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Age Structure and Hatchery Fraction of Elwha River Chinook Salmon: 2017 Carcass Survey Report

by Josh Weinheimer[1], Joseph Anderson[1], Randy Cooper[1], Scott Williams[1], Mike McHenry[2], Patrick Crain[3], Sam Brenkman[3] and Heidi Hugunin[3]

[1] Washington Department of Fish and Wildlife
[2] Lower Elwha Klallam Tribe
[3] Olympic National Park

Washington Department of Fish and Wildlife
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Prepared by:

Josh Weinheimer[1], Joseph Anderson[1], Randy Cooper[1], Scott Williams[1], Mike McHenry[2], Patrick Crain[3], Sam Brenkman[3] and Heidi Hugunin[3]

[1] Washington Department of Fish and Wildlife

[2] Lower Elwha Klallam Tribe

[3] Olympic National Park

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Executive Summary

Monitoring the recolonization of Pacific salmon and steelhead following the removal of two dams is a critical component of the Elwha Restoration Project. During the fall of 2017, we collected adult Chinook salmon (*Oncorhynchus tshawytscha*) carcasses from the Elwha River in order to evaluate the proportion of hatchery fish, the age distribution of returning adults, and the ratio of fish that exhibited stream vs ocean type life history strategies. Surveys were conducted in the upper watershed (river km 61.5) downstream to where the river enters into the Strait of Juan de Fuca, including three tributaries. Of the carcasses sampled from the river and its tributaries (N = 520), the majority (88 %) were located upstream of the former Elwha Dam site. We also sampled fish (N = 566) throughout the season at the WDFW hatchery in the lower Elwha River. Carcasses were sampled for physical measurements, hatchery marks, scales and genetics. We sampled 850 non-jack carcasses during the sampling season, representing 33.67 % of the estimated escapement above the Elwha SONAR site. Over 96% of the fish sampled were marked hatchery fish. Age-3 was the dominant age class (60%), and age-2 fish (jacks) accounted for less 6% of our total sample. We sampled one age-2 natural origin fish and ten age-3 natural origin fish, 20 age-4 natural origin fish and two age-5 natural origin fish whose parents had access to habitat upstream of the former Elwha dam site following its removal in 2012. However, we have not observed a reduction in hatchery mark rate for the age classes that might have been produced by spawners upstream of the Elwha Dam site, and thus have no evidence that recolonization of newly accessible habitat has boosted natural production of Chinook salmon. Natural origin fish returning to the river as age-4 or age-5 adults to date were exposed to extreme environmental conditions associated with dam removal. All of the Chinook that migrated to the ocean as yearlings were hatchery origin, and so we did not observe any stream-type life histories among unmarked fish. We estimated that Chinook that spawned naturally in the Elwha could have deposited over 2.6 million eggs in 2017. Finally, an analysis of spawner to spawner productivity indicated that naturally spawning fish from the five most recent complete cohorts (brood years 2008 – 2012) did not replace themselves (average productivity = 0.28), whereas the combined productivity of natural plus hatchery spawners exceeded replacement in four of the last five complete cohorts (average productivity = 2.2).

Introduction

The Elwha River is the site of the largest dam removal project in Unites States history. The passage of the Elwha River Ecosystem and Fisheries Restoration Act in 1992 authorized the removal of two dams, Elwha and Glines Canyon, from the mainstem Elwha River. The removal of the dams will allow all five species of Pacific salmon plus steelhead trout to recolonize approximately 115 km of habitat, the majority of which is located in the Olympic National Park, that has been blocked since 1913 (Hosey and Associates 1988). Removal will also facilitate the resumption of anadromous life history strategies in resident cutthroat trout and bull trout populations. The long term goal of the restoration project is the recovery of naturally producing, self-sustaining runs without reliance on hatchery production (Ward et al. 2008). Dam deconstruction began in September of 2011; demolition of Elwha Dam was completed in March of 2012 and Glines Canyon Dam in late August of 2014.

Compared to the Chinook salmon native population that historically inhabited the Elwha River prior to dam construction, the current population exhibits truncated life history diversity, notably the absence of the early-timed adult returns (Ruckelhaus et al. 2006). In recent decades, Elwha Chinook salmon have largely been supported by hatchery production in the limited habitat below the Elwha Dam. In an effort to preserve the genetic integrity of the Elwha Chinook stock, fishery managers intentionally limited the release of out of basin hatchery fish over the years (Brannon and Hershberger 1984; WDFW and WWTIT 1994). Contemporary genetic analyses confirm that the Elwha stock is unique with respect to Puget Sound and groups much more closely to Chinook salmon from the neighboring Dungeness River than other watersheds in the region (Ruckelshaus 2006).

Guidelines for monitoring the recovery of ESA-listed Chinook salmon and steelhead were laid out in the Elwha Monitoring and Adaptive Management (EMAM) plan for listed species of Chinook salmon and steelhead (Peters et al. 2014). A series of four recovery stages were described including: 1) Preservation, 2) Recolonization, 3) Local Adaptation and 4) Viable Natural Population. Progression through the phases is measured using the Viable Salmon Population (VSP) metrics abundance, productivity, spatial distribution and diversity (McElhany et al. 2000).

Several of these VSP metrics rely on data describing the hatchery mark rates, age structure, and juvenile life histories of fish returning to the Elwha River watershed. In order to estimate the abundance of natural-origin salmon, one must subtract the proportion of the total return that was produced in hatcheries. Age structure data are required for the cohort analysis needed to evaluate spawner to spawner productivity and smolt-to-adult return rates.

For Chinook salmon, a key diversity metric is the proportion of naturally spawned salmon that adopt stream-type vs. ocean-type life histories. Stream-type Chinook have a longer freshwater residency time than ocean-type Chinook salmon, spending an entire year in freshwater prior to seaward migration. Ocean-type Chinook migrate within their first year of life, either as small fry soon after emergence or as larger parr that have spent 1-6 months rearing and growing in freshwater. Within Puget Sound, dam construction has selectively restricted access to the majority of snow-melt dominated headwater streams that are typically associated with the stream-type life history (Beechie et al. 2006). Currently, the vast majority of natural-origin Elwha Chinook utilize the ocean type life history strategy (McHenry et al. 2017). It is hypothesized that access to the upper watershed might allow for the stream-type life history trait to reemerge (McHenry et al. 2018).

In response to this need for biological information, we conducted Chinook salmon carcass surveys in the fall of 2017. The primary hatchery marking strategy for Elwha River Chinook salmon are thermal otolith marks induced during hatchery rearing, and so samples must be collected from carcasses. The purpose of the thermal otolith rather than more common adipose clip mark is to reduce exposure to mark-selective fisheries. However, since brood year 2012, a small group of approximately 250,000 Chinook salmon subyearlings received otolith, adipose clips and coded wire tags as a means to evaluate mark-selective fishery mortality. Age structure and juvenile life history data are commonly derived from scales also collected during carcass surveys.

Our primary objectives for the carcass collections were to:

1) Measure the proportion of hatchery to natural-origin Chinook salmon returning to the Elwha River.

2) Describe the age structure of hatchery and natural-origin Chinook salmon returning to the Elwha River.

3) Assess the relative frequency of stream-type vs. ocean-type juvenile life histories of naturally produced Chinook salmon returning to the Elwha River.

We conducted carcass surveys throughout the Elwha River and tributaries downstream of Goblins Gate at river km 31.5, allowing us to evaluate two spatially explicit hypotheses. First, we predicted that the proportion of hatchery marked fish would decrease with the distance upstream from the WDFW Hatchery located at river km 5.6. Second, we predicted that adults adopting stream-type juvenile life history would tend to be found at more upstream locations nearer cold-water, snowmelt-dominated headwaters. We intend these hypotheses as long term guides for our monitoring efforts and expect that the data needed to evaluate them will accumulate in future years. This is particularly true for evaluating the rate of stream-type life histories, which may depend on colonizing habitats upstream of the former Glines Canyon Dam site.

This report describes the results from the carcass recovery project for the 2017 spawning season, summarizes trends in age structure and hatchery mark information in recent years, presents an analysis of spawner to spawner population productivity for Elwha River Chinook salmon, and evaluates CWT recoveries in mark-selective fisheries.

Methods

Sample collection

We surveyed the mainstem Elwha and tributaries from the head of the Elwha Grand Canyon at river km 31.5 to the mouth of the river at the Strait of Juan de Fuca. Surveys were conducted by foot and inflatable raft. The Elwha River was broken up into 8 sections (Table 1, Figure 1). Each reach below Rica Canyon was scheduled to be surveyed every 7 to 10 days. The Grand Canyon to Goblins Gate section was surveyed one time during the peak spawning period. Based on redd survey numbers from previous spawning seasons, we felt this sampling structure would allow us to sample most of the available carcasses in each reach throughout the season.

Table 1. Description of Sampling Reaches for the Elwha Chinook Carcass Recovery from August 29 to October 11, 2017.

Reach	Description	River Km		Survey Crew
		Start	End	
1	Former Elwha Dam Site to mouth of River	7.5	0.2	WDFW
2	Gooseneck to former Elwha Dam Site	9.8	7.5	WDFW
3	Highway 101 Bridge to the Gooseneck	12.1	9.8	WDFW
4	Fisherman’s Corner to Highway 101 Bridge	16.5	12.1	WDFW
5	Altaire Bridge to Fisherman’s Corner including Hughes Creek	19.8	16.5	WDFW
6	Glines Dam powerhouse site to Altaire Bridge	21.1	19.8	ONP, WDFW
7	Rica Canyon to Glines Dam	25.7	21.1	WDFW
8	Grand Canyon to Goblins Gate	31.5	28.2	ONP
9	Grand Canyon to upper foot bridge	61.5	38.0	Mult.
Tributary	Indian Creek	1.6	0	LEKT
Tributary	Little Creek	1.6	0	LEKT

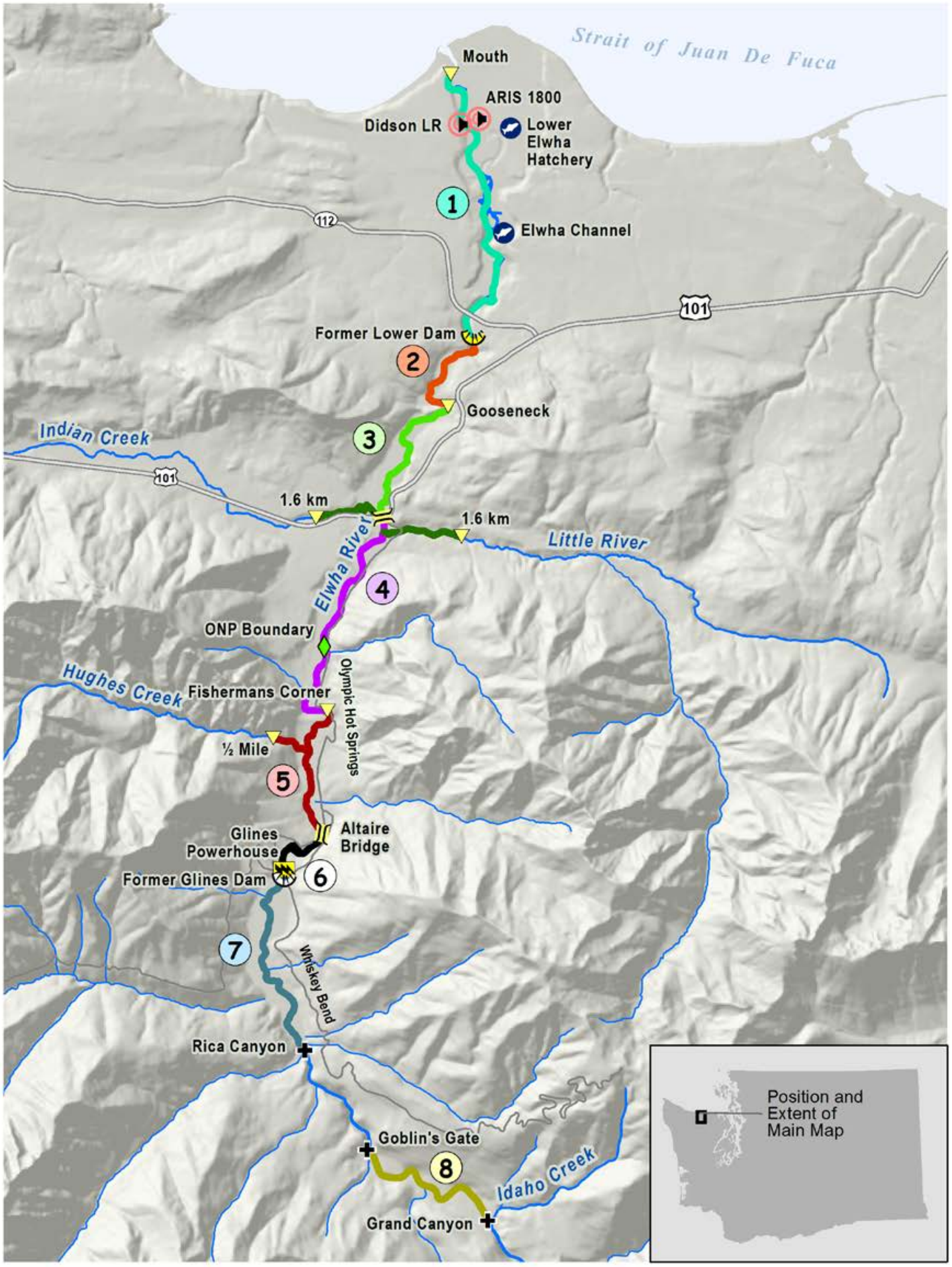

Figure 1. Map of Elwha River with carcass surveys sections for 2017 sampling season.

In addition, backcountry surveys were conducted. On September 20-21, the mainstem Elwha River was surveyed from the footbridge just downstream from Chicago Camp (approximately river km 61.7) downstream to the Mary's Falls campground (river km 38.8). Within this stretch of the river, approximately 4.3 km of river in the vicinity of Carlson Canyon was not surveyed due to its inaccessibility. None of the tributaries in this stretch of river were surveyed.

Chinook salmon carcasses were sampled weekly at the WDFW Elwha adult raceways (hereafter WDFW Hatchery) throughout the spawning season. Chinook salmon broodstock spawned at the WDFW hatchery were collected using a variety of methods. The primary collection method was by gill net from the Elwha River. Chinook salmon broodstock also included volunteers to the WDFW hatchery trap and volunteers to the LEKT hatchery trap that were subsequently transported to the WDFW adult holding ponds. Some broodstock were also collected from the river via gaffing and spawned on-site rather than at the hatchery.

At all locations, carcasses were sampled for fork length, postorbital-hypural (POH) length (length from the posterior margin of the eye orbit to the end of the hypural plate), sex, presence of CWT tag, presence of any adipose marks, otoliths, DNA fin clip and scales. If a CWT was detected, the snout was removed and taken to the lower Elwha Hatchery freezer for processing after the season. DNA was only collected from carcasses that showed more than 50% red coloration in the gills in order to maximize sample quality. DNA samples are currently archived at the WDFW Molecular Genetics Laboratory in Olympia, WA but were not analyzed in this study.

In addition to the measurements above, we also sampled up to 10 females per spawn day at the hatchery for egg mass and total eggs (fecundity). Females were spawned into individual buckets to measure total egg mass. A small subsample of the eggs was counted and measured for mass so that we could extrapolate for the total number of eggs for each female.

Daily stream discharge and turbidity data were downloaded from the U.S Geological Survey (USGS) Water Data website. Discharge data were reported as cubic feet per second (CFS) and collected at the McDonald Bridge station (site = 12045500). Turbidity was reported in formazin nephelometric units (FNU) from the water diversion immediately upstream from the WDFW Hatchery (site = 12046260).

Average daily discharge ranged between 371 and 3,240 cfs during the sampling season (Figure 2). Peak average flow occurred on October 22 and never fell below 685 CFS for the remainder of the season. Turbidity daily average ranged between 1.9 and 331 FNU, and stream visibility was greatly reduced following the increase in flow on October 18, when the river rose from 573 CFS to 1,830 CFS.

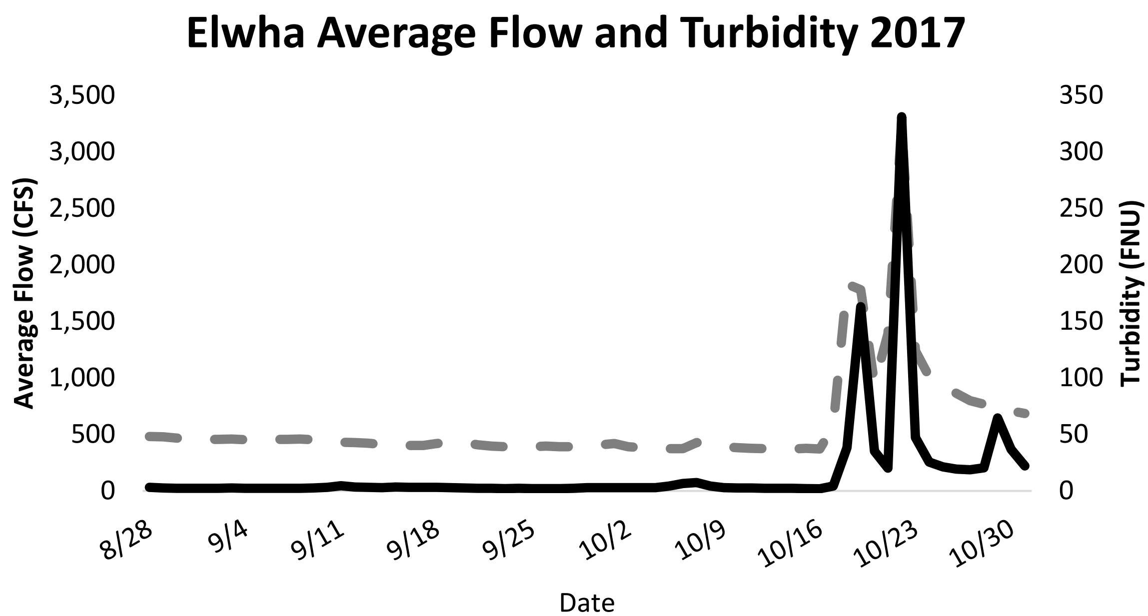

Figure 2. Average daily discharge (cfs) and turbidity (FNU) for the Elwha River, August 28 – October 31, 2017.

Evaluating hatchery mark rates

The primary hatchery marking strategy for brood years of Elwha Chinook salmon expected to return in 2017 was a thermal otolith mark (Table 2). Avoidance of the adipose clip was intended to reduce vulnerability to mark selective fisheries. Most hatchery Chinook salmon are released into the Elwha River as subyearlings, but there is also a smaller yearling release group (Table 2).

In some years, equipment malfunctions limited the capacity to induce thermal otolith marks. Thermal otolith marks require sequentially altering water temperature during embryonic development in a prescribed protocol over the course of approximately 1-3 weeks, and specialized chillers are required to accomplish this task. Any hatchery juveniles that were not otolith marked due to chiller malfunctions were selectively placed into the yearling program receiving the CWT mark (Table 2, brood year 2012).

Table 2. Releases of hatchery Chinook in the Elwha River Basin, brood years 2012-2015.

Brood Year	Type	Thermal Otolith	Thermal Otolith + CWT	CWT	AD + CWT + Thermal Otolith	Total
2012	Subyearling	907,387	0	0	251,892	1,159,279
	Yearling	0	0	201,074	0	201,074
2013	Subyearling	2,388,947	0	0	251,024	2,639,971
	Yearling	0	177,945	0	0	177,269
2014	Subyearling	2,429,097	0	0	250,295	2,679,392
	Yearling	0	158,799	0	0	158,799
2015	Subyearling	2,401,794	0	0	250,072	2,646,442
	Yearling	0	155,400	0	0	NA

Potential Egg Deposition

We attempted to estimate the total potential egg deposition (PED) from fish that spawned naturally in the Elwha River during the fall of 2017. To do this, we first assumed:

1) The proportion of males to females of fish in the hatchery was similar to fish in the river. Methods used to capture fish for the hatchery were random and did not selectively target one sex, whereas behavioral differences between the sexes may bias carcass surveys on the spawning grounds.
2) The lengths of the females we sampled from all locations, including the hatchery and the river, were representative of the fish that spawned naturally in the river.
3) Females that were gaffed from the spawning grounds but not spawned by hatchery staff were assumed to already have spawned in the river (Troy Tisdale, WDFW, personal communication).

Using the above assumptions, we took the non-jack estimate of returning adults from the sonar sites and applied our ratio of males to females based on data collected at the hatchery. This gave us the total number of returning females for the entire basin. To get the total number of females that spawned in the river, we subtracted all the females that were spawned in the hatchery or that were gaffed from the river and spawned. We then calculated the average length of all the females we sampled throughout the season. Using a regression relationship between size and fecundity, we estimated for the average fecundity for all females returning in 2017. To calculate the total PED for fish that spawned naturally, we multiplied the average fecundity by the total number of females spawning in the river.

Spawner to spawner productivity

In order to estimate productivity, we divided the total number of Chinook salmon spawning in each cohort 2004 – 2013 by the number of adults they produced that returned to the Elwha River in subsequent years. Our analysis began with the 2004 cohort because this was the first brood year with a mass marking goal at the hatchery of 100%. Following Peters' et al. (2014) guidelines, we calculated the productivity of Chinook salmon spawning naturally in the Elwha River, and the combined productivity of naturally spawning and hatchery spawned fish.

In our description of productivity methods and results, we distinguish between the terms “natural spawner” and “natural-origin.” We define “natural spawners” as fish that spawn naturally in the Elwha River and tributaries, regardless of whether they themselves were produced in a hatchery. Natural spawners could be marked or unmarked. We define “natural-origin” as unmarked fish whose parents spawned in the river. Natural origin fish could spawn themselves in the river, or be spawned at the hatchery.

Both productivity metrics required data on the proportion of hatchery-origin salmon returning to the river (pHOS), age structure and abundance. Data sources for hatchery mark and age information were WDFW unpublished, Anderson et al. (2015), Weinheimer et al. (2015), Weinheimer et al. (2016) Weinheimer et al. (2017) and this report. The data source for abundance was Elwha Chinook SONAR reports (Denton et al. 2017, and prior SONAR reports). We calculated the total number of hatchery-origin and natural-origin adult salmon within each return year by multiplying total abundance by pHOS and (1 – pHOS), respectively. Hatchery-origin and natural-origin returns were allocated to the cohort that produced them according to the age structure data. Our approach relied to two assumptions, both necessitated by the extremely small number of unmarked, natural-origin salmon encountered over the years:

1. Marked hatchery-origin and unmarked natural-origin Chinook salmon have the same age structure.

2. Hatchery broodstock and Chinook salmon spawning naturally in the Elwha River have the same pHOS value.

Our metrics of productivity did not account for fish harvested in fisheries.

Mark Selective Fisheries

We attempted to estimate the proportion of the 2012 brood year adipose marked, CWT subyearling release that was intercepted in mark selective fisheries. We queried the Regional Mark Processing Center (RMIS) website (www.rmpc.org) for all recoveries of the tag code applied to this release (636292). The total number of recoveries and expansions were sorted by recovery location. The proportion of tags recovered in mark selective fisheries was calculated by dividing the total number of expanded recoveries in mark selective fisheries by the total number of expanded recoveries in all locations. At the time of this report, CWT tag recoveries with catch expansions were only available for ages 2, 3 and 4 year old Chinook salmon. We expect that recoveries for 5 year olds will be available by the end of 2018. We emphasize that our analysis presents only the raw, expanded CWT recovery data directly accessible from RMIS, and not harvest rates calculated via the Fishery Regulation Assessment Model (FRAM) employed in salmon harvest management decisions.

Results

Carcass Recoveries

We sampled a total of 1,086 Chinook carcasses throughout the sampling season (Table 3). A total of 520 samples (48%) originated from the Elwha River and tributaries. Of the fish sampled outside the hatchery, 88.3% were sampled above the former Elwha Dam site. No carcasses were recovered during the single backcountry survey September 20-21.

The highest number of samples collected in one week from the river occurred during the week of September 25-29, and over three quarters (72%) of the samples we collected from the river were recovered during the month of September (Table 4). The number of carcasses found dropped significantly after October 9.

Sex data was recorded for each carcass. POH length was recorded for 1,080 (99.4%) carcasses and fork length for 1,039 (95.7%) carcasses. Otolith samples were taken from 1,084 (99.8%) carcasses, readable scale samples from 898 (82.7%) carcasses and DNA fin clips from 682 (62.8%) carcasses. A total of 26 carcasses were sampled in Indian Creek (N = 24) and Little River (N = 2).

Table 3. Total number of Chinook carcasses sampled by survey reach in the Elwha River Watershed 2017.

Reach	Number of Carcasses Sampled	Percent of Total
Reach 1 - Former Elwha Dam Site to river mouth	61	5.62%
Reach 2 - Gooseneck to former Elwha Dam Site	42	3.87%
Reach 3 - Highway 101 Bridge to Gooseneck	88	8.10%
Reach 4 – Fisherman’s Bend to Highway 101 Bridge	87	8.01%
Reach 5 - Altaire Bridge to Fisherman’s Bend plus Hughes	122	11.23%
Reach 6 - Glines Powerhouse to Altaire Bridge	43	3.96%
Reach 7 - Rica to Glines	50	4.60%
Reach 8 - Grand Canyon to Goblins Gate	1	0.09%
Reach 9	0	NA
Indian Creek	24	2.21%
Little River	2	0.18%
WDFW Hatchery	566	52.12%
Total	**1,086**	**100%**

Table 4. Number of Chinook carcasses sampled by week for individual reaches during the 2017 season. Zero indicates a survey was completed but no carcasses were sampled. A dash indicates no survey was conducted that week. No surveys were conducted during the weeks October 30 through November 3 due to lack of carcasses.

Week	Reach								Indian Creek	Little River	Hatchery
	1	2	3	4	5	6	7	8			
Aug 28 - Sep 1	0	-	-	-	-	-	-	-	-	-	
Sep 4 - Sep 8	0	0	0	0	0	0	-	-	-	-	20
Sep 11 - Sep 15	1	2	3	0	3	6	-	-	-	-	103
Sep 18 - Sep 22	14	12	23	21	32	14	9	1	-	-	110
Sep 25 - Sep 29	30	17	38	49	59	9	21	-	10	-	198
Oct 2 - Oct 6	12	8	19	16	24	11	13	-	14	2	120
Oct 9 - Oct 13	4	3	5	1	1	3	7	-	-	-	15
Oct 16 - Oct 20	-	-	-	0	3	-	0	-	-	-	-
Oct 23 - Oct 27	0	0	0	-	-	-	-	-	-	-	-
Totals	**61**	**42**	**88**	**87**	**122**	**43**	**50**	**1**	**24**	**2**	**566**

Broodstock collection method

Most of the fish sampled at WDFW Hatchery were net-collected fish rather than volunteers to either the WDFW or LEKT hatcheries (Table 5). We sampled over two thirds of all the gill net fish that came to the hatchery in 2017 and just over 48% of all the LEKT volunteer fish to the WDFW Hatchery (Table 6). We did not sample any gaffed fish during the 2017 season.

Table 5. Adult collection method summary for Elwha Chinook salmon carcass sampling 2017.

Sample Location	Collection Method	Number of Carcasses Sampled	Percent of Total Carcasses Sampled
Mainstem and Tributaries	Natural Spawners	520	47.88%
	Gaffed	0	0.00%
WDFW Hatchery	Gill net (N)	321	29.56%
	Lower Elwha Klallam (LEKT)	73	6.72%
	Volunteers (V)	172	15.84%

Table 6. Elwha Chinook salmon broodstock collection summary. Numbers include non-viable females and pond mortalities.

Broodstock collection method	Total Collected	Percent sampled
Gill net	388	82.73%
LEKT Hatchery volunteers	151	48.34%
WDFW Hatchery volunteers	496	34.68%
Gaffed	156	0.00%
Total	1,191	47.52%

Hatchery mark rates

We collected 1,077 otolith samples from Chinook salmon over the course of the season. Nine hundred and thirty six (86.9%) of the samples had an otolith mark present. Of the remaining 141 samples, 91 had no otolith mark but did have a CWT present, five fish were adipose marked but did not carry an otolith mark or CWT, two fish were not checked for hatchery marks or CWT, and three fish did not have an otolith mark, ad mark or CWT but had growth patterns on the scale samples that indicated hatchery rearing. Thus, 40 fish (3.7%) had no internal (Otolith or CWT) or external hatchery marks (Table 7).

Overall, the proportion of hatchery-origin Chinook salmon was 96.3%. Only one reach, reach 6, had a mark rate < 90% (Table 7). There was no consistent downstream to upstream trend in mark rates across the eight different survey reaches with > 20 samples (Table 7). However, when reaches 5 – 9 were pooled, they had a lower hatchery mark rate (91.6 %) than reaches 1 – 4 plus Little River and Indian Creek (96.3 %), a difference that was significant based on a binomial generalized linear model (p = 0.027).

Table 7. Hatchery mark rates of Chinook salmon sampled from the Elwha River 2017 based on thermal otolith, adipose and CWT marks.

Location		Otolith Mark		All Hatchery Marks	
		N	Percent Marked	N	Percent Marked
Hatchery	Net	320	85.63%	321	97.51%
	LEKT	73	84.93%	73	100.00%
	Volunteer	172	90.12%	172	98.26%
Carcass Survey	Reach 1	61	83.61%	61	93.44%
	Reach 2	41	95.12%	41	100.00%
	Reach 3	88	88.64%	88	94.32%
	Reach 4	85	85.88%	86	97.67%
	Reach 5	121	85.12%	122	90.98%
	Reach 6	42	83.33%	43	88.37%
	Reach 7	49	87.76%	49	95.92%
	Reach 8	1	100.00%	1	100.00%
	Reach 9	0	NA	0	NA
	Little River	2	50.00%	1	100.00%
	Indian Creek	22	95.45%	21	100.00%
	Total	1,077	86.91%	1,079	96.30%

CWT Data

We collected CWTs from 275 fish in the Elwha River watershed during fall 2017. One hundred and six of the CWTs were recovered from the river (Table 8). The 2017 season was the first year we found CWTs in every reach we sampled. The majority of the CWTs originated from releases into the Elwha River, but some were derived from releases into the neighboring Morse Creek (N = 17), Dungeness (N= 3) and Hurd Creek (N=1) watersheds (Table 8 and Table 9). We also had two fish that originated from other locations in Puget Sound, Purdy Creek (N=1) and Soos Creek (N=1). Fish that were released from the Elwha were mostly from the yearling program (84.4%), except for 39 tags from the 2012-2015 brood years when a portion of the subyearling releases were coded-wire tagged (Table 2).

Table 8. Chinook Coded Wire Tags (CWT) recovered from the Elwha River during spawn year 2017.

	Sampling Location	Number of CWT	Brood Year	Release Location
River	Elwha Dam to Mouth	12	2013	Elwha
		1	2014	Elwha
	Gooseneck to Elwha	8	2013	Elwha
		2	2014	Elwha
	101 Bridge to Gooseneck	2	2012	Elwha
		12	2013	Elwha
		1	2013	Morse
		2	2014	Elwha
		1	2015	Elwha
	Fisherman's Bend to 101	1	2011	Morse
		2	2012	Elwha
		2	2013	Morse
		13	2013	Elwha
		1	2014	Elwha
	Altaire to Fisherman's Bend	1	2012	Elwha
		5	2013	Morse
		16	2013	Elwha
		1	2014	Dungeness
		5	2014	Elwha
	Glines to Altaire	2	2012	Elwha
		4	2013	Elwha
	Rica to Glines	1	2012	Elwha
		1	2013	Dungeness
		3	2013	Morse
		5	2013	Elwha
		1	2014	Elwha
	Grand Canyon to Goblins Gate	1	2012	Elwha
	Total	106		

Table 9. Chinook Coded Wire Tags (CWT) recovered from the Elwha Hatchery during spawn year 2017.

	Sampling Location	Number of CWT	Brood Year	Release Location
Hatchery	Net	10	2012	Elwha
		1	2013	Dungeness
		4	2013	Morse
		84	2013	Elwha
		9	2014	Elwha
	LEKT	1	2012	Elwha
		1	2013	Morse
		16	2013	Elwha
		1	2014	Elwha
		1	2015	Hurd Creek
		2	2015	Elwha
	Volunteer	5	2012	Elwha
		1	2013	Morse
		22	2013	Elwha
		7	2014	Elwha
		1	2015	Soos Creek
		1	2015	Purdy Creek
		2	2015	Elwha
	Total	169		

Scale Data

Of the 1,065 scale samples collected, 898 (84.3%) were successfully aged in the laboratory. Age-3 was the dominate age class in each sampling reach and all the fish sampled at the hatchery, as over 60% of the entire collection was composed of age-3 Chinook salmon (Table 10). The highest percentage of age-5 Chinook salmon were collected from reach 2 which is just upstream of the former Elwha Dam site (Table 10). Forty-eight fish were aged as age 2 fish (jacks). One hundred and ninety six (21.9%) were identified as fish that migrated to the ocean at age-2 (stream-type Chinook, Table 11). All of these stream-type Chinook were hatchery origin.

Table 10. Chinook carcass age data from scale samples by reach for the Elwha River 2017.

Sample Location	Collection Method	Number of Samples	Total age				
			2	3	4	5	6
WDFW Hatchery	Net	253	0.00%	53.36%	40.32%	6.32%	0.00%
	LEKT	63	15.87%	61.90%	19.05%	3.17%	0.00%
	Volunteer	145	18.62%	60.00%	17.93%	3.45%	0.00%
Reach 1	Carcass Sample	54	1.85%	64.81%	29.63%	3.70%	0.00%
Reach 2		37	2.70%	62.16%	27.03%	8.11%	0.00%
Reach 3		77	2.60%	59.74%	31.17%	6.49%	0.00%
Reach 4		76	2.63%	68.42%	26.32%	2.63%	0.00%
Reach 5		107	2.80%	60.75%	29.91%	6.54%	0.00%
Reach 6		31	3.23%	61.29%	29.03%	6.45%	0.00%
Reach 7		39	2.56%	64.10%	30.77%	2.56%	0.00%
Reach 8		1	0.00%	0.00%	0.00%	100.00%	0.00%
Reach 9		0	NA	NA	NA	NA	NA
Indian Creek		13	0.00%	92.31%	7.69%	0.00%	0.00%
Little Creek		2	0.00%	50.00%	50.00%	0.00%	0.00%
All Samples		898	5.35%	60.02%	29.51%	5.12%	0.00%

Table 11. Total age and age at outmigration of Elwha River hatchery and unmarked Chinook salmon, return year 2017. Sample includes strays from other WDFW and Tribal hatcheries.

Origin	Age at Outmigration	N	Total Age				
			2	3	4	5	6
Unmarked	Subyearling	33	1	10	20	2	0
Unmarked	Yearling	0	NA	NA	NA	NA	NA
Hatchery	Subyearling	665	47	518	73	27	0
Hatchery	Yearling	196	0	9	171	16	0

Length

Postorbital-hypural lengths were taken for all but six carcasses in 2017 (Table 12). We sampled 1,039 carcasses for fork length (95.7%). All other carcasses we encountered were either too decomposed or torn up from predators to accurately measure. Of the carcasses collected from natural spawners in the river and its tributaries, there was no significant difference between those that were collected above vs. below the Elwha Dam site (above mean = 61.4 cm, below mean = 60.1 cm, *t*-test $p > 0.10$). There was also no significant difference between Chinook salmon sampled upstream of the Glines Canyon Dam site compared to below it (above mean = 61.4 cm, below mean = 61.2, *t*-test $p > 0.10$). Similar to both 2015 and 2016, at the hatchery, fish netted from the river were larger than either LEKT or volunteer fish, differences that were statistically significant (*t*-tests, $p < 0.001$, Table 12). There was no difference in the size of fish that volunteered to the LEKT hatchery vs. the WDFW Hatchery (*t*-test, $p > 0.10$, Table 12).

Table 12. Chinook average length (cm) data by reach for the Elwha River 2017.

	Sample Location	**Total Fish Sampled**		**POH**	
		Male	**Female**	**Male**	**Female**
Below Elwha Dam Site	Hatchery NET	213	108	63.9	68.7
	Hatchery LEKT	59	14	53.4	63.4
	Hatchery Volunteer	127	45	53.0	64.0
	Reach 1	52	9	59.5	63.7
	Below Average	-	-	**59.0**	**66.8**
Above Elwha Dam Site	Reach 2	28	14	62.2	63.3
	Reach 3	64	24	59.6	65.1
	Reach 4	67	20	60.5	63.2
	Reach 5	83	37	59.7	64.7
	Reach 6	29	14	61.0	67.9
	Reach 7	34	15	59.4	65.2
	Reach 8	-	1	-	70.5
	Reach 9	-	-	-	-
	Indian Creek	11	10	58.5	58.1
	Little River	2	-	68.0	-
	Above Average	**-**	**-**	**60.2**	**64.3**

Sonar Adult Abundance Estimate

Escapement of non-jack Chinook was estimated to be 3,083 fish above the SONAR sites (Denton et al. 2017). By combining the carcass samples with the SONAR data, we estimate that 116 of the returning non-jack adults were natural-origin (Table 13). The 2017 return was dominated by age-3 hatchery-origin Chinook salmon that were released in 2015 as subyearlings (Table 13).

Table 13. Estimated age composition of returning adults to the Elwha River 2017, based on age data from scales, SONAR abundance estimates (Denton et al. 2017) and hatchery mark rate information.

Origin	Juvenile life-history	Age				
		2	3	4	5	6
Natural	Sub Yearling	NA	36	73	7	0
	Yearling	NA	0	0	0	0
Hatchery	Sub Yearling	NA	1,888	266	98	0
	Yearling	NA	33	623	58	0

DNA Collection

We collected DNA fin clips from 682 Chinook salmon this season. These samples are stored for future analysis at the WDFW Molecular Genetics Laboratory.

Productivity Metrics

Spawner to spawner ratios for natural spawners and natural plus hatchery spawners are available for complete brood years 2004 through 2012, and returns through age-4 are available for brood year 2013. Natural spawner productivity averaged 0.18, or one returning adult for every five natural spawners, well below the replacement value of 1.0 (Table 14). Hatchery plus natural spawners had a combined average of 1.5 returning adults per spawner for complete brood years 2004-2012, and the four consecutive brood cycles from 2008 - 2011 each exceeded the replacement value of 1.0 (Table 15). Interestingly, both natural (Table 14) and hatchery plus natural spawners (Table 15) showed decreases in productivity coinciding with dam removal activities in 2012 and the incomplete 2013 brood year compared to brood years 2008 - 2011.

Table 14. Spawner per spawner ratio for naturally spawning Chinook salmon in the Elwha River, brood years 2004-2015.

Brood Year	Natural Spawners	Returning adults						Spawners per spawner
		Age-2	Age-3	Age-4	Age-5	Age-6	Total	
2004	2075	NA	16.4	47.4	0.5	0	64.2	0.03
2005	835	2.0	10.5	41.3	22.7	0	76.6	0.09
2006	693	0	2.3	10.1	0.1	0	12.6	0.02
2007	380	0.0	15.8	17.3	5.9	0	39.1	0.10
2008	470	8.6	29.2	66.3	5.9	0	110.0	0.23
2009	678	6.0	147.4	144.8	32.4	1.6	330.6	0.49
2010	569	11.8	47.0	95.1	32.6	0.2	186.4	0.33
2011	852	4.4	38.4	150.6	25.1	0.0	218.5	0.26
2012	1452	1.2	46.0	68.1	5.9		121.2	0.08
2013	2288	1.9	10.3	33.7			46.0[A]	0.02[A]
2014	2510	6.6	68.6					
2015	2548	6.1						

[A] Incomplete cohort, age-5 offspring will return in 2018.

Table 15. Spawner per spawner ratio for all spawners (natural + hatchery origin) Chinook in the Elwha River, brood years 2004-2015.

Brood Year	Hatchery + Natural Spawners	Returning adults						Spawners per spawner
		Age-2	Age-3	Age-4	Age-5	Age-6	Total	
2004	3,439	NA	143	279	23	0	445	0.13
2005	2,231	29	784	2,053	507	0	3,372	1.51
2006	1,920	0	116	226	5	0	347	0.18
2007	1,140	0	354	613	67	0	1,034	0.91
2008	1,137	191	1,034	756	123	0	2,105	1.85
2009	2,192	210	1,680	3,041	846	28	5,806	2.65
2010	1,278	134	986	2,481	576	6	4,183	3.27
2011	1,862	92	1,003	2,660	596	0	4,351	2.34
2012	2,638	31	813	1,618	158		2,620	0.99
2013	4,243	34	245	910			1,189[A]	0.28[A]
2014	4,360	158	1,850					
2015	4,112	165						

[A] Incomplete cohort, age-5 offspring will return in 2018.

Fecundity

Over the course of the season, we sampled 29 females for fecundity at the hatchery. The POH length of the females ranged between 60 cm and 78 cm and fecundity ranged between 3,646 and 9,051 eggs per female. Larger fish had more eggs (Figure 3) and but unlike the 2015 season, larger fish did not necessarily have larger eggs (Figure 4). We estimate a total PED of 2,633,175 for natural spawning

Chinook in the Elwha River for 2017. The hatchery collected 1,713,150 eggs for broodstock from netted, volunteer, gaffed and LEKT fish.

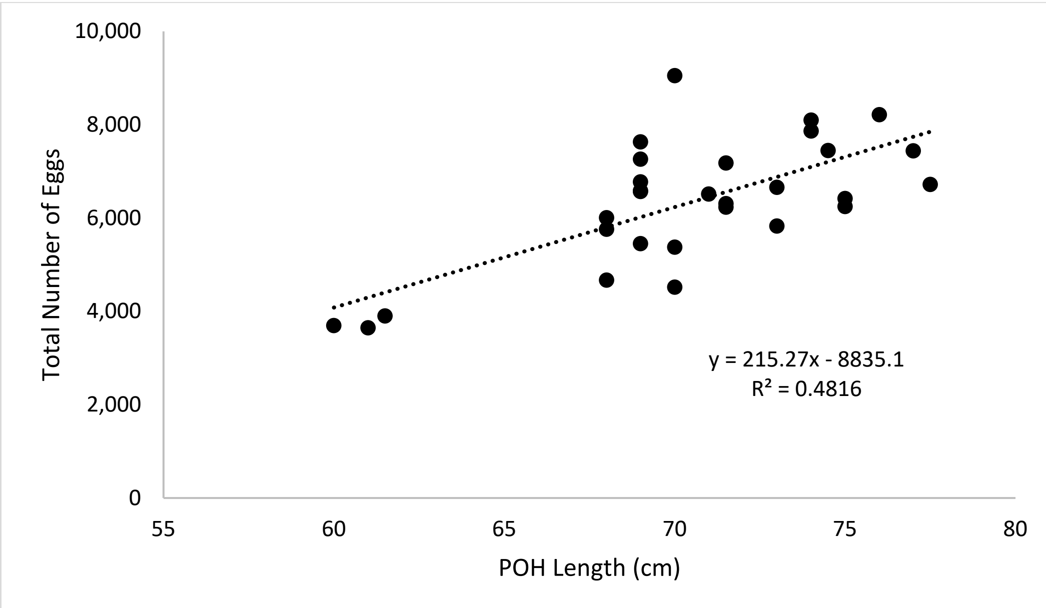

Figure 3. Fecundity and POH length for 29 female Chinook sampled at Elwha River Hatchery, 2017.

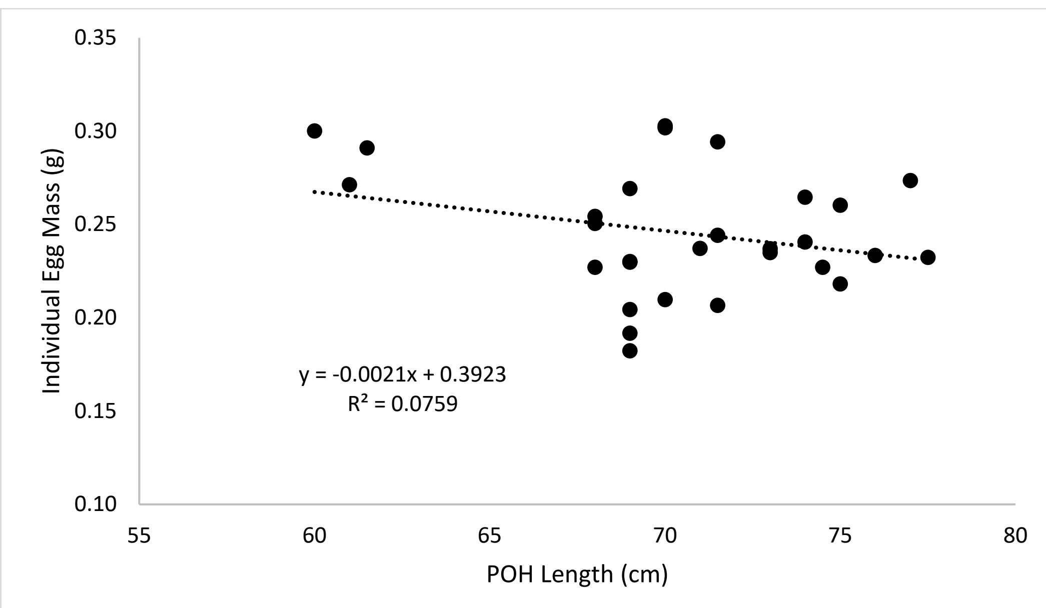

Figure 4. Individual egg mass and POH length for 29 female Chinook sampled at WDFW Hatchery, 2017.

Mark Selective Fisheries

A total of 329 expanded tag recoveries were reported for tag code 636292 from ages 2, 3 and 4 (Table 16). Thirty six (10.9%) of those recoveries originated from mark selective fisheries all in Washington

State marine waters. Nearly double the number of tags were recovered in non-selective fisheries compared to mark selective fisheries.

Table 16. Expanded Elwha River CWT tag recoveries for brood year 2012, tag code 636292, ages 2, 3 and 4.

	Fishery						Escapement
	Mark Selective			Non-Mark Selective			
Age	Alaska	British Columbia	Washington	Alaska	British Columbia	Washington	River
2	0	0	0	0	0	0	4
3	0	0	26	17	10	0	28
4	0	0	10	8	34	7	185
Total	0	0	36	25	44	7	217

Discussion

The fall of 2017 was the fourth year of our Chinook carcass recovery project on the Elwha River. In 2017, we sampled over 500 more fish compared to the 2016 season (Table 17).

Table 17. Total Chinook recoveries for Elwha River, 2014-2017.

Sampling Year	Reach									Hatchery	Indian Creek	Little River	Total Chinook Sampled	Percentage of non-jack Return
	1	2	3	4	5	5,6	6	7	8					
2014	36	41	27	54	40	-	85	-	-	500	19	0	802	18.28%
2015	45	26	49	85	64	-	62	-	-	487	10	26	854	20.62%
2016	31	5	6	45	75	34	31	29	2	290	6	0	554	20.05%
2017	61	42	88	87	122	-	43	50	1	566	24	2	1,086	33.67%

Sampling conditions during 2017 were good during the month of September and the first half of October. In past seasons, turbidity levels of 6 FNU or higher significantly limit our surveyors' ability to see carcasses deeper than 30 cm (Weinheimer et al. 2014, Weinheimer et al. 2015, Weinheimer et al. 2016). During 2017, average daily turbidity did not exceed 6 FNU until October 6th. Turbidity stayed above 6 FNU after October 18 for the remainder of the season. Average daily river flow did not exceed 1,000 cfs in until October 18.

We recovered 520 carcasses between Idaho Creek in Geyser Valley and the mouth of the river. At the WDFW Hatchery, we successfully sampled 566 (60%) of the 942 fish at the hatchery. Our total sample of 1,038 non-jack Chinook represented 33.67% of the fish that were estimated to have passed the sonar site in the lower river (Table 17).

We found that 3.7% of the fish we sampled did not carry any hatchery marks. This is similar to what has been reported from 2010-2016 (Anderson et al. 2015; Weinheimer et al. 2017). Hatchery-origin fish continue to dominate the population demographics of Elwha River Chinook salmon (Figure 5). Currently in the initial Preservation phase of the Elwha Monitoring and Adaptive Management Guidelines, there are no specific objectives for the percent of natural origin spawners (pNOS) to trigger movement to the subsequent Recolonization phase (Peters et al. 2014). The management goal of the Preservation phase is to protect the species from extinction during the period when high sediment loads are expected, at times, to be lethal to fish. Transition to the recolonization phase will largely be triggered by productivity targets, as the spatial distribution trigger ("portion of population accessing above Elwha Dam") has already been met (McHenry et al. 2018), the abundance trigger (natural spawners > 950) has already been met (Denton et al. 2017, and prior SONAR reports) and there are no diversity triggers (Peters et al. 2014).

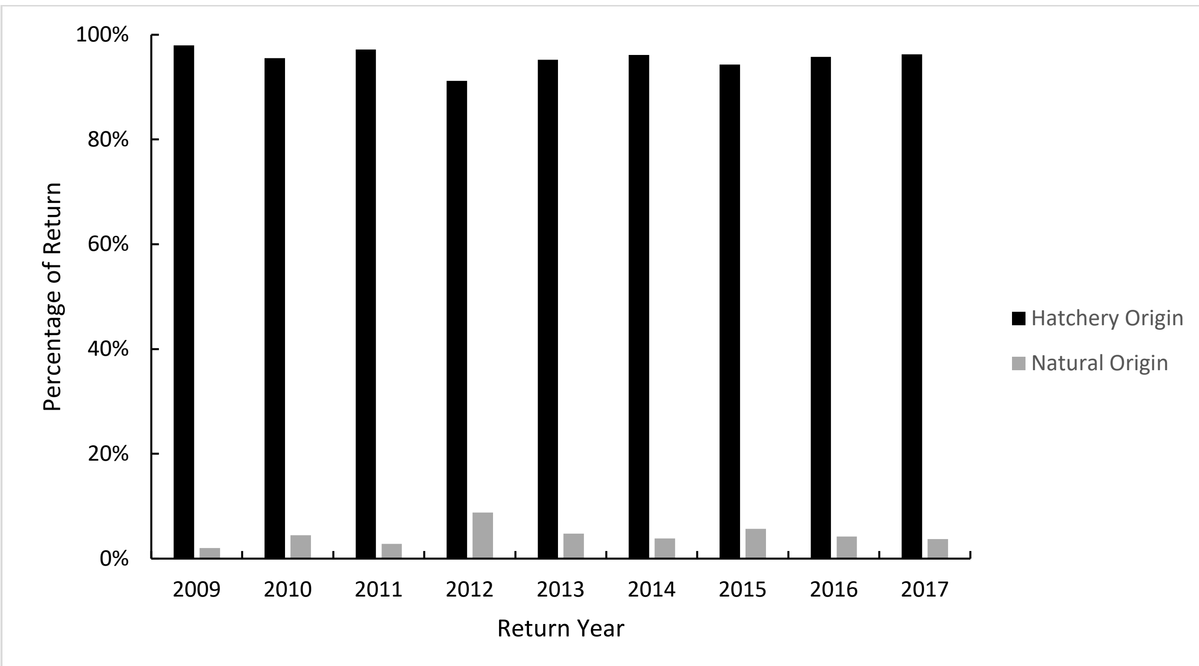

Figure 5. Natural and hatchery origin adult Chinook proportions for the Elwha River, return years 2010-2017.

Similar to 2016, we found some support for the hypothesis that hatchery mark rates decreased in an upstream direction. This was the second year in which we obtained carcass samples from Chinook salmon upstream of the Glines Canyon dam site. In 2017, when reaches 5 – 9 were pooled, they had a lower hatchery mark rate (91.2 %) than pooled reaches 1 – 4 (96.3 %), a difference that was statistically significant. This result was not observed in 2016, when reaches 5 – 9 had a higher hatchery mark rate (94.7 %) than reaches 1 – 4 (93.2 %). However, in 2016, the Lake Mills reach, which was the furthest upstream reach with > 10 samples, had the lowest hatchery mark rate among mainstem reaches (83%). This pattern was not sustained in 2017, as the Lake Mills reach had a hatchery mark rate of 96%, higher than four of the seven reaches with > 40 samples. Overall, the relatively small difference between reaches 1 – 4 vs. 5 – 9 in 2017 mark rates (5%) and lack of consistency between 2016 and 2017, suggests the supporting evidence that hatchery fish were less likely to migrate to the upstream reaches was weak to moderate. Monitoring in future years will determine if these patterns persist.

We did not observe any stream-type life histories among natural-origin fish, and thus could not evaluate their spatial distribution. We plan to continue to assess the hypothesis that Chinook salmon adopting stream type life histories are more likely to be found in upstream reaches via carcass recovery in future years.

The percentage of two year old fish (jacks) was the fourth highest we have observed since 2010 (Table 18). All but one of the jacks we sampled were of hatchery origin and were determined to be age-0, based on scale analysis, when they went to the ocean. This marks the first season we sampled a natural-origin jack whose parents could have spawned above Elwha Dam beginning in 2012.

Table 18. Age composition from scale samples from Elwha Chinook. 2010-2013: Elwha weir, 2014-2017: carcass + hatchery.

Sampling Year	Number Samples	Age				
		2	3	4	5	6
2010	401	14.96%	27.68%	17.71%	39.65%	0.00%
2011	407	11.30%	55.53%	32.92%	0.25%	0.00%
2012	157	5.10%	63.69%	28.66%	2.55%	0.00%
2013	413	2.18%	23.24%	71.67%	2.91%	0.00%
2014	738	0.68%	23.04%	56.91%	19.38%	0.00%
2015	728	0.82%	19.78%	64.70%	14.01%	0.69%
2016	449	6.00%	9.33%	61.56%	22.67%	0.22%
2017	898	5.35%	60.02%	29.51%	5.12%	0.00%

The 2017 season was the second season in which returning age-3 and age-4 natural-origin adults might be progeny of fish that spawned above the Elwha Dam in the fall of 2012. If access to the area above Elwha Dam (removed spring 2012) increased natural productivity, we would expect to observe an increasing proportion of unmarked natural-origin age-3 adults beginning in 2015 and an increasing proportion of unmarked natural-origin age-4 adults beginning in 2016. However, the hatchery mark rate for age-3 fish was similar in 2015 – 2017 to previous years; the hatchery mark rate for age-4 in 2016 and 2017 was also similar to previous years (Table 19). Thus, we do not have any evidence that access to spawning grounds upstream of the former Elwha Dam increased the total number of naturally produced adults returning to the Elwha River. We postulate that the high volume of sediment transported downstream from both dam sites (Warrick et al. 2015) impacted natural survival through much of the mainstem river downstream from the Glines Canyon dam site.

Table 19. Hatchery mark rate from scale samples of Chinook from the Elwha, return year 2014-2017.

Return Year	Number of Age 3	Hatchery Mark Rate	Number of Age 4	Hatchery Mark Rate
2012	73	98.60%	68	92.70%
2013	56	84.90%	183	98.40%
2014	170	97.70%	420	94.80%
2015	144	93.80%	469	95.50%
2016	41	95.10%	271	96.30%
2017	537	98.14%	244	91.80%

Age-3 were the dominant age class is 2017, with just over 60% of all the carcasses sampled (Table 10). We did not sample any age-6 fish in 2017 and we observed just over 5% age-5 fish. This is the first season since we started this project (2014), that we have observed less than 14% age-5 fish in our sample (Table 18).

The 2017 season marked the third year in a row we collected fecundity information from females at the hatchery. This information allowed us to estimate a total potential egg deposition (PED) for natural spawning Chinook in the basin. Our estimate suggests that naturally spawning Chinook salmon deposited nearly double as many eggs compared to those spawned at the hatchery. Combining PED with freshwater productivity data from the mainstem smolt trap operated by the Lower Elwha Klallam Tribe (McHenry et al. 2017), we can estimate egg to migrant survival. Increasing egg to migrant survival concomitant with an increase in the number of fish accessing the more stable river habitats upstream of the former Glines Canyon Dam site would be indicative of progress towards recovery.

Similar to 2015 and 2016, we also measured egg mass, which we hypothesize to increase in future years if a greater portion of the population is natural-origin. Salmon hatcheries typically relax selection for larger eggs because the hatchery environment is more benign than the more dynamic river, and instead select for greater egg number (Heath et al. 2003). Elwha Hatchery staff have noticed a trend towards smaller eggs over the years. We did sample one female that was natural origin in 2017 (individual egg mass 0.26 grams). The average sizes of individual eggs were similar between the 2015, 2016 and 2017 (Table 20). In future years, if selection on the egg size vs. egg number tradeoff is largely shaped by the river rather than the hatchery, we might observe evolution for larger eggs. We hope to continue monitoring Elwha Chinook salmon egg size to test this hypothesis.

Table 20. Average Chinook egg size of fish sampled at the Elwha Hatchery, return years 2015, 2016 and 2017. Weight reported in grams.

Return Year	Number Females Sampled	Average Individual Egg Mass (g)	Range Individual Egg Mass (g)
2015	26	0.25	0.19-0.30
2016	27	0.27	0.20-0.34
2017	29	0.25	0.18-0.30

Similar to previous reports, we provided estimates of spawner-to-spawner productivity. The results for natural spawners are striking, as fish spawning in the river failed to replace themselves in each cohort, and most cohorts fell far short of replacement. The majority of complete cohorts for which we reported productivity (brood years 2004 – 2012) spawned before removal of Elwha Dam, and therefore were restricted to poor quality spawning habitats in a reach of the river that had been starved of sediment for almost a century. A crucial question is whether productivity increases once Chinook salmon access habitats upstream of the former dam sites, particularly above Glines Canyon Dam, where the river is not subject to the instability related to the movement of sediment from the former reservoirs.

By contrast, productivity of the combined hatchery and natural spawners in each of the last five complete cohorts was much higher than the natural productivity, exceeding replacement (brood years 2008 - 2011) or nearly so (brood year 2012). This contrast to the natural spawner data provides evidence that the hatchery has maintained abundance of the population and is dominating population demographics. The role of the hatchery during the initial Preservation phase is to ensure that the unique genetic diversity of Elwha Chinook salmon does not go extinct during the large-scale disturbance to the Elwha River caused by dam removal (Peters et al. 2014). Our analysis suggests the hatchery has successfully accomplished this goal to date.

Finally, in this report, we attempt to evaluate the marine exploitation rate of adipose marked Elwha fish in mark selective fisheries. To limit the exposure of Elwha Chinook to exploitation in mark selective fisheries during the lead up to and during dam removal, ad-marking of hatchery origin juveniles was discontinued beginning in 1995. Beginning with brood year 2012, a release group of 250,000 sub-yearlings was ad-marked and coded wire tagged to evaluate the rate of exploitation in marine fisheries. The Biological Opinion guiding hatchery management of Elwha Chinook salmon states that mark selective harvest impacts < 5% are required to transition from otolith thermal marking to adipose clipping as the primary Elwha Chinook hatchery marking strategy (p. 185, (NMFS, 2012). We concluded that just over 10% of all the recoveries for age-2, age-3 and age-4 originated from mark selective fisheries, more than double the 5 % threshold (Table 16). However, we emphasize that our analysis was based on the raw CWT recovery data accessible directly from RMIS, and not the more comprehensive harvest impacts assessment provided by the Fishery Resource Assessment (FRAM) model. We plan to work with FRAM analysts for a complementary analysis of mark selective harvest impacts, and will continue to monitor these results as more tag recoveries for future brood year releases become available.

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