	148	9	3.0	~1	455,480	3,078	121,000	27%	4/8/2010
2009	21	25	46	24	70	20	6	30.0	40	53,435	2,672	22,236	42%	4/14/2011
2010	193	235	428	57	485	80	21	26	18	259,490	3,244	155,840	60%	3/29/2012
2011	248	204	452	134	586	57	26	23	11	151,241	2,653	39,250	26%	3/18/2013
2012	98	203	301	343	644	64	12	9	64	158,651	2,479	78,000	49%	3/17/2014
2013	552	653	1205	63	1268	80	37	23	17	224,071	2,801	89,500	40%	3/17/2015
2014*	39	95	134	250	384	62	24	31	51	121,421	1,958	27,568	23%	4/5/2016
					0	20				37,350	1,868	27,568	74%	4/5/2016
2015	13	21	34	38	72	13	9	52	40	22,240	1,711	17,232	77%	3/24/2017
2016	30	26	56	30	86	23	22	47	49	43,705	1,900	34,376	79%	3/16/2018
2017	33	60	93	29	122	39	24	31	32	74,966	1,922	57,242	76%	3/18/2019
2018	65	74	139	61	200	58	32	28	48	103,661	1,787	NA	NA	NA
Avg	**382**	**468**	**850**	**147**	**960**	**108**	**31**	**21**	**37**	**288,982**	**2,567**	**72,664**	**25%**	

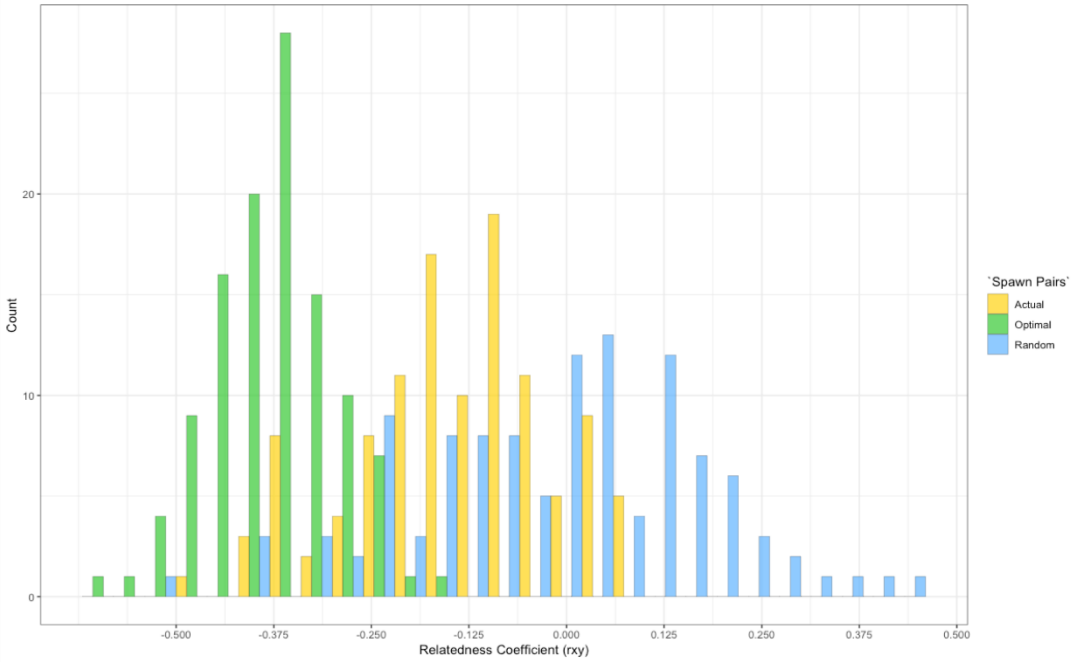

Figure 13: Observed relatedness coefficients of actual spawned pairs, optimally spawned pairs, and randomly chosen pairs for IGH Coho during the 2018 season (figure provided by NOAA SW Fisheries Science Center Salmonid Genetic Laboratory).

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