

Summary of 2018 winter steelhead (*Oncorhynchus mykiss*) surveys in the Elwha River

**A report submitted by the Lower Elwha Klallam
Natural Resources Department to the Olympic National Park
Contract number: 140P2018C0042
Task 6 (3)**

January 30, 2019



John R. McMillan, Trout Unlimited
Ray Moses, Lower Elwha Klallam Tribe (LEKT)
Mike McHenry (LEKT)
George Pess, NOAA/NWFSC
Martin Liermann, NOAA/NWFSC

Summary

2018 represents the seventh consecutive year of steelhead redd surveys in the Elwha River as part of the Elwha River Restoration Project. Consistent with previous years, we used data from an extensive series of redd surveys to characterize ongoing recolonization of adult steelhead into habitats formerly blocked by two impassable dams. Survey results from 2018 are significant in that it was the second consecutive year in which no adult steelhead were relocated from downstream hatcheries and all observations of redds were the result of volitional migration. Based on these data we report several important preliminary findings. First, we counted 239 total redds, which accounts for approximately 26%-29% of the total estimated run size of winter steelhead in 2018. Second, a substantial number of steelhead continue to volitionally colonize and spawn in several tributaries above the former Elwha Dam site. Third, more steelhead were observed spawning in the Upper Elwha (above the former Glines Canyon Dam site) than in any previous year. Fourth, the spatial distribution of redds continued to increase in the upper reach of Little River. The combined patterns suggest that the spatial distribution of spawning winter steelhead is likely to expand as riverine conditions continue to improve and the abundance of steelhead increases. The results of this year's survey effort strongly suggest the need to further expand survey effort in the upper Elwha in future years.

Introduction

Visual surveys of salmonid nests (hereafter "redds") and observations of spawning adults can be used to characterize features such as the spatial and temporal distribution of breeding activity (Gallagher et al. 2007) and the presence of alternative life histories including summer entry timing and half-pounders (McMillan et al. 2007). The overall purpose of our monitoring effort with respect to spawning steelhead (*Oncorhynchus mykiss*) in the Elwha River Basin is to document the spatial distribution of spawning steelhead as they regain access to their historic habitats in the Elwha River.

As part of the Elwha River Ecosystem and Fisheries Restoration Act, biologists with the Lower Elwha Klallam Tribe (LEKT), the National Oceanic and Atmospheric Administration – Northwest Fisheries Science Center (NOAA-NWFSC), Olympic National Park (ONP), United States Geological Survey (USGS), and Trout Unlimited (TU) have conducted systematic foot surveys to enumerate steelhead redds and estimate spawn timing and spatial distribution in several tributaries and conducted opportunistic surveys, as visibility allows, in the mainstem Elwha River from the river mouth upstream, beyond the former Glines Canyon Dam to the Dodger Point Bridge (Figure 1). Annual winter steelhead surveys began in 2012 following the removal of Elwha Dam. These surveys were further expanded above Glines Canyon Dam following its removal in 2014, but have, to date, been limited to the river mouth

upstream to the Dodger Pt. Bridge (Rkm 0-29.2). Since the inception of the project, a portion of the adult winter steelhead, which returned to the hatchery facilities have been relocated above the former Elwha Dam to two tributaries, Little River and Indian Creek. Adult steelhead relocation occurred as a requirement of the NMFS Biological Opinion for the Elwha Project (2012) to avoid potential negative impacts from high sediment levels during dam removal. Adult steelhead were not relocated in 2017 or 2018, as suspended sediment loads in the river no longer threatened the viability of the naturally spawning population, and adults that returned to the hatchery were needed to support the supplementation program (66 in 2017 and 42 in 2018). Hence, all redd survey data in 2018 reflect those steelhead that volunteered to spawn in the tributaries and main-stem Elwha River. Those fish likely represent a mixture of natural origin fish as well as fish from the LEKT captive brood program.

In this report we: 1) identify the number of redds observed in each tributary and surveyable sections of the main-stem Elwha River; 2) identify their locations within the watershed; 3) conduct comparisons of the timing and spatial distribution of redd excavation in tributaries from 2012-2018, and; 4) examine redd density levels and occupancy at the watershed-scale. In addition, we include observation on the location and timing of Pacific Lamprey (*Entosphenus tridentatus*) spawning nests that were observed during the surveys.

Methods

Redd survey location and timing

Spawning ground surveys conducted on foot were used to determine the location and timing of adult steelhead spawning (Gallagher et al. 2007). Survey areas (with estimated percent of potential steelhead spawning habitat surveyed) included Cat Creek (100%), Long Creek (90%), Hurricane Creek (100%) and Boulder Creek (100%) in the Upper Elwha and six tributaries in the Middle Elwha: Little River (100%) and Indian Creek (25%), Griff (100%), Madison (100%), and Hughes Creeks (100%) (Figure 1 and Table 1). Limited surveys of the main stem channel were conducted in 2018 due to sustained high flow and low visibility. Those one-time surveys included the Hunt Road Channel (Rkm 1-2.5), former Aldwell Reservoir (Rkm 7-10.8), and the area upstream of the former Glines Canyon Dam to the entrance of the Grand Canyon of the Elwha (excluding Rica Canyon) (Rkm 19.7-27.5). No other surveys of the mainstem were attempted in 2018 because of flow conditions generated by a large snowpack accumulated in the winter of 2017-2018. Redd counts took place from early-February through June or early July and were conducted once every 7-14 days as survey conditions allowed. Surveys were conducted in tributaries only when the bottom was visible in the deepest pools and in the mainstem Elwha when visibility allowed.

Surveyors generally walked upstream to enumerate redds. Steelhead redds were identified by disturbed areas in the streambed where gravels were overturned and where a

clear depression and associated tailspill were identifiable (Gallagher et al. 2007). Each individual redd was geolocated (latitude and longitude) using a Garmin GPS (model *GPSmap 60CSx*) and marked with a flag that included the redd number for the individual stream, date observed, surveyor initials and the distance (m) and direction to the redd from the flag. Observations of spawning Pacific Lamprey were also made during the 2017/2018 steelhead surveys. Their nests (redds) are distinct from steelhead and are smaller, circular, and resemble a small pit lined with rocks. In 2017/2018 we decided to include our observations on spawning Pacific Lamprey. This species is also recolonizing historic habitats in the Elwha River because documenting their progression is important to the overall project.

Data were analyzed in several ways. First, redd counts were organized by date for all sites combined and by tributary to describe spawn timing as a function of Julian day. In 2018, only data from Indian Creek, Hughes Creek and Little River were used in this analysis because of the relatively low numbers of redds encountered in other survey areas. Second, redd locations were mapped to show the spatial distribution of steelhead spawning using ArcGIS.

Results

Redd enumeration

We conducted a combined total of 83 redd surveys from early February through late July in the tributaries (Table 1 and Table 2). Most streams had been surveyed in previous years, including Little River, Indian Creek, Hughes Creek, Madison Creek, Griff Creek, Cat Creek, and Boulder Creek. However, this year, as with last year, we also surveyed Hurricane Creek, a small tributary just above the former Glines Canyon Dam, and Long Creek, a tributary located in Geyser Valley (Table 1 and Figure 4a). The most surveys were conducted in Indian Creek and the fewest in Long Creek (Table 1), which is the most remote tributary. This year's high water reduced visibility to the point where we could not conduct all our regular surveys in some tributaries. The conditions also precluded redd counts in the upper mainstem Elwha River except for a single survey of Hunt Channel, the Aldwell floodplain, and Geyser Valley in late April.

In 2018, we observed a total of 159 winter steelhead redds in the tributaries and an additional 80 redds during three surveys (conducted one day each) in three sections of the mainstem Elwha (Hunt Channel, Aldwell floodplain, and Geyser Valley) (Table 1). Similar to 2017 and previous years, the greatest number of redds were observed in the middle river tributaries. Hughes Creek had the greatest number of redds (58) (Figure 2) and we also counted 48 redds in Little River, 15 redds in Indian Creek, 13 redds in Griff Creek and 4 redds in Madison Creek. One other tributary (Sanders Creek) is no longer surveyed, as much of its former length is now occupied by the main stem river. (Table 1). The 2018 survey

represents the highest redd count total in Little River since 2014, which was the last year when adult steelhead were relocated to the stream (Table 3 and Figure 2).

Surveys from the upper Elwha indicate that winter steelhead continue to recolonize areas above the former Glines Canyon Dam. Of note this year were 28 redds counted in tributaries or the main stem above the former Glines Canyon Dam, including four redds above Rica Canyon. We counted 10 redds in Hurricane Creek, nine redds in Boulder Creek and an additional two redds in Cat Creek. These observations are the furthest upstream documentation of winter steelhead spawning in the Elwha River to date. In contrast, 22 redds were observed upstream of Glines Canyon in 2017, only four redds in 2016 (three in Boulder Creek and one in the mainstem near Windy Arm), and a single redd in 2015 (in Cat Creek).

Temporal and Spatial Redd Distribution

Temporal patterns indicated a protracted breeding season in 2018, similar to previous years. The earliest redd was observed in the last week of February in Indian Creek, while the latest redds were observed on July 3 in Hurricane and Boulder Creeks. As with the past two to three seasons however, most redds were observed in tributaries from late-March through mid-May. The median spawn timing (time at which 50% of the redds were counted) in Little River occurred in the third week of March, which is the earliest of all the years we have surveyed Little River (Figure 3a). Median spawn timing was the last week of April in Indian Creek, which was similar to the previous four years of surveys (Figure 3b). Median spawn timing was mid-May in Hughes Creek, which is the latest we have observed for Hughes Creek (Figure 3c). Of note, confidence in the timing of spawning in Little River is limited this year because the majority of redds were counted in the upper part of the creek, which we only surveyed once at the end of the spawning season. Also, there was a month-long gap between surveys in Hughes Creek, which could help explain why its median date was so late this year. Comparisons of spawn timing were not possible with other tributaries because of the relatively small number of redds counted in those places.

Spatially, there were several notable results. First, steelhead redds were documented in lower Indian Creek and throughout Little River as with previous years (Figures 4a, 4b, 4c, and 4d). However, this year was the second consecutive year that we observed more redds in the upper section of Little River compared to the lower section. In fact, over 75% of the redds were counted in the upper section of Little River, which is a large difference from all previous years when over 75% of the redds were counted in lower Little River. This is reflected in a more continuous distribution of steelhead redds in that section of the tributary (Figure 4a). Second, a similar observation was made in Indian Creek. However, it is important to remember that we survey a relatively small portion of Indian Creek due to limited access due to private property, so we are uncertain about the full

spatial distribution of spawning activity within Indian Creek. Lastly, the number of redds observed above the former Glines Canyon dam was higher than in any previous year.

Steelhead Redd Density and Occupancy

Examination of redd density data over time suggests the density of adult spawning steelhead varies below, between, and above the former dam locations. Redd density levels below the dams have an overall peak density near Rkm 4.0, while densities between the two former dam locations have a peak density at Little River and Indian Creek, respectively. It is important to note that tributary spawners were included in the density estimates and assigned to the nearest Rkm in the main stem. Above the dam peak density occurs near Rkm 23.0. Examination of redd occupancy (presence of at least one redd in each tenth of a Rkm) by tenth of a river kilometer, excluding the canyon areas where no surveys have been conducted as well as above RKM 30.0, reveals that spawning in habitat above the former dam locations has progressively increased from 2015 to 2018.

Observations of Pacific Lamprey Spawning

During the 2018 steelhead surveys, observers encountered small numbers of spawning Pacific Lamprey and/or their nests. Pacific Lamprey typically are spring spawners that construct nests with a unique morphology as compared to Pacific salmon (Beamish 1980; Kostow 2002). Pacific Lamprey quickly recolonized Indian Creek immediately following removal of Elwha Dam in 2012 (McHenry et al. 2016), however they have not been widely observed in other parts of the watershed to date. In 2018 we located a total of 6 lamprey nests during the steelhead survey effort. Five of those redds were found in Hughes Creek, and one nest was observed in Madison Creek.

Discussion

As with previous year's surveys (McMillan et al. 2011-2015; McMillan and Moses 2012; LEKT 2016, 2017), tributary flow and visibility conditions in the tributaries generally allowed for enough redd surveys to measure the spatial distribution of spawning by winter steelhead. However, high flows and reduced water clarity prohibited systematic surveys of the main-stem Elwha River in 2018, like past years, although we were able to conduct a few limited redd surveys. In comparison to last year however, nearly all the redds in Little River were counted in the upper survey reach, which we only sampled once during the season. This made it difficult to compare the timing of redd construction relative to previous years. Regardless, the 2018 redd surveys still provided information on the general timing of spawning and on the spatial distribution of spawning winter steelhead. The results of the surveys suggest that winter steelhead have continued to volitionally increase their distribution above the former dam sites.

We counted a total of 239 winter steelhead redds, 159 of which were located in tributaries and 80 in the mainstem. The SONAR monitoring estimated the steelhead run size to be 1,625 steelhead (Denton et al. 2018). If we assume a 50:50 sex ratio and that each female dug only one redd, the 239 redds equates to a total of 478 winter steelhead. Of course, those assumptions may vary if females excavate more than one redd and the sex ratio is biased. For example, WDFW's assumes 1.8 fish per redd to account for females digging more than one redd, though it still assumes a 50:50 sex ratio. Their method would equate to approximately 430 winter steelhead. This means the total number of redds we observed in tributaries, combined with 43 fish collected from the hatchery rack, accounts for 26% (assuming 1.8 fish/redd) to 29% (assuming 2 fish/redd) of the population, per the Denton et al. (2018) estimate. The reason our redd counts only account for a fairly small proportion of the total run is because we can only survey the tributaries consistently, while turbidity in the lower- and middle-Elwha makes it difficult to see redds and the remote location of the upper Elwha prohibits regular surveys.

The redd surveys continue to indicate that the middle river tributaries: Little River, Hughes Creek, and Indian Creek are important spawning habitat for winter steelhead. We are also beginning to see increased use of upper Elwha tributaries such as Boulder Creek and Hurricane Creek. The mouth of Boulder Creek is located above Glines Canyon (at rkm 24) and the number of redds increased from three in 2016, fourteen in 2017, and nine this year. And we counted 10 redds in Hurricane Creek this year, up from a single redd last year, and redd abundance above Glines Canyon appear to be increasing (McMillan et al. 2015, 2016, 2017). This is also supported by observations of summer run steelhead in the upper watershed during the last two years (Personal Communication, Heidi Hugunin, Olympic National Park). These observations suggest that more extensive surveys in the Upper Elwha would improve knowledge about the overall distribution of spawning steelhead. Regardless, the continued upstream distribution is a positive sign for recolonization.

Among tributaries, this year Hughes Creek contained the most redds for the first time in the years since dam removal (McMillan et al. 2011-2016; McMillan and Moses 2012). Little River had the second highest redd count, followed by Indian Creek and Griff Creek. However, as with previous years, we were unable to systematically survey the mainstem Elwha due to poor visibility during most of the spawning season. Three single-day mainstem-Elwha surveys revealed 80 redds, again suggesting there are quite a few fish spawning in the main-stem and highlighting a need to find a way to enumerate steelhead that spawn in the Elwha River proper.

Spatially we again observed an interesting pattern in Little River. Last year, for the first time, there were more redds observed in the upper survey reach compared to the lower one. This year the pattern was more pronounced. Over 75% of the redds were counted in the upper reach, while prior to 2017 about 75% of the redds were documented

in the lower reach. We are unsure of why this is occurring and will have to continue to monitor to determine whether the pattern will persist into the future.

As discussed last year, it's possible that more fish are spawning in the upper reaches of Little River could be related to homing. For example, returning adults may have homed back to upper areas if they survived at a higher rate than offspring from lower in the system where redd densities were highest. Understanding what proportion, if any, of juvenile and adult steelhead are from some of those initial colonizers in 2012-2014 could improve knowledge about recolonization (e.g., Pess et al. 2012), such as: What were the relative contributions of the hatchery and natural origin steelhead? Which life histories are the most successful during the initial stages of recolonization? Lastly, does spawning location or timing have any effect on colonization success? Answers to those questions could help better understand natural selection interactions and inform adaptive management on the Elwha and future dam removal projects in other watersheds.

This year we were not able to conduct spatially or temporally extensive redd counts in the main-stem Elwha River. Such information is critical to understanding where and when steelhead are spawning, and in turn, what that means for success of their offspring and recolonization overall. Given the challenges of conducting visual surveys in the Elwha, the partners may need to use alternative methods for estimating abundance and distribution of winter steelhead in the main-stem Elwha. Increasing survey effort in the upper Elwha would be particularly useful. Given the lack of access, which has been exacerbated by the road washout on Hot Springs Road, project managers could consider implementing either helicopter redd surveys or installing an additional SONAR camera at an upriver site. Either option would add considerable cost to the overall project monitoring budget.

In summary, we report three important preliminary findings. First, a substantial number of steelhead volitionally recolonized and spawned in several tributaries to the Middle Elwha River. Second, more steelhead were also observed spawning in the Upper Elwha than last year. Third, the spatial distribution of redds in Little River increased in the upper section of the river for the second consecutive year. These findings suggest that the spatial distribution of spawning winter steelhead is expanding and is likely to continue expanding as riverine processes continue to improve and the abundance and diversity of spawning steelhead increases.

Acknowledgements

We thank several additional people for their help in reviewing and providing comments (as well as help with conducting surveys), including Heidi Hugunin, Anna Geffre, Pat Crain, Josh Geffre, and Sam Brenkman with the Olympic National Park. John Mahan and Matt Beirne provided critical reviews from the Lower Elwha Klallam Tribe. We thank several people who also helped conduct surveys, including Anna Geffre, Phil Kennedy,

Kathryn Sutton, Heidi Hugunin, Pat Crain, Sam Brenkman (Olympic National Park), and Wilson Wells, Sonny Sampson, and Mel Elofson with the Lower Elwha Klallam Tribe. Randall McCoy with the LEKT GIS department assisted with data management and graphical support.

References

- Beamish, R.J. 1980. Adult biology of the River Lamprey (*Lampetra ayresi*) and the Pacific Lamprey (*Lampetra tridentata*) from the Pacific Coast of Canada. Canadian Journal of Fisheries and Aquatic Science 37:1906-1923.
- Denton, K., M. McHenry, R. Moses, E. Ward, M. Liermann, O. Stefankiv, W. Wells and G. Pess. 2018. Elwha River steelhead escapement estimate based on DIDSON/ARIS multi-beam SONAR data. This report is provided to Olympic National Park by the Lower Elwha Klallam Tribe in partial fulfillment of task number 6-1 of contract number P13PC0029.
- Gallagher, S.P., Hahn, P.K., and D.H. Johnson. 2007. Redd counts. Pages 197-234 in D.H. Johnson, B.M. Shrier, J.S. O'Neal, J.A. Knutzen, X. Augerot, T.A. O'Neil, and T.N. Pearsons. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.
- Kostow, K. 2002. Oregon lampreys: Natural history status and problem analysis. Oregon Department of Fish and Wildlife, Salem, Oregon.
- McHenry, M.L., M. Elofson, M. Lehrman, T. Bennett, S. Corbett, and G. Pess. 2016. Elwha River smolt enumeration report. Report to Olympic National Park, Port Angeles, WA 98363.
- McMillan, J. R., S. L. Katz, and G. R. Pess. 2007. Observational evidence of spatial and temporal structure in a sympatric anadromous (winter steelhead) and resident *Oncorhynchus mykiss* mating system on the Olympic Peninsula, Washington State. Transactions of the American Fisheries Society **136**:736-748.
- McMillan, J.R., Moses, R., and McHenry, M., Pess, G.R., Denton, K., and Liermann, M. 2011. Winter steelhead redd enumeration report for lower Elwha River 2010/2011. Elwha River Annual Reports for NOAA/NWFSC, Lower Elwha Klallam Tribe, and Olympic National Park.
- McMillan, J.R., and R. Moses. 2012. Winter Steelhead (*Oncorhynchus mykiss*) Redd Survey Summary for Middle Elwha River 2011/2012. Elwha River Annual Reports for NOAA/NWFSC, Lower Elwha Klallam Tribe, and Olympic National Park.
- McMillan, J.R., Moses, R., McHenry, M., Denton, K., Pess, G., Hugunin, H., and A. Geffre. 2013. Winter Steelhead (*Oncorhynchus mykiss*) Redd Survey Summary for Elwha River 2012/2013. Elwha River Annual Reports for NOAA/NWFSC, Lower Elwha Klallam Tribe, and Olympic National Park.

- McMillan, J.R., Moses, R., McHenry, M., Denton, K., Pess, G., Hugunin, H., and A. Geffre. 2014. Winter Steelhead (*Oncorhynchus mykiss*) Redd Survey Summary for Elwha River 2013/2014. Elwha River Annual Reports for NOAA/NWFSC, Lower Elwha Klallam Tribe, and Olympic National Park.
- McMillan, J.R., Moses, R., McHenry, M., Denton, K., Pess, G., Hugunin, H., and A. Geffre. 2015. Winter Steelhead (*Oncorhynchus mykiss*) Redd Survey Summary for Elwha River 2014/2015. Elwha River Annual Reports for NOAA/NWFSC, Lower Elwha Klallam Tribe, and Olympic National Park.
- Pess, G. R., R. Hilborn, K. Kloehn, T. P. Quinn. 2012. The influence of population dynamics and environmental conditions on pink salmon recolonization after barrier removal. Canadian Journal of Fisheries and Aquatic Sciences, 69:970-982. doi:10.1139/F2012-030

TABLES

Table 1. Description of survey locations, reach (all - indicates entire stream was surveyed), number of surveys conducted, number of steelhead relocated, and the total number of redds counted in 2018.

Site	Reach location (km)	# Surveys	Steelhead relocated	Redds (#/km)	% Surveyed
Little R.	0.0 - 4.7	19	None	48 (10.2)	100% ¹
Indian Ck.	0.0 – 2.4	22	None	15 (6.3)	25%
Mainstem Elwha	various	3	None	80	<5%
Madison Ck.	0.0 - 0.2	9	None	4 (20.0)	100%
Griff Ck.	0.0 - 0.4	9	None	13 (32.5)	100%
Campground Ck.	0.0 - 0.6	0	None	0 (0)	100%
Hughes Ck.	0.0 - 1.2	9	None	58 (48.3)	100%
Boulder Ck.	0.0 - 1.0	4	None	9 (9.0)	100%
Cat Ck.	0.0-1.1	4	None	2 (1.8)	100%
Hurricane Ck.	0.0 - 1.1	4	None	10 (9.1)	100%
Long Ck.	0.0 - 1.1	1	None	0 (0.0)	90%
Totals	16.9	83	0	239	

¹ Estimated proportion of usable habitat – total available habitat for steelhead is unknown for this tributary

Table 2. Months and weeks (1-4) when redd surveys were conducted (grey cells) for each location.

Site	February				March				April				May				June				July
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1
Little R.																					
Lower																					
Upper																					
Indian Ck.																					
Lower																					
Middle																					
Madison Ck.																					
Hughes Ck.																					
Campground Ck.																					
Griff Ck.																					
Boulder Ck.																					
Cat Ck.																					
Hurricane Ck.																					
Long Ck.																					

Table 3. Numbers of wild (W) and hatchery-origin (H) steelhead relocated to Indian Creek and Little River and steelhead redds (Rd) observed annually since the inception of steelhead monitoring in the Middle Elwha River in 2012. Rd = redd

Stream	2012			2013			2014			2015			2016			2017			2018		
	W	H	Rd	W	H	Rd	W	H	Rd	W	H	Rd	W	H	Rd	W	H	Rd	W	H	Rd
Indian Creek	11	0	9	0	0	24	0	0	36	0	0	6	3	32	7	0	0	16	0	0	15
Little River	35	0	43	53	35	47	1	58	73	0	0	36	0	0	28	0	0	37	0	0	48

FIGURES

Figure 1. Map of Elwha River basin and location of streams where redd surveys were conducted for winter steelhead from February-July 2018. Stars indicate locations of (working south to north) Long Creek, Cat Creek, Hurricane Creek, Boulder Creek, Griff Creek, Hughes Creek, Campground Creek (no longer surveyed), Madison Creek, Little River, Indian Creek, and the WDFW Hatchery outflow (no longer surveyed).

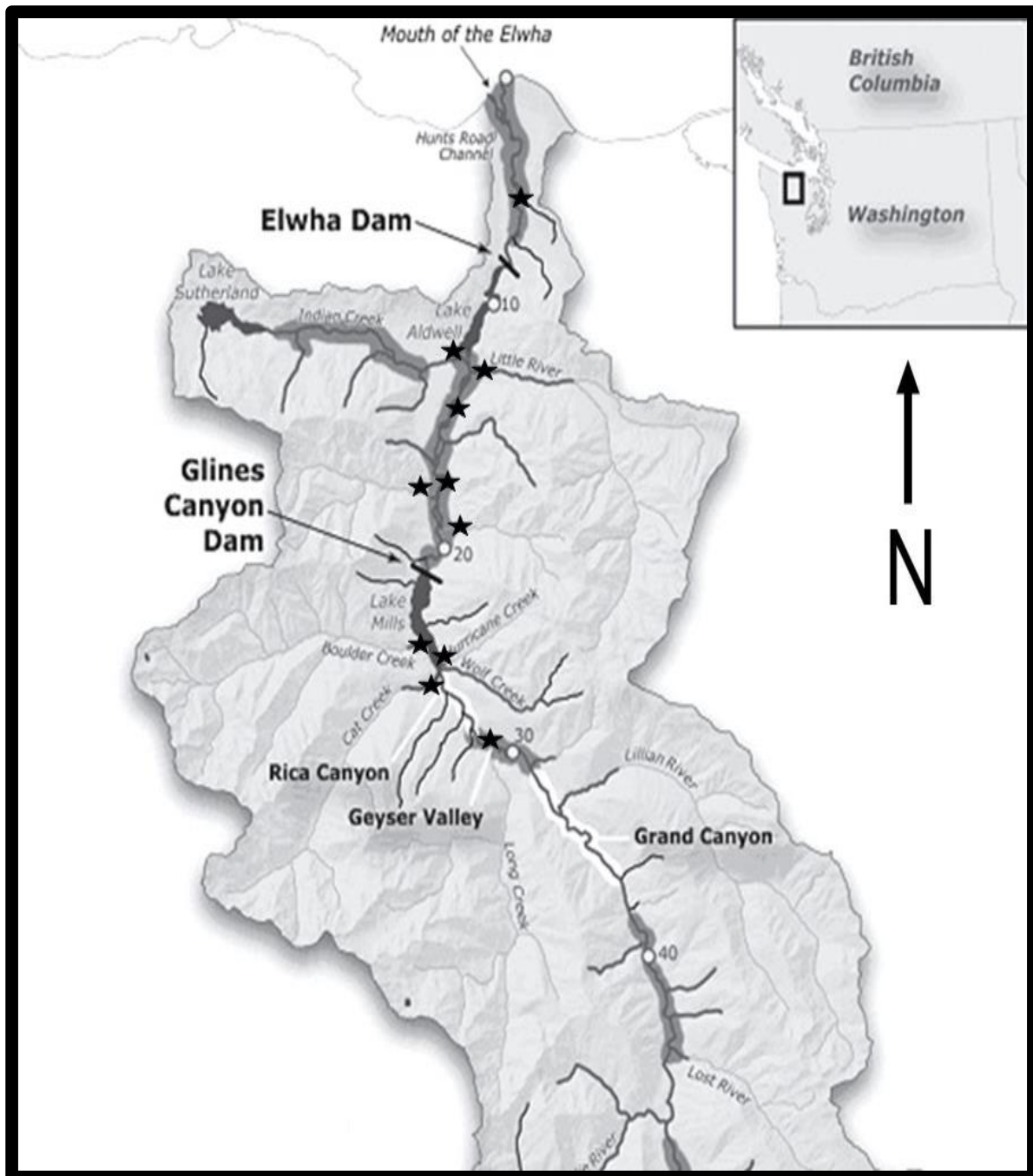


Figure 2. Number of winter steelhead redds counted in tributary by year in the Elwha River basin since steelhead were first reintroduced to habitat above the former Elwha Dam site. Location of stream confluence with main-stem Elwha River works upstream from left to right based on Figure 1, with Indian Creek being the lower most tributary and Long Creek the upper most stream that we have surveyed for steelhead redds. Asterisks indicate years in which surveys were not conducted, while blank areas indicate zero redds were observed.

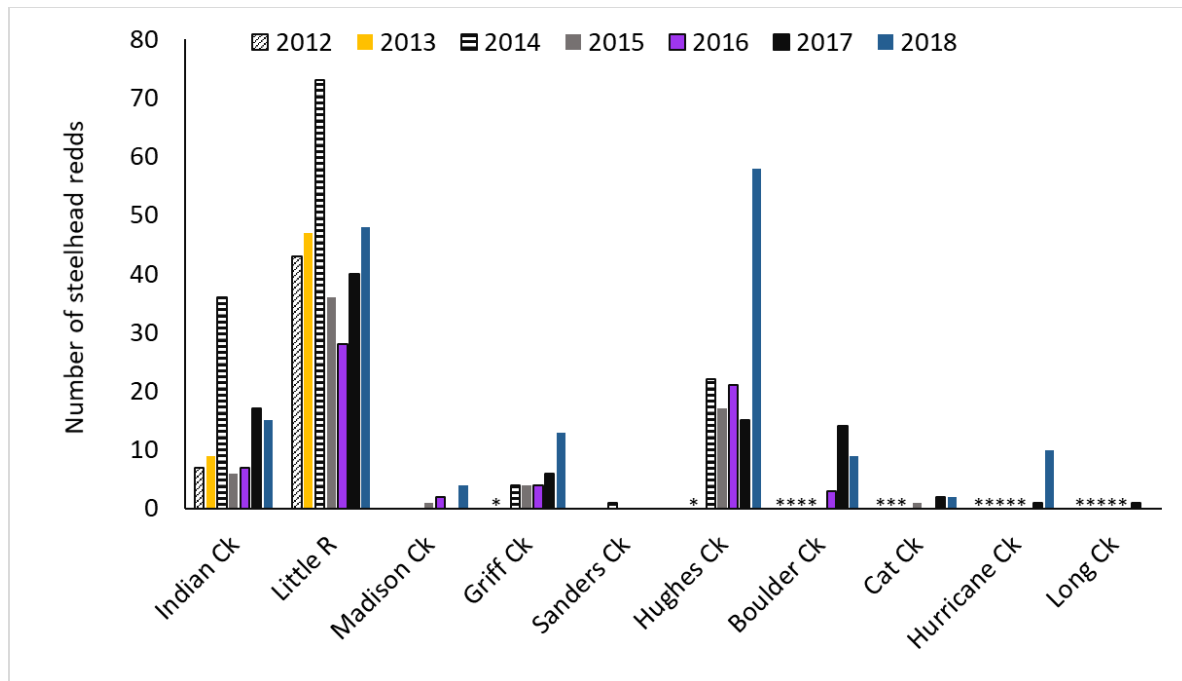
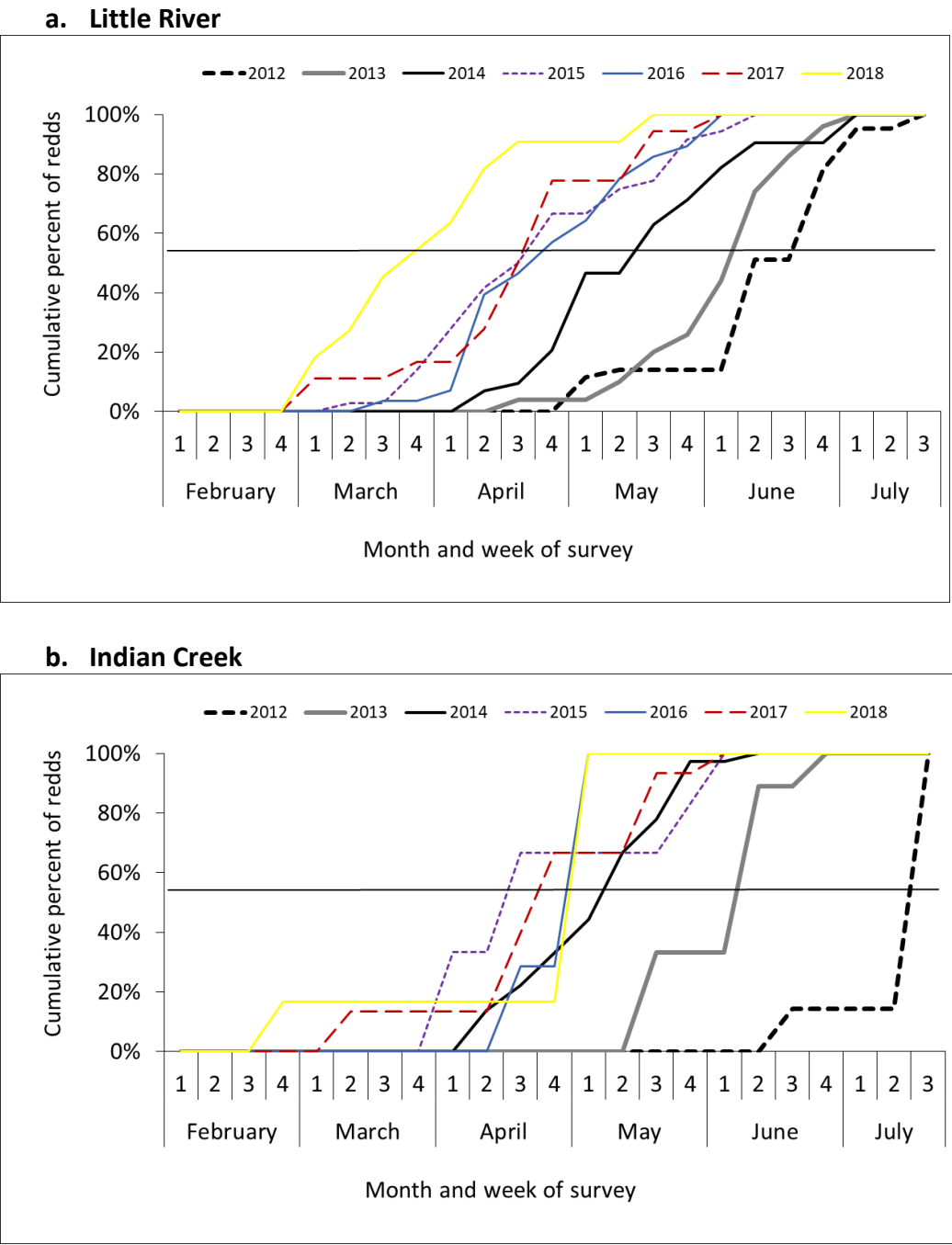
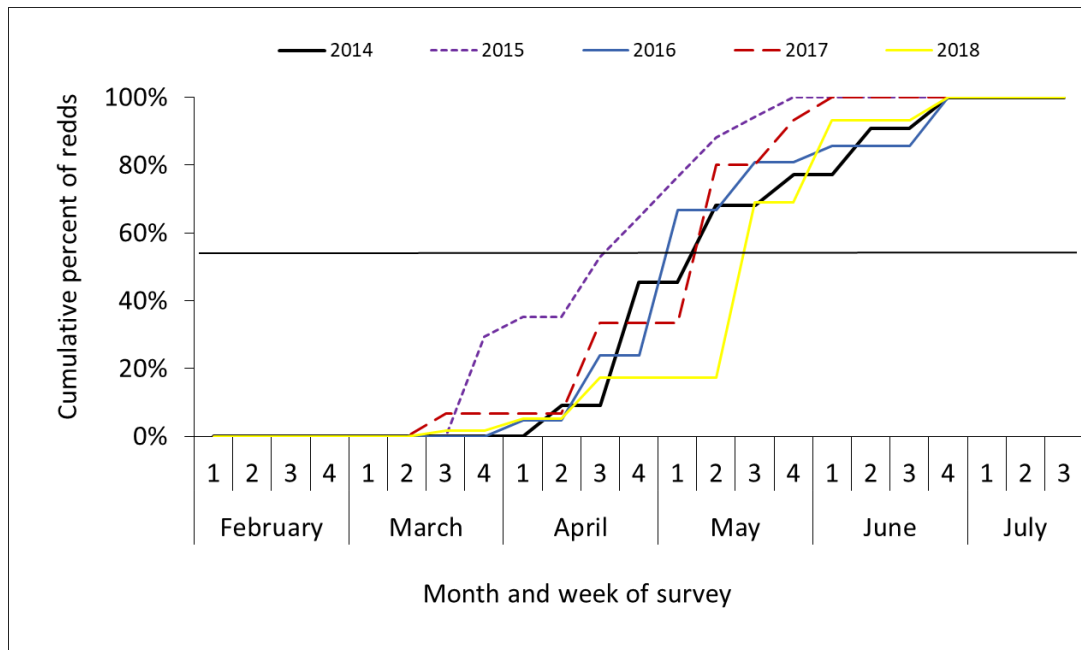


Figure 3. Cumulative distribution of winter steelhead redds counted during weekly redd surveys in (a.) Little River, (b.) Indian Creek, and (c.) Hughes Creek by year. Horizontal line indicates 50% threshold for cumulative distribution.



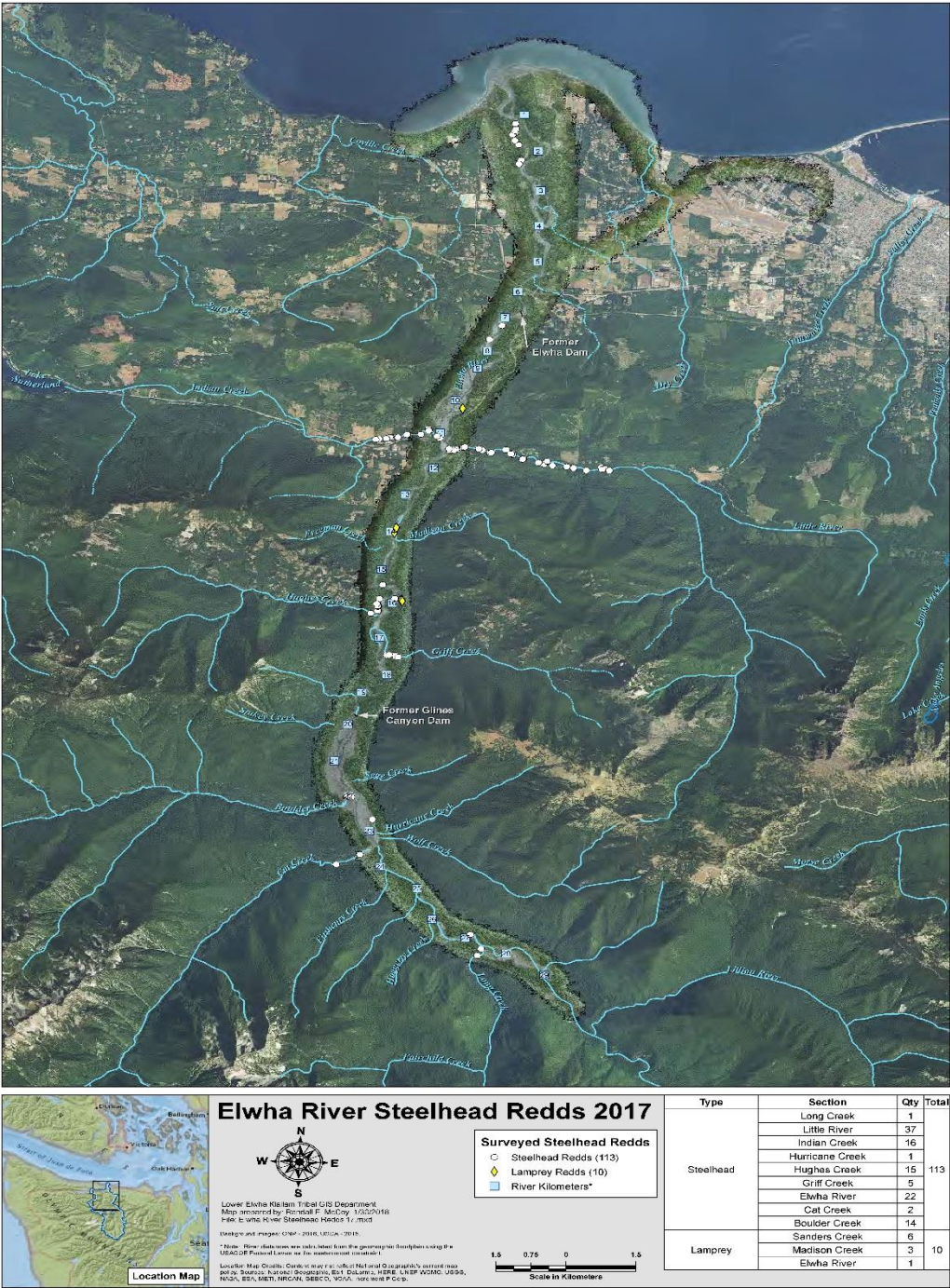
c. Hughes Creek



a. 2018



b. 2017



c. 2016



d. 2015



