

Spatial distribution of Chinook Salmon (*Oncorhynchus tshawytscha*) spawning in the Elwha River, Washington State during dam removal and early stages of recolonization (2012-2018)



Chinook spawning on former Aldwell Reservoir 2018

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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 in the Elwha River and its tributaries from 2012 to 2018, a period in which two impassable hydroelectric dams were removed. Chinook salmon redds were located by visual surveys conducted at or near the peak of spawn timing in mid- to late-September. Surveys were conducted in main stem, side-channel, and large tributary habitats for all years from the mouth of the Elwha River upstream to Glines Canyon Dam site at Rkm 21.7 at flows that ranged from 7.0 cubic meters per second (cms) to 11.9 cms. In 2014-2015 additional surveys were conducted immediately upstream of Glines Canyon Dam to Rica Canyon (Rkm 23.4). As Chinook salmon recolonized further upstream, new survey reaches were added in 2016-2018 that included the uppermost watershed to near Chicago Camp at Rkm 61.7. Redds were geo-referenced using GPS units, and live and dead adult Chinook 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 2014-2018 were conducted during very low turbidities (5.0 FNU, 0.8 FNU, 5.5 NTU, 2.3 FNU and 5.0 FNU 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 12.4-21.7 accounted for 24% and 94% 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 double the 20 year average. In 2013, a total of 765 Chinook salmon redds and 1,752 adults (live and dead) were observed during the peak of spawning with the majority of redds (79%) located above the former Elwha Dam. The vast majority (85%) of all Chinook salmon redds observed in the Middle Elwha in 2013 were in mainstem habitats. Of those, 162 (27%) 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. In contrast to 2013, over 95% of those Chinook salmon redds were observed in the mainstem Middle Elwha rather than the tributaries. The Middle Elwha accounted for 62% of the total redds observed and 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. A total of 4 adult Chinook salmon and 1 Chinook salmon redd were observed immediately upstream of Glines Canyon Dam and these represent the first confirmed observations of Chinook in over 100 years. The distribution of Chinook salmon redds in the Middle Elwha suggests that mainstem 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 again located in the Middle Elwha. Over 95% of those Chinook salmon redds were observed in mainstem 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 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. Additionally 107 pink salmon were observed during the survey with the majority being located in the Middle Elwha including Indian Creek, Little River and Hughes Creek.

In 2016, based on SONAR estimates (Denton et al. 2017) the total escapement of Chinook salmon to the Elwha River was 2,628. A total of 615 Chinook salmon redds and 374 adults (244 live/91 dead) were located in the Elwha River¹. The majority of the redds (67%) were located within the Middle Elwha. Over 95% of the redds were located in main stem habitats. 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 was the first significant number of Chinook observed above Glines Canyon since dam removal was initiated. This suggested that passage conditions for Chinook salmon improved following directed blasting operations at the Glines

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

rockfall. Forty-seven redds were located in the former Mills reservoir and ten in Geyser Valley. Areas above the Grand Canyon were surveyed for the first time and a single redd was located below the confluence with Godkin Creek at rkm 57.8. 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.

In 2017, based on SONAR estimates (Denton et al. 2017) the total escapement of Chinook salmon to the Elwha River was 3,083 fish. A total of 767 Chinook redds and 1,051 adults (827 live/219 dead) were observed during peak spawning surveys on the Elwha River. The majority of redds were again located in the Middle Elwha (68.2%). Similar to 2016, a relatively small percentage of the total redds were observed upstream of Glines Canyon (6.8%) and the majority of those were observed in the former Mills Reservoir. Very few Chinook salmon accessed the upper watershed above the Grand Canyon of the Elwha to date and in 2017 only 2 redds were observed in this reach. Both redds were located in the vicinity of the Lost River confluence at Rkm 43.0. In addition to Chinook, a total of thirty-eight pink salmon and 11 sockeye salmon adults were reported incidentally during the 2017 surveys. All observations of these species were in the Middle Elwha.

In 2018, a large number of Chinook salmon adults returned to spawn in the Elwha River. A preliminary escapement estimate of 7,400 adults by SONAR enumeration (Denton et al. In Preparation). A total of 1,601 Chinook redds and 2,299 adults (1,499 live/800 dead) were observed during peak spawning surveys in 2018. The majority of redds were again located in the Middle Elwha (56.7%). In 2018, the percentage of the total redds observed upstream of Glines Canyon more than doubled from 2017 from 6.8% to 13.8% and the majority of those were observed in the former Mills Reservoir including Boulder and Cat Creeks. Additionally, 42 adult Chinook salmon were observed above Rica Canyon in 2018, representing a significant increase from the prior two years (4 and 4 respectively). However, 36 of these fish were seen in Geyser Valley, while only five redds were observed in the upper watershed above the Grand Canyon of the Elwha. The most upstream redd was observed above the Hayes River confluence at Rkm 45.5.

The most obvious trends in terms of the spatial distribution of Chinook salmon redds has been an increasing number of redds observed initially in the Middle Elwha, and more recently in the upper Elwha. Fish passage conditions at Glines Canyon were not favorable until after consecutive years of blasting were completed in 2015 and 2016. In 2016-2018, the first significant numbers of Chinook salmon colonized the area above Glines Canyon with the majority of redd observations occurring on the former Mills Reservoir surface. Although still early in the recolonization process, relatively few adults have volitionally accessed the upper

watershed; meeting the viability triggers outlined by Peters et al. (2014) will depend on greater numbers of fish spawning above the Grand Canyon of the Elwha in future years.

Introduction

The removal of two hydroelectric dams on the Elwha River represents the largest intentional dam removal completed to date in the world. Located at Rkm 7.9 and 22, the 32 m tall Elwha Dam (completed in 1913) and 64 m tall 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, sufficiently abundant to support meaningful harvest, 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 the use of adaptive management targets 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, 2016, 2017). Productivity metrics are being assessed using a combination of abundance estimation by smolt outmigration monitoring (McHenry et al. 2016, 2017) and adult to adult cohort reconstruction (Weinheimer et al. 2016, 2017). Spatial distribution on the Elwha is being assessed using a combination of visual redd surveys (foot, snorkel, boat, and aerial), radiotelemetry, and eDNA techniques (Laramie et al. 2015). For diversity, Chinook salmon monitoring efforts focus on adult migration timing (SONAR) and the expression of stream-type juvenile life-histories, which utilizes information gained from the smolt traps.

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 has allowed for the recolonization of formerly occupied habitats. However, it is uncertain how quickly recolonization and the establishment of self-sustaining spawning populations will occur. Prior

to dam removal, it was predicted that Chinook salmon were expected to recolonize in the Elwha upstream of Carlson Canyon at Rkm 56.0 (DOI 1995). On the Cedar River, Washington, a much shorter system than the Elwha River, following the construction of fish passage facilities at Landsburg Dam, Chinook salmon spawned as high as 18 km above the facility the first year they were provided access, however the majority of spawners were concentrated 6 km below the facility (Burton et al. 2013). Additionally, on the Elwha River, dam removal has not recreated the exact physical habitat conditions that existed prior to dam removal or prior to dam construction, 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 age structure 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 characteristics is relatively small, compared to the Columbia Basin (Waples et al. 2008). This suggests a strong role for environmental conditions in stream versus 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.

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 the 1930's 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 2010-2017, > 90% of Chinook salmon returning to the Elwha River basin were hatchery origin (Anderson et al. 2015; Weinheimer et al. 2017). EMAM (Peters et al. 2014) has established a goal of 100% natural origin spawners for a self-sustaining population of Elwha River Chinook salmon. "Rewilding" this hatchery-dominated population represents a significant challenge for the overall Elwha project.

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 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 created blockages to upstream migrating salmon. In the fall of 2015 and 2016, 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 2014-17 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 from 2012 to 2018 in the Elwha watershed. Survey timing was based on the estimated historical date of peak spawning activity for Elwha River Chinook salmon, approximately September 15 - September 25 (WDFW Unpublished Data). For purposes of the survey, the Elwha River was divided into three broad sections. The Lower Elwha (LE) was defined as the area downstream of Elwha Dam (Rkm 0.0-7.9). 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). Lastly the Upper Elwha (UE) is defined as the reach above Glines Canyon Dam, including

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. There are currently no plans to conduct further removal activities.

the former Mills Reservoir, Cat and Boulder creeks, upstream to Chicago Camp (Rkm 21.7-61.6)³. The Lower Elwha⁴ and Middle Elwha were surveyed in all years, while the Upper Elwha was surveyed in 2016-2018. Supplemental surveys were conducted in the UE beginning in 2014 and 2015, however these only included the former Mills Reservoir area from Glines Canyon Dam upstream to the entrance of Rica Canyon. We did not generally survey any of the major canyon areas of the Elwha River during peak surveys with the exception of Rica Canyon in 2014 and 2015. These include the canyon immediately above Elwha Dam, Glines Canyon, Rica Canyon, Grand Canyon, and Carlson Canyon (Figure 1). Additionally no comprehensive surveys have occurred to date in larger upriver tributaries with the exception of Long Creek in 2018.

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 2015-2018 to simplify data collection (Tables 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. In some years observers also conducted snorkel surveys to collect observations of live Chinook salmon and associated nests (redds). This was particularly true in 2018 where a “riverscape” survey was conducted in mid-September.

The surveyors recorded the number of Chinook salmon 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), visual marks (floy tags or fin clips), as well as presence of pink and sockeye 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 (chiefly 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 6). Since 2015, turbidity has not been a factor during surveys in any reach.

³ The actual upper end of survey has varied by years. Please consult Figures 3-10 to determine that end by year.

⁴ Lower Elwha surveys were unsuccessful in 2012 and partially successful in 2013 due to elevated turbidity.

While it is generally true that visual survey techniques are not effective during high flows 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 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. 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 1,310 redds, an increase of 83% (Figure 2). In 2015 and 2016 the number of redds decreased by 28% (937) and 53% (614), respectively, from the peak number observed in 2014. In 2017, the number of redds increased slightly (767) in comparison to the previous year. In 2018, we observed the highest number of chinook redds (1,601) since the project began (Figure 2). In all years, the majority of Chinook salmon redds were located in the ME above the former Elwha Dam (Rkm 7.5) and just below the former Glines Canyon Dam (Rkm 21.7) (Figures 3-10). It is important to note that visibility was poor during 2012 and 2013 thus the number of redds below the former Elwha Dam in those years was likely an under-estimate. Abundance estimates derived from SONAR indicated that Chinook salmon abundance ranged from a low of 2,628 (2016) to a high of over 5,000 (2018) (Figure 12) .

In 2012, 217 Chinook salmon redds were located, of which 203 (93.5%) 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 turbidity effects (Figure 3). The spatial distribution of Chinook salmon redds in 2012 were clumped in three general areas Rkm 9.8 to 12.2 (Gooseneck to Highway 101 bridge), Rkm 16.5 to 18.0 (Fisherman's Bend to Rabbit Hole), and the two large ME tributaries (Indian Creek and Little River) (Figure 3).

In 2013, additional survey reaches were added in the LE due to better 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 collectively (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 reach from the Highway 112 Bridge to the weir at Rkm 5.5 (within lower Elwha) had the second highest density of Chinook salmon redds recorded in the survey (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% (811 out of 1,310) were located in the middle Elwha, 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 were located in the mainstem, 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 in the middle Elwha (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). A subsequent survey on September 22 identified a single Chinook salmon redd, of which only one was geolocated 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 near 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 (Figure 5, Table 7).

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 middle Elwha (Figure 6, Table 8). The trend toward mainstem spawning preference continued, with 90% of the Chinook salmon redds located in the mainstem habitats, while only 10% were identified in Little River, Indian Creek, and Hughes Creek (Figure 6, Table 8). The 1.1 km reach immediately below Glines Canyon remained among the highest density reaches in the middle Elwha, though at a lower density than previous years (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 extent of Chinook salmon spawning was the greatest observed since survey efforts began in 2012 (Figure 7, Table 9). Over 75% of the total redds observed were located above Elwha Dam and the first significant numbers (58) of redds were observed above Glines Canyon (Figure 6). Chinook redds were also observed in lower Boulder Creek (8) and in Cat Creek (2) for the first time. A single Chinook salmon redd was observed in the upper Elwha River just below the confluence with Godkin Creek (Rkm 57.8) during upriver surveys (to Rkm 61.6) by ONP personnel (Figure 7). However, no live or dead Chinook were observed above Grand Canyon. We also did not observe a high density of redds immediately below Glines Canyon as in past years. This would suggest that passage conditions for Chinook salmon were improved in 2016 over 2015.

In 2017, the spatial distribution of Chinook salmon redds was similar to that observed in 2016 (Figure 8, Table 10). The total number of redds located was 767, a 20% increase over 2016. A total of 523 (68%) redds were observed in the ME, and 192 (25%) redds were observed in the LE. In the UE we observed 52 total redds and 92% of these were located in the former Mills Reservoir including the lower portions of Cat and Boulder Creeks. Only two redds were observed above the Grand Canyon of the Elwha, both in the vicinity of the confluence of Lost Creek, at Rkm 43.0. Surveyors also observed one live Chinook salmon, and possibly one more, in this reach. We also made observations of pink salmon adults during the 2017 season. Thirty-

eight live pink salmon were reported during the surveys and all were in the middle Elwha. Ninety-two percent of the pink salmon were observed in Little River and Indian Creek.

In 2018, the highest number of Chinook redds were observed since the beginning of the project (Figure 9, Table 11). The peak count of 1,601 redds was over two times greater than the average count since 2012. Proportionally, the greatest number of redds were observed in the ME (57%), followed by the LE (30%), and the UE (13%). The 211 redds observed in the UE was the greatest observed since fish passage was reestablished in 2016. The distribution of Chinook redds in the UE was heavily skewed to areas below Goblins Gate and only 11 and 5 redds were observed in the Geyser Valley and above Grand Canyon, respectively. The most upstream redd was located above the confluence with Hayes River at Rkm 49.5. Surveyors also reported 5 sockeye salmon adults with confirmed spawning (3 redds) in the former Mills Reservoir.

Due to a surplus of hatchery Chinook salmon, a total of 604 adults (491 males/113 females) were relocated to a release point below the former Glines Powerhouse (Rkm 19.2). Those fish were visibly marked using colored Spaghetti tags. Relocated fish were observed on subsequent spawning ground surveys both upstream and downstream of their release point. Of the 327 adult chinook observed upstream of Glines Canyon, 55 (17%) were confirmed to have tags. A tagged fish ascended as high as the Geyser Valley.

Examination of redd density data over time suggests the density of adult spawning Chinook salmon in the most immediate portion above former Glines Canyon dam is increasing to levels seen in the Middle and Lower Elwha (Figure 10.a.). Redd density levels above Rkm 30.0 are still relatively low in comparison to the rest of the Elwha River (Figure 10.b.). Examination of redd occupancy (presence of at least one redd in each tenth of a Rkm) by tenth of a river kilometer, excluding the canyon areas where no surveys have been conducted, reveals that 2018 had the highest level of occupancy seen since Chinook salmon redd surveys have been initiated in 2012 in all three sections of the Elwha River (Figure 11).

Discussion

We conducted annual peak spawning ground surveys for Elwha River Chinook salmon during dam decommissioning (2012-2015) and the early stages of recolonization (2016-2018). 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 to enumerate the total number of Chinook salmon returning to the Elwha River.

In 2012, the proportion of Chinook salmon redds in the middle Elwha was evenly distributed between the mainstem and tributary habitat. The two major ME tributaries, Indian Creek and Little River, which enter on opposite sides of the Elwha River at Rkm 11.5, 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 middle Elwha, 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 more extensive in 2013 (Figure 4), as redds were observed in each survey reach above the former Elwha dam site, and the density in each reach was similar or higher than observed in 2012 (Table 4 & 6). Unlike 2012, the vast majority of Chinook salmon redds were in the mainstem middle Elwha rather than the tributaries. This difference in distribution was hypothesized to occur for three primary reasons. First, turbidity levels in the mainstem middle Elwha were lower in 2013 than 2012 (Table 4). Second, connectivity between Little River, Indian Creek, and the mainstem 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 amount 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 middle Elwha.

In 2012, the mainstem middle Elwha 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 the former Elwha dam (East et al. 2015). However, between October of 2012 and September of 2013 large scale geomorphic changes occurred in the middle Elwha 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 increased riffle crest and channel thalweg elevation and bar formation. Substrate size in the middle Elwha 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 middle Elwha 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 2016 Chinook return was one of the highest to the Elwha River in decades and we observed the second highest number of redds during the monitoring period. The spatial distribution of redds advanced upstream as the first significant number of redds was observed above Glines Canyon. In the fall of 2014, 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 3 redds were observed by ONP and LEKT employees. Chinook migration above Glines Canyon was inhibited 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 improving passage conditions (at least for chinook). While Chinook passage through Glines Canyon has been improved, it is uncertain if Chinook passage is optimal and if other species such as pink and chum salmon can pass through the canyon. This situation should be closely monitored as one of the Elwha project goals was to provide fish passage for all species of salmonids (DOI 1995).

The 2016-2018 Chinook salmon spawner surveys were the most spatially extensive chinook survey efforts to date, coupled with the lower flows and lowest turbidity levels (Table 4). The rather continuous distribution of Chinook salmon redds observed in 2013-2018 (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 2013-2018 was largely dominated by well sorted gravel deposits with minimal fine sediment. In contrast, many of the mainstem side-channels have persistent deposits of fine sediment on their channel beds (Pess et al. 2015; Peters et al. 2017). 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.

Monitoring the spatial distribution of Chinook salmon has provided insights into the colonization of chinook in the Elwha River following removal of two hydroelectric dams. Project partners have cooperated to extend survey coverage of the river in space and time. Immediately following dam removal, Chinook salmon volitionally recolonized habitats upstream

of Elwha Dam, including Little River and Indian Creek. That upstream recolonization was mostly restricted by the Glines Canyon Dam until 2015, when supplemental fish passage work was conducted. In 2016 and 2017, the first significant numbers of chinook ascended Glines Canyon and spawned in the upper watershed, primarily in the former Mills Reservoir area. While recolonization to the immediate areas upstream of Glines Canyon has initiated, the relatively few numbers of Chinook salmon documented to have reached watershed upstream of the Grand Canyon should be closely monitored (Figure 10).

The lack of Chinook to the headwaters may be the result of several factors. First, low densities of Chinook may result in redd selection occurring in the first suitable habitat encountered by migrating females. In this case, the newly exposed Mills Reservoir surface provided abundant, suitable spawning sites for early migrants. Burton et al. (2013) described this pattern for early Chinook migrants following installation of fish passage facilities on the Cedar River, Washington. Second, the Elwha Chinook population may have a high fidelity to the lower river where the WDFW hatchery (Rkm 8) is located. On the Chiwawa River, a higher proportion of hatchery female spring Chinook salmon spawned in the lower reaches of the river, while greater numbers of natural origin Chinook utilized upstream habitats (Hughes and Murdoch 2017). A third possibility is that the Grand Canyon represents a formidable migration challenge, and the traits required to ascend it have been lost or truncated from the population. The Grand Canyon of the Elwha is the longest canyon and contains over 6.4 km of hydraulic drops (chutes, falls). The historic run of Chinook salmon that utilized habitats above the Grand Canyon was likely spring timed (Brannon and Hershberger 1984), possibly encountering Grand Canyon at a time of year when it was more easily ascended. This component of the population is currently at very low abundance. The existing hatchery population, which might also differ from the historic population at other traits required to migrate through steep canyons, may not be capable of recolonizing these habitats.

We hypothesize that exposure to a natural selection regime in the upper river and reproductive isolation from hatchery-origin fish experiencing non-natural selection are important to the re-expression of the spring Chinook on the Elwha. Spring Chinook have declined dramatically not only in the Elwha, but coast wide, particularly where dams have been constructed. New research indicates that the phenotype for premature migration is genetically controlled in both steelhead and Chinook (Prince et al. 2017). Thompson et al. (2018) found that on both the Klamath and Rogue Rivers, the allele loss that controlled premature migration was rapid following dam construction. Extant mature (fall) Chinook populations on those rivers did not contain the premature allele at high enough frequency to prevent the complete loss the allele as a result of genetic drift. This genetic link may have significant implications to the recovery of this important life history.

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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 since 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	ALL
Rica Canyon to Dodger Point (Geyser Valley)	25.7	31.8	28.8	6.1	ALL
Glines Powerhouse to Rica Canyon (Mills)	21.1	25.7	23.4	4.6	ALL
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 12-17	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
2017	Sept 18-25	11.3 ($\pm$ 0.3)	2.3 ($\pm$ 0.3)		Visibility excellent in all reaches
2018	Sept 12-28	11.3 ($\pm$ 1.4)	(5.0 $\pm$ 3)		Two flow spikes during survey period. Flows quickly receded

Table 5. Number of redds, redds/kilometer and observation of live, dead and jack Chinook salmon on the Elwha River, 2012. 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 (93.5%)	11.0	66	48	173	82	25
Lower Elwha ⁵								
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 (6.5%)	1.5	0	0	0	2	0
TOTAL				66	48	173	84	25
		217						

⁵ 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. Number of redds, redds/kilometer and observation of live, dead and jack Chinook salmon on the Elwha River, 2013. 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 (78.6%)	32.7	296	225	315	460	13
Lower Elwha⁶								
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 (21.4%)	19.0	0	0	381	62	0
TOTAL				296	225	696	522	13
		765						

⁶ 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. Number of redds, redds/kilometer and observation of live, dead and jack Chinook salmon on the Elwha River, 2014.

Survey Reach	Rkm midpoint	Redds	Redds/km	Male	Female	Unknown	Dead	Jacks
Above Glines	21.5	1	-	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 (61.9%)	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 (38.1%)	27.1	0	0	245	0	0
TOTAL		1310		139	100	1111	398	0

Table 8. Number of redds, redds/kilometer and observation of live, dead and jack Chinook salmon on the Elwha River, 2015.

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
		(76.7%)						
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
		(23.3%)						
TOTAL				366	387	0	80	27
		937						

Table 9. Number of redds, redds/kilometer and observation of live, dead and jack Chinook salmon on the Elwha River, 2016.

Survey Reach	Rkm midpoint	Redds	Redds/km	Live Chinook	Dead Chinook	Jacks
Upper Elwha						
Upper Watershed	43.8	1	0.0	0	0	0
Geyser Valley	28.8	10	1.6	4	0	0
Former Mills Reservoir	23.4	47	10.4	29	6	2
UE Subtotal		58 (9.5%)	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 (66.7%)	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 (23.8%)	15.4	25	11	0
TOTAL		614		244	91	8

Table 10. Number of redds, redds/kilometer and observation of live, dead and jack Chinook salmon on the Elwha River, 2017. Note that live and dead counts were accidentally aggregated among some reaches in the middle Elwha.

Survey Reach	Rkm midpoint	Redds	Redds/km	Live Chinook	Dead Chinook	Jacks
Upper Elwha						
Upper Watershed	43.8	2	0.07	1	0	0
Geyser Valley	28.8	2	0.33	3	1	0
Former Mills Reservoir	23.4	48	10.4	87	10	0
UE Subtotal		52 (6.8%)		91	11	0
Middle Elwha						
Glines Power.	20.6	79	71.8	61	28	
Altaire Bridge	19.5	52	52.0			
Griff Creek	18.5	8	8.0			
Rabbit Hole	17.3	50	33.3	100	34	
Fisherman's C.	16.1	58	72.5			
ONP Boundary	14.7	32	16.0	127	22	
McDonald Br.	12.9	6	3.7			
Little River	12.2	9	4.7	26	0	
Indian Creek	12.1	35	18.4	68	13	
Aldwell South	11.0	128	55.6	100	47	4
Aldwell North	8.8	66	34.7	63	27	1
ME Subtotal		523 (68.2)		545	171	5
Lower Elwha						
Elwha Dam	7.3	7	5.8			
Hwy 112 Bridge	6.1	77	40.5	115	20	
County Bridge	3.8	37	18.5			
East Channel	1.4	31	19.8	44	4	
Hunt Rd. Chan.	2.0	40	14.3	32	13	
LE Subtotal		192 (25.0%)		191	37	
TOTAL		767		827	219	5

Table 11. Number of redds, redds/kilometer and observation of live, dead and jack Chinook salmon on the Elwha River, 2018.

Survey Reach	Rkm midpoint	Redds	Redds/km	Live Chinook	Dead Chinook	Jacks
Upper Elwha						
Upper Watershed	43.8	5	0.2	6	0	0
Long Creek		0	0.0	0	0	0
Geyser Valley	28.8	11	1.8	36	3	0
Cat Creek		25	25.0	26	10	0
Boulder Creek		21	42.0	91	25	1
Mills	23.4	149	32.4	129	32	1
UE Subtotal		211		257	70	2
		(13.2%)				
Middle Elwha						
Glines Power.	20.6	71	64.5	91	26	0
Altaire Bridge	19.5	28	28.0	112	45	0
Griff Creek	18.5	42	42.0	38	55	0
Rabbit Hole (Hughes)	17.3	132	88.0	133	65	0
Fisherman's C.	16.1	49	61.2	18	37	0
ONP Boundary	14.7	33	16.5	26	18	1
McDonald Br.	12.9	43	26.9	49	15	0
Little River	12.2	63	33.2	108	52	0
Indian Creek	12.1	144	75.8	97	58	0
Aldwell South	11.0	206	89.6	149	115	0
Aldwell North	8.8	98	51.6	62	71	0
ME Subtotal		909		883	557	1
		(56.8%)				
Lower Elwha						
Elwha Dam	7.3	84	70.0	151	40	0
Hwy 112 Bridge	6.1	186	97.9	182	104	0
County Bridge	3.8	87	43.5	-	-	-
East Channel	1.4	82	29.3	-	-	-
Hunt Rd. Chan.	2.0	42	26.3	26	29	0
LE Subtotal		481		359	17	
		(30.0%)				
TOTAL		1,601		1,499	800	3

Figures

Figure 1. The Elwha River watershed. Note that canyon areas depicted in white are not surveyed.

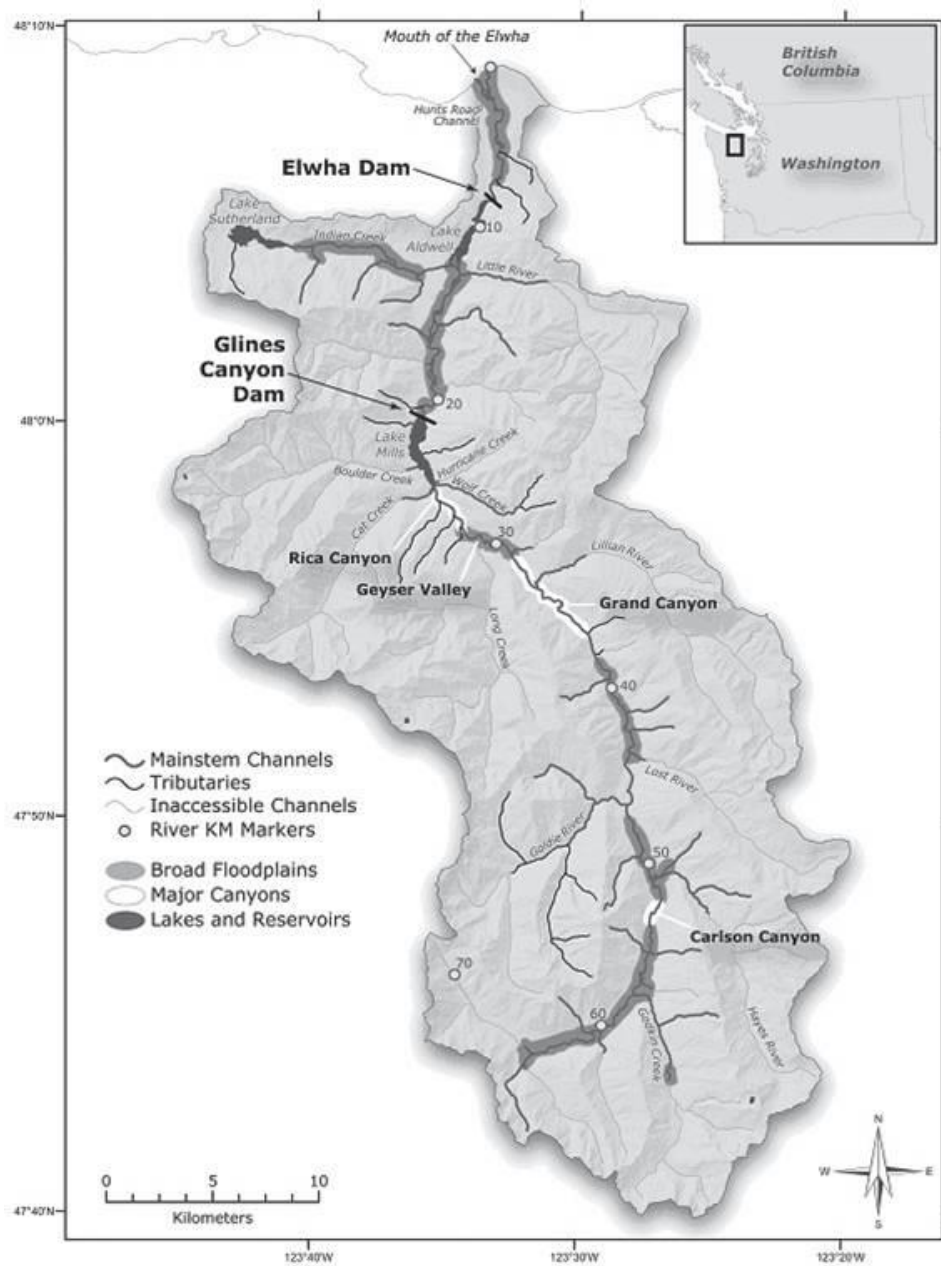
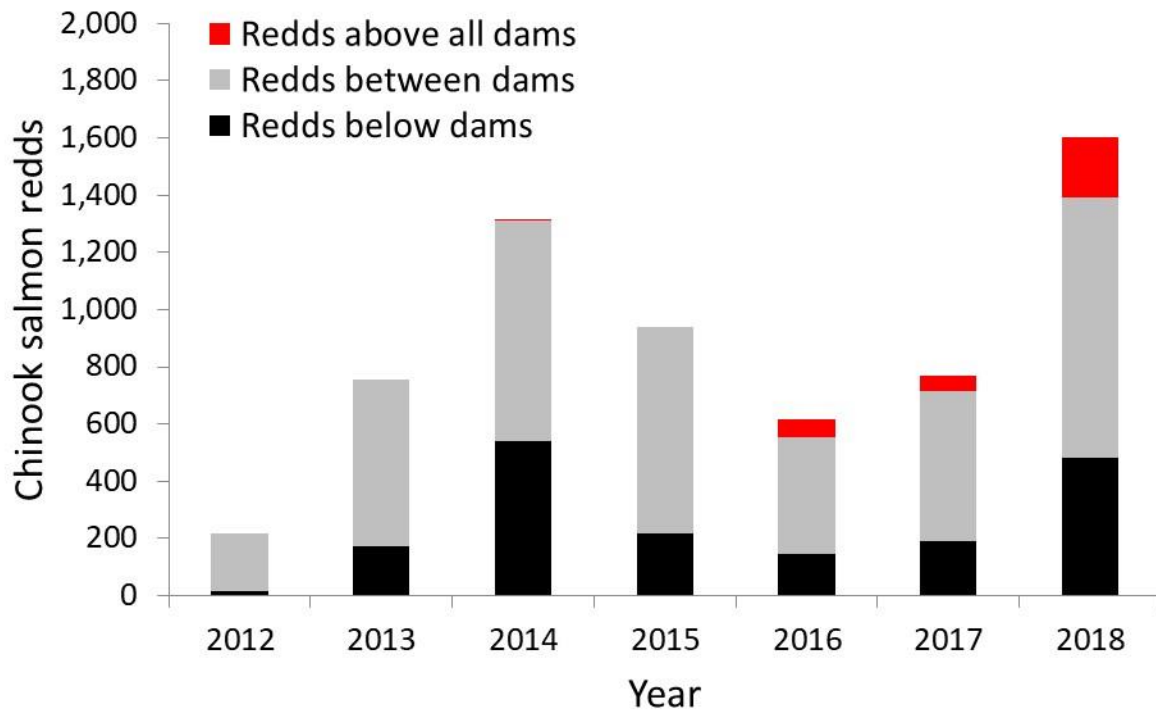
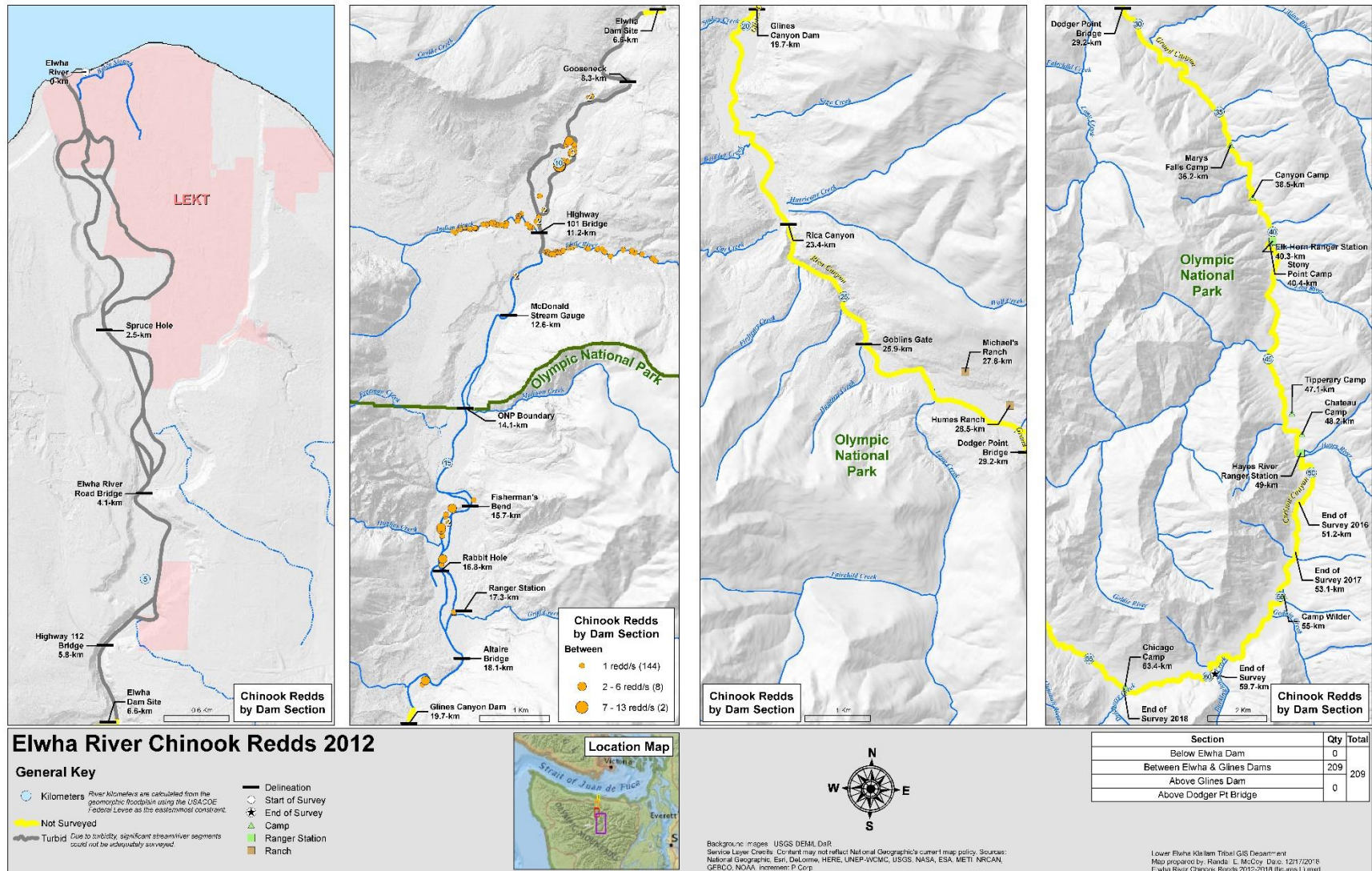


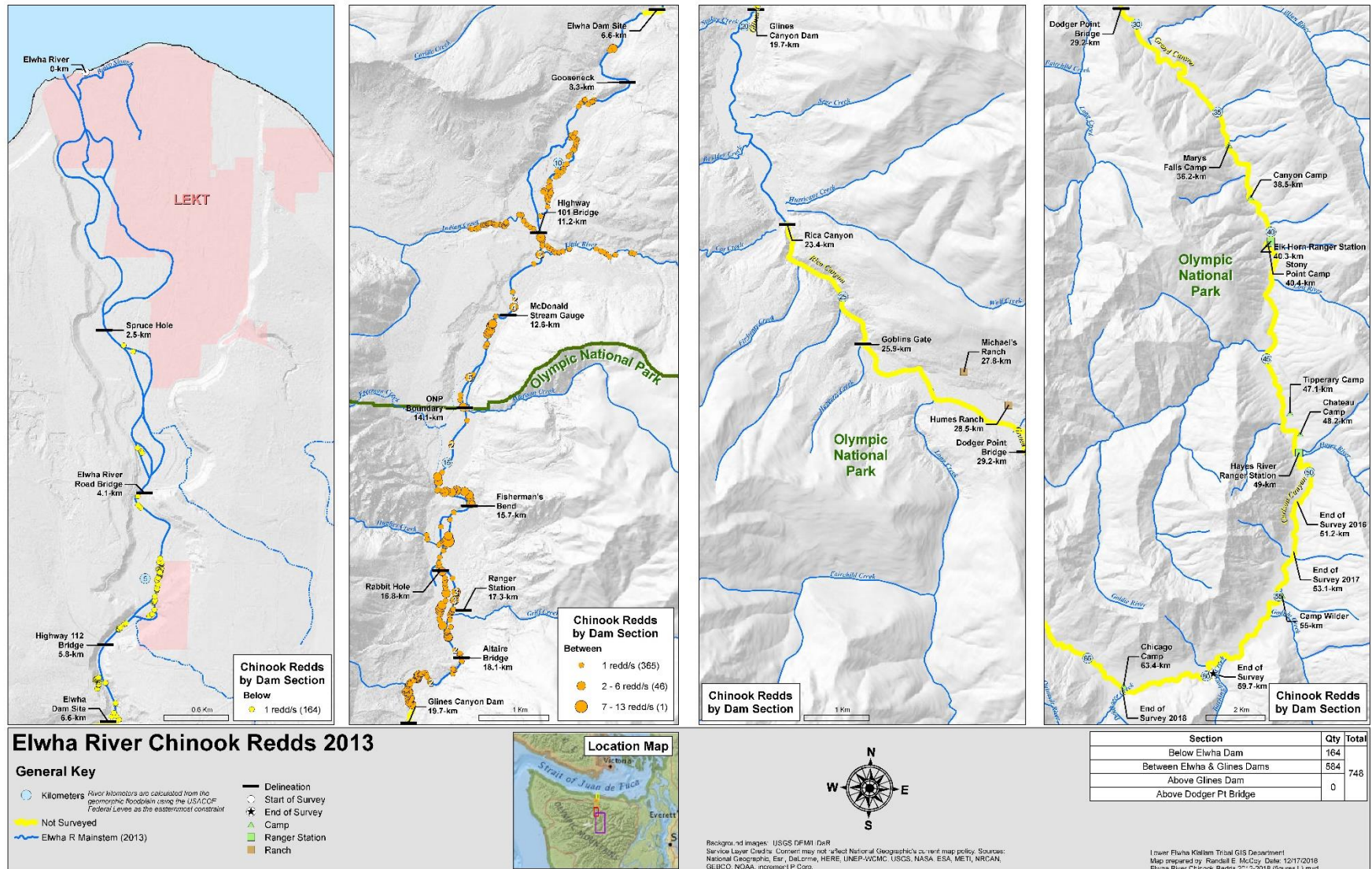
Figure 2. Total number of Chinook salmon redds between former Elwha dam and Glines Canyon dam 2012 to 2018. Black bars indicate the number of chinook redds below former Elwha dam. Grey bars indicate the number of Chinook redds between former Elwha dam and former Glines Canyon dam, and red bar indicates the number of redds above former Glines Canyon dam.



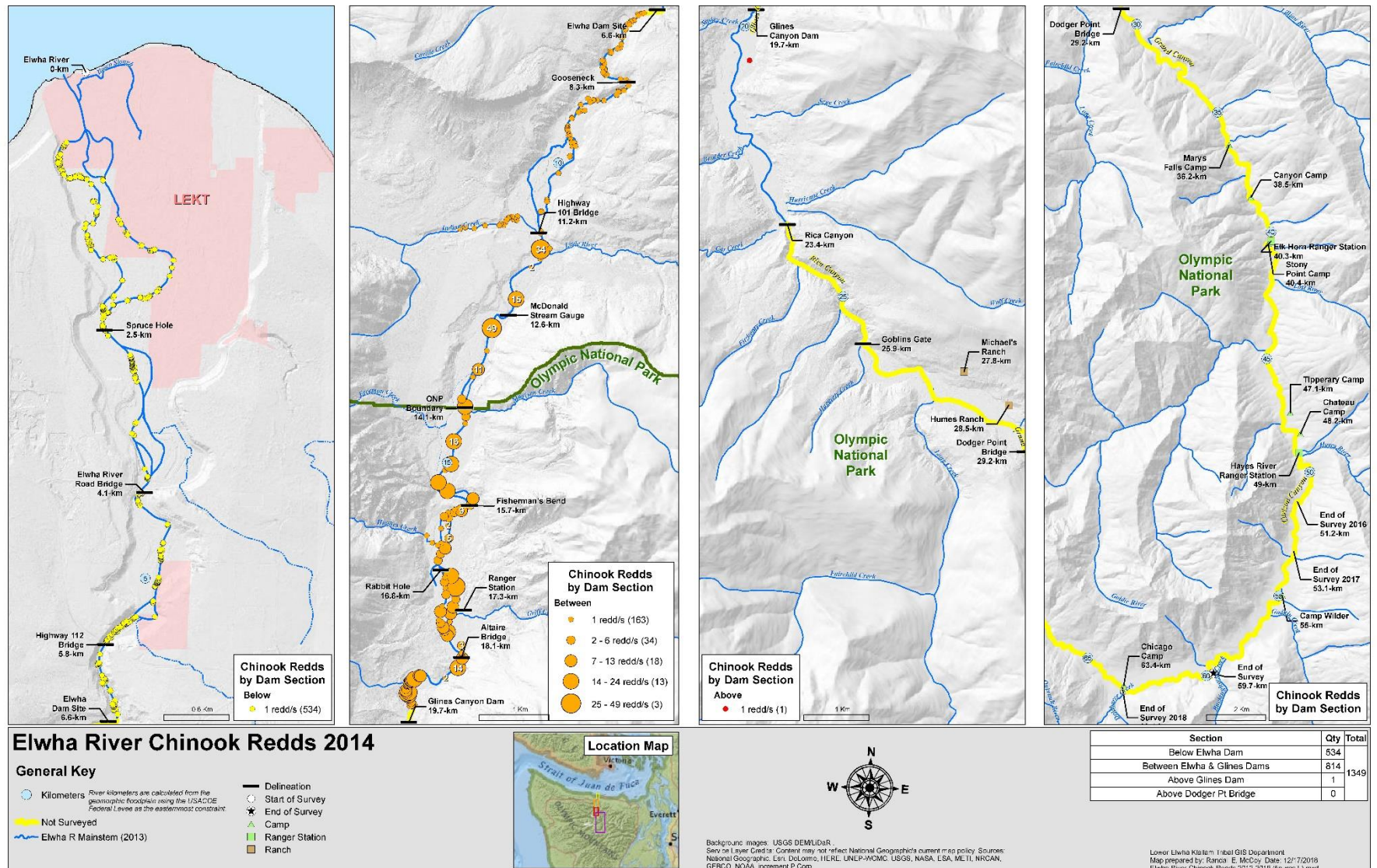
Figures 3. Distribution of Chinook redds in the Elwha River 2012.



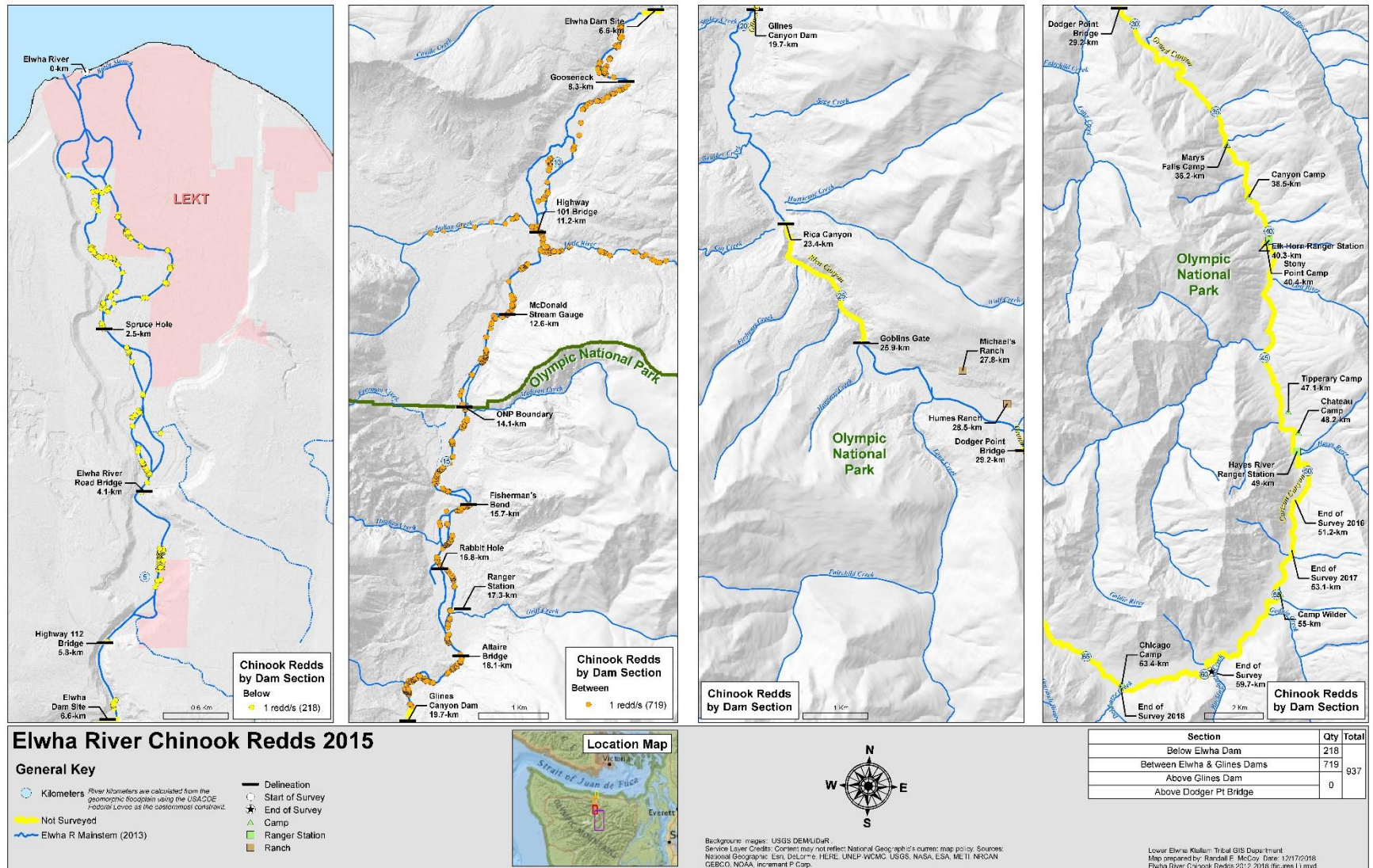
Figures 4. Distribution of Chinook redds in the Elwha River 2013.



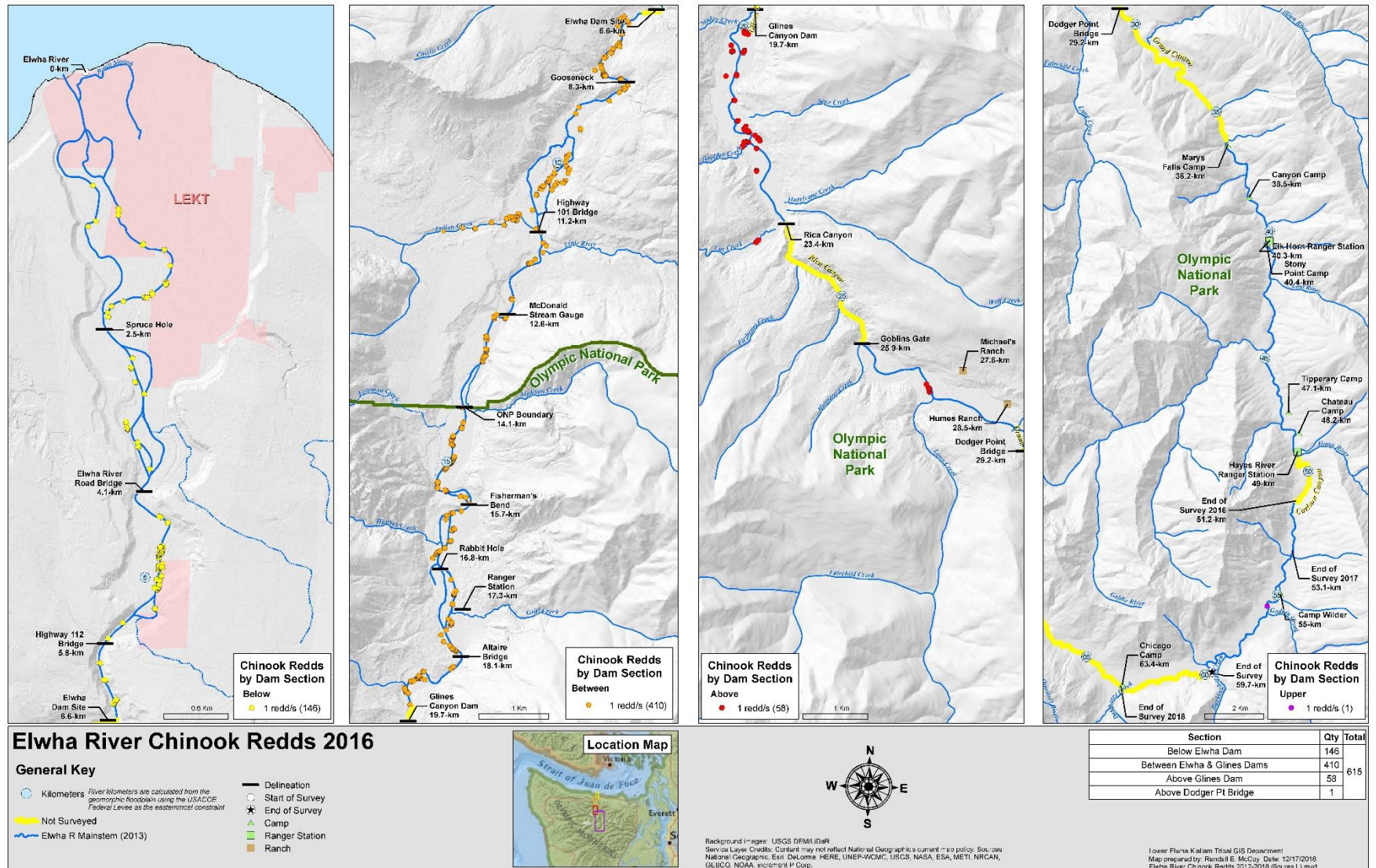
Figures 5. Distribution of Chinook redds in the Elwha River 2014.



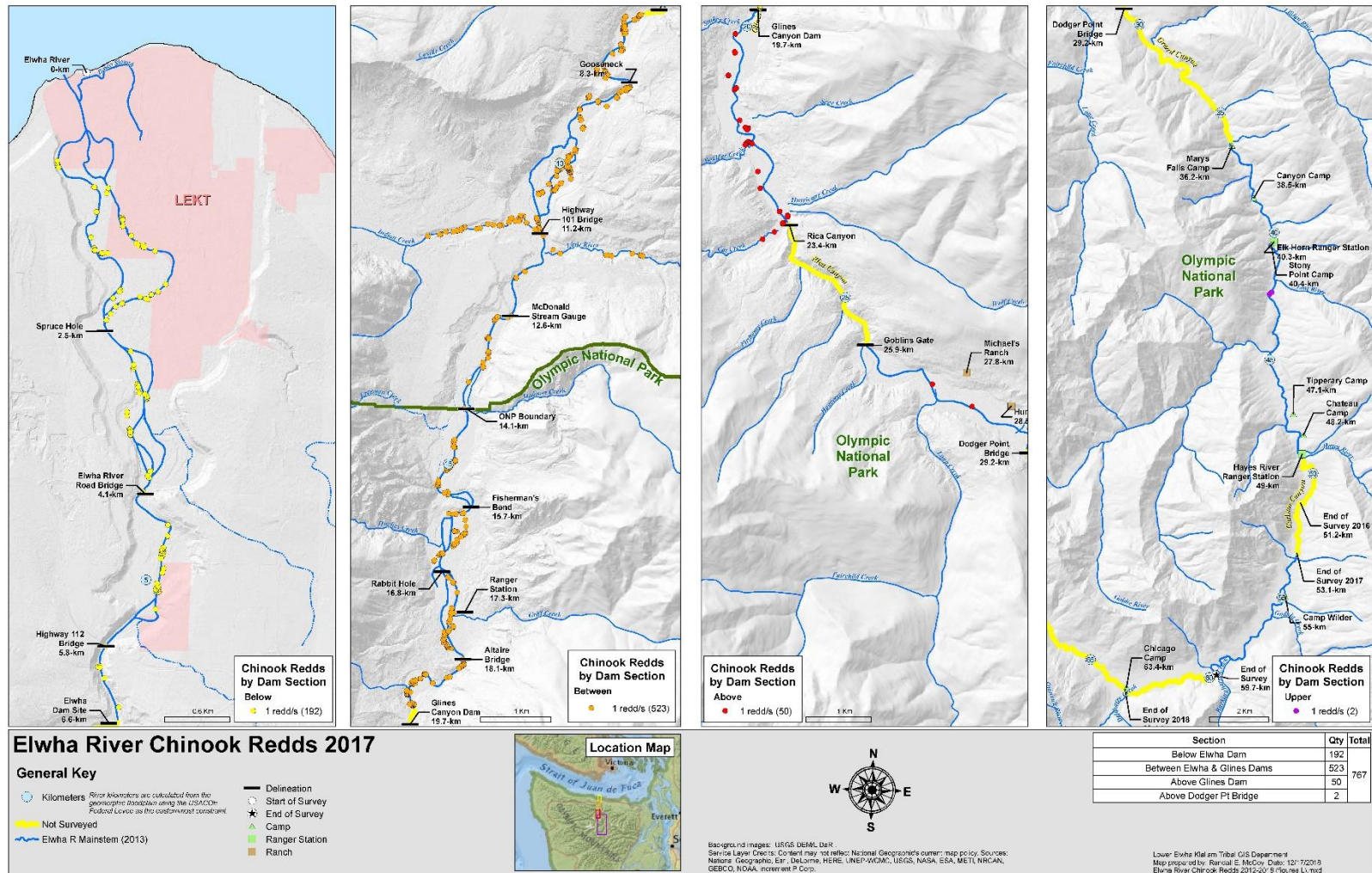
Figures 6. Distribution of Chinook redds in the Elwha River 2015.



Figures 7. Distribution of Chinook redds in the Elwha River 2016.



Figures 8. Distribution of Chinook redds in the Elwha River 2017.



Figures 9. Distribution of Chinook redds in the Elwha River 2018.

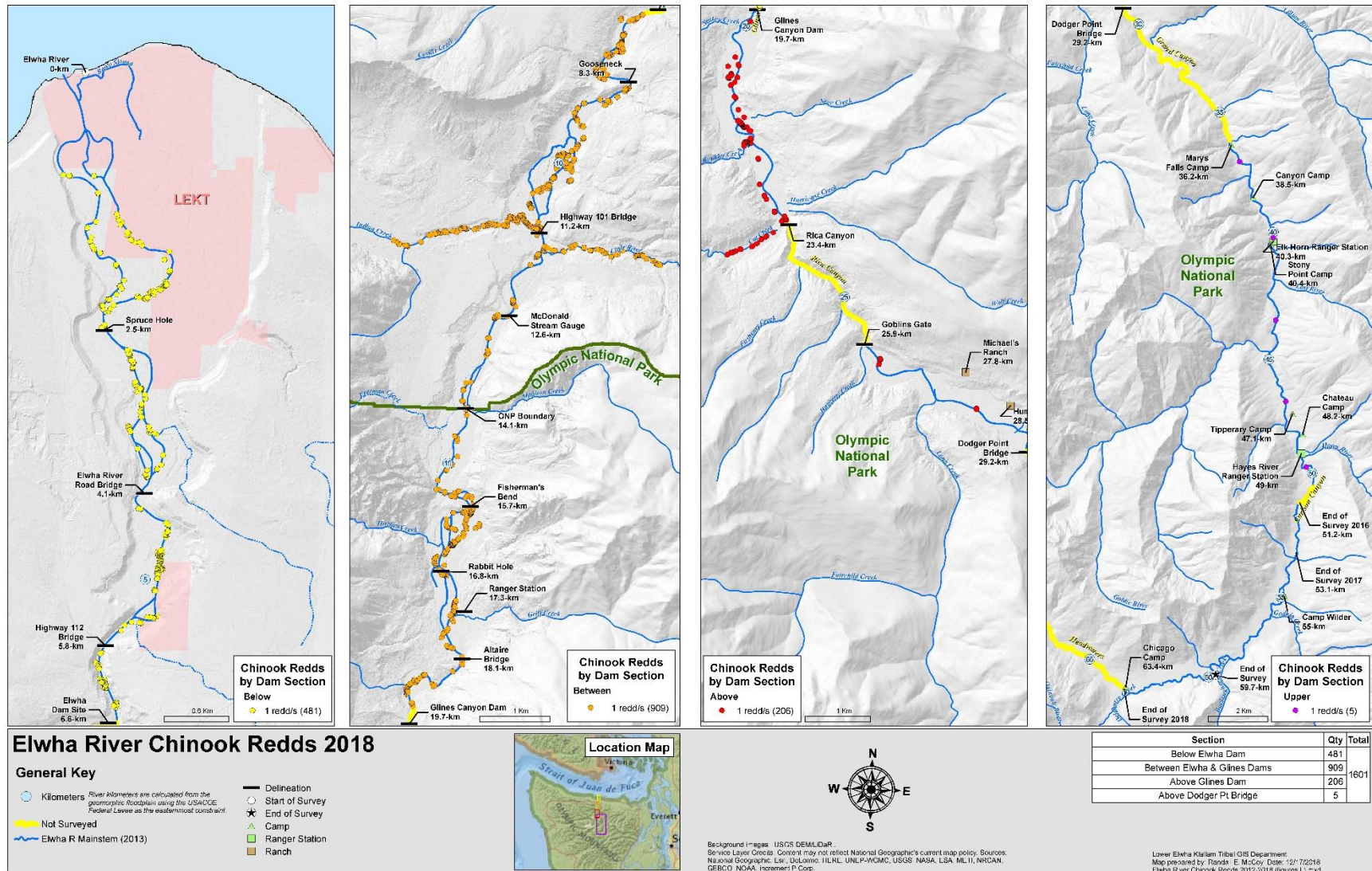
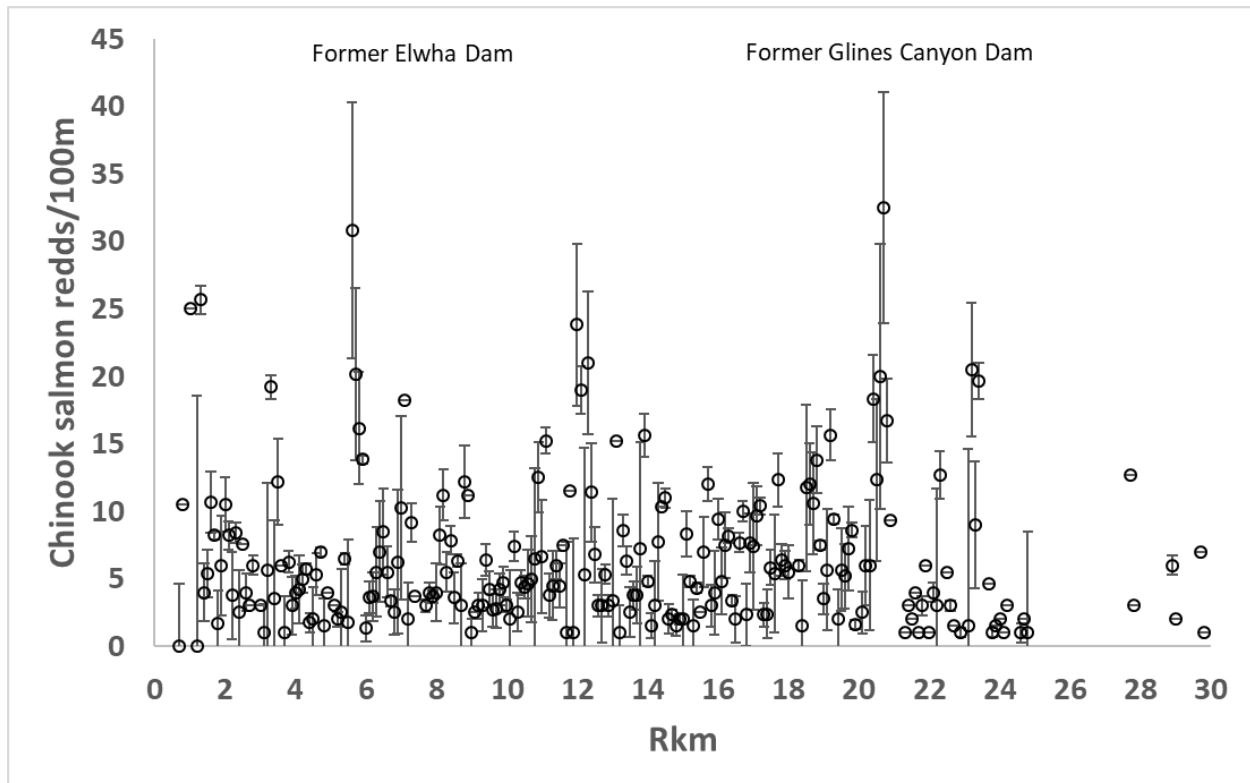


Figure 10. a. Density of Chinook salmon redds from river kilometer (RKM) 0.0 to 30.0 on the Elwha River 2012 to 2018. Open circles are the mean across years while solid lines with perpendicular bars are the standard errors. b. Density of Chinook salmon redds from river kilometer (RKM) 30.0 to 60.0 on the Elwha River 2012 to 2018. Open circles are the mean across years while solid lines with perpendicular bars are the standard errors.

a.



b.

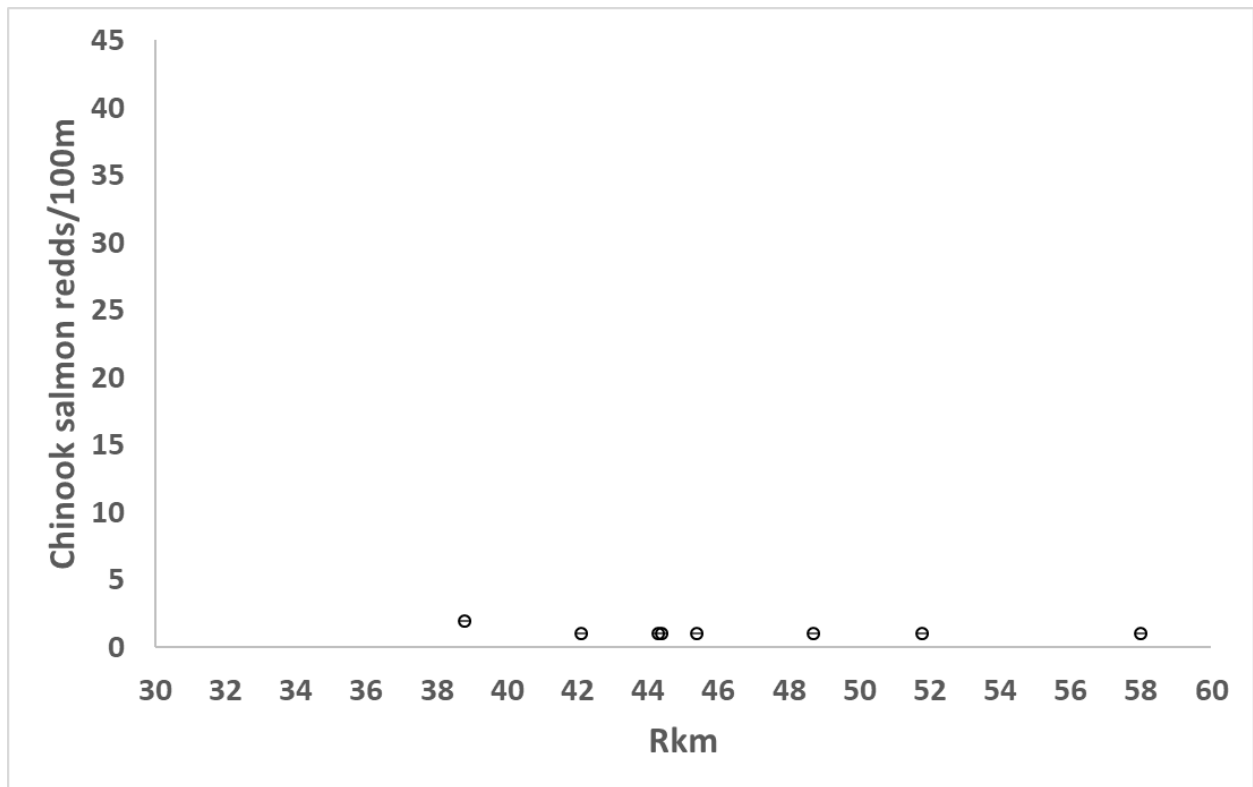


Figure 11. Chinook salmon redd occupancy by year and river section. Chinook salmon redd location was identified to the nearest tenth of a Rkm surveyed from 2012 to 2018 to estimate the total percent linear occupancy for the Elwha River.

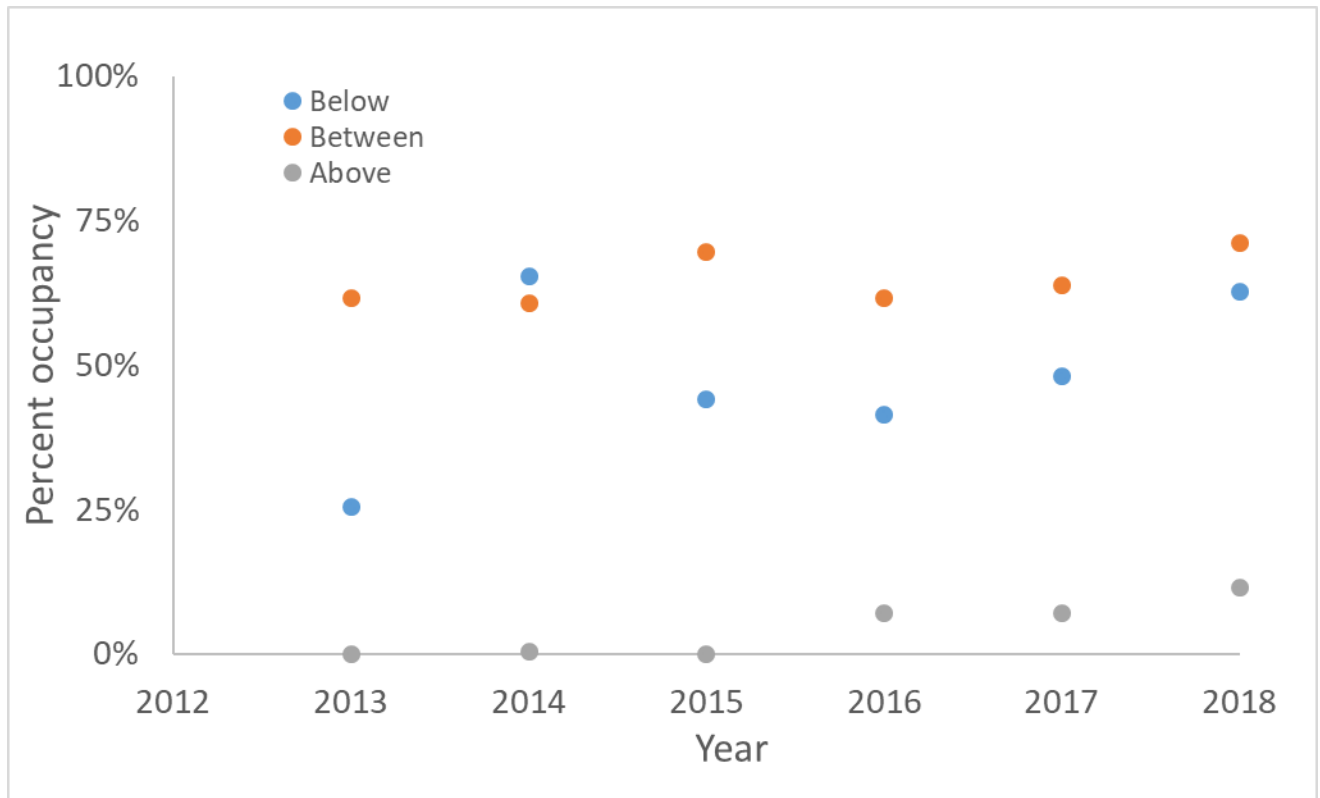


Figure 12. Historical escapement of Chinook salmon to the Elwha River 1984-2018 (from Denton et al 2018). Estimates were made by river surveys from 1984-2010. Estimates from 2010-2018 were made using SONAR cameras.

