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Age Structure and Hatchery Fraction of Elwha River Chinook Salmon: 2015 Carcass Survey Report

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Washington Department of FISH AND WILDLIFE
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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 fall of 2015, 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 from the base of the former Glines Canyon Dam at river km 21.4 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 = 367), the majority (88 %) were located upstream of the former Elwha Dam site. We also sampled fish (N = 487) 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 797 non-jack carcasses during the sampling season, representing 20.6 % of the estimated escapement above the Elwha SONAR site. Over 93% of the fish sampled were marked hatchery fish. Age-4 was the dominant age class (65%), and age-2 fish (jacks) accounted for less than 1% of our total sample. We sampled nine age-3 natural origin fish that are likely progeny of the first adults who ascended the former Elwha dam site following removal in 2012. All of the Chinook that migrated to the ocean as two year old juveniles 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 6.9 million eggs in 2015.

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 112 km of habitat in the Olympic National Park that has been blocked since 1913 (Wunderlich et al. 1994). 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. 2015). It is hypothesized that access to the upper watershed might allow for the stream type life history trait to reemerge (McHenry et al. 2016).

In response to this need for biological information, we conducted Chinook salmon carcass surveys in the fall of 2015. 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. 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 the former Glines Canyon Dam, 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 2015 spawning season, summarizes trends in age structure and hatchery mark information in recent years, and presents an analysis of spawner to spawner population productivity for Elwha River Chinook salmon.

Methods

Sample collection

We surveyed the mainstem Elwha and tributaries from the former Glines Dam Powerhouse site at river km 21.4 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 6 sections (Table 1, Figure 1). Each reach was scheduled to be surveyed every 7 to 10 days. 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 26 to October 19, 2015.

Reach	Description	River Km		Survey Crew
		Start	End	
1	Former Elwha Dam Site to mouth of River	7.9	0.2	WDFW
2	Gooseneck to former Elwha Dam Site	10.1	7.9	WDFW
3	Highway 101 Bridge to the Gooseneck	12.4	10.1	WDFW
4	Fisherman’s Corner to Highway 101 Bridge	20.1	12.4	WDFW
5	Altaire Bridge to Fishermans Corner including Hughes Creek	20.1	17.2	ONP, WDFW
6	Glines Dam powerhouse site to Rabbit Hole	21.4	18.2	ONP, WDFW
Tributary	Indian Creek	1.6	0	LEKT
Tributary	Little Creek	1.6	0	LEKT

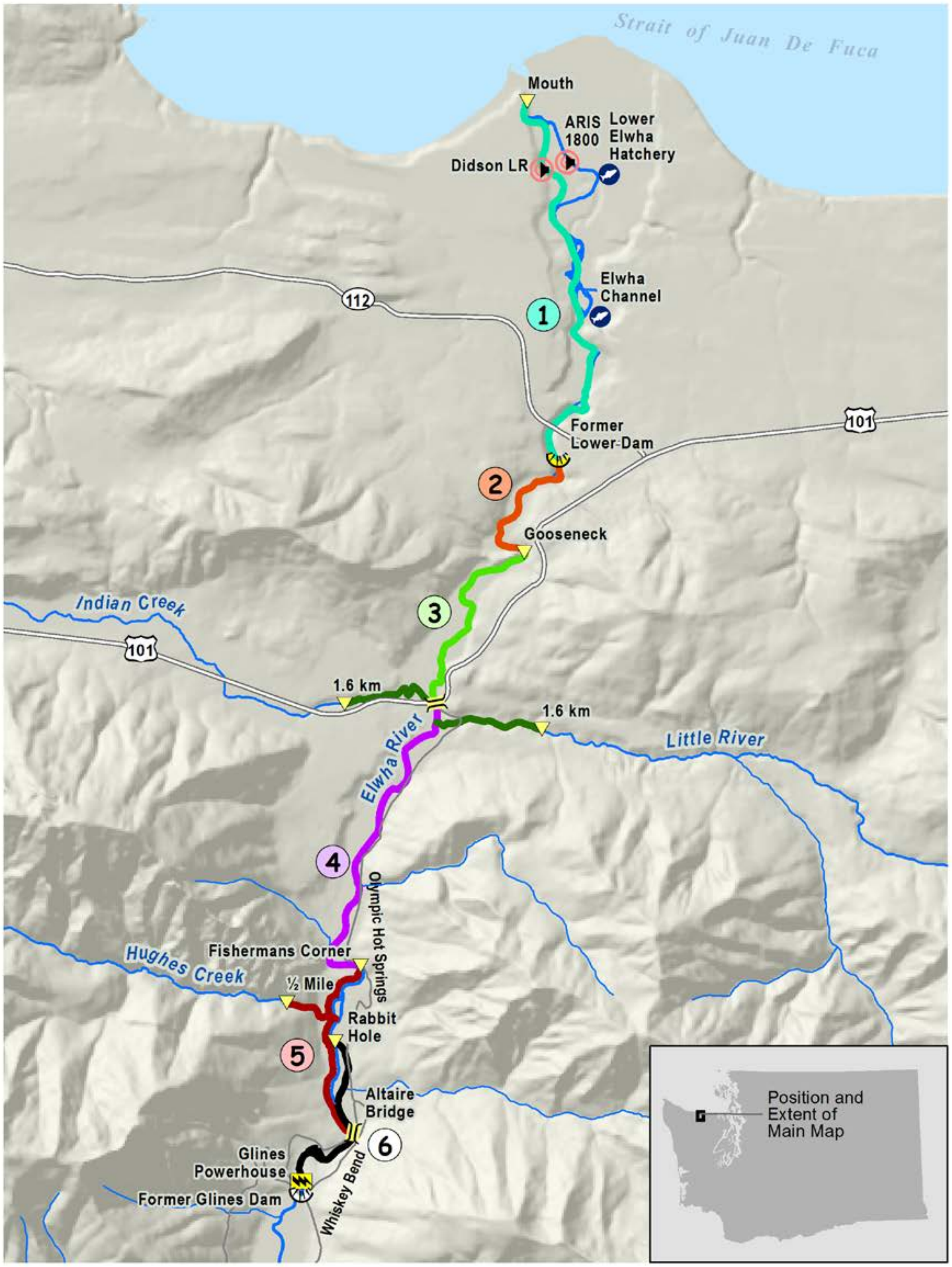

Figure 1. Map of Elwha River with carcass surveys sections for 2015 sampling season .

Chinook salmon carcasses were sampled weekly at the WDFW Elwha Rearing Channel (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 pond. WDFW used PIT tags, inserted upon capture, to identify the original collection method of Chinook salmon spawned at the hatchery. 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, postoribital-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 head 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. At the WDFW Hatchery, fish were also scanned for a PIT tag to determine their original capture location.

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 209 and 1,220 cfs during the sampling season (Figure 2). Average flow exceeded 1,000 cfs on August 30 and October 11. Turbidity ranged between 0 and 276 FNU and stream visibility was greatly reduced following the increase in flow on October 9, when the river rose from 324 CFS to 926 CFS. Turbidity measurements were not available for October 1-7.

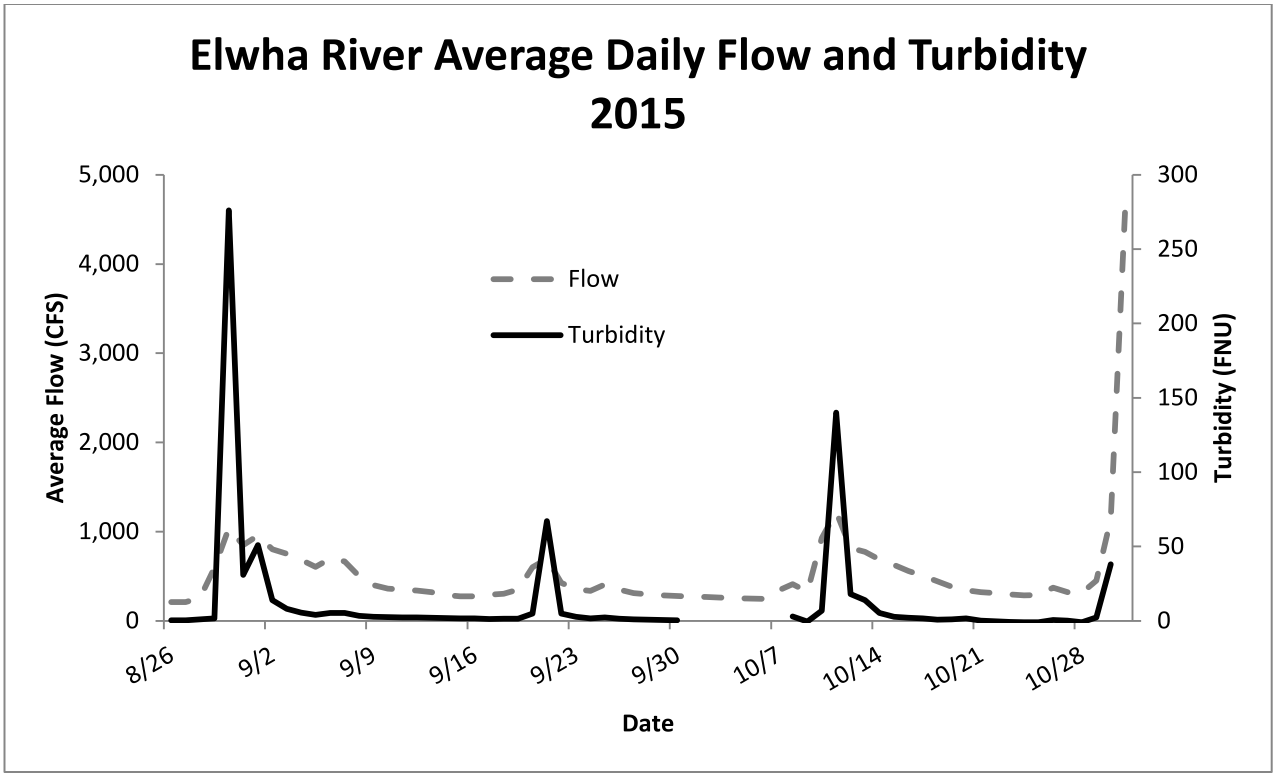

Figure 2. Average daily discharge (cfs) and turbidity (FNU) for the Elwha River, August 26 – October 19, 2015.

Evaluating hatchery mark rates

The primary hatchery marking strategy for brood years of Elwha Chinook salmon expected to return in 2015 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). All of the yearling releasesfrom brood years 2010 – 2013, and a portion of the subyearling releases in brood years 2012 and 2013, received a CWT mark in addition to the thermal otolith mark.

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). For brood year 2010, although all hatchery Chinook salmon were otolith marked, chiller malfunctions limited the number of cold water incubations for some fish, resulting in a mark that was less distinctive than desired.

Table 2. Releases of hatchery Chinook in the Elwha River Basin, brood years 2010-2013.

Brood Year	Type	Thermal Otolith	Thermal Otolith + CWT	CWT	AD + CWT + Thermal Otolith	Total
2010	Subyearling	1,236,562	0	0	0	1,236,562
	Yearling	0	212,900	0	0	212,900
2011	Subyearling	1,524,769	0	0	0	1,524,769
	Yearling	0	196,575	0	0	196,575
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	177,269	0	0	177,269

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 2015. 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 from the spawning grounds.
2) The lengths of the females we sampled from all locations, including the hatchery and the river, was 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 are 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. 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 2015. 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), and this report. The data source for abundance was Elwha Chinook SONAR reports (most recently: Denton et al. 2015). 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.

Results

Carcass Recoveries

We sampled a total of 854 carcasses throughout the sampling season (Table 3). A total of 367 samples (43%) originated from the Elwha River and tributaries. Of the fish sampled outside the hatchery, 87.7% were sampled above the former Elwha Dam site. The highest number of samples collected in one week occurred during the week of Sept 14-18, and over three quarters (82%) 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 12. Length and sex data were recorded for each carcass. Otolith samples were taken from 846 (99.1%) carcasses, readable scale samples from 728 (85.2%) and DNA fin clips from 586 (68.6%). A total of 36 carcasses were sampled in Indian Creek (10) and Little River (26).

Table 3. Total number of Chinook carcasses sampled by survey reach in the Elwha River Watershed 2015.

Reach	**Number of Carcasses Sampled**	**Percent of Total**
Reach 1 - Elwha Dam Site to river mouth	45	5.27%
Reach 2 - Gooseneck to former Elwha Dam Site	26	3.04%
Reach 3 - Highway 101 Bridge to Gooseneck	49	5.74%
Reach 4 - Fishermans Corner to Highway 101 Bridge	85	9.95%
Reach 5 - Altaire Bridge to Fishermans Corner plus Hughes (left channel)	64	7.49%
Reach 6 - Glines Powerhouse to Rabbit Hole (right channel)	62	7.26%
Indian Creek	10	1.17%
Little River	26	3.04%
WDFW Hatchery	487	57.03%
Total	**854**	**100%**

Table 4. Number of Chinook carcasses sampled by week for individual reaches during the 2015 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 week October 26-30 due to lack of carcasses.

Week	Reach						Indian Creek	Little River	Hatchery
	1	2	3	4	5	6			
Aug 24-28	0	-	-	0	0	-	-	-	-
Aug 31-Sept 4	0	-	-	0	1	-	-	-	-
Sept 7-11	15	3	3	5	-	8	-	7	74
Sept 14-18	25	9	24	50	40	-	8	19	111
Sept 21-25	-	6	10	18	11	20	2	-	140
Sept 28-Oct 2	5	5	8	9	8	23	-	-	120
Oct 5-9	-	3	4	2	4	11	-	-	42
Oct 12-16	-	0	0	1	0	0	-	-	-
Oct 19-23	-	0	0	-	-	-	-	-	-
Totals	45	26	49	85	64	62	10	26	487

Broodstock collection method . Most of the fish sampled at WDFW Hatchery were net-collected fish rather than volunteers to either the WDFW or LEKT Hatchery (Table 5). We sampled over two thirds of all the LEKT and volunteer fish that came to the hatchery in 2015 and just over 36% of all net fish to the WDFW Hatchery (Table 6). Less than 5% of the Chinook salmon gaffed for hatchery broodstock were sampled this season.

Table 5. Adult collection method summary for Elwha Chinook salmon carcass sampling 2015.

Sample Location	Collection Method	Number of Carcasses Sampled	Percent of Total Carcasses Sampled
Mainstem and Tributaries	Natural Spawners	345	40.40%
	Gaffed	22	2.58%
WDFW Hatchery	Gill Net (N)	309	36.18%
	Lower Elwha Klallam (LEKT)	93	10.89%
	Volunteers (V)	85	9.95%

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	853	36.11%
LEKT Hatchery volunteers	120	77.50%
WDFW Hatchery volunteers	127	66.93%
Gaffed	464	4.74%
Total	1,564	32.48%

Hatchery mark rates

We collected 846 otolith samples from Chinook salmon over the course of the season. Seven hundred and forty nine (88.5%) of the samples had an otolith mark present. Of the remaining 98 samples, 40 had no otolith mark but did have a CWT present and three fish were ad marked but did not carry an otolith mark or CWT. Thus, 55 fish (6.5%) had no internal (Otolith or CWT) or external hatchery marks (Table 7).

However, of the 55 fish without marks, seven had scales exhibiting signs of accelerated growth indicative of hatchery rearing. Experienced scale readers from the WDFW lab are certain that these fish, which were age-4 and age-5 yearlings, are hatchery origin. These fish (0.83 % of the N = 847 fish evaluated for hatchery marks) either originated from out of basin or a portion of the fish released from brood years 2010 and 2011 did not receive otolith and/or CWT. Prior to release, N = 500 yearlings from BY 2010 were checked for CWT and all were CWT positive. Note that BY 2010 included a portion of fish whose otolith mark was not as distinctive as desired due to chiller malfunctions (see Methods).

Overall, the proportion of hatchery-origin Chinook salmon was 94%, including fish with hatchery marks and scale patterns indicative of hatchery rearing. We observed relatively little differences in the mark rates of the different survey reaches and hatchery broodstock sources (Table 7). Only a single reach, reach 2, had a mark rate < 90% (Table 7).

We also collected otolith samples from pink salmon during the Chinook salmon surveys, and LEKT biologists collected otolith samples from chum salmon later in fall 2015. Of the N = 53 pink salmon sampled from the Elwha River and tributaries, none (0%) carried a hatchery mark. Of the N = 96 readable chum salmon otoliths sampled from the LEKT and WDFW hatcheries, N = 33 (33%) carried a hatchery mark. Of the marked hatchery-origin chum, N = 31 originated from the LEKT hatchery, and two were long distance strays: one from Gunnuk Creek Alaska, and one from Nitinat River, British Columbia.

Table 7. Hatchery mark rates of Chinook salmon sampled from the Elwha River 2015 based on thermal otolith, adipose and CWT marks.

	Location	Otolith Mark		All Hatchery Marks	
		N	Percent Marked	N	Percent Marked
Hatchery	Net	305	88.2%	306	95.4%
	LEKT	93	84.9%	93	90.3%
	Volunteer	84	79.8%	84	91.7%
Carcass Survey	Reach 1	45	91.1%	45	91.1%
	Reach 2	26	88.5%	26	88.5%
	Reach 3	49	95.9%	49	98.0%
	Reach 4	85	89.4%	85	90.6%
	Reach 5	63	92.1%	63	92.1%
	Reach 6	62	91.9%	62	91.9%
	Little River	24	91.7%	24	91.7%
	Indian Creek	10	100.0%	10	100.0%
	Total	846	88.5%	847	93.2%

CWT Data

We collected CWTs from 59 fish in the Elwha River watershed during fall 2015. All but three of the CWT samples were collected at the WDFW Hatchery. The three snouts from the river were recovered between Fisherman's corner and the Gooseneck. The majority of the CWTs originated from releases into the Elwha River, but some were derived from releases into the neighboring Morse Creek (N = 1) or Dungeness (N= 7) watersheds (Table 8). Fish that were released from the Elwha were mostly from the yearling program (87.6%), except for 11 tags from the 2012 brood year when a portion of the subyearling releases were coded-wire tagged (Table 2). One tag recovered from a netted fish was a blank wire and could not be assigned to a given brood year (Table 8).

Table 8. Chinook Coded Wire Tag (CWT) data for snouts recovered during spawn year 2015.

	Sampling Location	# of Snouts	Brood Year	Release Location
River	Elwha Dam to Mouth	1	2011	Dungeness
		1	2012	Dungeness
		1	2013	Elwha River
Hatchery	Net	1	2010	Hurd Creek
		8	2010	Elwha River
		1	2011	Morse River
		1	2011	Hurd Creek
		3	2011	Dungeness
		5	2011	Elwha River
		10	2012	Elwha River
		2	2013	Elwha River
		1	Unknown	Unknown
	LEKT	3	2010	Elwha River
		1	2011	Hurd Creek
		5	2012	Elwha River
	Volunteer	1	2009	Elwha River
		3	2010	Elwha River
		5	2011	Elwha River
		4	2012	Elwha River
		2	2013	Elwha River
	Total	59		

Scale Data

Of the 811 scale samples collected, 728 (89.8%) were successfully aged in the laboratory. Age 4 was the dominate age class in each sampling reach and the netted fish at the hatchery, as over 64% of the entire collection was composed of age-4 Chinook salmon (Table 9). The highest percentage of age-5 Chinook salmon were collected from reach 3 which is just upstream of the former Elwha Dam site (Table 9). Age 6 fish were only found in reach 1 and at the WDFW Hatchery. Thirty fish (4.2%) were identified as fish that migrated to the ocean as age 2 (stream type Chinook, Table 10). All of these stream-type Chinook were hatchery origin. No scale samples were collected from Indian Creek or Little River.

Table 9. Chinook carcass age data from scale samples by reach for the Elwha River 2015.

Sample Location	Collection Method	Number of Samples	Total age				
			2	3	4	5	6
WDFW Hatchery	Net	290	0.69%	18.62%	62.07%	17.93%	0.69%
	LEKT	84	0.00%	32.93%	57.32%	10.98%	1.22%
	Volunteer	80	2.50%	52.50%	37.50%	6.25%	1.25%
Reach 1	Carcass Sample	38*	0.00%	15.79%	71.05%	10.53%	2.63%
Reach 2		22	0.00%	0.00%	86.36%	13.64%	0.00%
Reach 3		44	2.27%	4.55%	72.73%	20.45%	0.00%
Reach 4		69	1.45%	8.70%	76.81%	13.04%	0.00%
Reach 5		48	0.00%	6.25%	85.42%	8.33%	0.00%
Reach 6		53	0.00%	7.84%	82.35%	13.73%	0.00%
Indian Creek		0	-	-	-	-	-
Little Creek		0	-	-	-	-	-
All Samples		728	0.82%	19.78%	64.70%	14.01%	0.69%

*Includes 19 Gaffed fish

Table 10. Age at return of hatchery and unmarked subyearling and yearling releases 2015.

Origin	Age at Outmigration	N	Total Age				
			2	3	4	5	6
Unmarked[1]	Subyearling	40	0	11	21	7	1
Unmarked[1]	Yearling	0	NA	NA	NA	NA	NA
WDFW Hatchery	Subyearling	646	3	131	430	79	3
WDFW Hatchery	Yearling	30	3	2	12	12	1

[1] Excludes N = 7 unmarked fish with scales showing accelerated growth indicative of hatchery rearing.

Length

Postorbital-hypural lengths were taken for all but two carcasses, one from Reach 5 and one from Little River (Table 11). We sampled 810 carcasses for fork length (94.8%). 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 = 67.9cm, below mean = 68.1cm, *t*-test $p > 0.10$). At the hatchery, fish netted from the river were larger than either LEKT or volunteer fish, differences that were statistically significant (*t*-test, $p < 0.01$). In addition, fish that volunteered to the LEKT hatchery were larger than fish that volunteered to the WDFW Hatchery (*t*-test, $p < 0.001$).

Table 11. Chinook average length (cm) data by reach for the Elwha River 2015.

	Sample Location	Total Fish Sampled		POH	
		Male	**Female**	**Male**	**Female**
Below Elwha Dam Site	Hatchery NET	150	159	66.3	71.1
	Hatchery LEKT	52	41	63.8	68.1
	Hatchery Volunteer	59	26	57.9	66.1
	Reach 1	10	35	67.2	68.4
Above Elwha Dam Site	Reach 2	5	21	72.4	70.7
	Reach 3	12	37	67.3	70.4
	Reach 4	40	45	67.9	69.3
	Reach 5	35	28	70.1	67.6
	Reach 6	26	36	65.8	66.0
	Indian Creek	4	6	59.8	67.3
	Little River	14	11	61.7	64.1
	Above Average	-	-	65.1	69.0

Sonar Adult Abundance Estimate

Escapement of non-jack Chinook was estimated to be 4,112 fish above the SONAR sites (Denton et al. 2015). Fifty percent of the Chinook run had passed the SONAR sites by July 30th. By combining the carcass samples with the SONAR data, we estimate that 232 of the returning non-jack adults were natural origin (Table 12). The 2015 return was dominated by age-4 hatchery-origin Chinook salmon that were released in 2011 as subyearlings (Table 12).

Table 12. Estimated age composition of returning adults to the Elwha River 2015, based on age data from scales and SONAR abundance estimates (Denton et al. 2015).

Origin	Juvenile life-history	Age				
		2	3	4	5	6
Natural	Sub Yearling	NA	64	122	41	6
	Yearling	NA	0	0	0	0
Hatchery	Sub Yearling	NA	759	2,490	458	17
	Yearling	NA	12	69	69	6

DNA Collection

We collected DNA fin clips from 588 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 2010, and returns through age-4 are available for brood year 2011. Natural spawners productivity averaged 0.20, or one returning adult for every five natural spawners, well below the replacement value of 1.0 (Table 13). Hatchery and natural spawners combined average 1.6 returning adults per spawner for complete brood years 2004-2010, and the last five brood cycles (2007 - 2011) have each exceeded the replacement value of 1.0 (Table 14).

Table 13. Spawner per spawner ratio for naturally spawning Chinook salmon in the Elwha River, brood years 2004-2015.

BroodYear	Natural Spawners	Returning adults						Spawners per spawner
		Age-2	Age-3	Age-4	Age-5	Age-6	Total	
2004	2,075	NA	16	47	0		64	0.03
2005	835	2	11	41	24		78	0.09
2006	693	0	2	11	0		13	0.02
2007	380	0	17	29	6		52	0.14
2008	470	9	50	66	6		131	0.28
2009	648	10	147	145	32	2	335	0.52
2010	564	12	47	95	35		189	0.33
2011	2,125	4	38	160			203[A]	0.10[A]
2012	1,452	1	50					
2013	2,288	2						
2014	2,510							
2015	2,548							

[A] Incomplete cohort, age-5 offspring will return in 2016.

Table 14. Spawner per spawner ratio for all spawners (natural + hatchery origin) Chinook in the Elwha River, brood years 2004-2015.

BroodYear	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		445	0.13
2005	2,231	29	784	2,024	547		3,384	1.52
2006	1,920	0	115	244	8		367	0.19
2007	1,140	0	382	1,038	67		1,487	1.30
2008	1,137	206	1,750	756	123		2,836	2.49
2009	2,162	356	1,680	3,041	846	28	5,951	2.75
2010	1,379	134	986	2,481	576		4,178	3.03
2011	3,152	92	1,003	2,660			3,756[A]	1.19[A]
2012	2,638	31	813					
2013	4,243	34						
2014	4,360							
2015	4,112							

[A] Incomplete cohort, age-5 offspring will return in 2016.

Fecundity

Over the course of the season we sampled 26 females for fecundity at the hatchery. The POH length of the females ranged between 59 cm and 83 cm and fecundity ranged between 3,990 and 7,847 per female. Larger fish had more eggs (Figure 3) and larger eggs (Figure 4). We estimate a total PED of 6,937,678 for natural spawning Chinook in the Elwha River for 2015. The hatchery collected 2,968,250 eggs for broodstock from netted, volunteer, gaffed and LEKT fish.

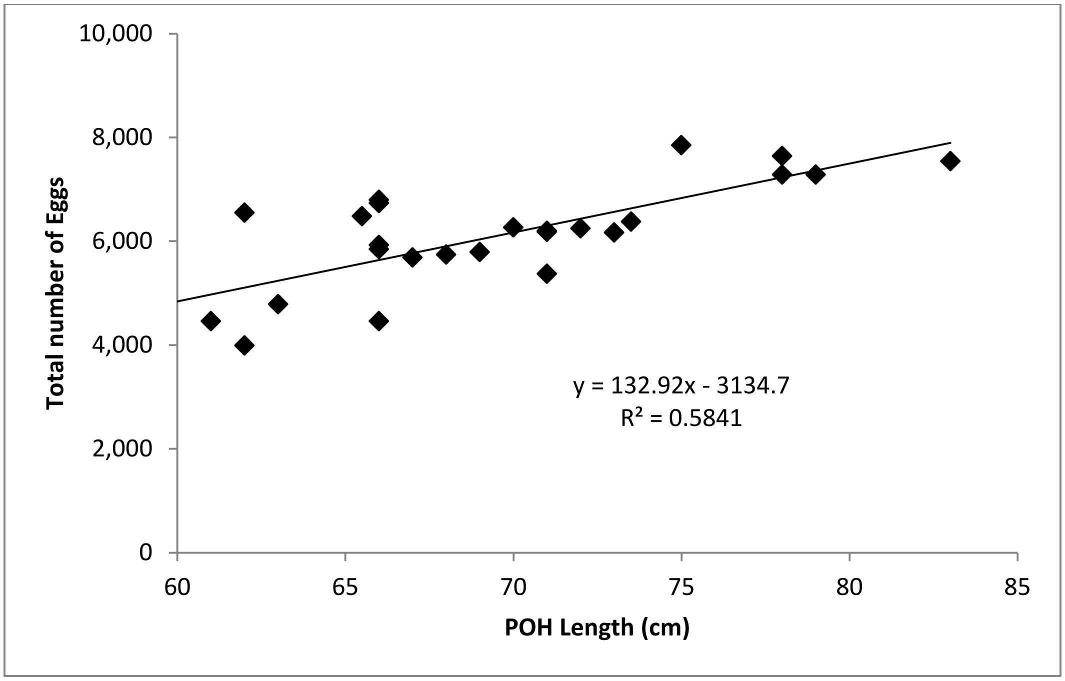

Figure 3. Fecundity and POH length for 26 female Chinook sampled at Elwha River Hatchery, 2015.

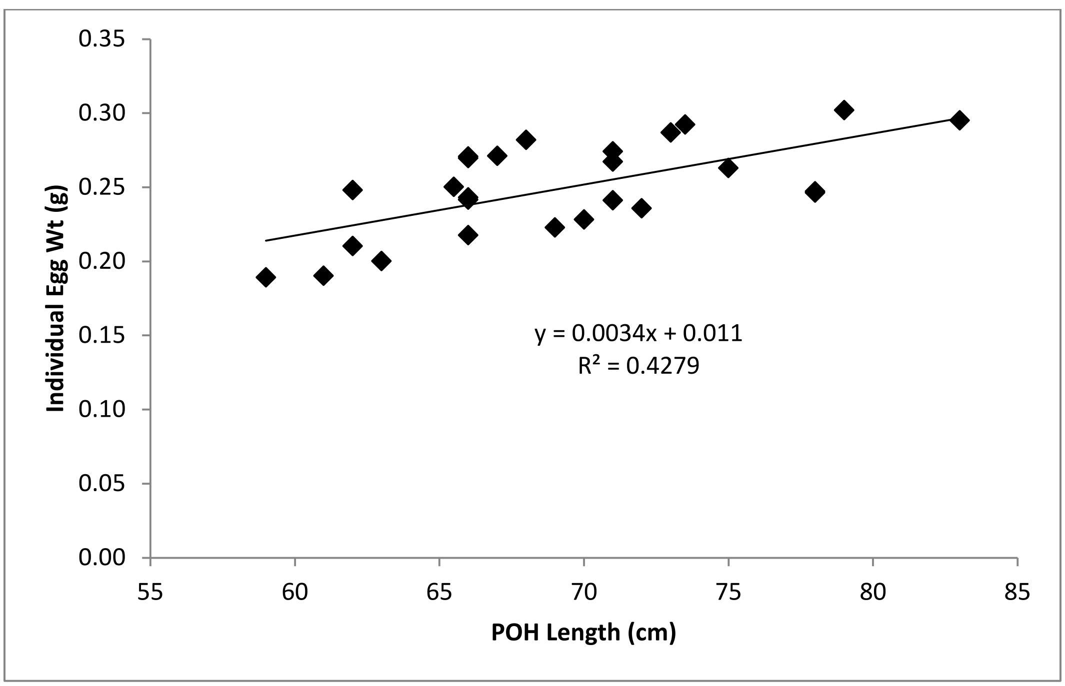

Figure 4. Individual egg weight and POH length for 26 female Chinook sampled at WDFW Hatchery, 2015.

Discussion

The fall of 2015 was the second year of our Chinook carcass recovery project on the Elwha River between the former Glines dam site and river mouth. In 2015, we sampled an additional 52 fish compared to the 2014 season (Table 15). In 2015, we sampled over 20% of the estimated non-jack returning Chinook salmon and the number of fish sampled in 4 of the 6 reaches was increased.

Table 15. Total Chinook recoveries for Elwha River, 2014-2015.

Sampling Year	Reach						Hatchery	Indian Creek	Little River	Total Chinook Sampled	Percentage of non-jack Return
	1	2	3	4	5	6					
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%

Sampling conditions during 2015 were good for a majority of the season. Last year we discovered that turbidity levels of 6 FNU significantly limited our surveyors' ability to see carcasses deeper than 30 cm (Weinheimer et al. 2015). During 2015, average daily turbidity only exceeded 6 FNU during 9 of our 56 day sampling season. The lack of particulates in the water allowed us to sample carcasses at the bottom of pools rather than having to focus only on shallow tailouts. Average daily river flow only exceeded 1,000 cfs on two occasions, once in early September and once in early October but dropped back down below 500 cfs after 4 or 5 days.

We recovered 367 carcasses between Glines Canyon Dam and the mouth to the river. At the WDFW Hatchery, we successfully sampled 487 (52%) of the 928 spawned fish. Our total sample of 848 non-jack Chinook, represented 20.62% of the fish that were estimated to have passed the sonar site in the lower river (Table 15).

We found that 6.8% of the fish we sampled did not carry any hatchery marks. This is similar to what has been reported from 2010-2014 (Anderson et al. 2015; Weinheimer et al. 2015). 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 load is 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. 2016), the abundance trigger (natural spawners > 950) has already been met (Denton et al. 2015, and prior SONAR reports) and there are no diversity triggers (Peters et al. 2014).

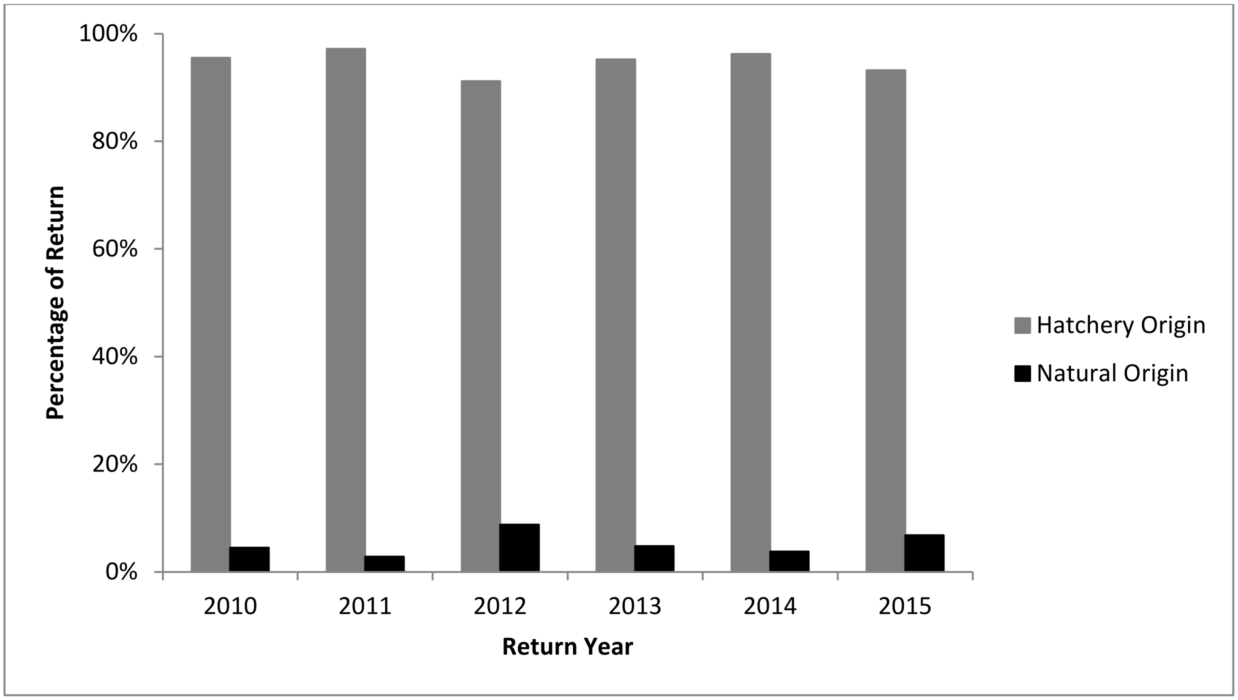

Figure 5. Natural and hatchery origin adult Chinook proportions for the Elwha River, return years 2010-2015.

Similar to 2014, we found no support for our two hypotheses regarding the spatial distribution of hatchery mark rates and stream-type life histories. Hatchery mark rates did not decrease in an upstream direction from the WDFW Hatchery in 2015. Hatchery fish appeared to distribute themselves evenly through all the reaches we sampled with the highest percentage occurring in Highway 101 to Gooseneck reach (3). 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 these hypotheses via carcass recovery in future years.

The percentage of two year old fish (jacks) was once again low in 2015 relative to the past 6 years of data (Table 16). All of the jacks we sampled were of hatchery origin and were released as yearlings to the ocean. This marks the second season in a row where no natural-origin jacks have been collected from cohorts whose parents could have spawned above Elwha Dam beginning in 2012. The number of returning age-2 fish can be an indicator of survival for a given brood, and used to forecast adult returns in future years. The lack of natural origin jacks may suggest poor survival and recruitment of adults above the former Elwha dam.

Table 16. Age composition from scale samples from Elwha Chinook. 2010-2013: Elwha weir, 2014-2015: 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%

The 2015 season was the first season in which returning age-3 natural-origin adults might be progeny of fish that spawned above the Elwha Dam in the fall of 2012. Based on the high volume of river material that was deposited downstream of the dam site following removal, it seems plausible that survival could have been higher for fish that migrated upstream from the Elwha Dam site, particularly fish that recruited into the middle Elwha tributaries (Little River or Indian Creek) during the fall of 2012 because these areas were unaffected by dam removal. If this were the case, we would expect to observe a higher proportion of unmarked natural-origin adults at age-3 compared to age-4 and age-5, age classes that did not have access to the areas above Elwha Dam. However, the hatchery mark rate for age-3 fish was similar to the age 4 and age 5 mark rate in 2015 (Table 17), and so we do not have any evidence that access to spawning grounds upstream of the former Elwha Dam increased survival of brood year 2012 relative to brood years 2011 and 2010.

Table 17. Hatchery mark rate from scale samples of Chinook from the Elwha, 2015.

Age	Number	Hatchery Mark Rate
2	6	100.00%
3	144	93.75%
4	468	95.51%
5	100	93.00%
6	5	80.00%
Total	723	

Age-4 were the dominant age class is 2015, with just over 64% of all the carcasses sampled (Table 16 and Table 17). We also sampled 1 unmarked and 4 marked fish that were aged as 6 year returners. No age-6 were observed at the Elwha weir 2010 – 2013, or during the carcass sampling in 2014 (Table 16). Furthermore, we observed > 10% age-5 fish for the second consecutive year, after three years in which age-5 fish were < 3% of the population (Table 16). Historically, the Elwha River was known for larger size Chinook, which may have been a local adaptation needed to negotiate the high velocity flows created by the steep topography of the watershed. To reach larger sizes, Chinook probably had to spend extra years in the ocean and returned as age 5 or older adults.

New for the 2015 season, 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 3 times 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. 2015), we can estimate egg to migrant survival. Increasing egg to migrant survival with fish accessing the more stable river habitats upstream of the former Glines Canyon Dam site would be indicative of progress towards recovery.

We also measured egg size, 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). Indeed, Elwha Hatchery staff has noticed a trend towards smaller eggs over the years. 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.

Finally, in this report, 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. All of the cohorts for which we reported productivity (brood years 2004 – 2010) 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.

Conversely, productivity of the combined hatchery and natural spawners exceeded replacement in each of the last five cohorts (brood years 2007 - 2011). 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.

References

Anderson, J., and coauthors. 2015. Elwha River Weir Project - 2013 Operations and Final Summary Report. Washington Department of Fish and Wildlife, Olympia, Washington. FPT 15-03.

Beechie, T. J., E. R. Buhle, M. H. Ruckelshaus, A. H. Fullerton, and L. Holsinger. 2006. Hydrologic regime and the conservation of salmon life history. Biological Conservation 130:560-572.

Brannon, E. L., and W. K. Hershberger. 1984. Elwha River fall Chinook Salmon. In J.M. Walton and D.B. Houston (eds.), Proceedings of the Olympic wild fish conference. Peninsula College, Fisheries Technology Program, Port Angeles, WA.

Denton, K., and coauthors. 2015. 2015 Elwha Chinook escapement based on DIDSON/ARIS multi-beam SONAR data.

Heath, D. D., J. W. Heath, C. A. Bryden, R. M. Johnson, and C. W. Fox. 2003. Rapid evolution of egg size in captive salmon. Science 299:1738-1740.

McElhany, P., M. H. Ruckelhaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionary significant units. U.S. Department of Commerce, NOAA Technical Memo, NMFS-NWFSC-42.

McHenry, M., M. Elofson, M. Liermann, and G. Pess. 2015. 2014 Elwha River smolt trap enumeration project report.

McHenry, M., and coauthors. 2016. Spawning distribution of Chinook Salmon (Oncorhynchus tshawytscha) in the Elwha River, Washington State during dam removal from 2012 to 2015. Report to Olympic National Park, Port Angeles, Washington.

Peters, R., and coauthors. 2014. Guidelines for Monitoring and Adaptively Managing Restoration of Chinook Salmon (Oncorhynchus tshawytscha) and Steelhead (O. mykiss) on the Elwha River. US Fish and Wildlife Service, Lacey, Washington.

Ruckelhaus, M. H., and coauthors. 2006. Independent populations of Chinook salmon in Puget Sound. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-78.

Ward, L., and coauthors. 2008. Elwha River Fish Restoration Plan - developed pursuant to the Elwha River Ecosystem and Fisheries Restoration Act, Public Law 102-495. U.S. Dept of Commerce NOAA Tech. Memo. NMFS-NWFSC-90.

WDFW, and WWTIT. 1994. 1992 Washington state salmon and steelhead stock inventory: Appendix on Puget Sound stocks, Hood Canal and Strait of Juan de Fuca.

Weinheimer, J., and coauthors. 2015. Age structure and hatchery fraction of Elwha River Chinook salmon: 2014 carcass survey report. Washington Department of Fish and Wildlife, Olympia, WA.

Wunderlich, B., B. Winter, and J. Meyer. 1994. Restoration of the Elwha River Ecosystem. Fisheries 19:12-19.