

Spatial distribution of Chinook Salmon (*Oncorhynchus tshawytscha*) spawning in the Elwha River, Washington State during dam removal and early stages of recolonization (2012-2021)



Adult Chinook, Boulder Creek. Photo: Olympic National Park

Submitted to Olympic National Park by the Lower Elwha Klallam Tribe

In partial fulfillment of the agreement for performance of monitoring pursuant to the National Park Service's Chinook and Steelhead Monitoring Plan for the Elwha River

Authors: Mike McHenry¹, George Pess², and Joe Anderson³

1. Lower Elwha Klallam Tribe, 760 Stratton Road, Port Angeles, WA 98363

2. NOAA-NWFSC, 2725 Montlake Blvd East, Seattle, WA 98112

3. Washington Department of Fish and Wildlife, PO Box 43200, Olympia, WA 98504-3200

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 alluvial reaches of the Elwha River and selected tributaries from 2012 to 2021, a period in which two hydroelectric dams were removed and migratory access restored. Chinook salmon redds were located by visual surveys conducted near the peak of spawn timing in September. Surveys were conducted in mainstem, side-channel, and large tributary habitats for all years from the mouth of the Elwha River upstream to Glines Canyon Dam site (Rkm 21.7) at flows less than 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 2016-2021 that included surveys of the uppermost watershed to near Chicago Camp (Rkm 61.7). Redds were geo-referenced using GPS units, and live and dead adult Chinook salmon were enumerated. Surveys in 2012-2013 were limited by poor visibility (72 FNU and 45 FNU average turbidity, respectively). Conversely, surveys in 2014-2021 were conducted during very low turbidities (<5.0 FNU average turbidity).

In 2021, the number of Chinook salmon adults returning to spawn in the Elwha River was similar to 2020 and much lower than the 2018 and 2019 brood years and no hatchery adult Chinook were relocated upstream. A total of 495 Chinook redds and 1,177 adults (966 live/211 dead) were observed during peak spawning surveys in 2021. The majority of redds were again located in the Middle Elwha (66%). However, in 2021, the percentage of the total redds observed upstream of Glines Canyon increased to 18%, the highest percentage to date. For the second consecutive year no Chinook salmon redds or adults were observed upstream of Rica Canyon in 2021.

Three patterns are apparent for the spatial distribution of Chinook salmon redds following dam removal on the Elwha River. The first has been the relatively low number of Chinook salmon spawning in the lower river (average=24.6% annually since 2013). This is affected directly by the hatchery broodstock program that annually removes hundreds of spawners from the lower river by gaffing and netting. Second, the proportion of Chinook salmon redds observed in the Middle Elwha increased rapidly following dam removal (average=65.6% annually since 2013), and more recently in the upper Elwha between Glines Canyon and Rica Canyon. Fish passage conditions at Glines Canyon were initially unfavorable for fish passage immediately following dam removal (2014) until after consecutive years of blasting were completed to remove hydraulic jumps in 2015 and 2016. In 2016-2021, increasing numbers of Chinook salmon (11.7% annually since 2016) colonized the area above Glines Canyon with the majority of redd

observations occurring on the former Mills Reservoir area. Finally, very few adults have volitionally accessed the upper watershed above the Grand Canyon of the Elwha River.

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. This is being accomplished through dam removal, sediment management, floodplain restoration, revegetation, and the conservation and amplification of native salmon populations. The long-term goal is to establish self-sustaining, naturally spawning populations of Pacific salmon and steelhead, sufficiently abundant to support meaningful harvest, reducing and ultimately 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 and the Hatchery Genetic Management Plans (HGMP) for the WDFW and Tribal hatchery programs suggest the use of adaptive management targets to inform management actions for the recovery of the populations. The HGMP targets differ significantly from the EMAM targets, so for this document, “triggers” or “targets” refer to values in the EMAM unless stated otherwise. 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, 2016-2021). Productivity metrics are being assessed using a combination of abundance estimation by smolt outmigration monitoring (McHenry et al. 2016, 2017) adult to juvenile outmigrant 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), 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.

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 over a period of 5 to 7 generations (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 above 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. Since dam removal, the channel is stabilizing and revegetating in those reaches impacted by dam removal. 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 the Washington Department of Fisheries 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 2010-2019, > 90% of Chinook salmon returning to the Elwha River basin were hatchery origin (Weinheimer et al. 2018). All recovery documents have established a recovery 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 removed¹. 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 mostly successful and all species except chum salmon have been documented passing through Glines Canyon.

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 2014-20 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 2021 in the Elwha watershed. Survey timing was based on the estimated contemporary 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 0.0-6.6). 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 6.6-19.7). Lastly the Upper Elwha (UE) is defined as the reach above Glines Canyon Dam, including the former Mills Reservoir, Cat and Boulder creeks, upstream to Chicago Camp (Rkm 19.7-

¹ 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.

63.4)². The Lower Elwha³ and Middle Elwha were surveyed in all years, while the Upper Elwha was surveyed in 2016-2020. Supplemental surveys were conducted in the UE in 2014 and 2015, however these only included the former Mills Reservoir area from Glines Canyon Dam upstream to the entrance of Rica Canyon and Geyser Valley. 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 and Carlson Canyon in 2020. These include the canyons immediately above Elwha Dam, Glines Canyon, Rica Canyon, Grand Canyon, and Carlson Canyon (Figure 1). Additionally, no comprehensive surveys during Chinook spawning season have occurred to date in larger tributaries upstream of the Grand Canyon, though most tributaries offer relatively little spawning habitat compared to the mainstem Elwha River.

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 2015-2021 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 2017, 2018, 2019, 2020 and 2021 when systematic snorkel surveys were conducted in the upper Elwha.

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

² The actual upper end of survey has varied by years. Please consult Figures 3-10 to determine that end by year.

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

Canyon dam (Table 6). Since 2015, turbidity has not been a factor during surveys in any reach. In fact, the McDonald Gauge flow monitoring site discontinued turbidity monitoring in 2020. 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.

Occupancy estimates based upon Chinook salmon redd location was quantified since 2012. The Elwha River was broken down into 1/10 of a kilometer sections, not including tributaries. Each 1/10 of a kilometer was then identified as to whether or not a Chinook salmon redd was located in that area. The total number of occupied areas was divided by the total number of areas that could be occupied within each section of river (below the former dams, between the former dams, and above the former dams) to give a percent occupancy. It is important to note that we assumed the canyon areas would not be occupied for Chinook salmon spawning.

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 and 2019, we observed the highest number of Chinook redds (1,601 and 1,672 respectively) since the project began. In 2020, the number of redds observed was reduced by 60% from the two previous years (625) (Figure 2). In all years, the majority of Chinook salmon redds were located in the Middle Elwha River (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 in the lower river 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 7,000 (2019) (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 Lower Elwha River (LE) due to better visibility (Figure 4, Table 6). A total of 765 Chinook redds were identified, 79% (602 out of 765) 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, which was geolocated by ONP. On September 15 and 30, two additional Chinook salmon snorkel/redd surveys were conducted in 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 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 (N = 58) of redds were observed above Glines Canyon (Figure 6). Chinook redds were also observed in lower Boulder Creek (N = 8) and in Cat Creek (N = 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 Chinook adults were observed above the Grand Canyon during the September surveys, and only one live Chinook was observed above Grand Canyon during a late August snorkel survey. 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 compared to 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 (7%) total redds and of these, 92% 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 two 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 second 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. It should be noted that a total of 604 adult Chinook salmon were relocated from lower river hatcheries to a release point at the entrance of Glines Canyon. 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, and the highest observed adult (a female) was observed on that redd. Six adults total were observed above the Grand Canyon. 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 998 adults (887 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 358 adult Chinook observed upstream of Glines Canyon, 44 (12%) were confirmed to have tags.

In 2019, the highest total number of Chinook redds were observed since the beginning of the project (Figure 10, Table 12), slightly eclipsing the total for 2018. Proportionally, the greatest number of redds were observed in the ME (66%), followed by the LE (28%), and the UE (6%).

The 104 redds observed in the UE was less than half what was observed in 2018. Similar to 2018, 576 adult Chinook (181 males/395 females/6 jacks) were relocated from lower river hatcheries to a release point just above the ONP entrance. The distribution of Chinook redds in the UE was heavily skewed to the former Mills reservoir and its tributaries, Cat and Boulder Creeks. Only two Chinook adults and one redd were observed upstream of the Grand Canyon during snorkel surveys in early September. . Those fish were visibly marked using colored Spaghetti tags. Some relocated fish were observed on subsequent spawning ground surveys both upstream and downstream of their release point, however there were not enough tag recoveries to determine the effect of that action. A small number of pink salmon redds (24) was observed, with the majority in Indian Creek and former Aldwell reservoir. One pair of pink salmon was observed above Glines Canyon, near the outlet of Rica Canyon, and a peak count of 26 pink salmon were observed in mainstem river snorkel surveys between Glines Canyon and Fisherman's Bend. A total of 95 pink salmon were observed during the riverscape survey. This is the first year that pink salmon have been observed above the former Glines Canyon Dam site.

In 2020, the number of Chinook redds observed was the third lowest since the inception of the project. A total of 625 redds were counted with the majority (52.6%) in the middle Elwha, followed by the lower Elwha (30.4%) and upper Elwha (16.9%). We observed three discrete areas of high Chinook redd density including the reach from the Highway 112 bridge downstream to the Elwha River Road Bridge, Indian Creek, and the former Mills Reservoir surface. Although the total number of redds was low, the percentage that spawned above the former Glines Canyon site was the highest to date (16.9%). Those Chinook that ascended above Glines Canyon spawned on the former Mills Reservoir surface as well in Cat and Boulder Creeks. No adult Chinook or redds were observed upstream of Rica Canyon in 2020.

In 2021, the number of Chinook redds observed was the lowest since the inception of the project. A total of 495 redds were counted with the majority (65.8%) in the ME, followed by the LE (17.9%) and Upper Elwha River (UE) (16.2%). No adult Chinook salmon or redds were observed upstream of Rica Canyon for the second consecutive year. However, the proportion of redds in the UE increased for the second consecutive year. Three areas of relatively high Chinook salmon redd density were observed in 2021: Fisherman's Bend area in the middle Elwha, and Indian and Boulder Creeks (Figure 13), the later of which had the highest redd density of all reaches surveyed. A total of 1,246 pink salmon were also counted, the largest number observed in the Elwha since the early 1960's. Pink salmon were observed in the majority of reaches from the lower river extending to the entrance to Rica Canyon at Cat Creek. The highest abundance of pink salmon was in Little River in 2021 (198 total).

Redd density levels above Rkm 30.0 are still quite low in comparison to the rest of the Elwha River. Examination of redd occupancy (presence of at least one redd in each tenth of a Rkm),

excluding the canyon areas where few surveys have been conducted, reveals that 2018 and 2019 had the highest level of occupancy seen since Chinook salmon redd surveys have been initiated in 2012 between and above the former dam locations (Figure 13). However, no chinook redds have been observed above Rica Canyon in 2020 and 2021.

Chinook salmon redd occupancy exhibited three clear patterns across the time series. First, redd occupancy in the upper Elwha was substantially lower than the lower and middle Elwha in all years. Second, the middle Elwha had the highest redd occupancy in all years except 2013 and 2019. Third, redd occupancy across all reaches was higher in high abundance years, notably 2018 and 2019.

Discussion

We conducted annual peak spawning ground surveys for Elwha River Chinook salmon during dam decommissioning (2012-2015) and the early stages of recolonization (2016-2021). These surveys were designed to provide information on the spatial distribution of Chinook salmon spawning nest locations as access to historic habitats was 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) (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 former barriers (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 Lower Elwha were lower at the time of the survey 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 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 mainstem 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 improved 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).

In 2016 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 passage is restricted for other

species such as pink and chum salmon. 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 2016-2021 Chinook salmon spawner surveys were the most spatially extensive Chinook survey efforts to date, and were unaffected by turbidity (Table 4). The continuous distribution of Chinook salmon redds observed in 2013-2019 (Figures 4-10) is likely due to the combination of relatively high abundance of spawners and an increase in the quantity and quality of accessible spawning habitat. In contrast, in 2020 and 2021, Chinook spawning density was much reduced (625 and 495 total redds) and the distribution of redds more patchy (Figure 11, Figure 14). Visual observations made by spawning ground surveyors indicated that the mainstem spawning habitat in 2013-2021 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. 2015). 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 provides insights into the colonization of Chinook in the Elwha River following removal of two hydroelectric dams. 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 through Glines Canyon 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 11 & 13). Additionally, no chinook were observed above Rica Canyon (Rkm 25.7) in either 2020 or 2021. It is not known if this is the result of low Chinook escapement or a newly formed barrier.

Between 2014-2017, environmental DNA monitoring conducted in the upper Elwha found that Chinook salmon presence was detected in decreasing frequency as one progressed upstream (Duda et al. 2020). The authors reported the presence of Chinook salmon in all four years at Mills, three of four years at Geyser Valley, two of four years at Elkhorn and one of four years at Hayes. No detections were reported at Camp Wilder (Rkm 58.3). These observations are consistent with redd and snorkel surveys in upper watershed and suggest low numbers of chinook above the Grand Canyon. The Lower Elwha Klallam Tribe has proposed to relocate

adult Chinook salmon into the upper watershed for a period of five years as a means of accelerating recolonization of upstream habitats.

The lack of Chinook salmon to the headwaters may be the result of several factors. First, low densities of Chinook salmon may result in redd selection occurring in the first suitable habitat encountered by migrating females. In this case, the middle Elwha and newly exposed Mills Reservoir surface provided abundant, suitable spawning sites for early migrants immediately following dam removal. Burton et al. (2013) described this pattern for Chinook migrants immediately following installation of fish passage facilities on the Cedar River, Washington. Second, the Elwha Chinook salmon population, which is currently dominated by Hatchery Origin Recruits (HOR) 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 near acclimation release site, while greater numbers of natural origin Chinook utilized upstream habitats (Hughes and Murdoch 2017). Under this scenario, an increasing proportion of natural-origin adult returns in future years may lead to a shift towards a more upstream spawning distribution. 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). Rica Canyon also presents a challenge to many migrating fish species including Chinook, and while it is shorter in length (2.5 km), it also maintains significant drops and higher velocity sections. The lack of adult salmon observations above Rica Canyon in 2020 and 2021 warrants further investigation as to whether a partial barrier has formed within the canyon recently.

The historic run of Chinook salmon that utilized habitats above Rica Canyon and especially the Grand Canyon was likely a mixture of spring/summer timing, while the current run is dominated by summer run fish (Brannon and Hershberger 1984; Brenkman et al. 2008). Given the cooler stream temperatures in the upper Elwha, juvenile growth associated with spring run timing may also be an important factor for the successful colonization of upriver habitats. The spring run component of the Elwha River Chinook salmon population is currently unknown. It is unknown if the existing Chinook salmon hatchery dominated population, which likely differs from the historic population, is capable of recolonizing these River above Rica Canyon. Under this scenario, some level of natural selection and adaptive evolution may be required to initiate colonization of upriver habitats.

Through a combination of the above reasons, the returning adults may be capable of ascending the difficult canyons, but not sufficiently motivated to make this effort. Regardless of the precise reason, or combination of reasons, Chinook salmon have not populated the upper watershed in significant numbers. Actively transporting adults would place more fish into

suitable upriver habitats potentially accelerating the recolonization of habitats high in the watershed. Some believe this carries risks of undermining natural ecological and genetic processes that may be important for successful numerical and spatial expansion. Others think that the level of risk is low in areas where Chinook salmon are currently in extremely low densities, and if progeny of adults relocated to the upper watershed are not genetically fit they will simply not survive. As this debate continues it should be noted that there are two large cohorts (2019 and 2020) of natural origin Chinook salmon smolts at sea. These progeny of hatchery adults that spawned in the wild may be more likely to colonize upriver habitats. Ford et al. (2015) found that Natural-origin offspring of naturally spawning hatchery-origin fish in the Chiwawa River, Washington tended to spawn up to 20-30 km further upstream than their mothers. If this pattern is consistent on the Elwha River, returning adults beginning in 2022 (as three year olds) may expand into upriver habitats.

To date, there has been little evidence in spawning ground surveys to suggest the revitalization of the spring Chinook salmon component of the run. Chinook salmon are observed in the stock composition surveys for the SONAR operation in late May (Denton et al, 2019), which is consistent with historic spring Chinook salmon entry timing on the Elwha (Wunderlich et al, 1993). It may be that exposure to the 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 salmon on the Elwha River. Spring Chinook salmon have declined dramatically coast-wide, and research indicates a strong association between genotype at single genomic region and early migration in both steelhead and Chinook salmon (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 migration allele at high enough frequency to prevent the complete loss the allele because of genetic drift. This genetic link may have significant implications to the recovery of this important early timed life history, and genotypes associated with early (spring-run) migration are still currently found in the Elwha River Chinook salmon population (Personal communication with Garrett McKinney, Washington Department of Fish and Wildlife July 26, 2021).

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References

- Anderson, J., M. Mizell, M. Ackley, M. Mayer, M. Zimmerman and P. Crain. 2015. Elwha River weir project: 2013 operations and final summary report. FPT 15-03. Washington Department of Fish and Wildlife, Olympia, WA.
- Beechie, T. J., E. Buhle, M. H. Ruckelshaus, A. H. Fullerton, L. Holsinger. 2006. Hydrologic regime and the conservation of salmon life history diversity. *Biological Conservation*, 130(4):560-572.
- Beechie, T.J., and H. Imaki. 2014. Predicting natural channel patterns based on landscape and geomorphic controls in the Columbia River basin, USA. *Water Resources Research* 50:1-39.
- Brannon, E. L., and W. K. Hershberger. 1984. Elwha River fall Chinook salmon. J. M. Walton, and D. B. Houston, editors. *Proceedings of the Olympic wild fish conference*, Peninsula College, Fisheries Technology Program, Port Angeles, WA.
- Brenkman, S.E., G.R. Pess, C.E. Torgerson, K.K. Kloehn, J.J. Duda, and S.C. Corbett. 2008. Predicting recolonization patterns and interactions between potadromous and anadromous salmonids in response to dam removal in the Elwha River, Washington State, USA. *Northwest Science* 82:91-106.
- Burton, K.D., L.G. Lowe, H.B. Berge, H.K. Barnett, and P.L. Faulds. 2013. Dispersal patterns for recolonizing Cedar River Chinook salmon above Landsburg Dam, Washington and the source population below the dam. *Transactions of the American Fisheries Society* 142:703-716.
- Denton, K., McHenry, M., Moses, R., Ward, E., Liermann, M., Stefankiv, O., Wells, W., and G. Pess. 2020. 2019 Elwha River Chinook estimation based on DIDSON/ARIS multi-beam SONAR data. Report to Olympic National Park, Port Angeles, Washington.

Denton, K., McHenry, M., Moses, R., Ward, E., Liermann, M., Stefankiv, O., Wells, W., and G. Pess. 2018. 2018 Elwha River Chinook estimation based on DIDSON/ARIS multi-beam SONAR data. Report to Olympic National Park, Port Angeles, Washington.

Denton, K., McHenry, M., Moses, R., Ward, E., Liermann, M., Stefankiv, O., Wells, W., and G. Pess. 2017. 2017 Elwha River Chinook estimation based on DIDSON/ARIS multi-beam SONAR data. Report to Olympic National Park, Port Angeles, Washington.

Denton, K., McHenry, M., Moses, R., Ward, E., Liermann, M., Stefankiv, O., Wells, W., and G. Pess. 2016. 2016 Elwha River Chinook estimation based on DIDSON/ARIS multi-beam SONAR data. Report to Olympic National Park, Port Angeles, Washington.

Denton, K., McHenry, M., Moses, R., Ward, E., Liermann, M., Stefankiv, O., Wells, W., and G. Pess. 2015. 2015 Elwha River Chinook estimation based on DIDSON/ARIS multi-beam SONAR data. Report to Olympic National Park, Port Angeles, Washington.

Denton, K., McHenry, M., Moses, R., Ward, E., Liermann, M., Stefankiv, O., Wells, W., and G. Pess. 2014. 2014 Elwha River Chinook estimation based on DIDSON/ARIS multi-beam SONAR data. Report to Olympic National Park, Port Angeles, Washington.

Denton, K., McHenry, M., Moses, R., E., Liermann, M., and G. Pess. 2013. 2013 Elwha River Chinook estimation based on DIDSON/ARIS multi-beam SONAR data. Report to Olympic National Park, Port Angeles, Washington.

Denton, K., and M. Liermann. 2012. Estimation of the 2012 Chinook escapement in the Elwha River using DIDSON multi-beam Sonar technology. Report to Lower Elwha Klallam Tribe, Port Angeles, Washington.

Denton, K., and M. Liermann. 2011. Estimation of the 2010 Chinook escapement in the Elwha River using DIDSON multi-beam Sonar technology. Report to Lower Elwha Klallam Tribe, Port Angeles, Washington.

Department of Interior (DOI). 1995. The Elwha Report: Restoration of the Elwha River ecosystem and native anadromous fisheries.

Duda, J.J., M.S. Hoy, D.M. Chase, G.R. Pess, S.J. Brenkman, M.L. McHenry, and C. O. Ostberg. 2020. Environmental DNA is an effective tool to track recolonizing migratory fish following large-scale dam removal. Environmental DNA 2020: 1-21.

East, A.E., Pess, G.R., Bountry, J.A., Magirl, C.S., Ritchie, A.C., Logan, J.B., Randle, T.J., Mastin, M.C., Minear, J.T., Duda, J.J., Liermann, M.C., McHenry, M.L., Beechie, T.J., Shafroth, P.B., 2015.

Large-scale dam removal on the Elwha River, Washington, USA: river channel and floodplain geomorphic change. *Geomorphology* 228: 765–786.

Ford, M.J., A. Murdoch, and M. Hughes. 2015. Using parentage analysis to estimate rates of straying and homing in Chinook salmon (*Oncorhynchus tshawytscha*). *Molecular Ecology* 24: 1109-1121.

Gallagher, S. P., Hahn, P. K., & Johnson, D. H. 2007. Redd counts. *Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations*. American Fisheries Society, Bethesda, Maryland, 197-234.

Geist, D. R. (2000). Hyporheic discharge of river water into fall Chinook salmon (*Oncorhynchus tshawytscha*) spawning areas in the Hanford Reach, Columbia River. *Canadian Journal of Fisheries and Aquatic Sciences*, 57(8), 1647-1656.

Huges, M.S., and A.R. Murdoch. 2017. Spawning habitat of hatchery spring Chinook salmon and possible mechanisms contributing to lower reproductive success. *Transactions of the American Fisheries Society* 146:1006-1017.

Kiffney, P. M., G. R. Pess, J. H. Anderson, P. Faulds, K. Burton, S. Riley. 2008. Changes in fish communities following recolonization of the Cedar River, WA, USA by Pacific salmon after 103 years of local extirpation. *River Research and Applications*, 25(4):438-452.

Laramie, M.B., Pilliod, D.S., Goldberg, C.S., and Strickler, K.M., 2015, Environmental DNA sampling protocol—Filtering water to capture DNA from aquatic organisms: U.S. Geological Survey Techniques and Methods, book 2, chap. A13, 15 p., <http://dx.doi.org/10.3133/tm2A13>.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable Salmonid Population and the Recovery of Evolutionarily Significant Units. U.S. Department of Commerce. NOAA Technical Memorandum NMFS-NWFSC-42.

McHenry, M.L., M. Elofson, M. Liermann, and G. Pess. 2016. 2016 Elwha River smolt enumeration project. Report to Olympic National Park, 600 Park Ave., Port Angeles, Washington.

Myers, J. M., R. G. Kope, G. J. Bryant, D. J. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grant, F. W. Waknitz, K. Neely, S. Lindley and R. S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-NWFSC-35, Seattle, WA.

Pess, G.R., M.C. Liermann, T. R. Bennett, T.J. Beechie, and M.McHenry. 2015 Longitudinal profiles in floodplain channels of the Middle and Lower Elwha River 2012 and 2014. Report to Olympic National Park. 21 pages. Seattle, WA.

Pess, G. R., R. Hilborn, K. Kloehn, T. P. Quinn. 2012. The influence of population dynamics and environmental conditions on pink salmon (*Oncorhynchus gorbuscha*) recolonization after barrier removal in the Fraser River, British Columbia, Canada. *Canadian Journal of Fisheries and Aquatic Sciences*, 69(5):970-982.

Pess, G. R., M. L. McHenry, T. J. Beechie and J. Davies. 2008. Biological impacts of the Elwha River dams and potential salmonid responses to dam removal. *Northwest Science* 82:72-90.

Peters, R.J., J.J Duda, G.R. Pess, M. Zimmerman, P. Crain, Z. Hughes, A. Wilson, M.C. Liermann, S.A. Morley, J.R. McMillan, K. Denton, D. Morrill, and K. Warheit. 2014. Guidelines for monitoring and adaptively managing restoration of Chinook Salmon (*Oncorhynchus tshawytscha*) and Steelhead (*O. Mykiss*) on the Elwha River. U.S. Fish and Wildlife Service, Olympia.

Peters, R.J., G.R. Pess, M.L. McHenry, P.D. Bakke, M. Elofson, and S. Sampson. 2015. Quantifying changes in streambed composition following the removal of the Elwha and Glines Canyon Dam on the Elwha River. U.S. Fish and Wildlife Service report. 16 pages. Lacey, WA.

Peters, R.J., M. Liermann, M.L. McHenry, P. Bakke, and G. Pess. 2017. Changes in streambed composition in salmonid spawning habitat of the Elwha River during dam removal. *Journal of the American Water Resources Association* 53 (4): 871-885.

Prince, D.J. et al. 2017. The evolutionary basis of premature migration in Pacific salmon highlights the utility of genomics for informing conservation. *Science Advances* 3:e1603198.

Ruckelshaus, M.H., Currens, K.P., Graeber, W.H., Fuerstenberg, R.R., Rawson, K., Sands, N.J., and Scott, J.B. 2006. Independent populations of Chinook salmon in Puget Sound, U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-78, Seattle, WA.

Thompson, T.Q. et al. 2018. Anthropogenic habitat alteration leads to rapid loss of adaptive variation and restoration potential in wild salmon populations. *Proceedings of the National Academy of Science*. www.pnas.org/cgi/doi/10.1073/pnas.1811559115.

Vronskiy, B. B. 1972. Reproductive biology of the Kamchatka River Chinook salmon [*Oncorhynchus tshawytscha* (Walbaum)]. *Journal of Ichthyology* 12:259–273.

- Vronskiy, B. B., and V. N. Leman. 1991. Spawning stations, hydrological regime, and survival of progeny in nests of Chinook salmon, *Oncorhynchus tshawytscha*, in the Kamchatka River Basin. *Voprosy Ikhtiologii* 31:282–291.
- Waples, R. S., G. R. Pess, T. J. Beechie. 2008. Evolutionary history of Pacific salmon in dynamic environments. *Evolutionary Applications*, 1(2):189-206.
- Ward, L., P. Crain, B. Freymond, M. McHenry, D. Morrill, G. Pess, R. Peters, J.A. Shaffer, B. Winter, and B. Wunderlich. 2008. Elwha River Fish Restoration Plan: Developed pursuant to the Elwha River Ecosystem and Fisheries Restoration Act, Public Law 102-495.
- Warrick, J.A., Bountry, J.A., East, A.E., Magirl, C.S., Randle, T.J., Gelfenbaum, G., Ritchie, A.C., Pess, G.R., Leung, V., Duda, J.J., 2015. Large-scale dam removal on the Elwha River, Washington, USA: source-to-sink sediment budget and synthesis. *Geomorphology* 246: 729-750.
- Weinheimer, J., J. Anderson, R. Cooper, S. Williams, M. McHenry, P. Crain, S. Brenkman, and H. Hugunin. 2017. Age structure and hatchery fraction of Elwha River Chinook salmon: 2016 carcass survey report. FPA 17-05. Washington Department of Fish and Wildlife, Olympia.
- Weinheimer, J., J. Anderson, R. Cooper, S. Williams, M. McHenry, P. Crain, S. Brenkman, and H. Hugunin. 2016. Age structure and hatchery fraction of Elwha River Chinook salmon: 2015 carcass survey report. FPA 18-05. Washington Department of Fish and Wildlife, Olympia.
- Winter, B.D. and P.Crain. 2008. Making the case for ecosystem restoration by dam removal in the Elwha River, Washington. *Northwest Science*, Volume 82:1-245.

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. Surveys conducted upriver of Glines Canyon were a combination of snorkel/foot surveys.

Survey Reach	Rkm start	Rkm end	Midpoint (Rkm)	Length (km)	Lead survey team
Rica Canyon to Dodger Point (Geyser 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
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. Surveys conducted upriver of Glines Canyon were a combination of snorkel/foot surveys.

Survey Reach	Rkm start	Rkm end	Midpoint (Rkm)	Length (km)	Lead survey team
Rica Canyon to Dodger Point (Geyser 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
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					
Marys Falls Camp to Chicago Camp	36.4	63.5	49.9	27.1	ONP
Rica Canyon to Dodger Point (Geyser Valley)	26.0	29.5	27.7	3.5	ONP
Glines Powerhouse to Rica Canyon (Mills)	19.5	23.5	21.5	4.0	ONP
Cat Creek	0.0	0.7	0.35	0.7	ONP
Boulder Creek	0.0	0.3	0.15	0.3	ONP
Middle Elwha					
Glines Powerhouse to Altaire Canyon	18.7	19.5	19.1	0.8	ONP
Altaire Canyon to Elwha Ranger St.	17.5	18.7	18.1	1.2	ONP
Elwha Ranger Station to Hughes Creek	16.9	17.5	17.8	0.6	ONP
Hughes Creek to Fishermans Corner	15.5	16.9	16.2	1.4	ONP
Fishermans Corner to Park Boundary	14.4	15.5	14.9	1.1	WDFW
Park Boundary to McDonald Bridge Gage	12.7	14.4	13.5	1.7	WDFW
McDonald Gage to 101 Bridge	11.2	12.7	11.9	1.5	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)	8.9	11.2	10.0	2.3	LEKT
Aldwell North (Gooseneck to Elwha Dam)	6.5	8.9	7.7	2.4	LEKT
Lower River					
Dam Dam to Hwy 112 bridge	5.7	6.5	6.1	0.8	LEKT
Hwy 112 bridge to County bridge	4.2	5.7	4.9	1.5	LEKT
County bridge to Spruce Hole	2.3	4.2	3.2	1.9	LEKT
East Channel (LEKT Hatchery)	0.0	2.3	1.1	2.3	LEKT
Hunt's Road Channel	0.8	2.3	1.5	1.5	LEKT

Table 4. Discharge, turbidity levels and suspended sediment concentration during Chinook salmon spawning ground surveys conducted in the Elwha River, 2012-2021. Water quality measurements were measured at monitoring station 12046200, while discharge measurements were at station 12045500 (Curran et al. 2014). Note the turbidity gauge went off-line in 2020.

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	High turbidity below Elwha Dam
2013	Sept 17	11.1 ($\pm$ 0.7)	45 ($\pm$ 2.0)	77	High turbidity below Elwha Dam
2014	Sept 17	7.0 ($\pm$ 0.2)	5 ($\pm$ 2.0)	55	Visibility excellent
2015	Sept 23-24	9.9 ($\pm$ 0.2)	0.8 ($\pm$ 0.4)	-	Visibility excellent
2016	Sept 19-23	8.5 ($\pm$ 0.2)	5.0 ($\pm$ 2.0)	-	Visibility excellent
2017	Sept 18-25	11.3 ($\pm$ 0.3)	2.3 ($\pm$ 0.3)	-	Visibility excellent
2018	Sept 12-28	11.3 ($\pm$ 1.4)	(5.0 $\pm$ 3.0)	-	Two flow spikes during survey period. Flows quickly receded
2019	Sept 26	11.3 ($\pm$ 1.8)	(2.1 $\pm$ 0.1)	-	Visibility excellent
2020	Sept 21-23	8.5 ($\pm$ 0.1)	-	-	Visibility excellent
2021	Sept 15-21		-	-	Visibility excellent

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 ⁴								
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						

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. 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 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 (21.4%)	19.0	0	0	381	62	0
TOTAL				296	225	696	522	13
		765						

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. 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. The former Mills reservoir counts include redds from Boulder and Cat Creeks.

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	2.9	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. The former Mills reservoir counts include redds from Boulder and Cat Creeks.

Survey Reach	Rkm midpoint	Redds	Redds/km	Live Chinook	Dead Chinook	Jacks
Upper Elwha						
Upper Watershed	43.8	2	0.07	2	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%)		92	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		828	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		288	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		1,530	800	3

Table 12. Number of redds, redds/kilometer and observation of live, dead and jack Chinook salmon on the Elwha River, 2019.

Survey Reach	Rkm midpoint	Redds	Redds/km	Live Chinook	Dead Chinook	Jacks
Upper Elwha						
Upper Watershed	43.8	1	0.04	2	0	0
Long Creek ⁶						
Geyser Valley	28.8	5	0.8	8	7	0
Cat Creek		9	6.0	3	8	0
Boulder Creek		22	44.0	8	39	0
Mills	23.4	67	14.5	73	61	0
UE Subtotal		104		94	115	0
		(6.2%)				
Middle Elwha						
Glines Power.	20.6	46	41.8	51	164	0
Altaire Bridge	19.5	34	34.0	23	16	0
Griff Creek	18.5	34	34.0	176	125	0
Rabbit Hole (Hughes) ⁷	17.3	133	88.7	-	-	-
Fisherman's	16.1	67	83.7	17	0	0
ONP Boundary	14.7	42	21.0	29	0	0
McDonald Br.	12.9	14	8.7	6	0	0
Little River	12.2	124	65.3	30	91	0
Indian Creek	12.1	215	113.2	48	159	0
Aldwell South	11.0	259	112.6	33	60	0
Aldwell North	8.8	131	68.9	8	69	0
ME Subtotal		1099		421	684	0
		(65.7%)				
Lower Elwha						
Elwha Dam	7.3	36	45.0	-	-	-
Hwy 112 Bridge	6.1	248	145.9	-	-	-
County Bridge ⁸	3.8	120	66.7	400	398	0
East Mainstem	1.4	42	18.3	11	45	0
Hunt Rd. Chan.	2.0	24	16.0	11	12	0
LE Subtotal		470		422	455	
		(28.1%)				
TOTAL		1673		937	1,254	0

⁶ Long Creek was not surveyed in 2019

⁷ Live/Dead Counts aggregated for Hughes/Griff survey reaches

⁸ Live/Dead Counts aggregated for Dam/112 Bridge/County Bridge reaches

Table 13. Number of redds, redds/kilometer and observation of live, dead and jack Chinook salmon on the Elwha River, 2020.

Survey Reach	Rkm midpoint	Redds	Redds/km	Live Chinook	Dead Chinook	Jacks
Upper Elwha						
Upper Watershed	43.8	0	0	0	0	0
Geyser Valley	28.8	0	0	0	0	0
Cat Creek		6	4.0	0	1	0
Boulder Creek		18	36.0	1	1	0
Mills	23.4	82	17.8	67	32	2
UE Subtotal		106		68	34	2
		(16.9%)				
Middle Elwha						
Glines Power.	20.6	41	37.3	30	15	0
Altaire Bridge	19.5	19	19.0	18	1	0
Griff Creek	18.5	15	15.0	27	2	0
Rabbit Hole (Hughes)	17.3	26	17.3	11	2	0
Fisherman's C.	16.1	20	25.0	15	4	0
ONP Boundary	14.7	12	6.0	14	7	0
McDonald Br.	12.9	21	13.1	25	9	0
Little River	12.2	6	3.2	9	0	0
Indian Creek	12.1	76	33.0	60	33	0
Aldwell South	11.0	52	22.6	37	30	0
Aldwell North	8.8	41	21.6	22	12	0
ME Subtotal		329		268	115	0
		(52.6%)				
Lower Elwha						
Elwha Dam	7.3	19	23.7			
Hwy 112 Bridge	6.1	109	64.2			
County Bridge ⁹	3.8	26	14.4	65	95	
East Channel	1.4	36	15.6	43	12	0
Hunt Rd. Chan.	2.0	0	0	0	0	0
LE Subtotal		190		108	107	
		(30.4%)				
TOTAL		625		444	256	2

⁹ Live/Dead Counts aggregated for Elwha Dam to County Bridge

Table 14. Number of redds, redds/kilometer and observation of live, dead and jack Chinook salmon on the Elwha River, 2021.

Survey Reach	Rkm midpoint	Redds	Redds/km	Live Chinook	Dead Chinook	Jacks
Upper Elwha						
Upper Watershed	49.9	0	0	0	0	0
Geyser Valley	27.7	0	0	0	0	0
Cat Creek	0.7	4	2.7	3	1	0
Boulder Creek	0.2	27	54.0	43	4	0
Mills	21.5	58	14.5	137	4	2
UE Subtotal		89		183	9	2
		(17.9%)				
Middle Elwha						
Glines Power.	19.1	26	32.5	50	4	0
Altaire Bridge	18.1	2	1.7	4	1	0
Elwha RS	17.8	2	3.3	5	0	0
Hughes Creek	16.2	34	15.0	26	9	0
Fisherman's	16.1	21	24.2	81	11	0
ONP Boundary	14.9	16	9.4	39	14	0
McDonald Br.	11.9	11	7.3	21	5	0
Little River	12.2	40	21.0	76	15	0
Indian Creek	12.1	94	49.4	104	36	0
Aldwell South	11.0	62	26.9	104	36	0
Aldwell North	8.8	18	7.5	13	12	0
ME Subtotal		326		523	143	0
		(65.9%)				
Lower Elwha¹⁰						
Elwha Dam	6.1	4	5.0			
Hwy 112 Bridge	4.9	31	20.6			
County Bridge	3.2	28	14.7			
East Channel	1.1	17	7.4	236	59	0
Hunt Rd. Chan.	1.5	0	0			
LE Subtotal		80		236	59	
		(16.2%)				
TOTAL		495		966	211	2

¹⁰ Live/Dead Counts aggregated for Elwha Dam to County Bridge

Figures

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

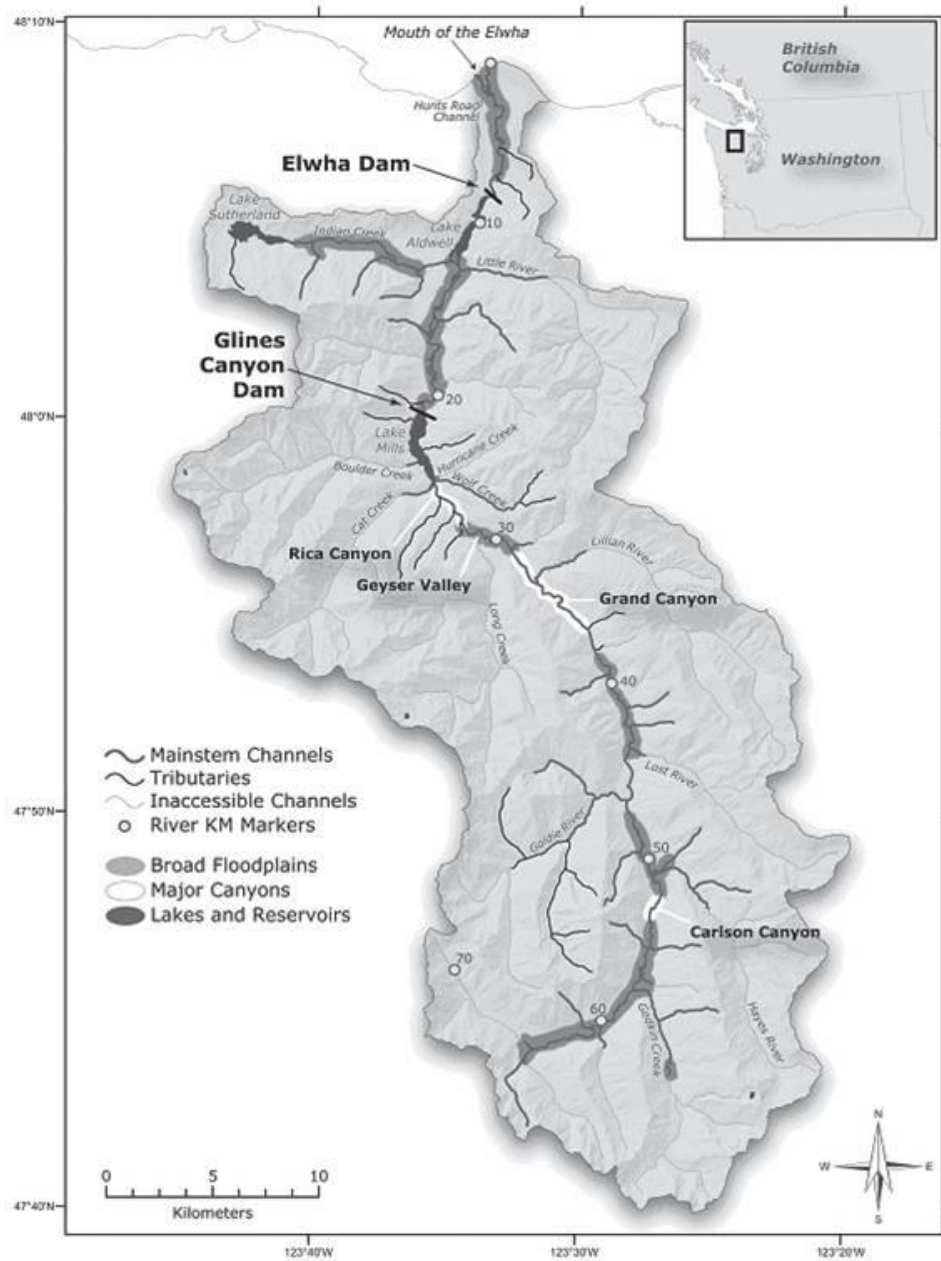
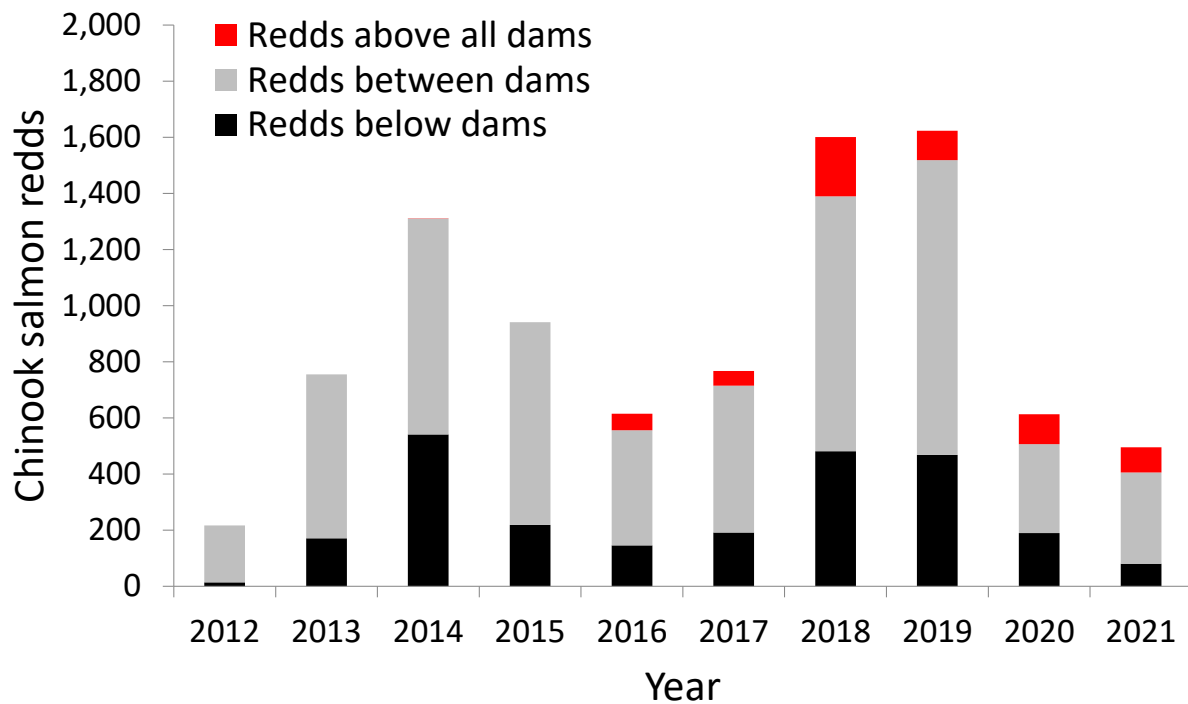
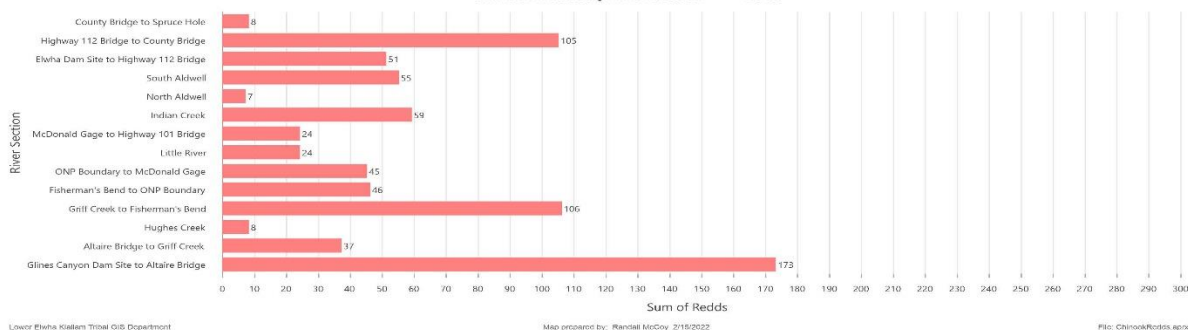
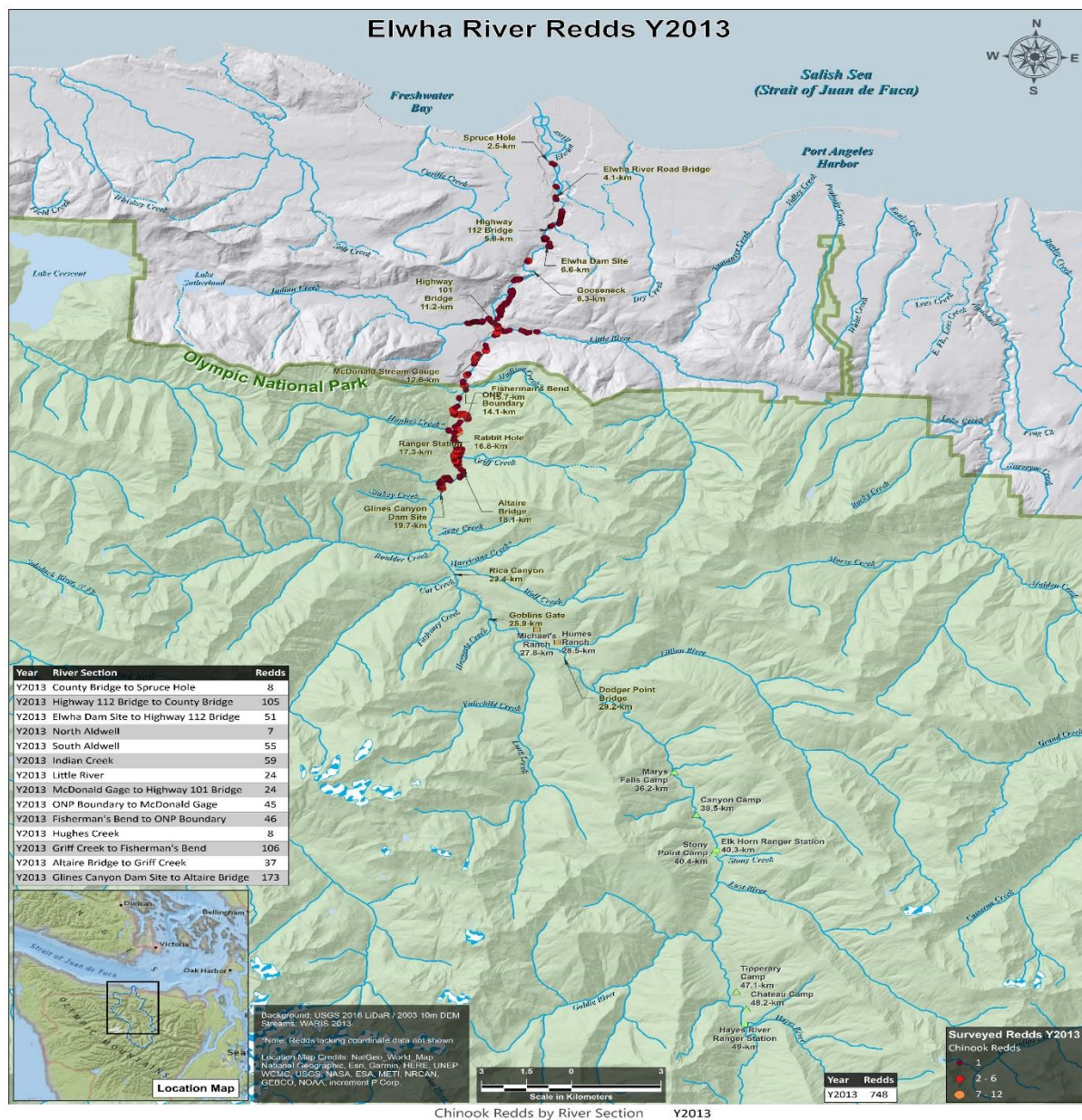


Figure 2. Total number of Chinook salmon redds between former Elwha dam and Glines Canyon dam 2012 to 2021. Black bars indicate the number of Chinook redds below former Elwha dam. Grey bars indicate the number of Chinook redds between former Elwha dam and former Glines Canyon dam, and red bar indicates 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.

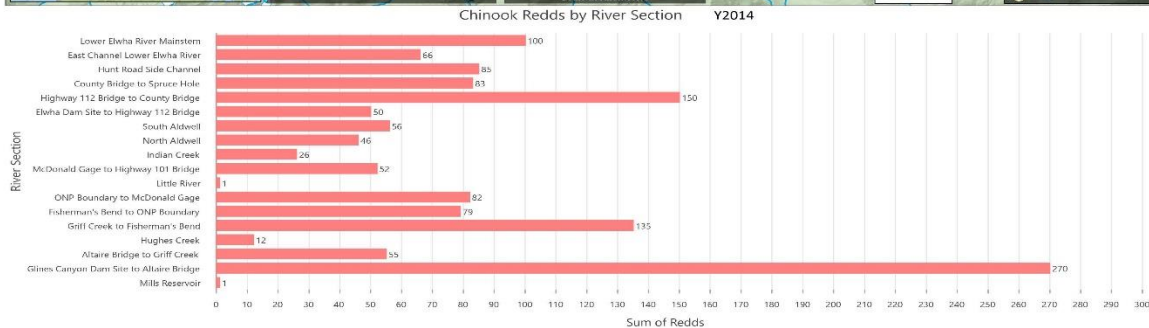
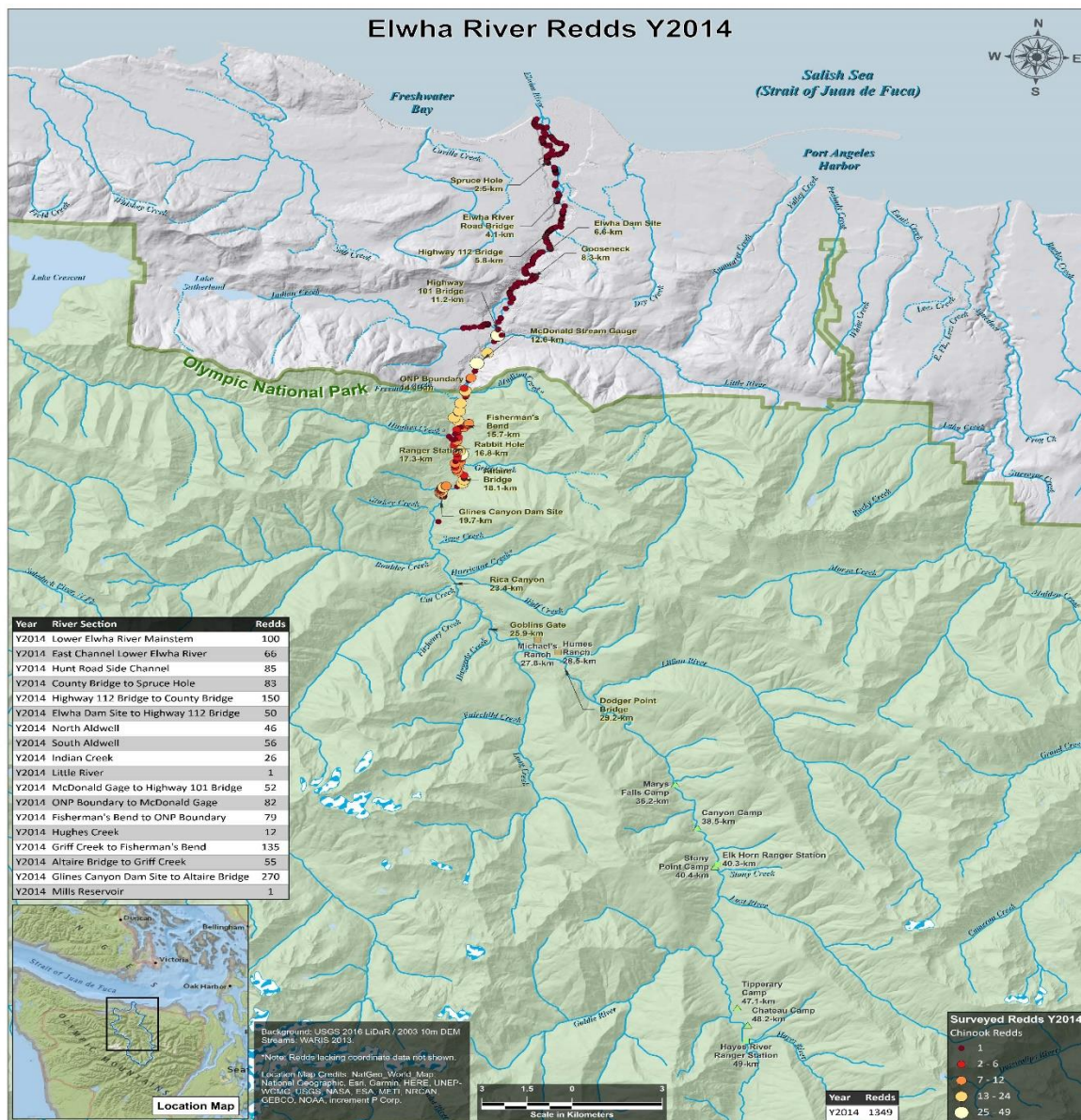


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Map prepared by: Randall McCoy 2/15/2022

File: ChinookRedds.aprx

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

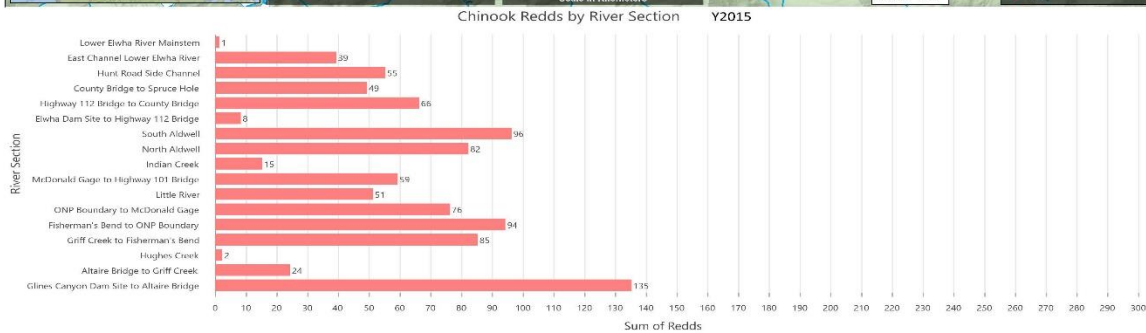
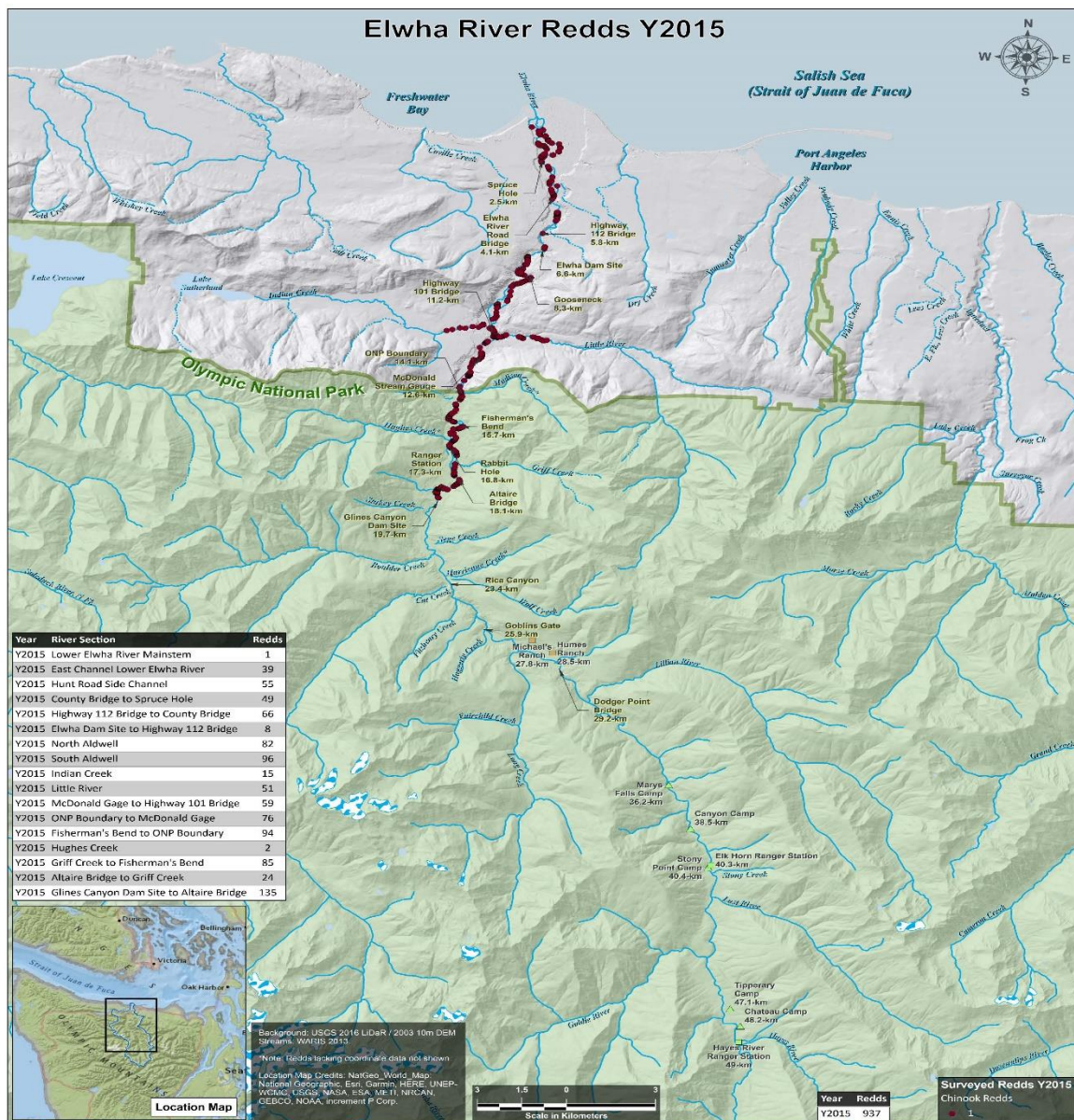


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Map prepared by: Randell McCoy 3/18/2022

File: ChinookRedds.aprx

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

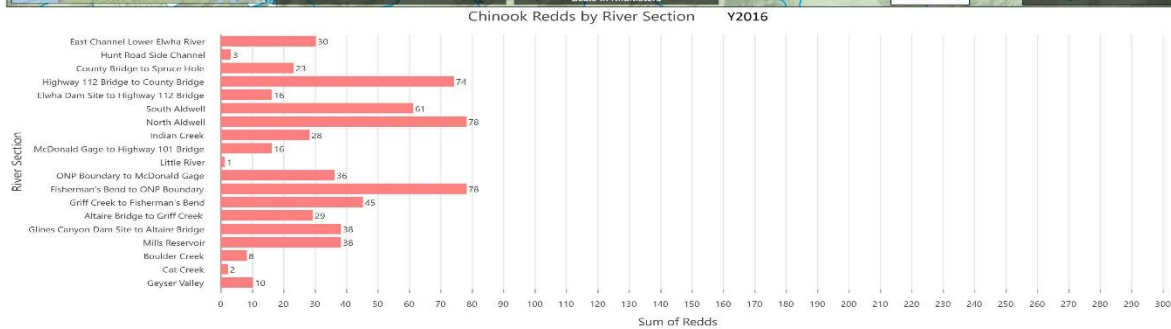
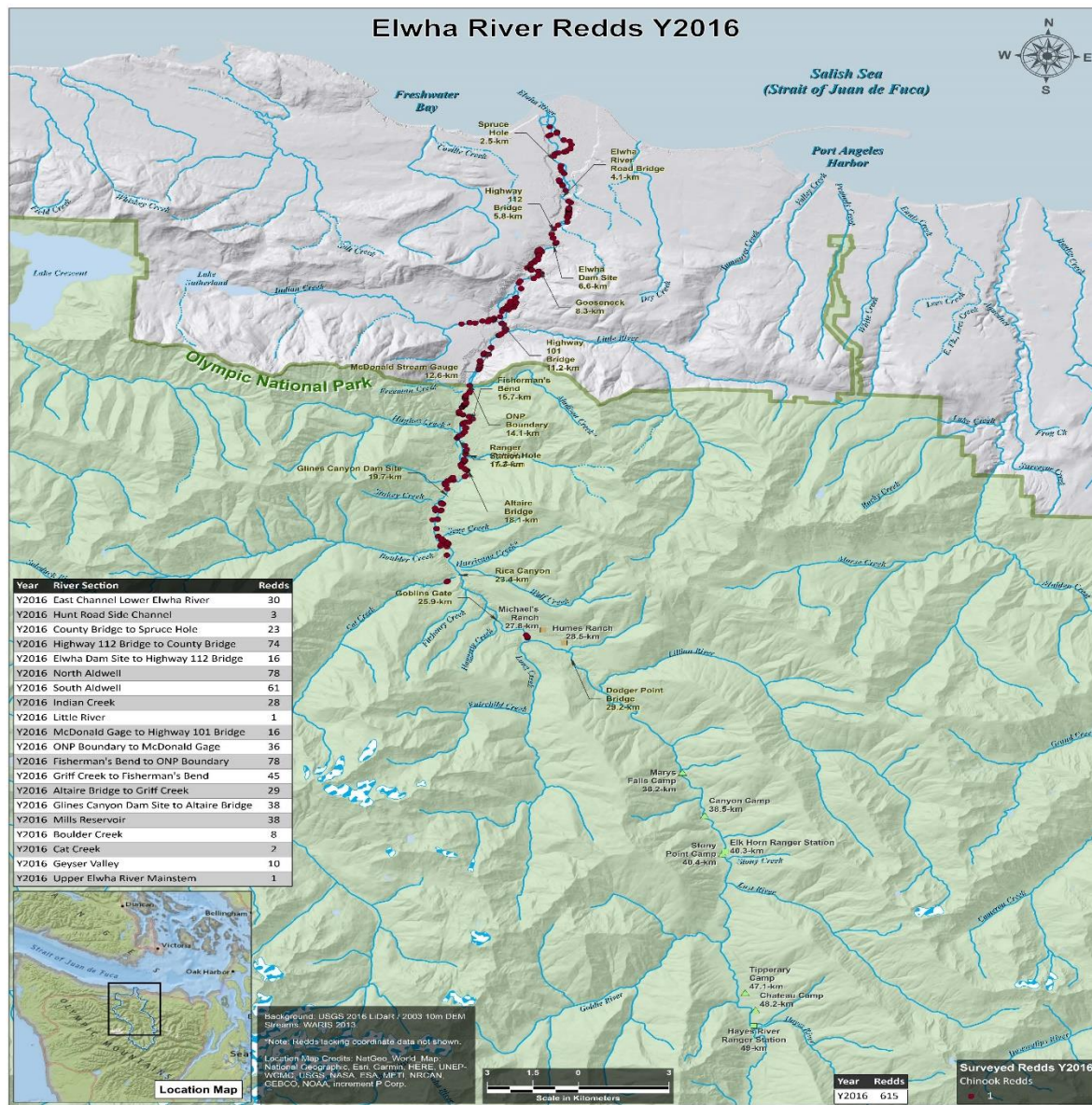


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Map prepared by: Randall McCoy 2/15/2022

File: ChinookRedds.aprx

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

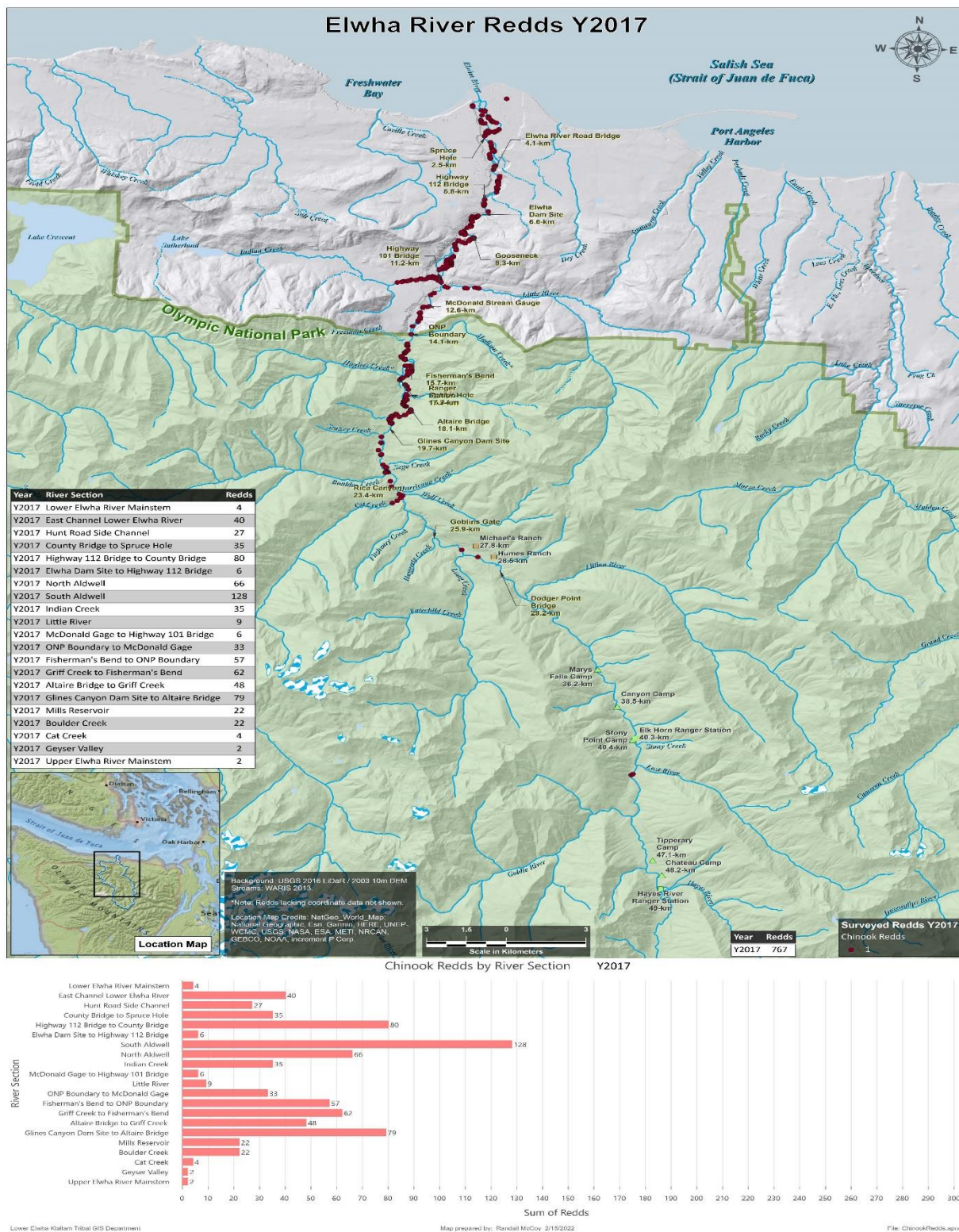


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Map prepared by: Randal McCoy 2/15/2022

File: ChinookRedds.aprx

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



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

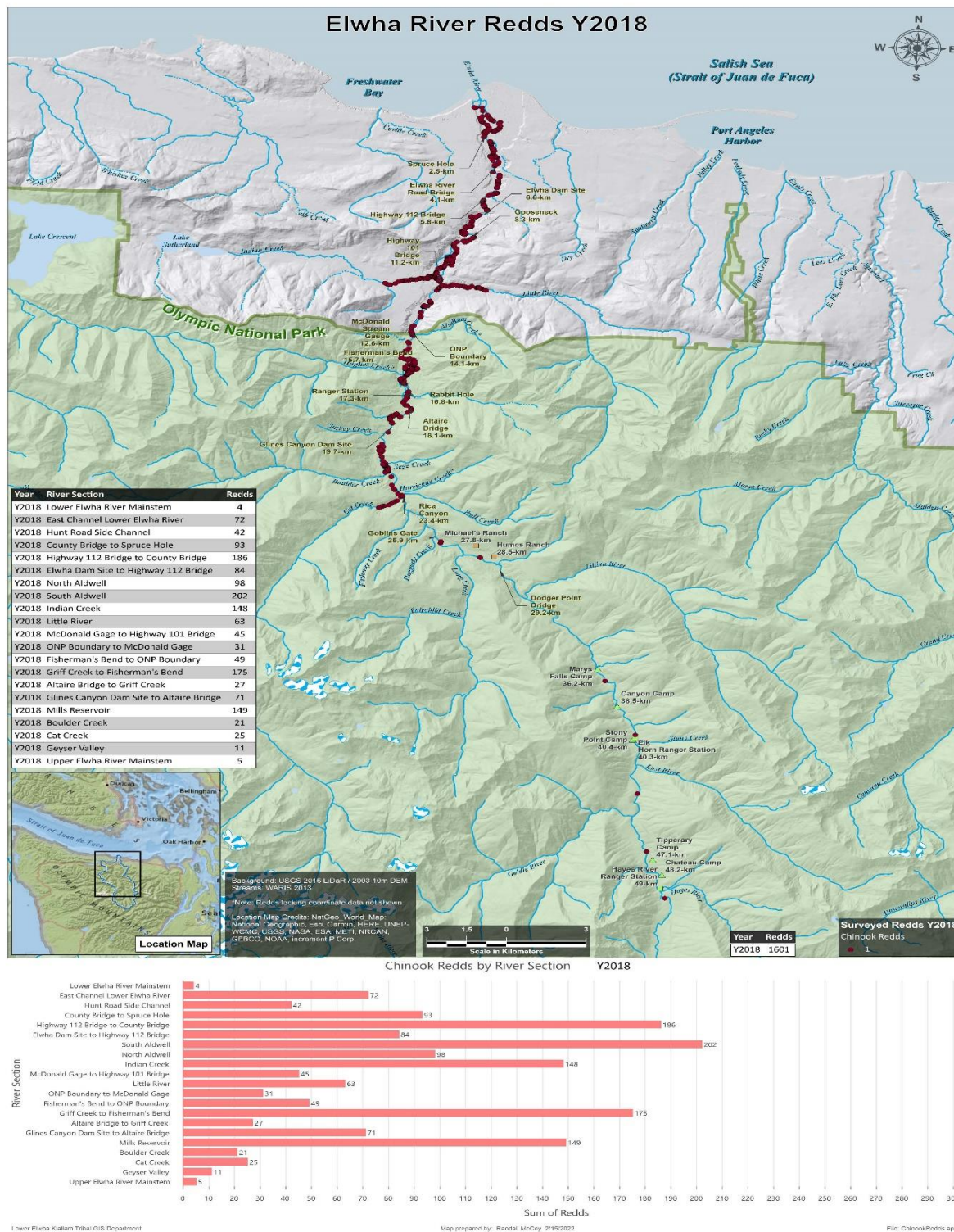


Figure 10. Distribution of Chinook redds in the Elwha River 2019.

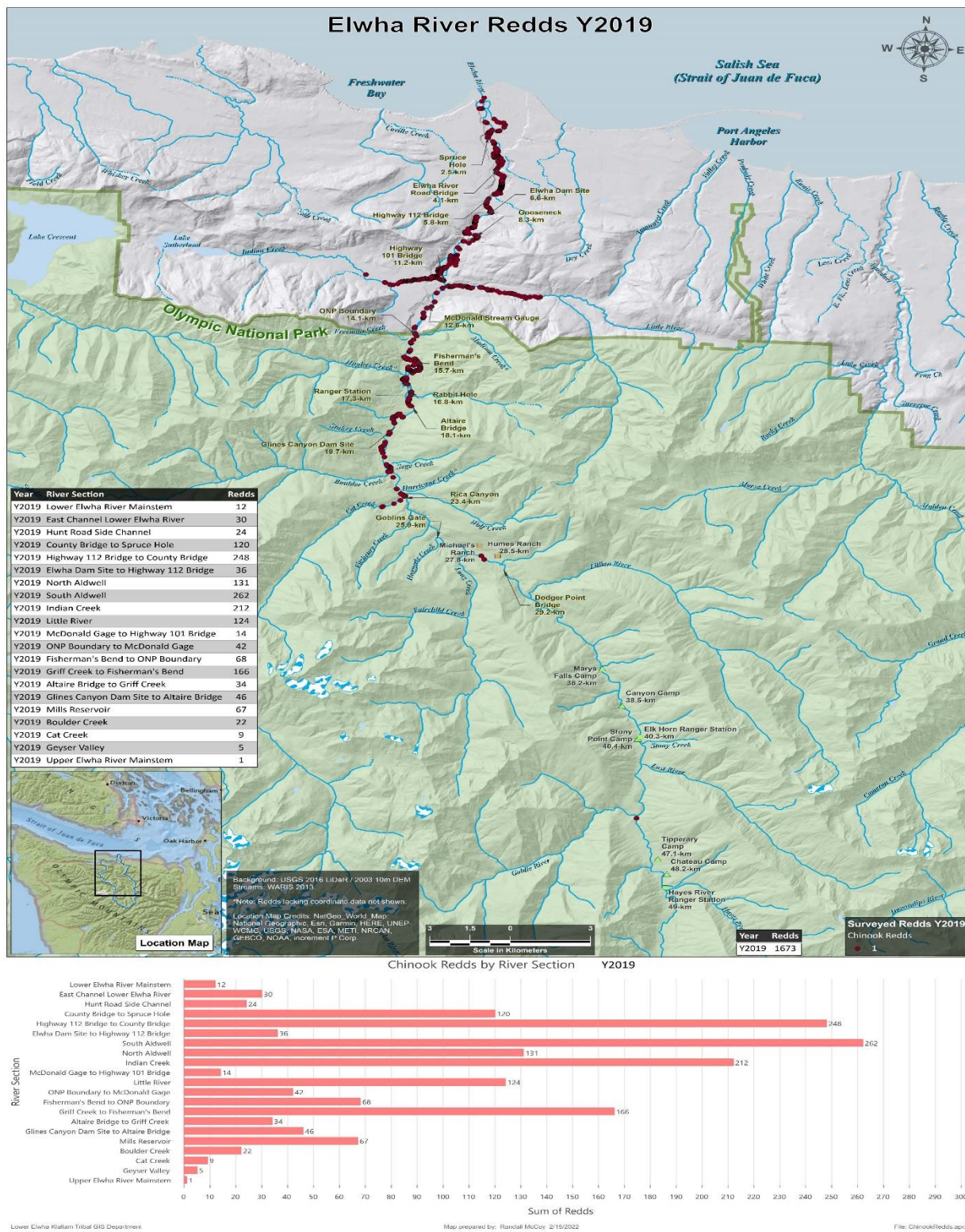
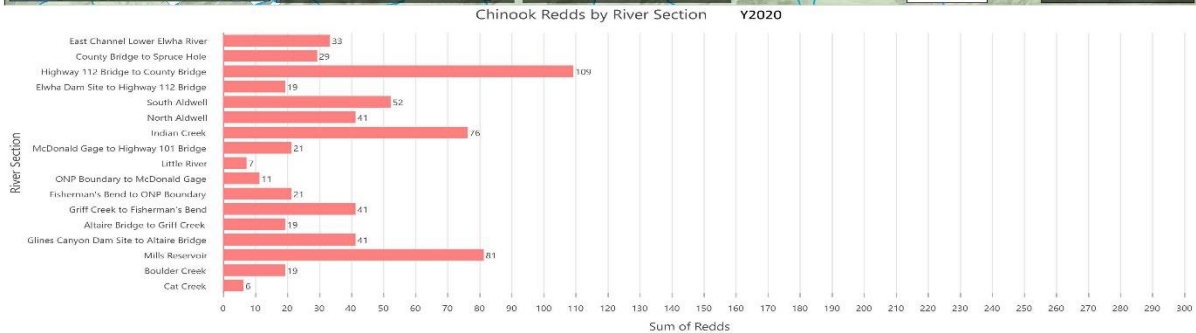
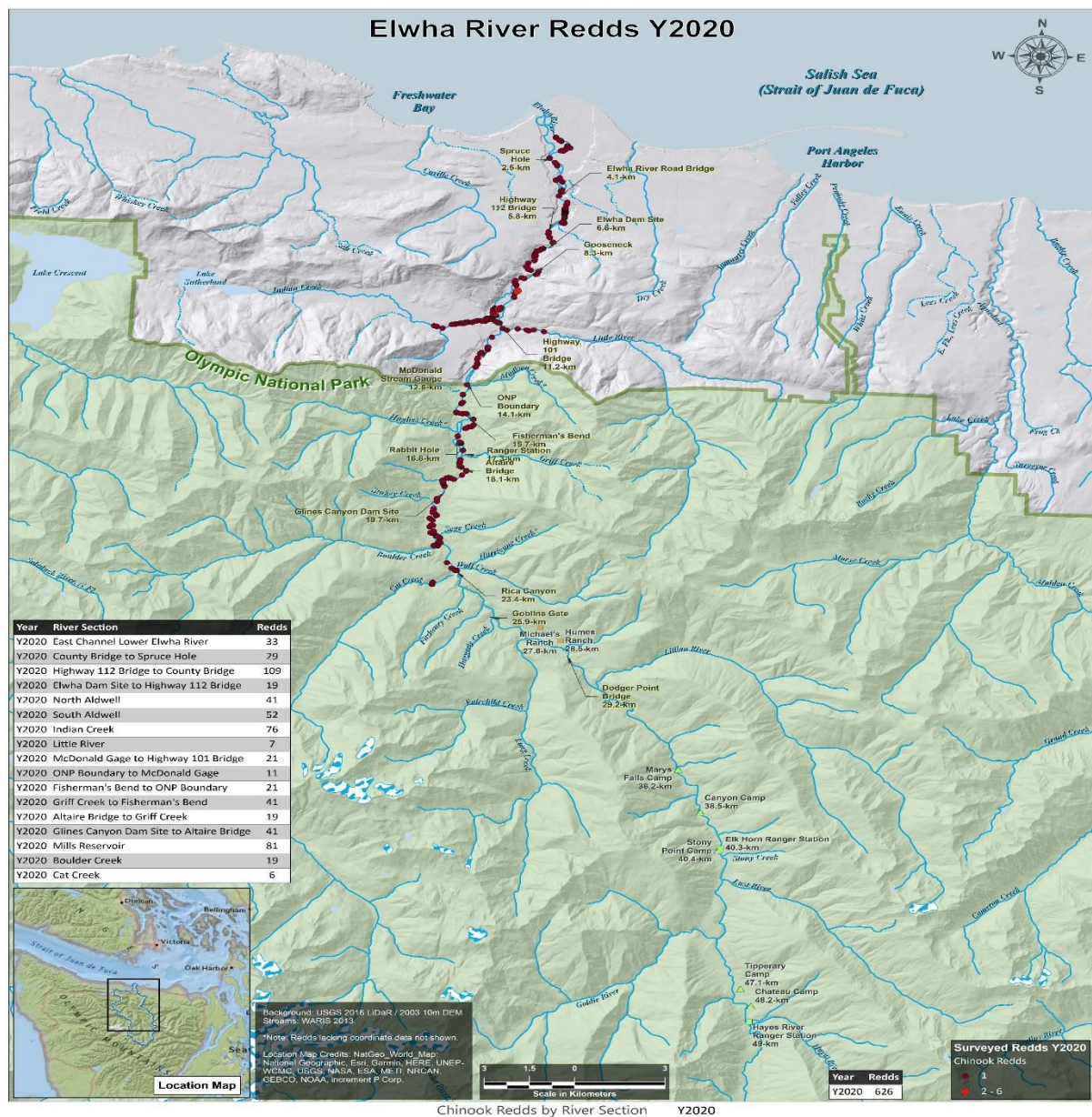


Figure 11. Distribution of Chinook redds in the Elwha River during 2020.



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File: ChinookRedds.aprx

Figure 12. Distribution of Chinook redds in the Elwha River during 2021.

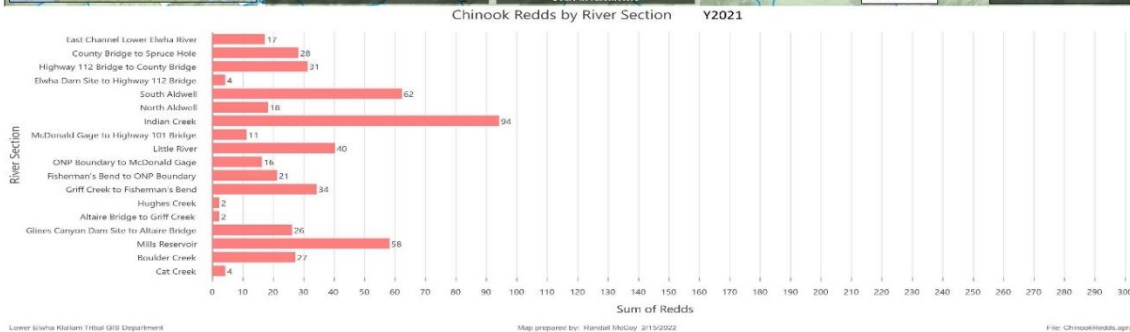
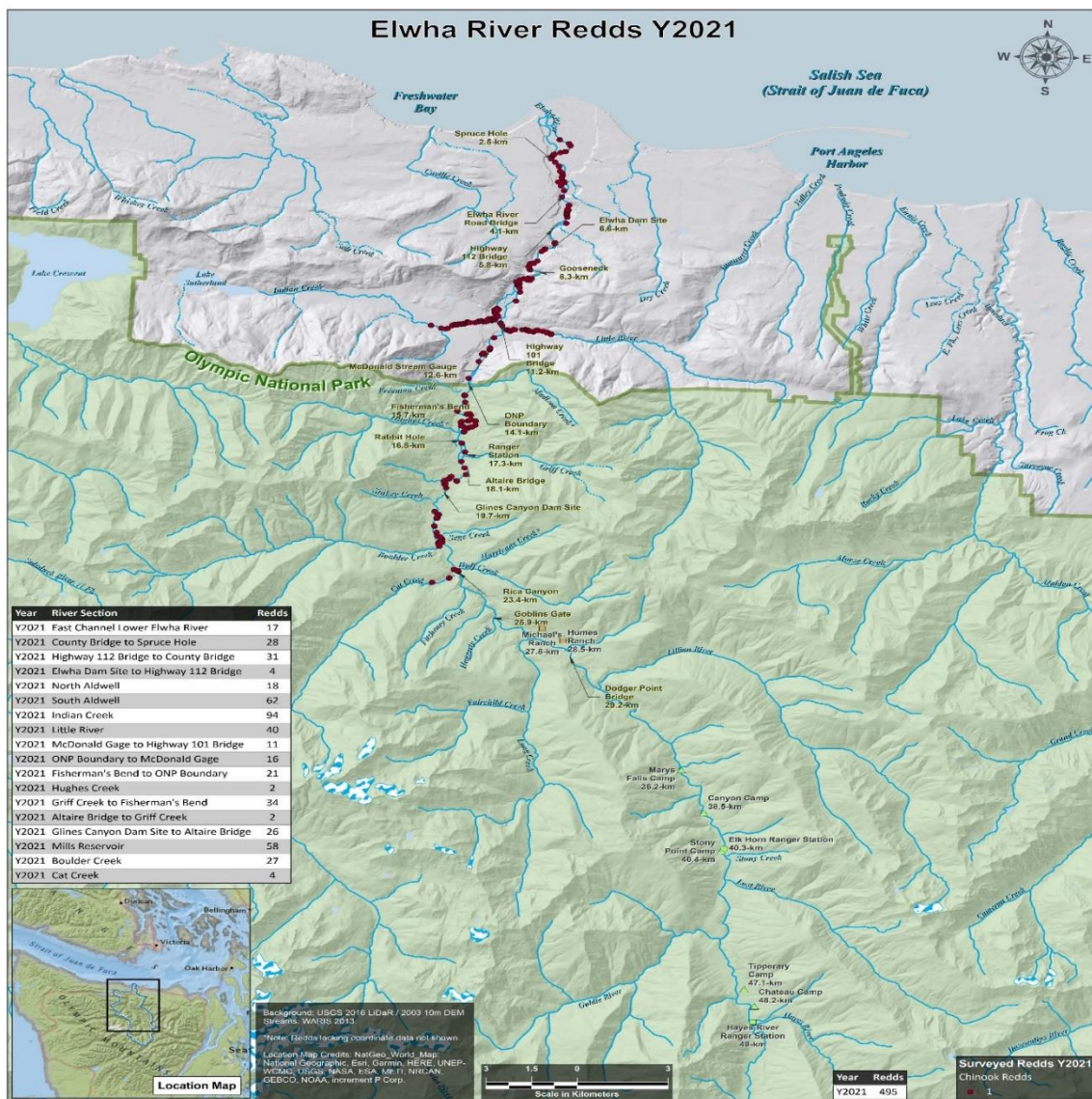


Figure 13. Density of Chinook salmon redds from river kilometer (RKM) 0.0 to 30.0 on the Elwha River 2012 to 2021. Open circles are the mean across years while solid lines with perpendicular bars are the standard errors.

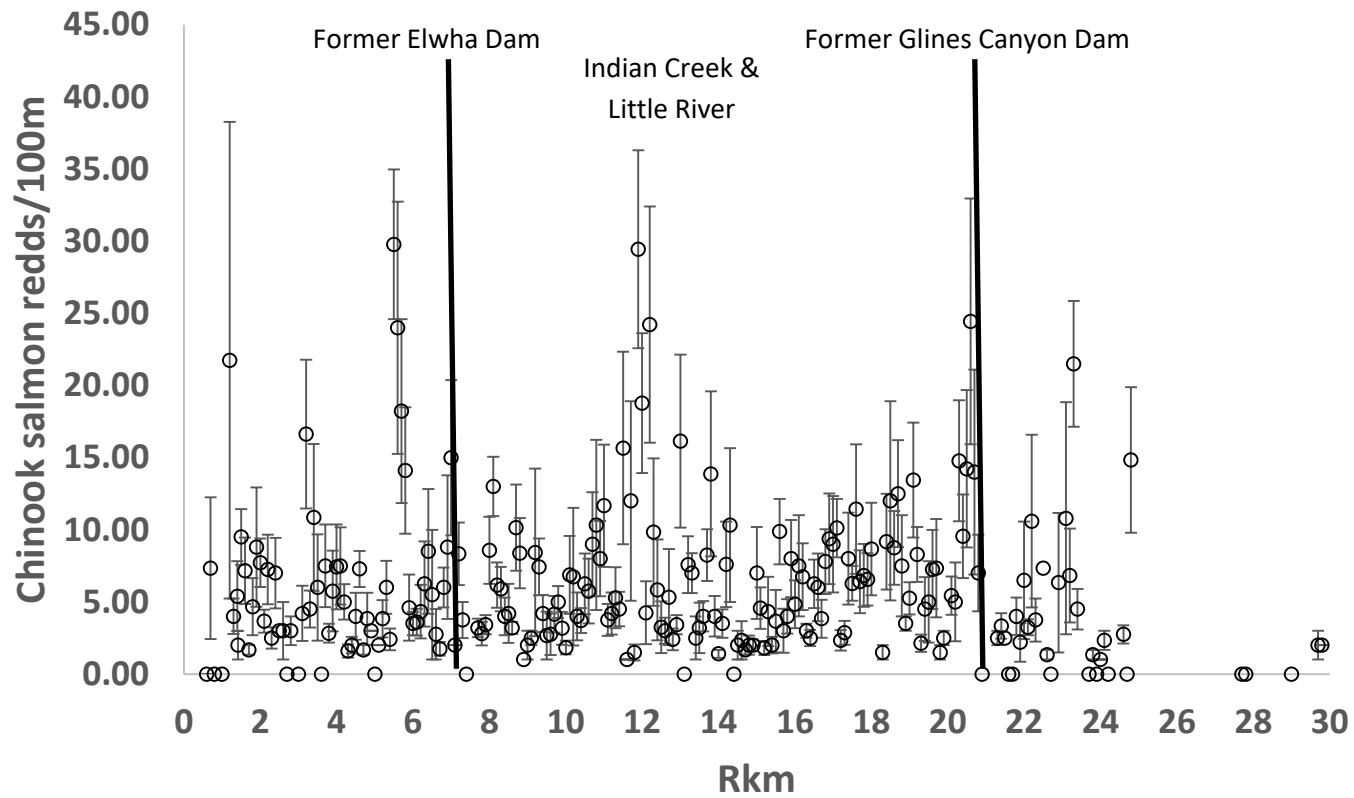


Figure 14. Chinook salmon redd occupancy by year. Chinook salmon redd location was identified to the nearest tenth of a Rkm surveyed from 2012 to 2021 to estimate the total percent linear occupancy for the lower, middle and upper Elwha River.

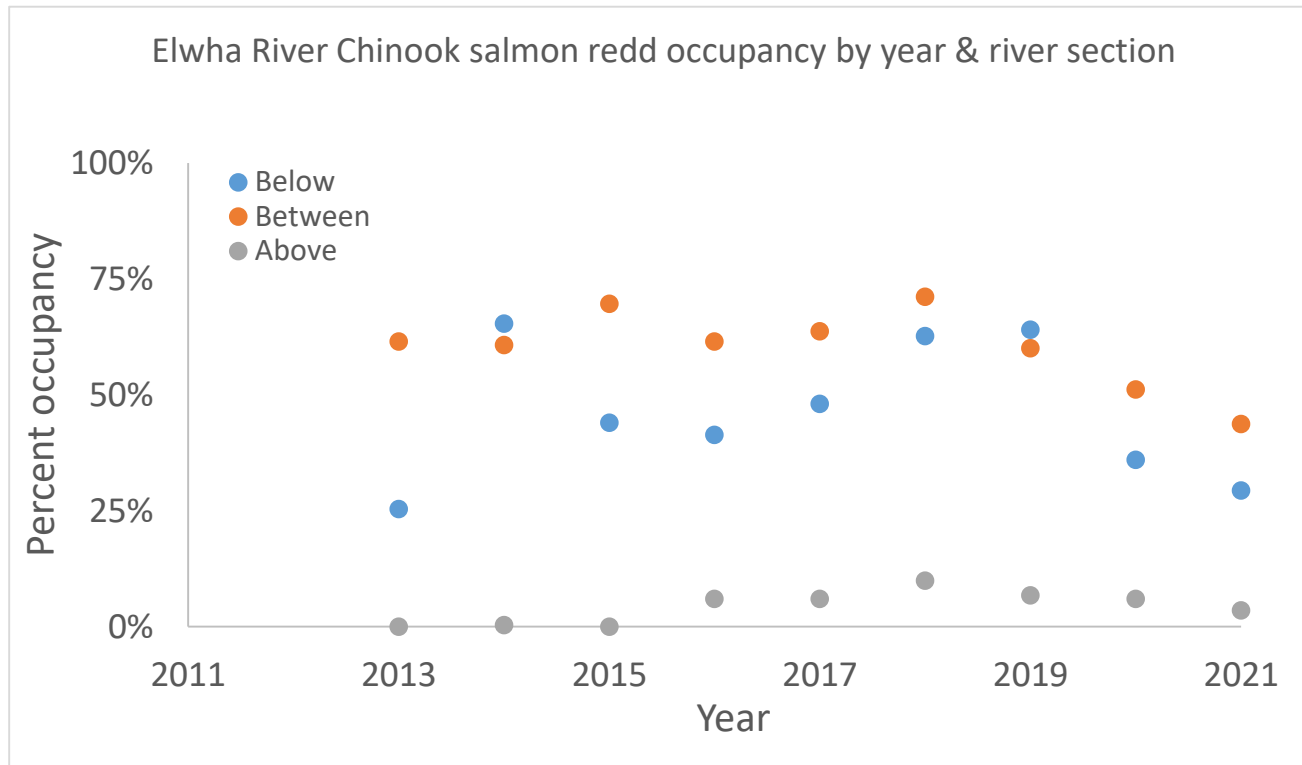


Figure 15. Historical escapement of Chinook salmon to the Elwha River 1984-2021 (from Denton et al 2022). Estimates were made by river surveys from 1984-2010. Estimates from 2010-2021 were made using SONAR cameras.

