

Spawning distribution of Chinook Salmon (*Oncorhynchus tshawytscha*) in the Elwha River, Washington State during dam removal (2012-2015)



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Executive Summary

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

In 2012, 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 major portion of Chinook salmon redds (48%) observed in the two clearwater tributaries: Indian Creek and Little River. The former Aldwell Reservoir (Rkm 7.9-12.4) and the mainstem Middle Elwha from Rkm 17.2-18.1 accounted for 15% and 16% of the redd locations in 2012, respectively.

In 2013, based on SONAR estimates (Denton et al. 2014), the total escapement of Chinook salmon (4,243 adults) approximately doubled over its long term 20 year average. This doubling resulted in observations of Chinook salmon spawning in all habitats, including the Middle Elwha. In 2013, a total of 765 Chinook Salmon redds and 1,741 adults (live and dead) were observed during the peak of spawning with the majority of redds (73%) above the former Elwha Dam. The vast majority (85%) of all Chinook salmon redds observed in the Middle Elwha in 2013 were in the mainstem. Of those, 164 Chinook salmon redds were located in the 1.1 km immediately below the former Glines Canyon Dam site.

In 2014, based on SONAR estimates (Denton et al. 2015), the total escapement of Chinook salmon was 4,112. A total of 1,310 Chinook salmon redds (1,744 adults) were observed and 62% of those redds were above the former Elwha Dam site. Over 95% of those Chinook salmon redds were observed in the mainstem Middle Elwha River rather than the tributaries. A high number (241) of Chinook salmon redds were again observed immediately downstream of the former Glines Canyon Dam. A total of 4 adult Chinook salmon and 3 Chinook salmon redds were observed immediately upstream of Glines Canyon Dam in 2014. The distribution of Chinook

salmon redds in the Middle Elwha suggest that mainstem spawning habitat, and to a lesser extent tributary habitat, in the Elwha River is being colonized by Chinook salmon.

In 2015, a total of 937 Chinook salmon redds and 753 adults (366 live/387 dead) were observed and 77% of those redds were located above the former Elwha Dam site. Over 95% of those Chinook salmon redds were observed in mainstem Middle Elwha River habitats rather than the tributaries. A high number (100) of Chinook salmon redds were again observed immediately downstream of the former Glines Canyon Dam. Neither adult Chinook salmon nor Chinook salmon redds were observed immediately upstream of Glines Canyon Dam in 2015. Large boulders originating from Glines Canyon fell into the channel shortly after dam removal was completed in 2014. These boulders created a vertical drop of 12-15' through the canyon reach and were blasted in October of 2015 in an effort to improve fish passage. The blasting was too late, however, to affect passage conditions during the chinook migration period. The distribution of Chinook salmon redds in the Middle Elwha suggest that mainstem spawning habitat, and to a lesser extent tributary habitat, in the Elwha River is being colonized by Chinook salmon.

Introduction

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

To help guide this process the Elwha Monitoring and Adaptive Management (EMAM) plan was developed for federally listed populations of Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) (Peters et al. 2014). This document suggests adaptive management targets that could be used to affect management actions for the recovery of the populations. The EMAM suggests 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. 2012, 2013, and 2014). Productivity metrics are being assessed using a combination of abundance estimation by adult age class and smolt outmigration monitoring. Spatial distribution is being assessed using a combination of visual redd surveys (foot, boat, and aerial), radiotelemetry, and may include eDNA techniques (Laramie et al. 2015) in the future. For diversity, Chinook salmon monitoring efforts focus on adult migration timing (SONAR) and the expression of stream-type juvenile life-histories (adult scales and smolt trap).

Elwha River salmon populations were spatially limited to approximately 8.0 km of habitat below Elwha Dam for over a century. The removal of the Elwha and Glines Canyon dams is now allowing for the recolonization of formerly occupied habitats, however, it is uncertain how quickly recolonization and the establishment of self-sustaining spawning populations will occur. Additionally, dam removal may not necessarily recreate the exact physical habitat conditions that existed prior to dam removal and other barriers may ultimately limit the distribution of different salmonid species within the watershed. It was predicted that Chinook salmon were expected to recolonize in the Elwha up to the headwaters in the vicinity of Chicago Camp at Rkm 56.0 (Pess et al. 2008).

The spatial distribution of Chinook Salmon also potentially affects other VSP parameters such as life history diversity (Beechie et al. 2006). In the Puget Sound region, Chinook salmon populations in snowmelt-dominated areas, such as the Elwha River, typically contain a higher proportion of the stream-type life history (juvenile residence ≥ 1 year in freshwater), and have older spawners than Chinook Salmon populations in rainfall-dominated areas (Beechie et al. 2006). Furthermore, in Puget Sound, the fraction of Chinook salmon genetic differentiation that can be attributed to life history characters is relatively small, compared to the Columbia Basin (Waples 2008). This suggests a strong role for environmental conditions in stream vs ocean-type juvenile rearing strategies of Puget Sound Chinook salmon. Thus, to the extent that spawning in snowmelt dominated headwater reaches will promote stream-type life histories, allowing some portion of the extant Chinook salmon population to recolonize habitats above the dam sites on the Elwha can 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 1930 and maintained to the present (Ward et al. 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 2010-2013, > 90% of Chinook salmon returning to the Elwha River basin were considered of hatchery origin (Anderson et al. in press). EMAM (Peters et al. 2014) has established a goal of 100% natural origin spawners for a self-sustaining population of Elwha River Chinook salmon.

Dam removal was initiated in the fall of 2011 and by the spring of 2012, Elwha Dam had been removed. Glines Canyon Dam was removed by August 26th, 2014 and the first Chinook Salmon above the Glines Canyon Dam site was reported approximately 10 days later on September 9th, 2014. Several weeks later in the fall of 2014 large boulders fell from the canyon walls and created vertical drops of 12-15' through the entrance to Glines Canyon. It was feared these boulders created blockages to upstream migrating salmon.

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. In 2014 and 2015 additional surveys were conducted upstream of Glines Canyon Dam in order to ascertain chinook passage.

This report summarizes those survey efforts as our objectives were to; 1) map the distribution of Chinook salmon redds, 2) calculate the density of redds by Rkm, and compare the relative distribution of spawning within and between years.

Methods

One day to five day spawning ground surveys of the mainstem Elwha River, larger floodplain channels, and several major tributaries were conducted in mid-September of 2012, 2013, 2014 and 2015 (Figure 1). Five days were needed in 2012 due to flow and turbidity related issues, while only one day (September 17th) was used in 2013 and 2014 based on the estimated historical date of peak spawning activity for Elwha River Chinook salmon (WDFW Unpublished Data). The Elwha River was divided into two sections in 2012 and 2013 and three sections in 2014 and 2015. The Lower Elwha (LE) was defined as the area downstream of Elwha Dam (Rkm 0.0-7.9), while the Middle Elwha (ME) includes the reach immediately above the former Elwha Dam, including the former Aldwell Reservoir, upstream to the former Glines Canyon Dam (Rkm 7.9-21.7). An additional section was added in 2014, the Upper Elwha (UE), which is defined as the reach above Glines Canyon Dam upstream to entrance to the Grand Canyon of the Elwha (Rkm – 21.7 – 31.4) and includes the former Mills Reservoir (Figure 1). The LE and ME were surveyed in all years, while the UE was only surveyed in 2014 and 2015.

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

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

Flow levels, turbidity, and suspended sediment concentration levels varied each year (Table 3). Both flow and turbidity levels were highest in 2012 which limited surveys to above the Elwha

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

Results

The total number of observed Chinook salmon redds increased between 2012 and 2014 from 217 to over 1,300 redds (Figure 2). In 2015 the number of redds decreased by 28% from 2014 (937). In all years the majority of these Chinook salmon redds were located in the area above the former Elwha dam (Rkm 7.5) and just below the former Glines Canyon dam (Rkm 21.1) (Figure 2 & 7). It is important to note that visibility was poor during September of 2012 thus the number of redds below the former Elwha dam in 2012 is likely an under-estimate. Abundance estimates derived from SONAR indicated that Chinook salmon were less numerous in 2012 (estimate = 2,638) than either 2013 (estimate = 4,243), 2014 (estimate = 4,360), or 2015 (estimate = 4,112) (Denton and Liermann 2013, Denton et al. 2014, 2015, 2016).

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

In 2013, additional survey reaches were added in the LE due to greater visibility (Figure 4, Table 5). A total of 765 chinook redds were identified, 79% of which were observed above the former Elwha Dam location (Table 4). The distribution of mainstem vs. tributaries changed in 2013, with the vast majority of Chinook salmon redds (85%) being identified in the mainstem and 15% being identified in Little River, Indian Creek, and Hughes Creek (Figure 4, Table 5). 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 5). 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 4). The section that had the second highest number of Chinook salmon redds recorded in the survey was immediately below the former Elwha dam site downstream to the weir at Rkm 5.5 (Figure 4, Table 5).

In 2014, visibility was excellent and survey reaches from the previous year were used to conduct a river wide survey (Figure 5, Table 6). A total of 1,310 Chinook salmon redds were located and identified, of which 62% (812 out of 1,310) were located in the ME, upstream of the Elwha Dam and below the former Glines Canyon Dam (Figure 5, Table 5). The distribution of mainstem vs. tributaries changed again in 2014 relative to the two previous years, with 95% of the Chinook salmon redds above the dam sites were located in the main stem ME, while only 5% were identified in Little River, Indian Creek, and Hughes Creek (Figure 5, Table 6). Only one redd was observed in Little River. The low number was likely a result of low attraction flows, as the mouth of Little River joined the Elwha River across a broad gravel bar that had flow only several centimeters deep. Over one quarter of the Chinook salmon redds (30%, 241 out of 812) were located in the 1.1 km immediately below Glines Canyon Dam in 2013, while over 60% (61%, 496 out of 812) of the Chinook salmon redds were located within 5.0 km downstream of the Glines Canyon Dam site (Figure 5, Table 6).

Glines Canyon Dam was still being removed in 2014, a process that was not complete until August 26th. However, it should be noted that small numbers of Chinook salmon were observed above Glines Canyon in 2014. During the first week of September, Mel Elofson, a member and employee of the Lower Elwha Klallam Tribe, reported seeing a Chinook salmon just above the Glines Canyon site. On September 9, ONP staff snorkeled from Rica Canyon downstream to the Glines Canyon Dam and visually identified 3 adult Chinook salmon (Personal Communication, Anna Geffre and Heidi Huginin, ONP). A subsequent redd survey on September 22 identified 3 Chinook salmon redds of which 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 in the vicinity of Elkhorn Ranger Station (Rkm 40.2).

In 2014, below the former Elwha dam site, Chinook salmon spawning activity was continuous and documented in all reaches (Table 6). This contrasted with 2012 and 2013, when at least four reaches had been surveyed without any redd observations. Over 35% (38%, 499 out of 1310) of all Chinook salmon redds observed in 2014 were found below the former Elwha dam

site, making it the highest number and percentage of Chinook salmon redds below the dam since pre dam removal (Table 6, Figure 5).

In 2015, visibility was again excellent and survey reaches from the previous year were used to conduct a river wide survey (Figure 6, Table 7). We counted 366 live and 387 dead chinook adults of which 82% and 94% were located upstream of the former Elwha Dam site. A total of 937 Chinook salmon redds were located and identified, of which 77% (719 out of 937) were located in the ME, upstream of the Elwha Dam and below the former Glines Canyon Dam (Figure 6, Table 7). The distribution of mainstem vs. tributaries changed again in 2015 relative to the three previous years, with 90% of the Chinook salmon redds above the former Elwha dam were located in the main stem ME, while only 10% were identified in Little River, Indian Creek, and Hughes Creek (Figure 6, Table 7). Over one tenth of the Chinook salmon redds (10%, 100 out of 937) were located in the 1.1 km immediately below Glines Canyon Dam in 2013, while over a quarter (26%, 246 out of 937) of the Chinook salmon redds were located within 5.0 km downstream of the Glines Canyon Dam site (Figure 6, Table 7).

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% (provide ratio XX/XX) 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.

Discussion

We conducted annual peak spawner ground surveys for Elwha River Chinook salmon during dam decommissioning from 2012 to 2015. These surveys were designed to provide information on the spatial distribution of Chinook salmon spawning nest locations as access to historic habitats was being restored. The surveys were not intended nor designed to enumerate the total number of Chinook salmon returning to the Elwha River.

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

The distribution of Chinook salmon redds was much more extensive in 2013 (Figure 4), as redds were observed in each reach above the former Elwha dam site, and the density in each reach was similar or higher than in 2012 (Table 3). Unlike 2012, the vast majority of Chinook salmon redds were in the mainstem ME rather than the tributaries. This difference in distribution was hypothesized to occur for three primary reasons. First, turbidity levels in the mainstem ME were lower in 2013 than 2012 (Table 2). Second, connectivity between Little River, Indian Creek, and the mainstem ME was reduced in 2013 due to the development of mainstem gravel bars at the confluence of each tributary. Lastly and most importantly, between September 2012 and September 2013, there was a large increase in the source, amount, and type of sediment released from the former Mills reservoir (Warrick et al. 2015), a process that increased the quantity and quality of Chinook salmon spawning habitat in the mainstem ME.

In 2012, the mainstem ME did not markedly change in terms of sediment load and channel characteristics because the majority of sediment released by October of 2012 came from the former Elwha dam site (Warrick et al. 2015). Thus, the major changes in 2012 occurred below former Elwha dam and in the LE (East et al. 2015). However, between October of 2012 and September of 2013 large scale geomorphic changes occurred in the ME due to the substantial increase in sediment flux from the former Lake Mills delta, which was fully prograded to Glines Canyon and released ~ 8.9 million tons of sediment (Warrick et al. 2015). During that time period, the entire river aggraded due to an order of magnitude increase in bedload material (Warrick et al. 2015). The bedload increase resulted in an increase riffle crest and channel thalweg elevation and bar formation. Substrate size in the ME also decreased 16 fold due to the influx of sand and gravel, and the density of main stem channels increased (East et al. 2015). Prior to dam removal, the ME was characterized by cobble and boulder sized substrates greater than 64 mm (East et al. 2015), and so the reduction in substrate size may have provided a particularly large benefit to Chinook salmon spawning habitat quality. Much of this change occurred within the first 5 km downstream of the former Glines Canyon dam site (Figure 5), an area of high spawning density in 2013 and 2014 (Tables 4 and 5) (Figure 2).

The 2014 and 2015 Chinook salmon spawner surveys represents the most complete survey effort coupled with the lower flows and lowest turbidity levels (Table 5, Figure 5). The number of Chinook salmon redds increased as did the Chinook salmon redd density, while the relative distribution was similar. Glines Canyon Dam was in the final stages of removal during the bulk of the Chinook salmon migration, a process that was not complete until August 26th. The first Chinook salmon were observed in the former Mills Reservoir only 10 days after dam removal was completed and at least 3 redds were observed by ONP and LEKT employees. Chinook migration above Glines Canyon was prevented in 2015 as a result of a rock fall shortly following dam removal in 2014. This blockage was subsequently blasted in the fall of 2015, but too late to allow upstream migration in 2015. Continued monitoring of Chinook salmon spawner distribution will be important to assess long term passage through Glines Canyon in 2016.

The rather continuous distribution of Chinook salmon redds observed in 2013, 2014, and 2015 (Figure 7) is likely due to the combination of relatively high abundance of spawners and an increase in the quantity and quality spawning habitat. Visual observations made by spawning ground surveyors indicated that the mainstem spawning habitat in 2013-2015 was largely dominated by well sorted gravel deposits with minimal fine sediment. In contrast many of the mainstem side-channels have large deposits of fine sediment on their channel beds (Pess et al. 2015). The post-dam removal Elwha River continues to be an active channel characterized by dynamic changes. Monitoring of surface and subsurface sediment at riffle crests downstream of Glines Canyon Dam to the mouth of the Elwha River has been conducted in concert with the Chinook spawning ground surveys. In addition to documenting geomorphic changes, we expect that the sediment monitoring will help us better understand the linkages between spawning habitat and the distribution of Chinook salmon redds.

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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.
- Denton, K., McHenry, M., Moses, R., Ward, E., Liermann, M., Stefanik, 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., Stefanik, 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.
- 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. <http://dx.doi.org/10.1016/j.geomorph.2014.08.028>.
- 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.

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.

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.

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*.

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

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

Table 4. 2012 Elwha River Chinook salmon spawners from Glines Canyon Dam to the mouth. NS = Not Surveyed.

Survey Reach	Rkm midpoint	Redds	Redds/km	Male	Female	Unknown	Dead	Jacks
Above Glines	21.5	NS	NS	NS	NS	NS	NS	NS
Middle Elwha								
Glines Powerhouse	20.6	6	5.5	0	0	23	1	1
Altaire Canyon	19.8	NS	NS	NS	NS	NS	NS	NS
Altaire Bridge	19.4	0	0.0	2	3	3	1	1
Griff Creek	18.5	8	8.0	0	0	0	1	0
Hughes Creek	17.7	NS	NS	NS	NS	NS	NS	NS
Rabbit Hole	17.3	33	22.0	7	1	102	18	1
Fishermans Corner	16.1	0	0.0	0	0	0	0	0
Park Boundary	14.7	0	0.0	0	0	0	0	0
McDonald Bridge	13.1	2	1.7	0	0	0	1	0
A-Frame	12.3	0	0.0	0	0	0	0	0
Little River	12.2	40	21.1	28	16	0	18	8
Indian Creek	12.1	58	30.5	29	28	0	27	14
101 Bridge	12.0	10	33.3	0	0	6	0	0
Boat launch	11.6	1	2.5	0	0	3	2	0
Oxbow Reach	11.3	30	100.0	0	0	31	5	0
Oxbow Reach2	10.5	15	11.5	0	0	5	8	0
Gooseneck	8.7	0	0.0	0	0	0	0	0
ME Subtotal		203	11.0	66	48	173	82	25
Lower Elwha¹								
Dam outflow	7.1	0	0.0	0	0	0	0	0
Hwy 112 bridge	6.1	0	0.0	0	0	0	0	0
Weir	5.2	4	5.7	0	0	0	2	0
New bridge	4.4	4	4.4	0	0	0	0	0
Sisson's riffle1	3.6	4	6.7	0	0	0	0	0
Sisson's riffle2	3.1	2	4.0	0	0	0	0	0
Right bank channel	2.0	0	0.0	NS	NS	NS	NS	NS
Hunt's Road channel	2.0	0	0.0	NS	NS	NS	NS	NS
Elwha bluff to mouth	0.6	0	0.0	NS	NS	NS	NS	NS
LE Subtotal		14	1.5	0	0	0	2	0

¹ 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 5. 2013 Elwha River Chinook salmon spawners from Glines Canyon Dam to the mouth. NS = Not Surveyed.

Survey Reach	Rkm midpoint	Redds	Redds/km	Male	Female	Unknown	Dead	Jacks
Above Glines	21.5	NS	NS	NS	NS	NS	NS	NS
Middle Elwha								
Glines Powerhouse	20.6	162	147.3	132	103	60	77	2
Altaire Canyon	19.8	11	22.0	0	2	0	10	0
Altaire Bridge	19.4	42	52.5	11	14	25	30	0
Griff Creek	18.5	73	73.0	30	18	22	51	1
Hughes Creek	17.7	8	11.4	6	7	0	39	1
Rabbit Hole	17.3	59	39.3	8	19	14	32	0
Fishermans Corner	16.1	13	16.3	7	3	23	33	0
Park Boundary	14.7	45	22.5	4	0	108	47	4
McDonald Bridge	13.1	8	6.7	1	3	6	35	0
A-Frame	12.3	16	40.0	0	0	13	6	0
Little River	12.2	23	12.1	23	12	0	9	0
Indian Creek	12.1	58	30.5	43	19	0	64	5
101 Bridge	12.0	68	29.6	19	19	24	20	0
Boat launch	11.6							
Oxbow Reach	11.3							
Oxbow Reach2	10.5							
Gooseneck	8.7	16	7.0	12	6	20	7	0
ME Subtotal		602	32.7	296	225	315	460	13
Lower Elwha²								
Dam outflow	7.1	51	63.8	0	0	81	16	0
Hwy 112 bridge	6.1	100	83.3	0	0	251	25	0
Weir	5.2	9	12.9	0	0	13	20	0
New bridge	4.4	3	3.3	0	0	0	0	0
Sisson's riffle1	3.6	0	0.0	0	0	13	0	0
Right bank channel	2.0	0	0.0	0	0	23	1	0
Hunt's Road channel	2.0	NS	NS	NS	NS	NS	NS	NS
Elwha bluff to mouth	0.6	0	0.0	0	0	0	0	0
LE Subtotal		163	19.0	0	0	381	62	0

² 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 6. 2014 Elwha River Chinook salmon spawners from Glines Canyon Dam to the mouth. NA = Not Applicable.

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

Table 7. 2015 Elwha River Chinook salmon spawners from Glines Canyon Dam to the mouth.
NA = Not Applicable.

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

Figures

Figure 1. The Elwha River watershed

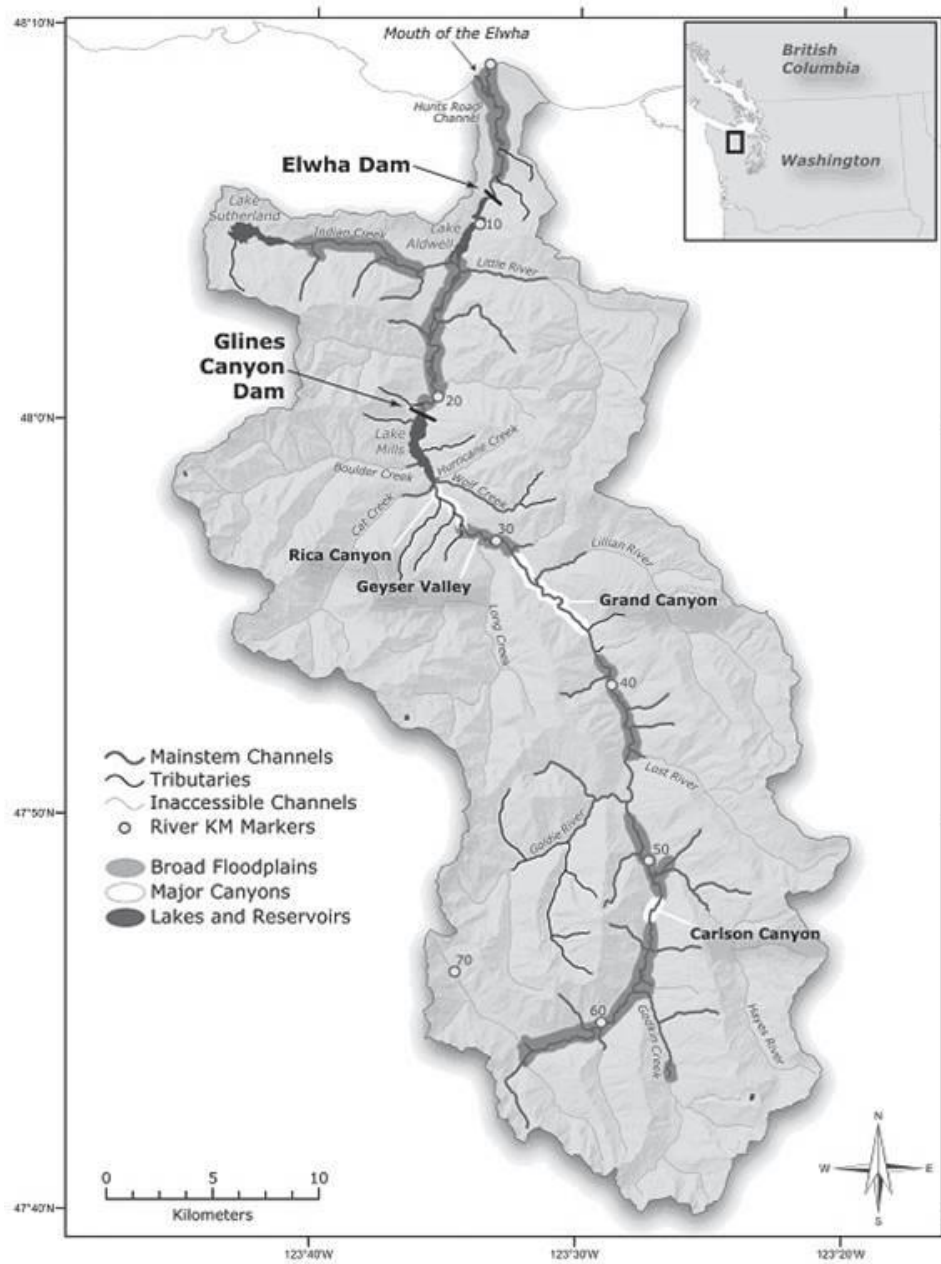


Figure 2. Total number of Chinook salmon redds between former Elwha dam and Glines Canyon dam 2012 to 2015. Black bars indicate the number of chinook redds below Elwha Dam. Grey bars indicate the number of chinook redds above Elwha Dam.

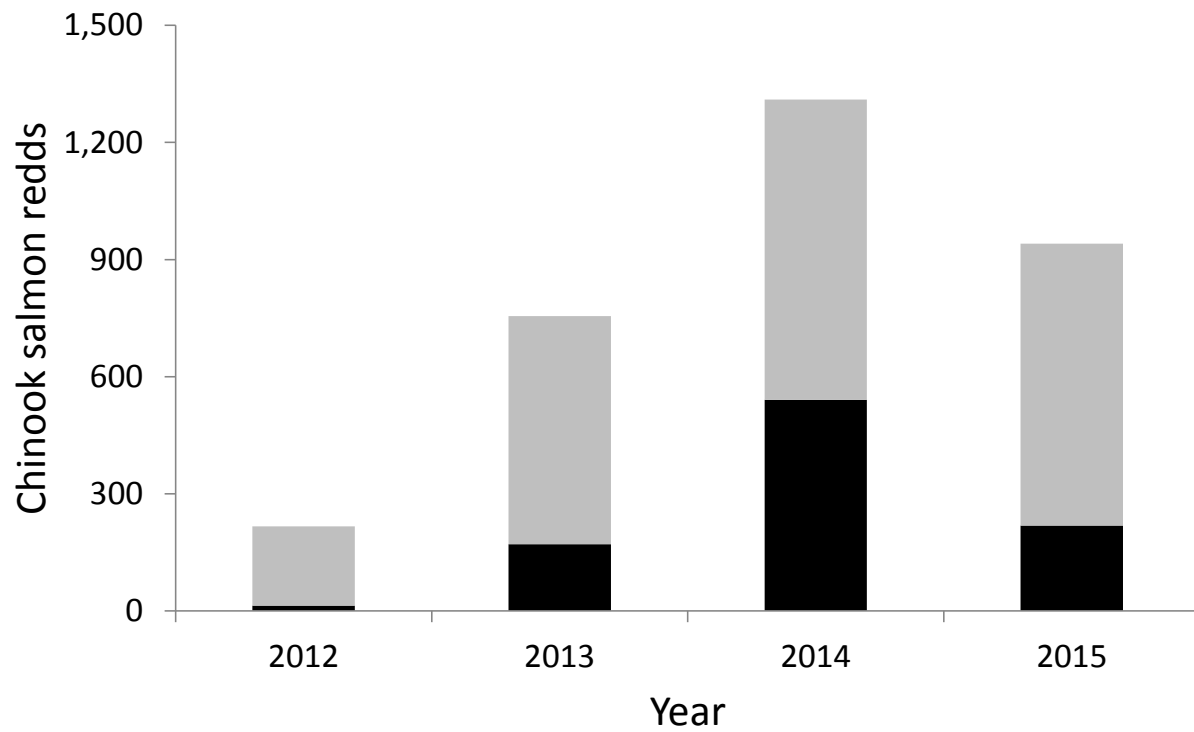


Figure 3. Distribution of Chinook salmon redds in the Elwha River during 2012. Note that the lower Elwha (below Elwha Dam site) was not surveyable due to dam decommissioning.

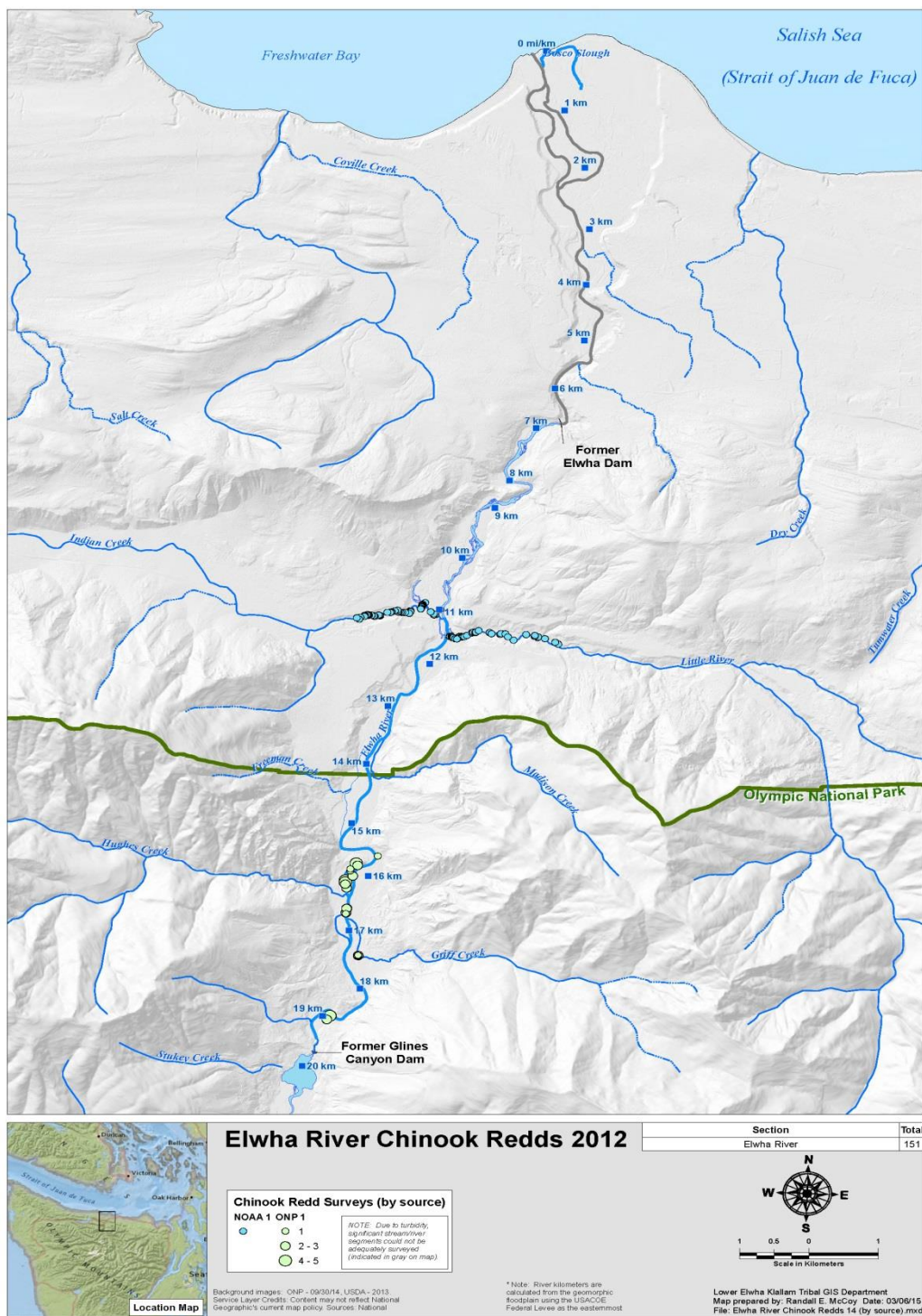


Figure 4. Distribution of Chinook salmon redds in the Elwha River during 2013. Note that the lower Elwha (below Elwha Dam site) only partially surveyable due to dam decommissioning.

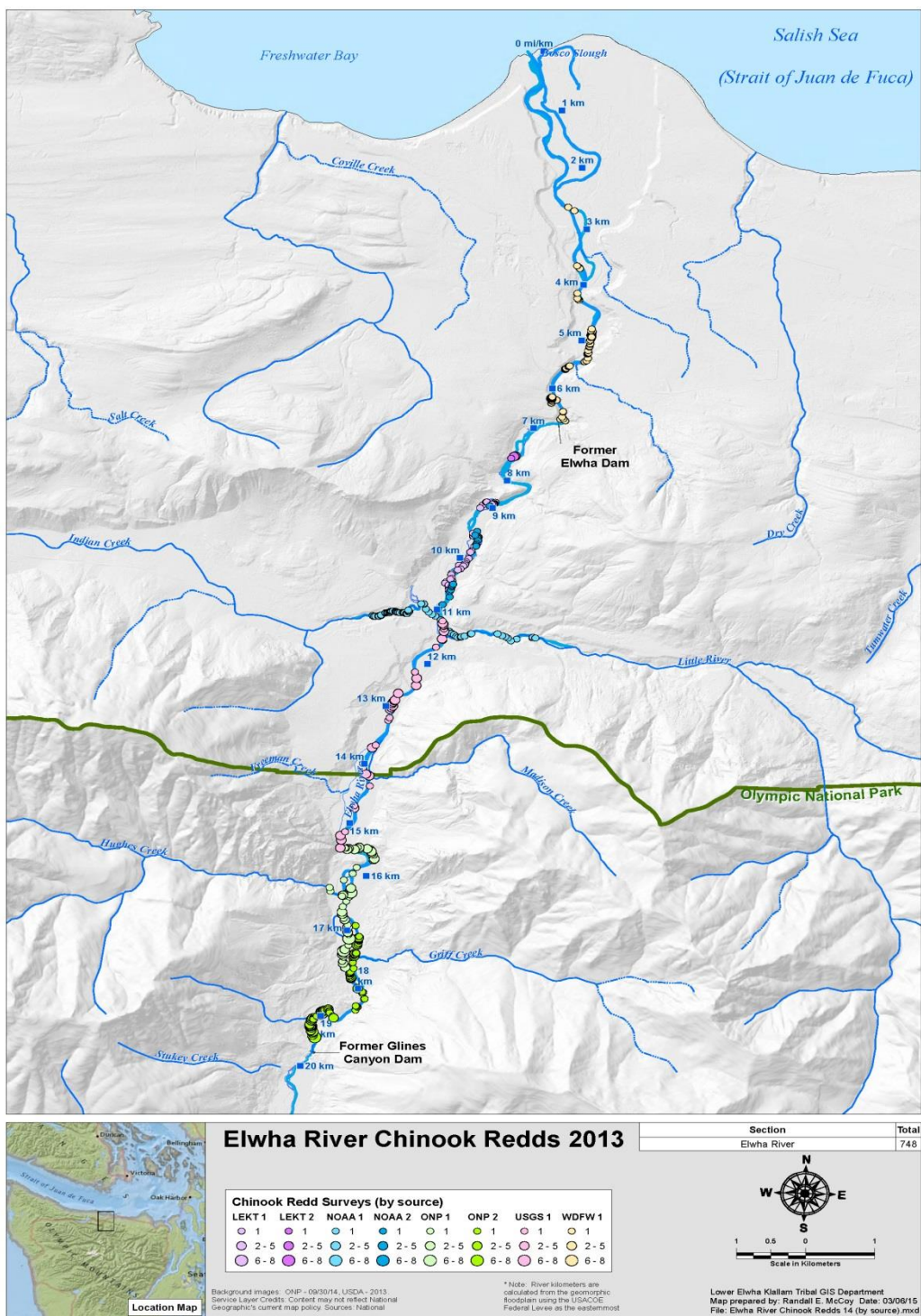


Figure 5. Distribution of Chinook salmon redds in the Elwha River during 2014. Survey conditions were good throughout.

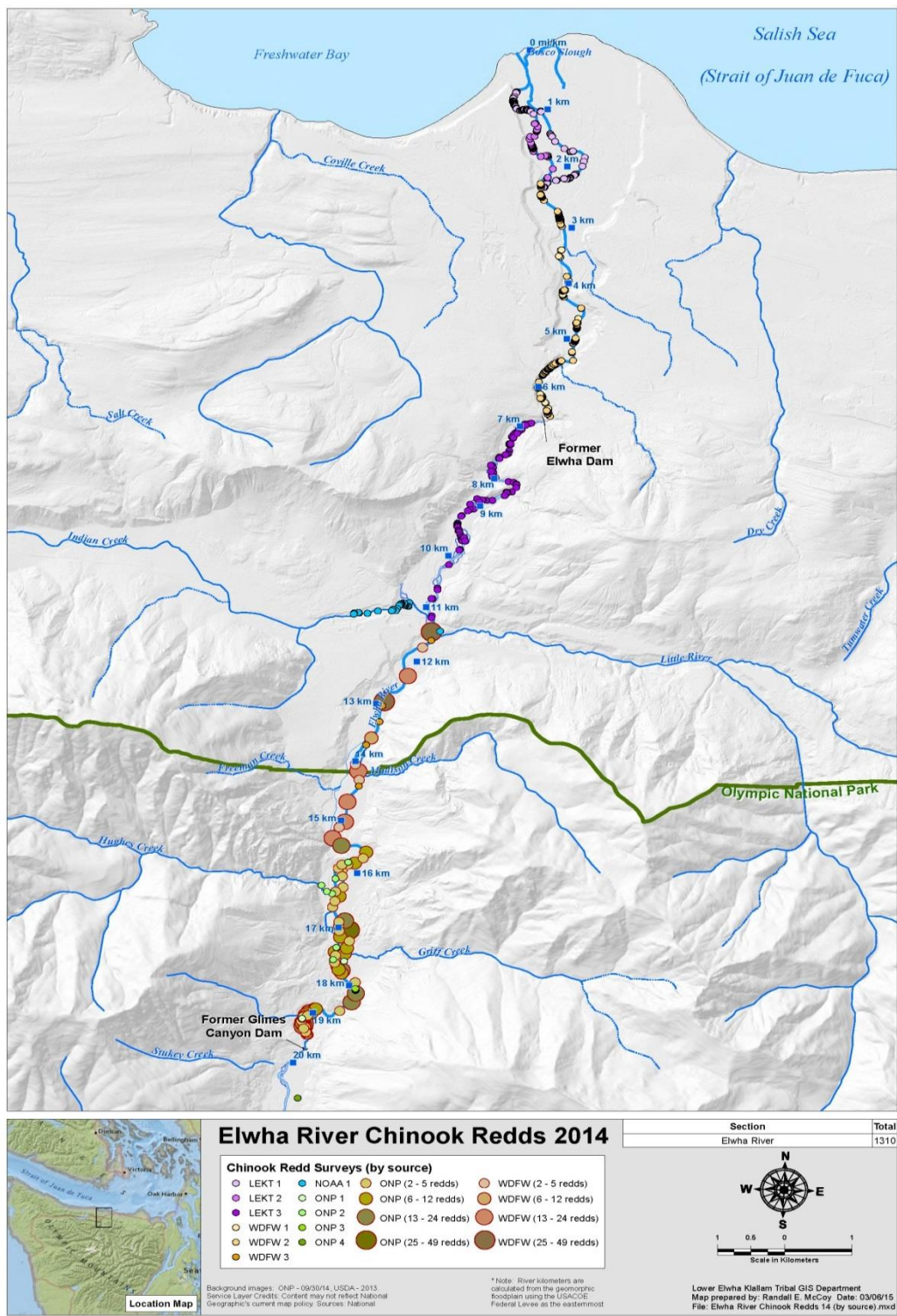


Figure 6. Distribution of Chinook salmon redds in the Elwha River during 2015. Survey conditions were good throughout reach.

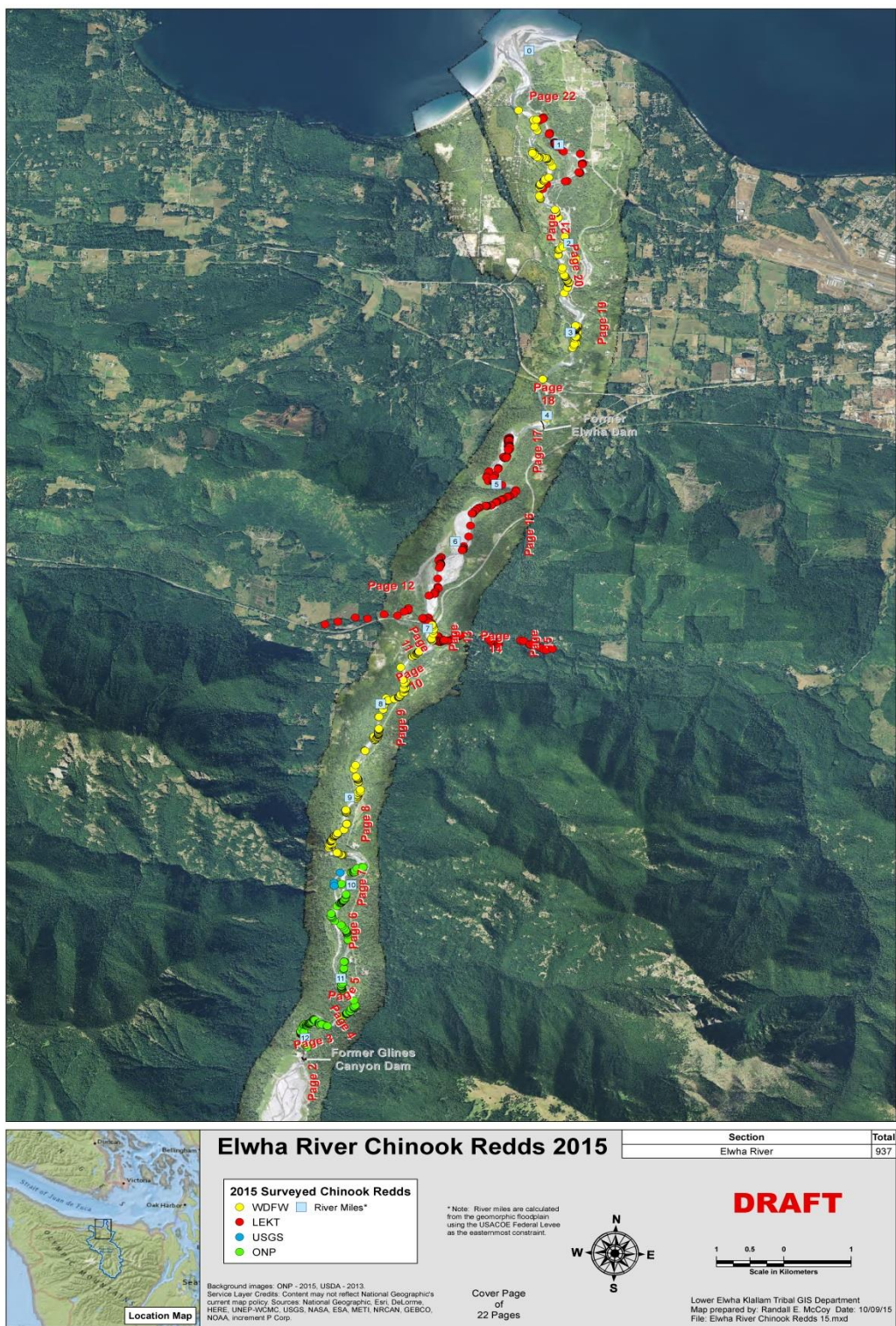


Figure 7. Density of Chinook salmon redds by river kilometer on the Elwha River 2012 to 2015. Solid diamonds are the mean, while solid lines with perpendicular bars are the standard errors. Former Elwha dam is at 8 Rkm and Former Glines Canyon dam is at 21.5 Rkm.

