

Spatial distribution of Chinook Salmon (*Oncorhynchus tshawytscha*) spawning in the Elwha River, Washington State during dam removal and early stages of recolonization (2012-2016)



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Executive Summary

The distribution of spawning nests, or redds, is an important metric to assess the recolonization success by adult salmonids in newly available stream habitats. We assessed the spatial distribution of adult Chinook salmon spawning throughout 29 km of Elwha River and its tributaries from 2012 to 2015, a period in which two impassable hydroelectric dams were removed, and again in 2016 when fish passage was established above Glines Canyon. Each year, Chinook salmon redds were located by walking surveys conducted at or near the peak of spawn timing in mid-September. Surveys were conducted in main stem, side-channel, and tributary habitats from the mouth of the Elwha River upstream to Glines Canyon Dam site at Rkm 22 at flows that ranged from 7.0 cubic meters per second (cms) to 11.9 cms. In 2014-2016 additional surveys were conducted upstream of Glines Canyon Dam. Redds were georeferenced using GPS units and live and dead adult salmon were enumerated. Surveys in 2012 and 2013 were limited by poor visibility (72 FNU and 45 FNU average turbidity respectively) in the Lower Elwha River downstream of the Elwha Dam site. Conversely, surveys in 2014, 2015, and 2016 were conducted during very low turbidities (5.0 FNU, 0.8 FNU and 5.5 NTU average turbidity, respectively).

In 2012, based on SONAR estimates (Denton et al. 2013), the total escapement of Chinook salmon to the Elwha River was 2,638. Chinook salmon had access to the area above Elwha Dam and below Glines Canyon Dam (henceforth Middle Elwha) for the first time in a century. A total of 203 Chinook redds (396 live and dead adults) were documented upstream of Elwha Dam with the majority of Chinook salmon redds (48%) observed in the two clear water tributaries: Indian Creek and Little River. The former Aldwell Reservoir (Rkm 7.9-12.4) and the main stem Middle Elwha from Rkm 17.2-18.1 accounted for 44% of the redd locations in 2012, respectively. Surveys in the lower river were not completed because of turbidity issues. The high proportion of chinook observed in the tributaries suggests that they were providing refugia from the effects of dam removal.

In 2013, based on SONAR estimates (Denton et al. 2014), the total escapement of Chinook salmon (4,243 adults) approximately doubled over its long term 20 year average. This doubling resulted in observations of Chinook salmon spawning in all habitats, including the Middle Elwha. In 2013, a total of 765 Chinook salmon redds and 1,741 adults (live and dead) were observed during the peak of spawning with the majority of redds (73%) located above the former Elwha Dam. The vast majority (85%) of all Chinook salmon redds observed in the Middle Elwha in 2013 were in the main stem. Of those, 164 (25%) of Chinook salmon redds were located in the 1.1 km immediately below the Glines Canyon Dam site, which was not yet removed.

In 2014, based on SONAR estimates (Denton et al. 2015), the total escapement of Chinook salmon was 4,360. A total of 1,310 Chinook salmon redds (1,744 adults) were observed and 62% of those redds were above the former Elwha Dam site. Over 95% of those Chinook salmon redds were observed in the main stem Middle Elwha River rather than the tributaries. A high number (241) of Chinook salmon redds were again observed immediately downstream of the former Glines Canyon Dam, which had not been completely removed during the bulk of the upstream migration. A total of 4 adult Chinook salmon and 1 Chinook salmon redd were observed immediately upstream of Glines Canyon Dam during the peak of spawning activity in 2014. The distribution of Chinook salmon redds in the Middle Elwha suggests that main stem spawning habitat, and to a lesser extent tributary habitat, in the Elwha River was being colonized by Chinook salmon.

In 2015, based on SONAR estimates (Denton et al. 2016), the total escapement of Chinook salmon to the Elwha River was 4,112. A total of 937 Chinook salmon redds and 753 adults (366 live/387 dead) were observed and 77% of those redds were located above the former Elwha Dam site. Over 95% of those Chinook salmon redds were observed in main stem Middle Elwha River habitats rather than the tributaries. A high number (100) of Chinook salmon redds were again observed in the 1.1 km reach immediately downstream of the former Glines Canyon Dam. Only 1 adult Chinook salmon and no Chinook salmon redds were observed immediately upstream of Glines Canyon Dam in 2015. Large boulders originating from Glines Canyon fell into the channel shortly after dam removal was completed in 2014. These boulders created a vertical drop of 12-15' through the canyon reach and were subsequently blasted in October of 2015 in an effort to improve fish passage. The blasting was too late, however, to affect passage conditions during the 2015 chinook migration period. The distribution of Chinook salmon redds in the Middle Elwha suggests that main stem spawning habitat, and to a lesser extent tributary habitat, in the Elwha River is being colonized by Chinook salmon.

In 2016, a total of 615 Chinook salmon redds and 374 adults (319 live/55 dead) were located in the Elwha River¹. Over 95% of the redds were located in main stem habitats. The majority of the redds (~67%) were located within the Middle Elwha. However, unlike previous years we did not observe large numbers of redds and fish immediately below former Glines Canyon Dam. A total of 58 redds (~10%) were observed upstream of the former Glines Canyon dam site during mid-September. This suggests that passage conditions for Chinook salmon have improved following directed blasting operations at the Glines rockfall. Forty-seven redds were located in the former Mills reservoir and ten in Geyser Valley. Areas above the Grand Canyon were surveyed and a single redd was located below the confluence with Godkin Creek at rkm 57.8

¹ This is a partial count as not all observers reported live/dead fish in 2016.

The distribution of redds suggests that recolonization is advancing upstream and that efforts to correct passage issues were helpful, at least for adult Chinook salmon.

The most obvious trends from 2012 to 2016 in terms of the spatial distribution of Chinook salmon redds have been an increasing number upstream of the former dam sites over time. In addition we have seen an increasing number in the main stem habitats of the Elwha River, which is similar to what has been observed in other river systems throughout the Puget Sound (Beechie et al. 2006; Ruckelshaus et al. 2006). This suggests that habitat conditions are improving and stabilizing in the mainstem.

Introduction

The removal of two hydroelectric dams on the Elwha River represents the largest dam removal attempted to date in the world. Located at Rkm 7.9 and 22, the 32 m Elwha Dam (completed in 1913) and 64 m Glines Canyon Dam (completed in 1927) were identified for removal under the Elwha River Ecosystem and Fisheries Restoration Act of 1992 (Elwha Act). The goal of the Elwha Act is to restore the Elwha River ecosystem and associated anadromous fish populations through dam removal, sediment management, revegetation, and the conservation and amplification of native salmon populations. The long term goal is to establish self-sustaining, natural populations of Pacific salmon and steelhead, reducing and eliminating hatchery supplementation over time (Ward et al. 2008).

To help guide this process the Elwha Monitoring and Adaptive Management (EMAM) plan was developed for federally listed populations of Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) (Peters et al. 2014). This document suggests adaptive management targets that could be used to inform management actions for the recovery of the populations. The EMAM provides performance indicators coupled with management triggers to guide project managers through four stages of recovery including: 1) preservation, 2) recolonization, 3) local adaptation, and 4) viable natural population. Performance indicators used in the EMAM are based upon the general Viable Salmon Population (VSP) metrics including abundance, productivity, spatial distribution and diversity (McElhany et al. 2000). For Elwha River Chinook salmon, abundance is being estimated using SONAR (Denton et al. 2013, 2014, 2015 and 2016). Productivity metrics are being assessed using a combination of abundance estimation by smolt outmigration monitoring (McHenry et al. 2016) and adult to adult cohort reconstruction (Weinheimer et al. 2016). Spatial distribution is being assessed using a combination of visual redd surveys (foot, snorkel, boat, and aerial), radiotelemetry, and may include eDNA techniques (Laramie et al. 2015) in the future. For diversity, Chinook salmon monitoring efforts focus on

adult migration timing (SONAR) and the expression of stream-type juvenile life-histories (adult scales and smolt trap).

Elwha River salmon populations were spatially limited to approximately 8.0 km of habitat below Elwha Dam for over a century. The removal of the Elwha and Glines Canyon dams is now allowing for the recolonization of formerly occupied habitats. However, it is uncertain how quickly recolonization and the establishment of self-sustaining spawning populations will occur. Additionally, dam removal will not recreate the exact physical habitat conditions that existed prior to dam removal, and other barriers may ultimately limit the distribution of different salmonid species within the watershed.

The spatial distribution of Chinook salmon also potentially affects other VSP parameters such as life history diversity (Beechie et al. 2006). In the Puget Sound region, Chinook salmon populations in snowmelt-dominated areas, such as the Elwha River, typically contain a higher proportion of the stream-type life history (juvenile residence ≥ 1 year in freshwater), and have older spawners than Chinook Salmon populations in rainfall-dominated areas which produce primarily zero aged migrants (Beechie et al. 2006). Furthermore, in Puget Sound, the fraction of Chinook salmon genetic differentiation that can be attributed to life history characters is relatively small, compared to the Columbia Basin (Waples 2008). This suggests a strong role for environmental conditions in stream vs ocean-type juvenile rearing strategies of Puget Sound Chinook salmon. Thus, to the extent that spawning in snowmelt dominated headwater reaches will promote stream-type life histories, allowing some portion of the extant Chinook salmon population to recolonize habitats above the dam sites on the Elwha may result in the re-expression of this suppressed life history characteristic. It was predicted that Chinook salmon were expected to recolonize in the Elwha upstream of Carlson Canyon at Rkm 56.0 (DOI 1995).

Dam construction, which began in 1910, blocked the vast majority of the spawning habitat in the Elwha River basin, including all of the snowmelt dominated areas typically associated with stream-type life histories. Chinook salmon persisted in the lower river and were maintained by a large hatchery supplementation program initiated by WDFW beginning in 1930 and maintained to the present (Winter and Crain 2008). This program uses broodstock directly descended from the remnant Elwha Chinook salmon population, with relatively minor contributions from other rivers over the years (Myers et al. 1998). From 2010-2015, > 90% of Chinook salmon returning to the Elwha River basin were hatchery origin (Anderson et al. 2015; Weinheimer et al. 2016). EMAM (Peters et al. 2014) has established a goal of 100% natural origin spawners for a self-sustaining population of Elwha River Chinook salmon.

Dam removal was initiated in the fall of 2011 and by the spring of 2012, Elwha Dam had been removed². Glines Canyon Dam was removed by August 26th, 2014 and the first Chinook salmon above the Glines Canyon Dam site was reported approximately 10 days later on September 9th, 2014. Several weeks later, in the fall of 2014 large boulders fell from the canyon walls and created vertical drops of 12-15' through the entrance to Glines Canyon. It was feared and later confirmed that these boulders amplified blockages to upstream migrating salmon. In the fall of 2015, selective blasting was conducted to reduce vertical drops and increase effective stream width through the rock fall. Those treatments have been partially successful and the vertical drop through the reach has been reduced to approximately 6' (Personal Communication, Andy Ritchie, Olympic National Park).

In order to collect information on the spatial extent of Chinook salmon spawning, biologists from the Washington Department of Fish and Wildlife (WDFW), Lower Elwha Klallam Tribe (LEKT), Olympic National Park (ONP), National Oceanic and Atmospheric Administration (NOAA), U.S. Fish and Wildlife Service (USFWS), and United States Geological Survey (USGS) initiated a one-day, peak spawning survey event in 2012. This survey event was repeated in 2013 and focused on the areas downstream of Glines Canyon Dam. In 2014, 2015 and 2016 additional surveys were conducted upstream of Glines Canyon Dam in order to ascertain Chinook salmon passage at Glines Canyon and to document the recolonization of habitat by Chinook salmon. This report summarizes those survey efforts as our objectives were to; 1) map the spatial distribution of Chinook salmon redds, 2) calculate the density of Chinook salmon redds by River kilometer (Rkm), and to compare the relative distribution of spawning Chinook salmon within and between years.

Methods

One day to five-day spawning ground surveys of the mainstem Elwha River, larger floodplain channels, and several major tributaries were conducted in mid-September of 2012, 2013, 2014, 2015 and 2016 in the Elwha watershed (Figure 1). Survey timing was based on the estimated historical date of peak spawning activity for Elwha River Chinook salmon, approximately Sept 15 - 25 (WDFW Unpublished Data). The Elwha River was divided into two sections in 2012 and 2013 and three sections in 2014-2016. The Lower Elwha (LE) was defined as the area downstream of Elwha Dam (Rkm 0.0-7.9), while the Middle Elwha (ME) includes the reach immediately above the former Elwha Dam, including the former Aldwell Reservoir, upstream to the former Glines Canyon Dam (Rkm 7.9-21.7). An additional section was added in 2014 and

² During extreme low flows of 2015 it was discovered that the base of Elwha Dam along with a caisson constructed after the initial dam failed in 1912 had actually not been removed. Planning is currently underway to address this issue.

2015, the Upper Elwha (UE), which is defined as the reach above Glines Canyon Dam upstream to the entrance of the Grand Canyon of the Elwha (Rkm 21.7–31.4) and includes the former Mills Reservoir and Press Valley (Figure 1). Surveys in the upper Elwha were further expanded in 2016 to include the areas between Marys Falls Camp and where the main trail crosses the Elwha several miles below Chicago Camp. The LE³ and ME were surveyed in all years, while the UE was surveyed in 2014, 2015 and 2016.

Each survey reach was originally partitioned using local geographic features or place names that have an associated River Kilometer (Rkm) (Table 1). These reaches were consolidated in 2015 and 2016 to simplify data collection (Table 2 & 3). Individual reach surveys were assigned to two person crews consisting of biologists and biological technicians from the Lower Elwha Klallam Tribe (LEKT), Olympic National Park (ONP) and Washington Department of Fish and Wildlife (WDFW). Additional support was also provided by staff from the United States Fish and Wildlife Service (USFWS), National Oceanographic and Atmospheric Administration (NOAA) and the United States Geological Survey (USGS). Within each survey reach, two person crews conducted standard spawning ground surveys by walking from the upper end of the reach downstream to its terminus (Gallagher et al. 2007), typically with one surveyor on each side of the river.

The surveyors recorded the number of Chinook salmon nests (redds), and live and dead Chinook salmon observed within each survey reach. Opportunistic determination of the sex of live and dead Chinook salmon, jacks (precocious males) as well as record the presence of pink salmon and steelhead was also documented in some years. Redds were identified as disturbed areas in the stream bed where the substrate was overturned (Gallagher et al. 2007). Each redd was geo-located (latitude and longitude) using a Garmin GPS (model GPSmap 60CSx).

Flow levels, turbidity, and suspended sediment concentration levels varied each year (Table 4). Both flow and turbidity levels were highest in 2012 which limited surveys to above the Elwha dam site (Table 5). In 2013, conditions improved to allow for surveys below the former Elwha dam, and 2014 conditions allowed for a full survey from the mouth to just above former Glines Canyon dam (Table 5). While it is generally true that visual survey techniques are not effective most of the year on the Elwha River because of elevated suspended sediment levels, we have identified a low-discharge, low turbidity window that corresponds to the period of peak spawning for Chinook salmon. We typically note a general decline in visibility moving in a downstream direction, likely due to the river interacting with additional stored sediments from dam removal. This was particularly true in the lower Elwha during 2012 and 2013 when turbidity levels were elevated enough through the low flow window to preclude surveys.

³ Lower Elwha surveys were unsuccessful in 2012 and partially successful in 2013 due to elevated turbidity.

However, over time survey conditions have greatly improved, enhancing precision of the peak count method.

Results

The total number of observed Chinook salmon redds increased between 2012 and 2014 from 217 to over 1,300 redds, an increase of 83% (Figure 2). In 2015 and 2016 the number of redds has decreased by 28% and 53%, respectively from the peak number observed in 2014 (1,310). In all years the majority of Chinook salmon redds were located in the area above the former Elwha dam (Rkm 7.5) and just below the former Glines Canyon dam (Rkm 21.1) (Figure 2 & 8). It is important to note that visibility was poor during September of 2012 thus the number of redds below the former Elwha dam in 2012 was likely an under-estimate. Abundance estimates derived from SONAR indicated that Chinook salmon were less numerous in 2012 (estimate = 2,638) than either 2013 (estimate = 4,243), 2014 (estimate = 4,360), or 2015 (estimate = 4,112) (Denton and Liermann 2013, Denton et al. 2014, 2015, 2016). A SONAR abundance estimate is currently not available for the 2016, however the escapement was likely in the range of 2012 (i.e. approximately 2,500) (Denton et al, in prep).

In 2012, a total of 217 Chinook salmon redds were located, of which 203 were identified upstream of the former Elwha Dam (Figure 3, Table 5). Fifty-two percent of these redds were located either in the mainstem ME or in the former Aldwell Reservoir area (Table 5). Forty-eight percent of the Chinook salmon redds were found in Indian Creek and Little River, two middle Elwha tributaries unaffected by dam removal (Figure 3). The spatial distribution of Chinook salmon redds in 2012 clumped in three general areas Rkm 9.8 to 12.2 (Gooseneck to Highway 101 bridge), Rkm 16.5 to 18.0 (Rabbit Hole to Fisherman's Corner), and the two main tributaries (Indian Creek and Little River) (Figure 4).

In 2013, additional survey reaches were added in the LE due to greater visibility (Figure 4, Table 6). A total of 765 chinook redds were identified, 79% of which were observed above the former Elwha Dam location (Table 6). The distribution of mainstem vs. tributaries changed in 2013, with the vast majority of Chinook salmon redds (85%) being identified in the mainstem and 15% being identified in Little River, Indian Creek, and Hughes Creek (Figure 4, Table 6). Over one quarter of the Chinook salmon redds 27% (162 out of 602) were located in the 1.1 km immediately below Glines Canyon Dam in 2013. Fifty-eight percent (347 out of 602) of the Chinook salmon redds were located within 5.0 km of the Glines Canyon Dam site (Table 6). Glines Canyon Dam was still being removed in 2013 and was not passable to anadromous fish. In addition to Chinook salmon, surveyors reported one pink salmon and three sockeye

upstream of Elwha Dam. Below the former Elwha Dam site, Chinook salmon spawning activity was only documented upstream of Rkm 3.9 due to deteriorating visibility in the reaches further downstream (Figure 4, Table 6). The section that had the second highest number of Chinook salmon redds recorded in the survey was immediately below the former Elwha dam site downstream to the weir at Rkm 5.5 (Figure 4, Table 6).

In 2014, visibility was excellent and survey reaches from the previous year were used to conduct a river wide survey (Figure 5, Table 7). A total of 1,310 Chinook salmon redds were located and identified, of which 62% (812 out of 1,310) were located in the ME, upstream of the Elwha Dam and below the former Glines Canyon Dam (Figure 5, Table 7). The distribution of mainstem vs. tributaries changed again in 2014 relative to the two previous years: 95% of the Chinook salmon redds above the dam sites were located in the main stem ME, while only 5% were identified in Little River, Indian Creek, and Hughes Creek (Figure 5, Table 7). Only one redd was observed in Little River. The low number was likely a result of low attraction flows, as the mouth of Little River joined the Elwha River across a broad gravel bar that had flow only several centimeters deep. Over one quarter of the Chinook salmon redds (30%, 241 out of 812) were located in the 1.1 km immediately below Glines Canyon Dam in 2013, while over 60% (61%, 496 out of 812) of the Chinook salmon redds were located within 5.0 km downstream of the Glines Canyon Dam site (Figure 5, Table 7).

Glines Canyon Dam was still being removed in 2014, a process that was not complete until August 26th. However, it should be noted that small numbers of Chinook salmon were observed above Glines Canyon in 2014. During the first week of September, Mel Elofson, a member and employee of the Lower Elwha Klallam Tribe, reported seeing a Chinook salmon just above the Glines Canyon site. On September 9, ONP staff snorkeled from Rica Canyon downstream to the Glines Canyon Dam and visually identified 3 adult Chinook salmon (Personal Communication, Anna Geffre and Heidi Hugunin, ONP). A subsequent survey on September 22 identified 3 Chinook salmon redds of which only one was located by ONP. On September 30 an additional Chinook salmon redd survey was conducted in the Geyser Valley (Rica Canyon to Dodger Point) and no Chinook salmon or Chinook salmon redds were located. It should be noted that a citizen reported to ONP staff observing a Chinook salmon in the vicinity of Elkhorn Ranger Station (Rkm 40.2).

In 2014, below the former Elwha dam site, Chinook salmon spawning activity was continuous and documented in all reaches (Table 7). This contrasted with 2012 and 2013, when at least four reaches had been surveyed without any redd observations. Over 38% (499 out of 1310) of all Chinook salmon redds observed in 2014 were found below the former Elwha dam site, making it the highest number and percentage of Chinook salmon redds below the dam since pre dam removal (Table 7, Figure 5).

In 2015, visibility was again excellent and survey reaches from the previous year were used to conduct a river wide survey (Figure 6, Table 8). We counted 366 live and 387 dead chinook adults of which 82% and 94% were located upstream of the former Elwha Dam site. A total of 937 Chinook salmon redds were located and identified, of which 77% (719 out of 937) were located in the ME, upstream of the Elwha Dam and below the former Glines Canyon Dam (Figure 6, Table 8). The distribution of mainstem vs. tributaries changed again in 2015 relative to the three previous years, with 90% of the Chinook salmon redds above the former Elwha dam were located in the main stem ME, while only 10% were identified in Little River, Indian Creek, and Hughes Creek (Figure 6, Table 8). Over one tenth of the Chinook salmon redds (10%, 100 out of 937) were located in the 1.1 km immediately below Glines Canyon Dam in 2013, while over a quarter (26%, 246 out of 937) of the Chinook salmon redds were located within 5.0 km downstream of the Glines Canyon Dam site (Figure 6, Table 8).

We also made observations of pink salmon adults during the 2015 survey. A total of 80 live and 27 dead pink salmon adults were observed during the survey. Of these the majority (68%) were located above the former Elwha Dam site. Furthermore 77% of the pink salmon adults were observed in Little River, Indian and Hughes Creek. This was the first documented return of pink salmon adults to the middle river tributaries and was likely the first significant return of pink salmon above the former Elwha Dam site.

In 2016, despite the apparent reduction in total escapement, the spatial distribution of Chinook salmon was the greatest observed since survey efforts began in 2012 (Table 8; Figures 2, 7, and 8). Nearly one-quarter of the total redds observed were located above Glines Canyon Dam and significant numbers were observed in both the former Mills reservoir and the Geyser Valley (Figures 7 and 8). Redds were observed in lower Boulder Creek (8) and in Cat Creek (2) for the first time. A single Chinook salmon redd was observed in the Elwha River just below the confluence with Godkin Creek (Rkm 57.8) during upriver surveys (to Rkm 61.6) by ONP personnel (Figure 7). In addition we did not observe a high density of redds immediately below Glines Canyon as in recent years. This would suggest that passage conditions for chinook salmon were much improved in 2016 over previous years.

Discussion

We conducted annual peak spawner ground surveys for Elwha River Chinook salmon during dam decommissioning and the early stages of recolonization from 2012 to 2016. These surveys were designed to provide information on the spatial distribution of Chinook salmon spawning nest locations as access to historic habitats was being restored. The surveys were not intended nor designed to enumerate the total number of Chinook salmon returning to the Elwha River.

In 2012, the proportion of Chinook salmon redds in the ME was evenly distributed between the mainstem and tributary habitat, but because of their smaller sizes, densities were much higher in the tributaries. The two major ME tributaries, Indian Creek and Little River, which enter on opposite sides of the Elwha River at roughly the same Rkm, are the first clear water refugia above the former Elwha dam site and newly exposed former Aldwell Reservoir (Figure 3). Two other areas of concentrated Chinook salmon spawning activity were Rkm 16.5 to 18.0 (Rabbit Hole) and Rkm 9.8 to 11.4 (former Aldwell reservoir – Oxbow reach) (Figure 3). These patterns can largely be attributed to two factors. First, within the ME, Rkm 16.5 to 18.0 is one of several anastomosing forested island reaches, a habitat type where higher occurrence of Chinook salmon spawning activity has been documented in other studies due to local hydraulic conditions that promote upwelling (Vronskiy 1972, Vronskiy et al. 1991, Geist 2000). Second, mainstem Chinook salmon spawning was also concentrated in the former Aldwell Reservoir that had similar hydraulic characteristics as the Rabbit Hole reach, but was identified as less stable and more transient, similar to braided reaches (Beechie and Imaki 2014). However, it should also be noted that the Aldwell reach was immediately upstream of Elwha Dam and therefore the closest spawning habitat for recolonizing fish, which may select spawning sites according to distance upstream from the former barrier (Kiffney et al, 2008, Pess et al. 2012).

The distribution of Chinook salmon redds was much more extensive in 2013 (Figure 4), as redds were observed in each reach above the former Elwha dam site, and the density in each reach was similar or higher than in 2012 (Table 4&6). Unlike 2012, the vast majority of Chinook salmon redds were in the mainstem ME rather than the tributaries. This difference in distribution was hypothesized to occur for three primary reasons. First, turbidity levels in the mainstem ME were lower in 2013 than 2012 (Table 4). Second, connectivity between Little River, Indian Creek, and the mainstem ME was reduced in 2013 due to the development of mainstem gravel bars at the confluence of each tributary. Lastly and most importantly, between September 2012 and September 2013, there was a large increase in the source, amount, and type of sediment released from the former Mills reservoir (Warrick et al. 2015), a process that increased the quantity and quality of Chinook salmon spawning habitat in the mainstem ME.

In 2012, the mainstem ME did not markedly change in terms of sediment load and channel characteristics because the majority of sediment released by October of 2012 came from the former Elwha dam site (Warrick et al. 2015). Thus, the major changes in 2012 occurred below former Elwha dam and in the LE (East et al. 2015). However, between October of 2012 and September of 2013 large scale geomorphic changes occurred in the ME due to the substantial increase in sediment flux from the former Lake Mills delta, which was fully prograded to Glines Canyon and released ~ 8.9 million tons of sediment (Warrick et al. 2015). During that time period, the entire river aggraded due to an order of magnitude increase in bedload material (Warrick et al. 2015). The bedload increase resulted in an increase riffle crest and channel

thalweg elevation and bar formation. Substrate size in the ME also decreased 16 fold due to the influx of sand and gravel, and the density of main stem channels increased (East et al. 2015). Prior to dam removal, the ME was characterized by cobble and boulder sized substrates greater than 64 mm (East et al. 2015), and so the reduction in substrate size may have provided a particularly large benefit to Chinook salmon spawning habitat quality. Much of this change occurred within the first 5 km downstream of the former Glines Canyon dam site (Figure 5), an area of high spawning density in 2013 and 2014 (Tables 6 and 7) (Figure 2).

The 2014, 2015 and 2016 Chinook salmon spawner surveys represents the most spatially extensive chinook survey efforts coupled with the lower flows and lowest turbidity levels (Table 4). The number of Chinook salmon redds increased as did the Chinook salmon redd density, while the relative distribution was similar. Glines Canyon Dam was in the final stages of removal during the bulk of the Chinook salmon migration, a process that was not complete until August 26th. The first Chinook salmon were observed in the former Mills Reservoir only 10 days after dam removal was completed and at least 3 redds were observed by ONP and LEKT employees. Chinook migration above Glines Canyon was prevented in 2015 as a result of a rock fall shortly following dam removal in 2014. This blockage was subsequently blasted in the fall of 2015, but too late to allow upstream migration in the 2015 spawning year. Additional blasting was conducted in 2016 and those efforts appear to have been successful (at least for chinook). Continued monitoring of Chinook salmon spawner distribution will be important to assess long term passage through Glines Canyon in the future.

The rather continuous distribution of Chinook salmon redds observed in 2013-2016 (Figure 8) is likely due to the combination of relatively high abundance of spawners and an increase in the quantity and quality of spawning habitat. Visual observations made by spawning ground surveyors indicated that the main stem spawning habitat in 2013-2016 was largely dominated by well sorted gravel deposits with minimal fine sediment. In contrast many of the mainstem side-channels have large deposits of fine sediment on their channel beds (Pess et al. 2015; Peters et al. In Review). The post-dam removal Elwha River continues to be an active channel characterized by dynamic changes. Monitoring of surface and subsurface sediment at riffle crests downstream of Glines Canyon Dam to the mouth of the Elwha River has been conducted in concert with the Chinook spawning ground surveys. In addition to documenting geomorphic changes, we expect that the sediment monitoring will help us better understand the linkages between spawning habitat and the distribution of Chinook salmon redds.

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Tables

Table 1. Survey reaches, Rkm, and lead survey agency from 2012 to 2014. ONP = Olympic National Park, LEKT = Lower Elwha Klallam Tribe, and WDFW = Washington Department of Fish and Wildlife. Assistance in these surveys included other partners including the USGS, NOAA, and independent contractors.

Survey Reach	Rkm start	Rkm end	Midpoint (Rkm)	Length (km)	Lead survey team
Above Glines powerhouse			21.5		ONP
Glines Powerhouse to Top of Altaire Canyon	21.1	20.0	20.6	1.1	ONP
Altaire Canyon to Altaire Bridge	20.0	19.5	19.8	0.5	ONP
Altaire Bridge to Griff Creek	19.8	19.0	19.4	0.8	ONP
Griff Creek to Rabbit Hole	19.0	18.0	18.5	1.0	ONP
Hughes Creek	0.0	0.7	17.7	0.7	ONP
Rabbit Hole to Fishermans Corner	18.0	16.5	17.3	1.5	ONP
Fishermans Corner to Park Boundary	16.5	15.7	16.1	0.8	ONP
Park Boundary to McDonald Bridge Gage	15.7	13.7	14.7	2.0	ONP
McDonald Bridge Gage to A-Frame	13.7	12.5	13.1	1.2	ONP
A-Frame to 101 Bridge	12.5	12.1	12.3	0.4	ONP
Little River	0.0	1.9	12.2	1.9	LEKT
Indian Creek	0.0	1.9	12.1	1.9	LEKT
101 Bridge to Boat Launch (Aldwell)	12.1	11.8	12.0	0.3	LEKT
Boat launch to Oxbow (Aldwell)	11.8	11.4	11.6	0.4	LEKT
Oxbow Reach (Aldwell)	11.4	11.1	11.3	0.3	LEKT
Oxbow Reach to Goosneck	11.1	9.8	10.5	1.3	LEKT
Gooseneck to Elwha Dam	9.8	7.5	8.7	2.3	LEKT
Dam outflow to hwy 112 bridge	7.5	6.7	7.1	0.8	WDFW
Hwy 112 bridge to weir	6.7	5.5	6.1	1.2	WDFW
Weir to new bridge	5.5	4.8	5.2	0.7	WDFW
New bridge to sisson's riffle	4.8	3.9	4.4	0.9	WDFW
Sisson's riffle to spruce hole	3.9	3.3	3.6	0.6	WDFW
Sisson's riffle to Hunt's Road Channel	3.3	2.8	3.1	0.5	WDFW
Right bank channel (LEKT hatchery)	2.8	1.2	2.0	1.6	LEKT
Hunt's Road channel	2.8	1.2	2.0	1.6	LEKT
Elwha bluff to mouth	1.2	0.0	0.6	1.2	LEKT

Table 2. Revised survey reaches, Rkm, and lead survey agency adopted for 2015. ONP = Olympic National Park, LEKT = Lower Elwha Klallam Tribe, and WDFW = Washington Department of Fish and Wildlife. Assistance in these surveys included other partners including the USGS, NOAA, and independent contractors.

Survey Reach	Rkm start	Rkm end	Midpoint (Rkm)	Length (km)	Lead survey team
Above Glines powerhouse			21.5		ONP
Glines Powerhouse to Top of Altaire Canyon	21.1	20.0	20.6	1.1	ONP
Altaire Canyon to Altaire Bridge	20.0	19.5	19.8	0.5	ONP
Altaire Bridge to Griff Creek	19.8	19.0	19.4	0.8	ONP
Griff Creek to Rabbit Hole	19.0	18.0	18.5	1.0	ONP
Hughes Creek	0.0	0.7	17.7	0.7	ONP
Rabbit Hole to Fishermans Corner	18.0	16.5	17.3	1.5	ONP
Fishermans Corner to Park Boundary	16.5	15.7	16.1	0.8	ONP
Park Boundary to McDonald Bridge Gage	15.7	13.7	14.7	2.0	ONP
McDonald Bridge Gage to A-Frame	13.7	12.5	13.1	1.2	ONP
A-Frame to 101 Bridge	12.5	12.1	12.3	0.4	ONP
Little River	0.0	1.9	12.2	1.9	LEKT
Indian Creek	0.0	1.9	12.1	1.9	LEKT
Aldwell South (101 Bridge to Gooseneck)	12.1	9.8	11.0	2.3	LEKT
Aldwell North (Gooseneck to Elwha Dam)	9.8	7.5	8.7	2.3	LEKT
Dam outflow to Hwy 112 bridge	7.5	6.7	7.1	0.8	WDFW
Hwy 112 bridge to County bridge	6.7	5.8	6.1	1.9	WDFW
County bridge to Spruce Hole	4.8	2.8	3.8	2.0	WDFW
East Channel (LEKT Hatchery)	2.8	1.2	2.0	1.6	LEKT
Hunt's Road channel	2.8	1.2	2.0	1.6	LEKT
Elwha bluff to mouth	1.2	0.0	0.6	1.2	LEKT

Table 3. Revised survey reaches, Rkm, and lead survey agency adopted for 2016. ONP = Olympic National Park, LEKT = Lower Elwha Klallam Tribe, and WDFW = Washington Department of Fish and Wildlife. Assistance in these surveys included other partners including the USGS, NOAA, and independent contractors.

Survey Reach	Rkm start	Rkm end	Midpoint (Rkm)	Length (km)	Lead survey team
Upper Elwha					
Upper Watershed	31.8	56.0	43.8	24.2	ONP
Rica Canyon to Dodger Point (Press Valley)	25.7	31.8	28.8	6.1	ONP
Glines Powerhouse to Rica Canyon (Mills)	21.1	25.7	23.4	4.6	ONP
Middle Elwha					
Glines Powerhouse to Top of Altaire Canyon	21.1	20.0	20.6	1.1	ONP
Top of Altaire Canyon to Elwha Ranger St.	20.0	19.0	19.5	1.0	ONP
Elwha Ranger Station to Rabbit Hole	19.0	18.0	18.5	1.0	ONP
Rabbit Hole (Hughes) to Fishermans Corner	18.0	16.5	17.3	1.5	ONP
Fishermans Corner to Park Boundary	16.5	15.7	16.1	0.8	WDFW
Park Boundary to McDonald Bridge Gage	15.7	13.7	14.7	2.0	WDFW
McDonald Gage to 101 Bridge	13.7	12.1	12.9	1.6	WDFW
Little River	0.0	1.9	12.2	1.9	LEKT
Indian Creek	0.0	1.9	12.1	1.9	LEKT
Aldwell South (101 Bridge to Gooseneck)	12.3	9.8	11.0	2.5	LEKT
Aldwell North (Gooseneck to Elwha Dam)	9.8	7.9	8.8	1.9	LEKT
Lower River					
Dam outflow to Hwy 112 bridge	7.9	6.7	7.3	1.2	WDFW
Hwy 112 bridge to County bridge	6.7	4.8	6.1	1.9	WDFW
County bridge to Spruce Hole	4.8	2.8	3.8	2.0	WDFW
East Channel (LEKT Hatchery)	2.8	0.0	1.4	2.8	LEKT
Hunt's Road Channel	2.8	1.2	2.0	1.6	LEKT

Table 4. Discharge, turbidity levels and suspended sediment concentration during Chinook salmon spawning ground surveys conducted in the Elwha River, 2012-2016. Water quality measurements were measured at monitoring station 12046200, while discharge measurements were at station 12045500 (Curran et al. 2014).

Year	Date	Flow (cms)	Turbidity level (FNU) ($\pm$ S.D.)	Median SSC (mg/L)	Comments
2012	Sept 12 to Sept 17	11.9 ($\pm$ 2.9)	72 ($\pm$ 30)	57	Visibility good above Elwha Dam, limited surveys conducted below due to high turbidity from dam removal
2013	Sept 17	11.1 ($\pm$ 0.7)	45 ($\pm$ 2)	77	Visibility good above Elwha Dam, fair below Elwha Dam due to high turbidity from dam removal
2014	Sept 17	7.0 ($\pm$ 0.2)	5 ($\pm$ 2)	55	Visibility excellent in all reaches
2015	Sept 23-24	9.9 ($\pm$ 0.2)	0.8($\pm$ 0.4)	-	Visibility excellent in all reaches
2016	Sept 19-23	8.5($\pm$ 0.2)	5.0($\pm$ 2)		Visibility generally good with exception of construction disturbances in lower river

Table 5. 2012 Elwha River Chinook salmon spawners from Glines Canyon Dam to the mouth. NS = Not Surveyed.

Survey Reach	Rkm midpoint	Redds	Redds/km	Male	Female	Unknown	Dead	Jacks
Above Glines	21.5	NS	NS	NS	NS	NS	NS	NS
Middle Elwha								
Glines Powerhouse	20.6	6	5.5	0	0	23	1	1
Altaire Canyon	19.8	NS	NS	NS	NS	NS	NS	NS
Altaire Bridge	19.4	0	0.0	2	3	3	1	1
Griff Creek	18.5	8	8.0	0	0	0	1	0
Hughes Creek	17.7	NS	NS	NS	NS	NS	NS	NS
Rabbit Hole	17.3	33	22.0	7	1	102	18	1
Fishermans Corner	16.1	0	0.0	0	0	0	0	0
Park Boundary	14.7	0	0.0	0	0	0	0	0
McDonald Bridge	13.1	2	1.7	0	0	0	1	0
A-Frame	12.3	0	0.0	0	0	0	0	0
Little River	12.2	40	21.1	28	16	0	18	8
Indian Creek	12.1	58	30.5	29	28	0	27	14
101 Bridge	12.0	10	33.3	0	0	6	0	0
Boat launch	11.6	1	2.5	0	0	3	2	0
Oxbow Reach	11.3	30	100.0	0	0	31	5	0
Oxbow Reach2	10.5	15	11.5	0	0	5	8	0
Gooseneck	8.7	0	0.0	0	0	0	0	0
ME Subtotal		203	11.0	66	48	173	82	25
Lower Elwha⁴								
Dam outflow	7.1	0	0.0	0	0	0	0	0
Hwy 112 bridge	6.1	0	0.0	0	0	0	0	0
Weir	5.2	4	5.7	0	0	0	2	0
New bridge	4.4	4	4.4	0	0	0	0	0
Sisson's riffle1	3.6	4	6.7	0	0	0	0	0
Sisson's riffle2	3.1	2	4.0	0	0	0	0	0
Right bank channel	2.0	0	0.0	NS	NS	NS	NS	NS
Hunt's Road channel	2.0	0	0.0	NS	NS	NS	NS	NS
Elwha bluff to mouth	0.6	0	0.0	NS	NS	NS	NS	NS
LE Subtotal		14	1.5	0	0	0	2	0

⁴ Observations of redds in the lower Elwha below Rkm 5.2 were limited or not possible during 2012 surveys because of limited visibility associated with dam removal activities.

Table 6. 2013 Elwha River Chinook salmon spawners from Glines Canyon Dam to the mouth. NS = Not Surveyed.

Survey Reach	Rkm midpoint	Redds	Redds/km	Male	Female	Unknown	Dead	Jacks
Above Glines	21.5	NS	NS	NS	NS	NS	NS	NS
Middle Elwha								
Glines Powerhouse	20.6	162	147.3	132	103	60	77	2
Altaire Canyon	19.8	11	22.0	0	2	0	10	0
Altaire Bridge	19.4	42	52.5	11	14	25	30	0
Griff Creek	18.5	73	73.0	30	18	22	51	1
Hughes Creek	17.7	8	11.4	6	7	0	39	1
Rabbit Hole	17.3	59	39.3	8	19	14	32	0
Fishermans Corner	16.1	13	16.3	7	3	23	33	0
Park Boundary	14.7	45	22.5	4	0	108	47	4
McDonald Bridge	13.1	8	6.7	1	3	6	35	0
A-Frame	12.3	16	40.0	0	0	13	6	0
Little River	12.2	23	12.1	23	12	0	9	0
Indian Creek	12.1	58	30.5	43	19	0	64	5
101 Bridge	12.0	68	29.6	19	19	24	20	0
Boat launch	11.6							
Oxbow Reach	11.3							
Oxbow Reach2	10.5							
Gooseneck	8.7	16	7.0	12	6	20	7	0
ME Subtotal		602	32.7	296	225	315	460	13
Lower Elwha⁵								
Dam outflow	7.1	51	63.8	0	0	81	16	0
Hwy 112 bridge	6.1	100	83.3	0	0	251	25	0
Weir	5.2	9	12.9	0	0	13	20	0
New bridge	4.4	3	3.3	0	0	0	0	0
Sisson's riffle1	3.6	0	0.0	0	0	13	0	0
Right bank channel	2.0	0	0.0	0	0	23	1	0
Hunt's Road channel	2.0	NS	NS	NS	NS	NS	NS	NS
Elwha bluff to mouth	0.6	0	0.0	0	0	0	0	0
LE Subtotal		163	19.0	0	0	381	62	0

⁵ Observations of redds in the lower Elwha below Rkm 5.2 were limited or not possible during 2013 surveys because of limited visibility associated with dam removal activities.

Table 7. 2014 Elwha River Chinook salmon spawners from Glines Canyon Dam to the mouth. NA = Not Applicable.

Survey Reach	Rkm midpoint	Redds	Redds/km	Male	Female	Unknown	Dead	Jacks
Above Glines	21.5	1	NA	0	0	4	0	0
Middle Elwha								
Glines Powerhouse	20.6	241	219.1	0	0	257	57	0
Altaire Canyon	19.8	29	58.0	0	0	23	19	0
Altaire Bridge	19.4	63	78.8	18	22	29	21	0
Griff Creek	18.5	82	82.0	9	12	24	49	0
Hughes Creek	17.7	12	17.1	3	5	0	3	0
Rabbit Hole	17.3	69	46.0	43	29	14	56	0
Fishermans Corner	16.1	55	68.8	25	7	58	49	0
Park Boundary	14.7	82	41.0	36	22	148	49	0
McDonald Bridge	13.1	17	14.2	2	1	24	17	0
A-Frame	12.3	35	87.5	3	2	73	12	0
Little River	12.2	1	0.5	0	0	0	0	0
Indian Creek	12.1	26	13.7	0	0	89	0	0
101 Bridge	12.0	57	24.8	0	0	62	26	0
Boat launch	11.6							
Oxbow Reach	11.3							
Oxbow Reach2	10.5							
Gooseneck	8.7	42	18.3	0	0	61	40	0
ME Subtotal		811	44.1	139	100	862	398	0
Lower Elwha								
Dam outflow	7.1	50	62.5	0	0	10	NA	0
Hwy 112 bridge	6.1	125	104.2	0	0	65	NA	0
Weir	5.2	25	35.7	0	0	33	NA	0
New bridge	4.4	14	15.6	0	0	36	NA	0
Sisson's riffle1	3.6	83	138.3	0	0	87	NA	0
Right bank channel	2.0	154	96.3	0	0	0	NA	0
Hunt's Road channel	2.0	47	29.4	0	0	14	NA	0
Elwha bluff to mouth	0.6	1	0.8	0	0	0	NA	0
LE Subtotal		499	27.1	0	0	245	0	0

Table 8. 2015 Elwha River Chinook salmon spawners from Glines Canyon Dam to the mouth.
NA = Not Applicable.

Survey Reach	Rkm midpoint	Redds	Redds/km	Live Chinook	Dead Chinook	Jacks	Live Pinks	Dead Pinks
Above Glines	21.5	0	0	0	0	0	0	0
Middle Elwha								
Glines Power.	20.6	100	90.9	68	14	0	0	0
Altaire Canyon	19.8	35	70.0	12	2	0	0	0
Altaire Bridge	19.4	24	30.0	14	4	0	0	0
Griff Creek	18.5	34	34.0	13	5	0	0	0
Hughes Creek	17.7	3	4.3	1	4	0	16	13
Rabbit Hole	17.3	50	33.3	37	6	0	0	0
Fisherman's C.	16.1	84	105.0	8	32	0	0	1
ONP Boundary	14.7	77	38.5	23	12	0	2	0
McDonald Br.	13.1	31	25.8	5	2	0	3	0
A-Frame	12.8	37	92.5	6	28	0	0	1
Little River	12.2	51	26.8	25	32	0	17	3
Indian Creek	12.1	18	9.5	24	5	0	5	2
Aldwell South	11.6	93	40.4	29	132	0	1	1
Aldwell North	8.7	82	35.6	34	87	0	5	3
ME Subtotal		719	45.5	299	365	0	49	24
Lower Elwha								
Dam outflow	7.1	8	10.0	0	2	0	0	0
Hwy 112 Bridge	6.1	66	55.0	5	2	0	19	0
County Bridge	4.4	31	16.3	16	2	0	3	1
Sisson's Riffle	3.6	18	9.0	5	1	0	0	0
East Channel	2.0	40	25.0	18	9	0	3	2
Hunt Rd. Chan.	2.0	55	34.4	26	6	0	6	0
Elwha Bluff	0.6	0	0.0	0	0	0	0	0
LE Subtotal		218	21.4	67	22	0	31	3

Table 8. 2016 Elwha River Chinook salmon spawners from Glines Canyon Dam to the mouth.
NA = Not Applicable.

Survey Reach	Rkm midpoint	Redds	Redds/km	Live Chinook	Dead Chinook	Jacks
Upper Elwha						
Upper Watershed	43.8	1	0.0	0	0	0
Press/Geyser Valley	28.8	10	1.6	4	0	0
Former Mills Reservoir	23.4	47	10.4	29	6	2
UE Subtotal		58	1.5	33	6	2
Middle Elwha						
Glines Power.	20.6	36	32.7	36	0	5
Altaire Bridge	19.5	19	19.0	15	0	0
Griff Creek	18.5	27	4.0	0	0	0
Rabbit Hole	17.3	30	20.0	24	0	0
Fisherman's C.	16.1	78	97.5	31	0	0
ONP Boundary	14.7	42	21.0	29	28	0
McDonald Br.	12.9	15	9.4			0
Little River	12.2	1	0.5	0	0	0
Indian Creek	12.1	28	14.7	24	14	0
Aldwell South	11.0	48	20.9	14	12	1
Aldwell North	8.8	86	45.3	13	20	0
ME Subtotal		410	24.1	186	74	6
Lower Elwha						
Dam outflow	7.3	16	13.3	17	8	0
Hwy 112 Bridge	6.1	74	38.9			0
County Bridge	3.8	23	11.5			0
East Channel	1.4	30	10.7	6	3	0
Hunt Rd. Chan.	2.0	3	1.9	2	0	0
LE Subtotal		146	15.4	25	11	0

Figures

Figure 1. The Elwha River watershed

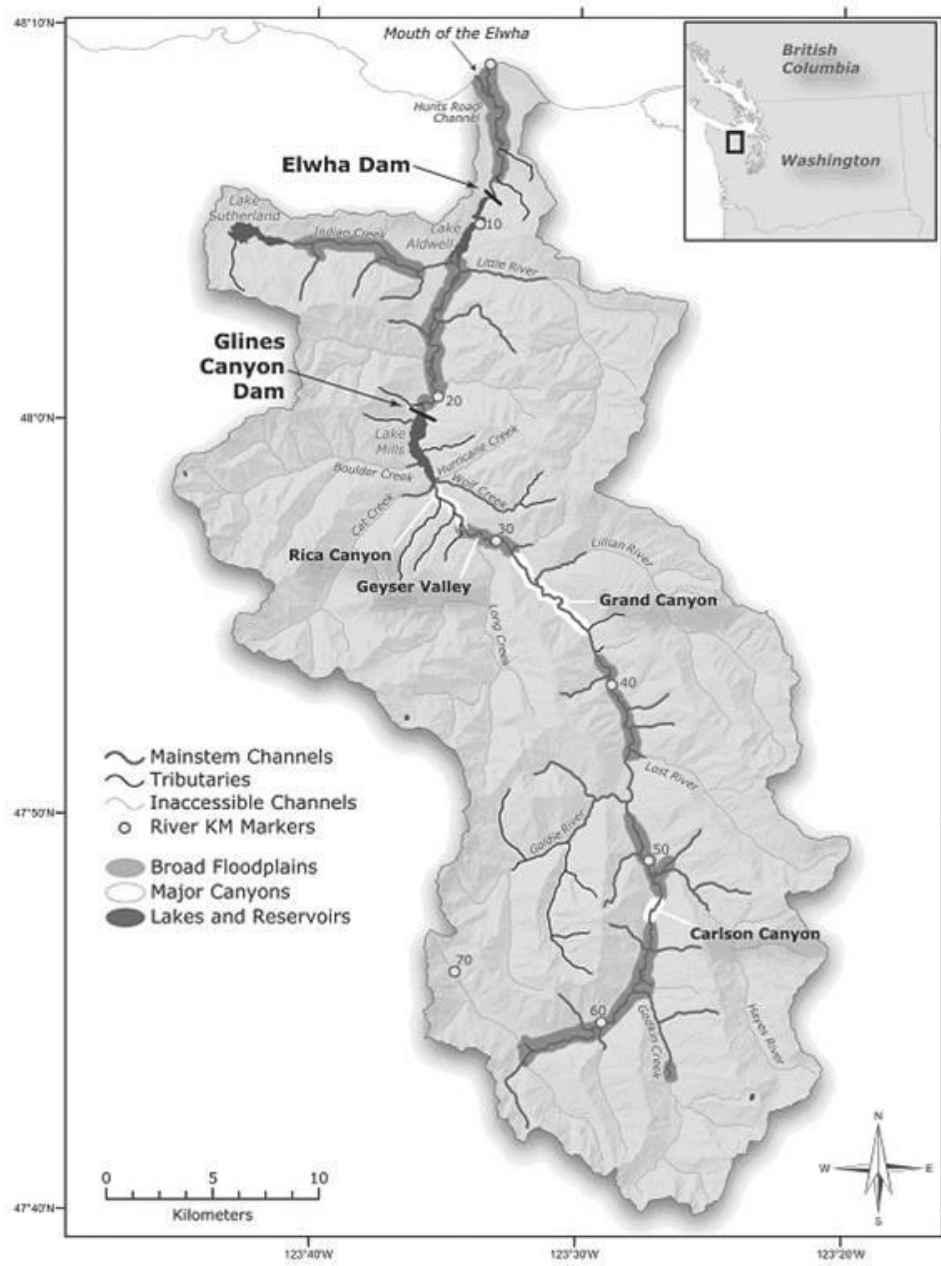


Figure 2. Total number of Chinook salmon redds between former Elwha dam and Glines Canyon dam 2012 to 2016. Black bars indicate the number of chinook redds below former Elwha dam. Grey bars indicate the number of Chinook redds between former Elwha dam and former Glines Canyon dam, and red bar indicates the number of redds above former Glines Canyon dam.

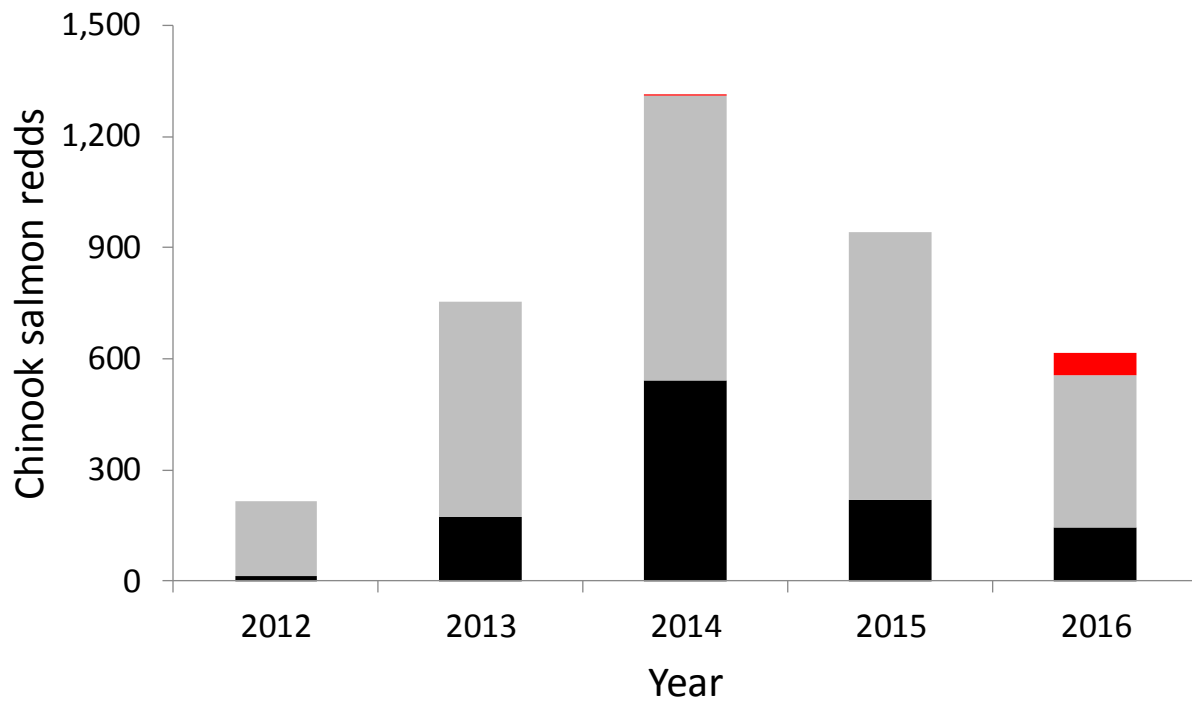
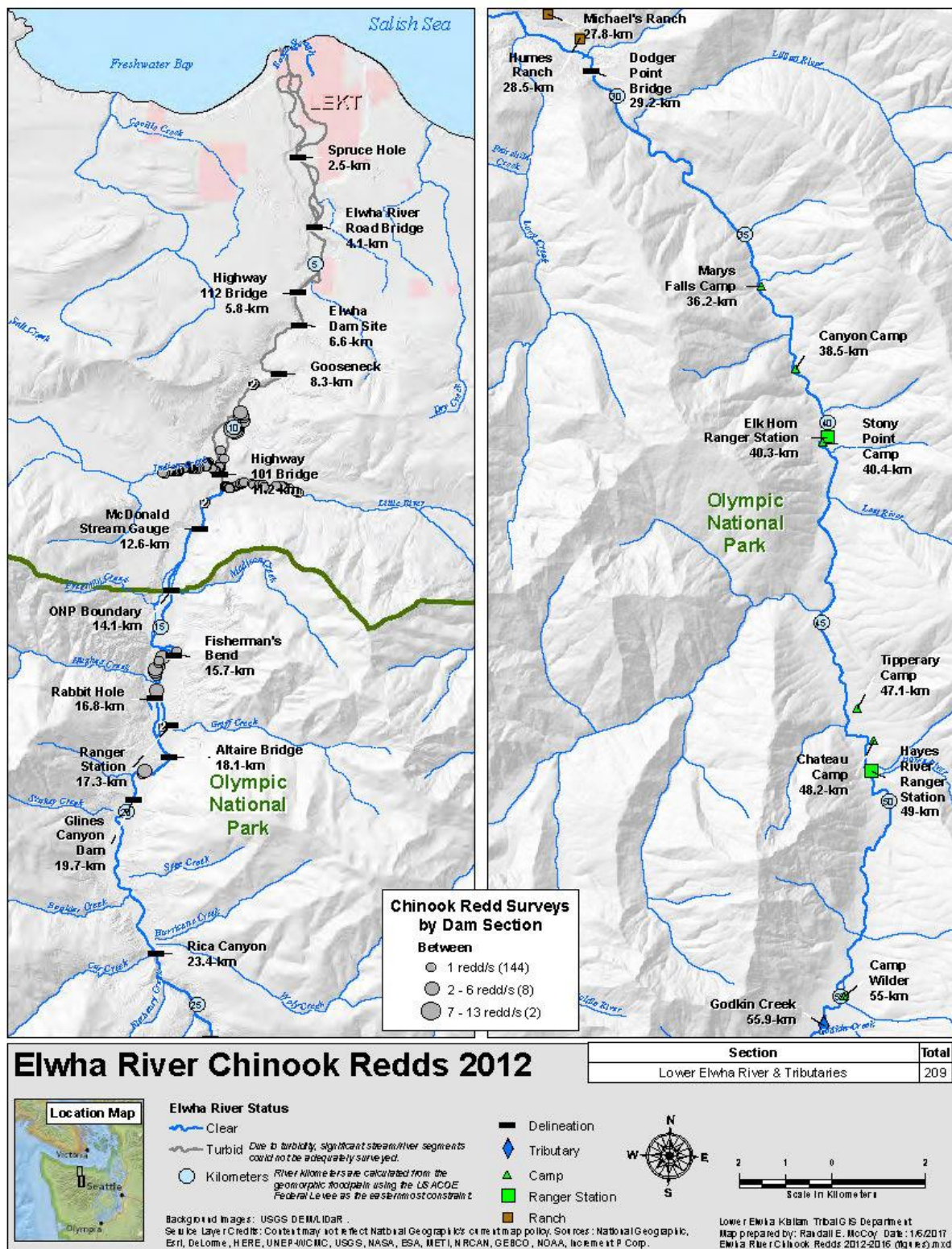
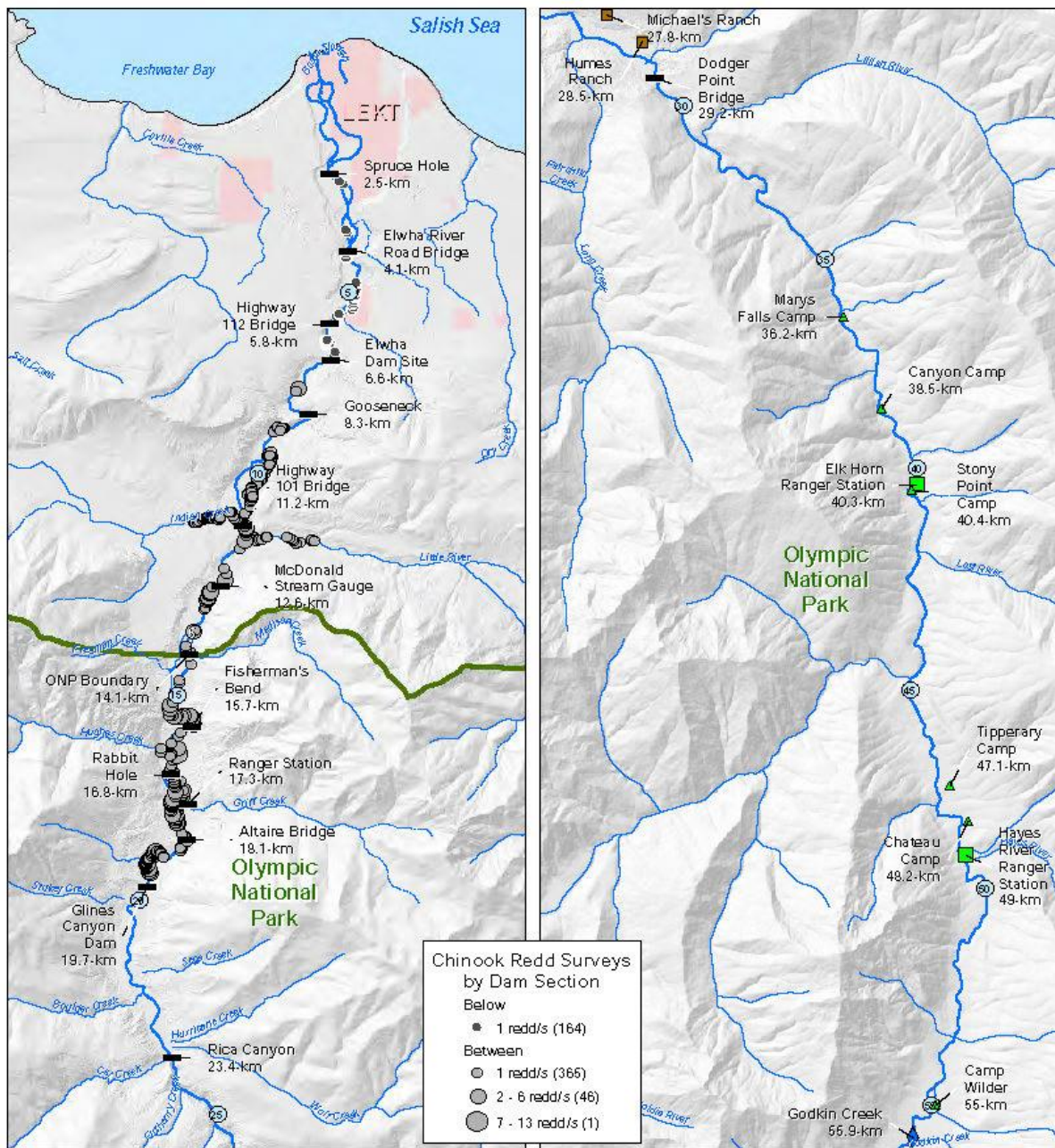


Figure 3-7. Distribution of Chinook redds in the Elwha River 2012-2016.





Elwha River Chinook Redds 2013

Section	Total
Lower Elwha River & Tributaries	748



General Key

Elwha R Mainstem
Kilometers
River kilometers are calculated from the geomorphic floodplain using the USA COE Federal Levee as the easternmost constraint.

Background images: USGS DEM/LiDAR.

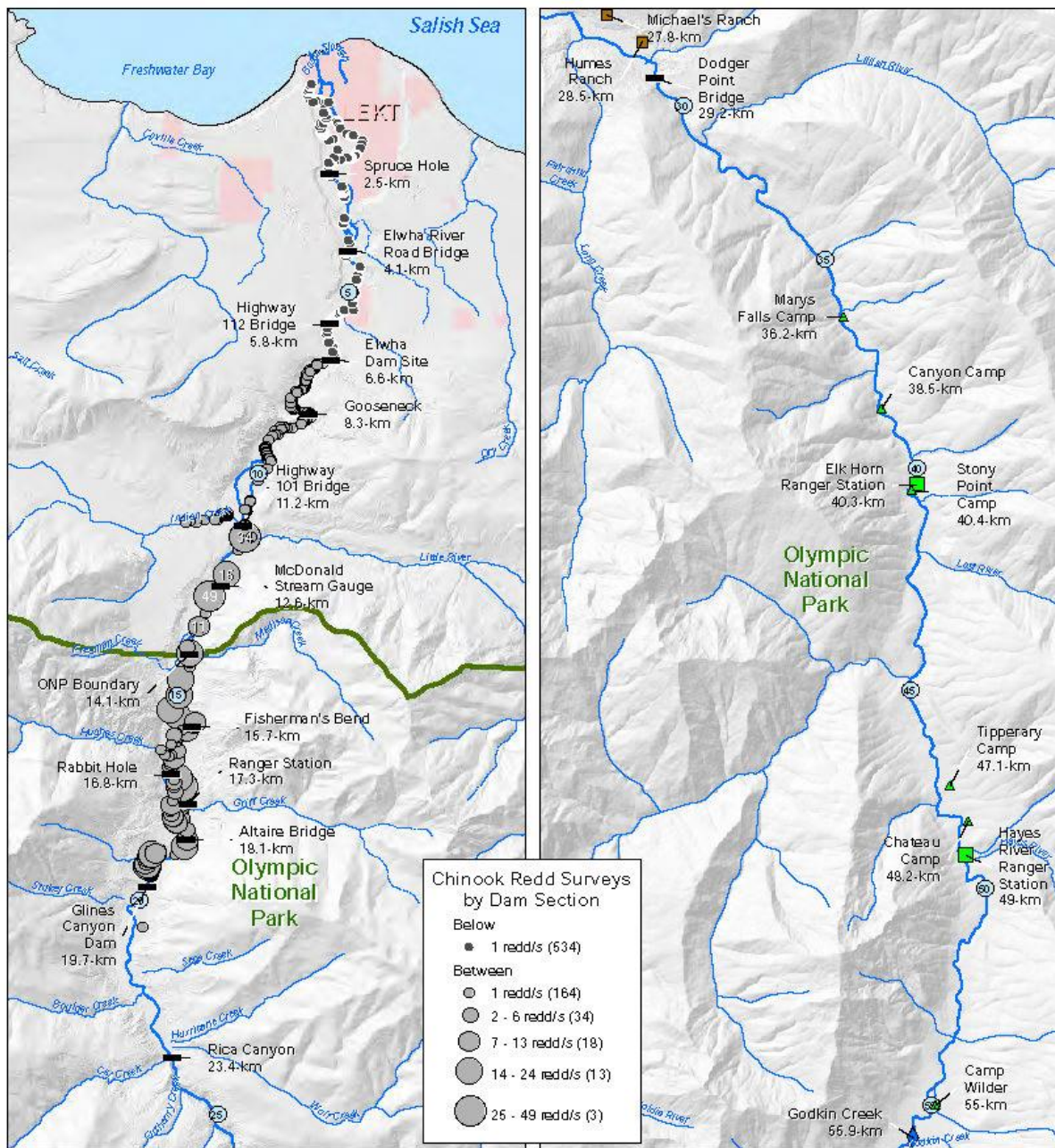
Service Layer Credits: Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Delineation
Tributary
Camp
Ranger Station
Ranch



Scale in Kilometers

Lower Elwha Klamath Tribal GIS Department
Map prepared by: Randal E. McCoy Date: 1/5/2017
Elwha River Chinook Redds 2012-2016 (figures) road



Elwha River Chinook Redds 2014



General Key

Elwha R Mainstem

Kilometers

River kilometers are calculated from the geomorphic floodplain using the USAOEE Federal Levee as the easternmost constraint.

Background images: USGS DEM/LiDAR.

Service Layer Credits: Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

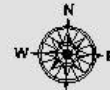
Delineation

Tributary

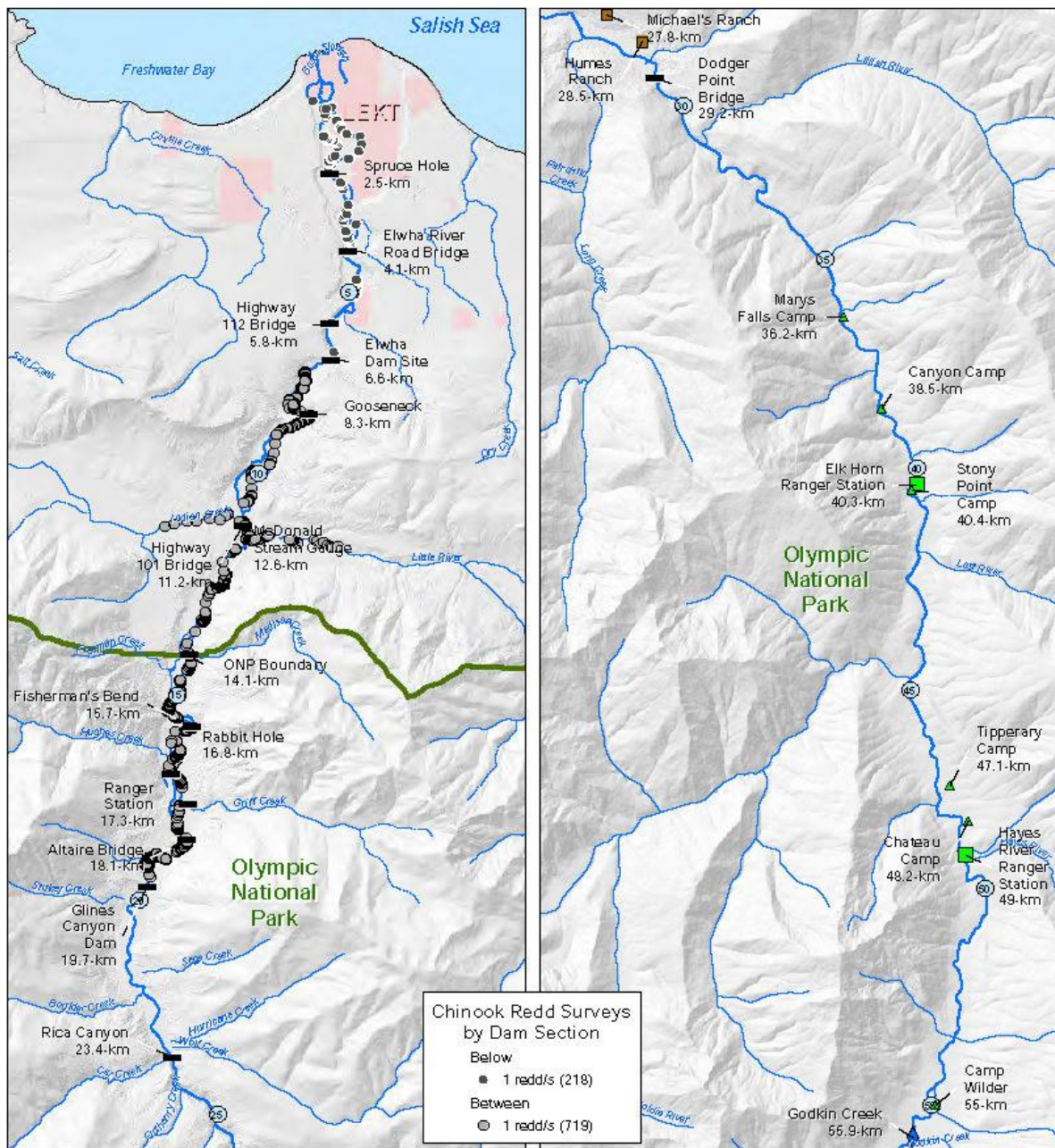
Camp

Ranger Station

Ranch



Lower Elwha Klamath Tribal GIS Department
Map prepared by: Randal E. McCoy Date: 1/5/2017
Elwha River Chinook Redds 2012-2016 (figures).road



Elwha River Chinook Redds 2015

Section	Total
Lower Elwha River & Tributaries	937



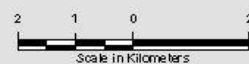
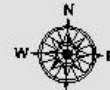
General Key

Elwha R Mainstem
 Kilometers
 River kilometers are calculated from the geomorphic floodplain using the USAOCE Federal Levee as the easternmost constraint.

Background images: USGS DEM/LiDAR.

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- Delineation
- Tributary
- Camp
- Ranger Station
- Ranch



Lower Elwha Klamath Tribal GIS Department
 Map prepared by: Randal E. McCoy Date: 1/5/2017
 Elwha River Chinook Redds 2012-2016 (figures).road

Figure 8. Density of Chinook salmon redds by river kilometer on the Elwha River 2012 to 2016. Solid diamonds are the mean across years while solid lines with perpendicular bars are the standard errors. Note: We did not depict the single redd observed at Godkin Creek in 2016.

