Cramer Fish Sciences
Fish Ecology Lab
7525 NE Ambassador Pl., Ste C
Portland, OR 97220
www.fishsciences.net

2022 Spring Chinook Salmon Spawning Surveys in Quartzville Creek

Final Report

Prepared by Cramer Fish Sciences for United States Army Corps of Engineers, Portland District

31 May 2023

Contract# W9127N19D0009; Task Order# W9127N22F0049

COR Approved 230601 Robert H. Wertheimer

Introduction

In the Pacific Northwest, Pacific salmon (*Oncorhynchus spp.*) are an important economic, biological, and cultural resource that embodies the values of the region. Habitat degradation and fragmentation coupled with harvest and hatchery practices have led to an acute decline in the abundance of Pacific salmon, culminating in several listings under the U.S. Endangered Species Act (ESA) (Nehlsen et al. 1991; Huntington et al. 1996; Gregory and Bisson 1997; Myers et al. 1998; Lichatowich 1999; Bradford and Irvine 2000; Blumm 2002). In response to this precipitous decline, the National Marine Fisheries Service (NMFS) identified over 50 Evolutionarily Significant Units (ESUs) for salmon and steelhead throughout the Pacific Northwest (California, Washington, Oregon, and Idaho) to evaluate individual populations that are reproductively isolated from adjacent ESUs and represent an important segment of the evolutionary legacy of the species (Good et al. 2005). The ESU we will be studying during this project is the Upper Willamette River (UWR) Spring Chinook salmon.

In its 2008 Biological Opinion (BiOp) for the Willamette River Basin Flood Control Project, NMFS identified lack of fish passage at Project dams as a major limiting factor to the viability of UWR spring Chinook salmon (NMFS 2008). The BiOp directed actions to identify, address and reduce impacts from existing dam passage conditions for adult and juvenile Chinook salmon, including continued trap, transport, and release of adult salmon into above-dam habitats (Reasonable and Prudent Alternative [RPA] 4.1), and studies to investigate the feasibility of improving downstream fish passage at Project dams (RPA 4.12) (NMFS 2008). Together, these actions are intended to re-establish viable populations of naturally-spawning UWR spring Chinook salmon *Oncorhynchus tshawytscha* in habitats they once occupied upstream of Willamette Project dams.

On September 1, 2021, the U.S. District Court for the District of Oregon issued an Interim Injunction that directs the Corps to implement interim injunction measures intended to improve conditions for fish passage and water quality in the Willamette Valley Project (WVP) to avoid irreparable harm to ESA listed salmonids during the interim period until the completion of the reinitiated consultation. These measures must be carried out "to the greatest extent practicable under existing hydrologic conditions and necessary flood control operations" while making "every effort to comply with the various water quality standards governing the WVP." Pertinent to this project, one requirement of the Injunction was: "Within one year of this Interim Injunction, the Corps SHALL begin outplanting adult UWR Chinook salmon above Green Peter Dam." The Corps will outplant up to 800 fish above Green Peter Dam during the summer and fall of 2022. Of those 800 fish, up to 200 are slated to be released into Quartzville Creek. The primary objective of this project is to monitor the distribution of those 200 individuals and to describe the spatial and temporal distribution of any redds that they build in Quartzville Creek and major tributaries thereof, from their mouths to the first natural barrier to upstream migration.

In response to those directives, the Corps contracted with Cramer Fish Sciences through contract W9127N19D0009 and Task Order W9127N22F0049 to monitor the spawning success of 200 spring Chinook salmon released into Quartzville Creek in September of 2022. The two main objectives of monitoring were:

1. Documenting the spatial and temporal distribution of spring Chinook salmon redds constructed in Quartzville Creek and its tributaries.
2. Locate and sample spring Chinook carcasses to provide estimates of length, sex, age, pre-spawn mortality, and life history type (i.e., hatchery vs. adfluvial), and to recover any active or passive tags.

Methods and Materials

Study Area

The project study area is from the mouth of Quartzville Creek, upstream to anadromous fish barriers and including any tributaries with potential spawning habitat (Figure 1). After initial surveys began, we divided the project area into five survey reaches. Four of these reaches are in Quartzville Creek and one reach is in Canal Creek (Table1 and Figure 1).

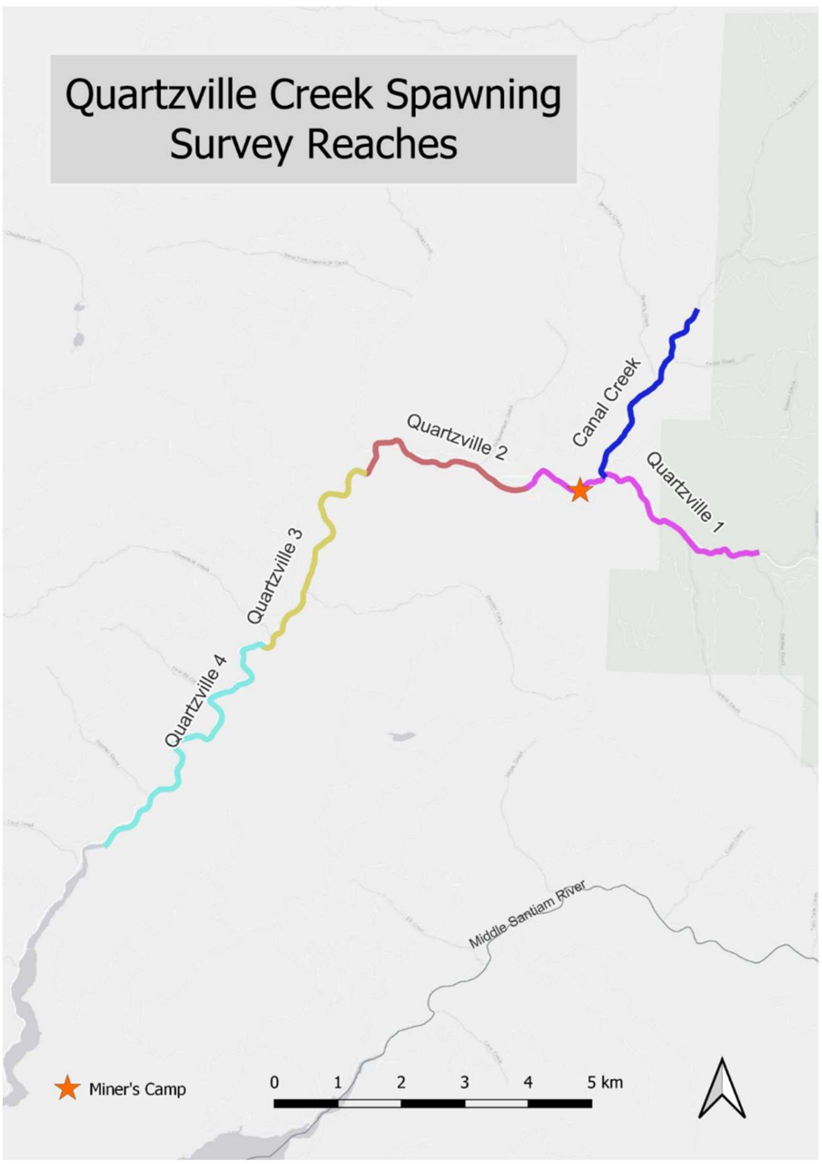

Figure 1. Map of survey reaches and adult outplanting location (Miner’s Camp).

Table 1. Quartzville Creek Spawning Survey Project reach names and estimated lengths (km). Reaches are oriented from upstream to downstream, with Quartzville 1 being the uppermost reach.

Reach Name	Length (km)
Quartzville 1	4.7
Canal Creek	3.3
Quartzville 2	3.3
Quartzville 3	3.9
Quartzville 4	5.3

Spawning Surveys

On Thursday September 8th, 2022, the Corps and Oregon Department of Fish and Wildlife (ODFW) released 200 adult spring Chinook salmon marked with floy tags into Quartzville Creek. Following the release, the each of the five survey reaches was sampled at least once per week as water clarity and safe flows allowed. Surveys were generally conducted on foot by a single team of two trained individuals. Surveys were conducted on Quartzville Creek reaches in a downstream direction and Canal Creek was surveyed in an upstream direction. Inflatable kayaks were tested in Quartzville Creek but they were unnecessary and did not increase survey efficiency. Data collected during surveys included observations of Chinook salmon adults, carcasses, and redds following protocols established by Crawford et al. (2007), Gallagher and Gallagher (2005), and Schroder et al. (2007). Specific metrics were collected for each observation (Table 2).

Table 2. Metrics recorded for each observation during the Quartzville Creek spawning surveys, 2022.

Survey Variable	Redd Variables	Carcass Variables	Scale Aging Variables	Adult Variables
Survey ID	Survey ID	Survey ID	Survey ID	Survey ID
Date	Redd ID	Carcass ID	Carcass ID	Adult ID
Start Time	Lat/Lon	Unit Type	Scale ID	Number Observed
End Time	Redd Number	Fork Length	Technician 1	Unit Type
Stream Name	Pot Length (m)	Post-Orbital Hypural Plate Length	Technician 2	Size Class
Reach Name	Pot Width (m)	Sex	Age Estimate 1	Sex
Discharge	Pot Depth (m)	Adipose fin presence	Age Estimate 2	Adipose fin presence
Weather	Pot Substrate (cm)	Scale Sample ID	Age Final	Activity
Water Visibility	Tail Spill Length (m)	Otolith Sample ID	Notes	Photo ID
Surveyor 1	Tail Spill Width 1 (m)	Fin Clip ID		Lat/Lon
Surveyor 2	Tail Spill Width 2 (m)	Egg Retention %		Notes
Air Temperature	Tail Spill Substrate (cm)	CWT Snout Retention		
Water Temperature	Fish on Redd?	PIT #		
Start Lat/Lon	Remeasure?	Carcass Photo ID		
End Lat/Lon	Photo ID	Carcass Lat/Lon		
Start Photo	Unit Type	Floy Tag		
End Photo	Notes	Notes		
Notes				

Adults

All live adult Chinook salmon observed were counted. Their approximate locations were captured via GPS, a photograph was taken when possible, the channel unit type (pool, riffle, etc.) they were observed in was recorded, and a description of their current activity was recorded to identify whether they were holding, migrating, spawning, or defending a redd.

Carcasses

Carcass surveys were conducted along with the live fish and redd surveys to gather information on the success of the 200 released fish in spawning. Carcasses were examined for fin clips, external tags, and all biological metrics were recorded into an electronic tablet (Table 2). Gonads were examined to determine the sex of the individual, and if female, the proportion of eggs retained in the skeins was estimated. We had planned to collect otoliths on any unmarked Chinook carcasses found, but the only chinook observed were marked with an adipose fin clip. Carcasses were photographed, and their locations were documented with a GPS.

Redds

Individual redds were identified and their locations recorded. Polarized glasses with yellow or amber lenses were used to aid in observation of adults and redds. All observed redds were counted, and uniquely marked with labeled flagging tied to the nearest solid object directly upstream of the pit. For each redd, the unique redd identification number, date first observed, date of completion, and location relative to the flag (distance and compass direction) were recorded on the flag and in the electronic record. Redd locations were captured using a high-accuracy GPS unit (Bad Elf GNSS Surveyor) tethered via Bluetooth to the data collection tablet. Redds were classified as either “under construction”, or “complete”. It is common that redds identified as not yet complete at the time of first observation are actually test redds or stream features that are not actually redds. Once a redd was completed it was measured for pit depth, overall length, width and height and dominant substrate size. A photograph of each redd was captured along with the type of channel unit that the redd was built in (pool tail, glide, riffle, etc.).

Spawning Habitat

Spawning habitat was assessed by measuring all gravel patches with suitable substrate and surface area within surveyed stream segments. All patches greater than two meters squared were recorded. Any dry gravel patches matching the same area requirements and at least 24 cm below the bankfull elevation were also surveyed, with separate notation for those that are dry versus wet. For each gravel patch, the channel unit number containing the patch was recorded, and depth, length, width, and substrate composition of the patch were assessed. Substrate composition in patches was recorded following the USFS Level II categories, except that gravel was further classified as small (2-20 millimeters [mm]), medium (21-40 mm), and large (41-64 mm). Dry patches were assessed for the previously listed measurements, in addition to vertical and horizontal distances from current water surface. Gravel patches highly embedded with fines (>40 percent) were excluded as unsuitable for spawning.

To estimate the number of redds that could be supported, methods were based on the recommendations of Burner (1951). Burner (1951) suggests that the maximum number of redds the habitat can support can be conservatively estimated by dividing the area of suitable habitat within a channel unit by the defended territory size for a pair of adult salmon. Habitat considered suitable is based on substrate composition and species-specific minimum depth criteria.

Discharge during the spawning period was approximated by evaluating monthly flow data at the USGS stream gage location in Quartzville 4. To capture annual variability in discharge, the mean, 25th percentile and 75th percentile of monthly flow during the month of September was used to model spawning capacity. After adjusting for flow conditions during spawning, any spawning patches with depth shallower than the 24 cm were excluded. Additionally, patches were excluded if less than 50 percent of the substrate fell within the suitable range for the spring Chinook salmon. The surface area of each remaining patch was calculated, and the number of potential redds calculated as the area divided by the defended territory size. The number of potential redds was summed across all spawning patches within each survey reach.

Results

Surveys commenced on 9 September 2022, the day after two hundred hatchery marked and floy tagged adult spring Chinook salmon were released at Miner's Camp on Quartzville (Table 3).

Table 3. Statistical sampling weeks, dates, and the number of surveys completed by week in Quartzville Creek during 2022. Note that the hatchery adult Chinook salmon were released on September 8th.

Week	Date Range	Surveys Completed
36	Sep 5 - Sep 9	1
37	Sep 12 - Sep 16	5
38	Sep 19 - Sep 23	5
39	Sep 26 - Sep 30	5
40	Oct 03 - Oct 07	5
41	Oct 10 - Oct 14	5

Water Quality

Stream temperatures dropped steadily throughout the season. Water temperatures were relatively cooler in the upper reaches of the study area (e.g., Quartzville 1 and Canal Creek; Figure 2). After fish were released on 8 September, the maximum temperature of the reach stayed below 18^{o} C.

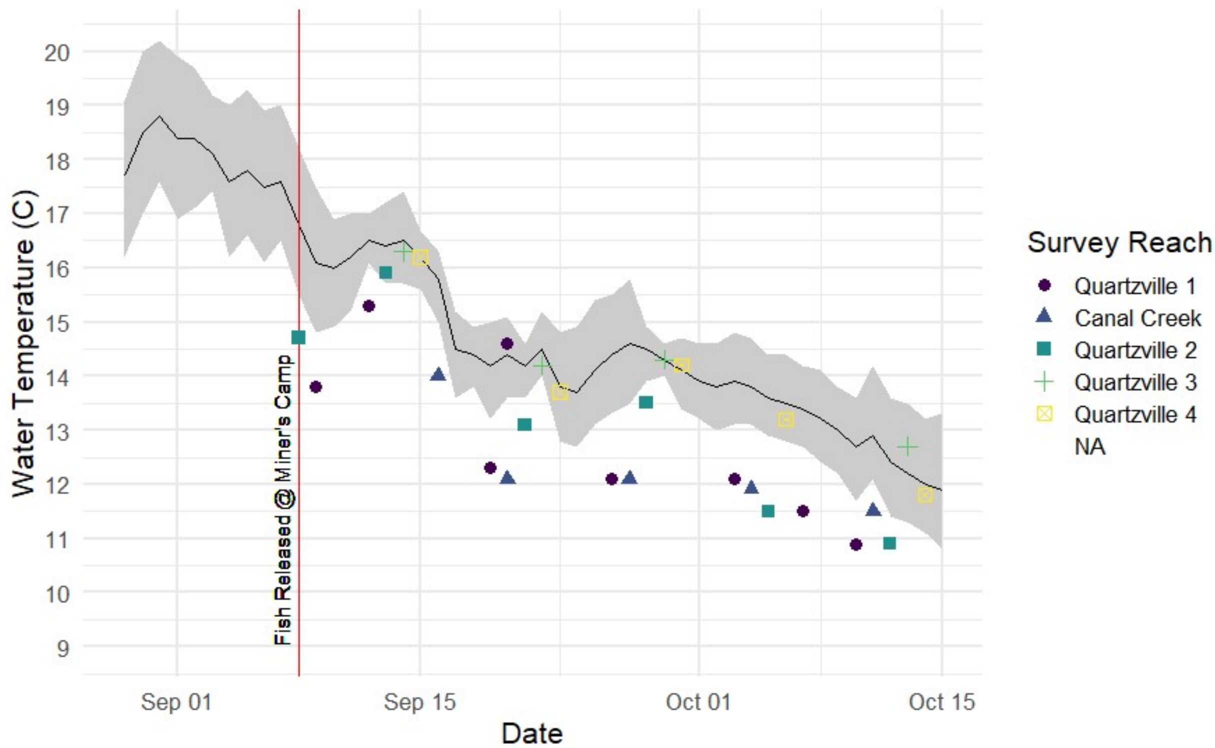

Figure 2. The ribbon plot *(grey polygon)* illustrates the daily maximum and minimum temperatures as reported by USGS gage #14185900 which is located within the Quartzville 4 survey reach (Figure 1). The dark black line represents the daily mean water temperature as reported by the USGS gage. The assorted points represent water temperatures taken at the beginning of each survey and the vertical red line represents the date when the adult Chinook salmon were released at Miner's Camp.

Adult Observations

During the first full week of surveys (week 37) we observed 123 of the 200 hatchery Chinook salmon adults that were released on 8 September (Table 4). The overwhelming majority of those observations were made in the Quartzville 1 and Canal Creek reaches (Figure 3). The following week 59 adults were observed, the majority were within Quartzville 1 and Canal Creek, though six Chinook traveled as far as Quartzville 4. Week 39 was the final week that we observed live fish within the survey area with 10 adults spotted within the upper reaches of the survey area. No unmarked adfluvial Chinook salmon were observed this season.

Table 4. Observations of live adult Chinook salmon by statistical week and survey reach.

Week	Quartzville 1	Canal Creek	Quartzville 2	Quartzville 3	Quartzville 4	Total Observations
36	39	NA	NA	NA	NA	39
37	96	25	2	0	0	123
38	28	23	2	0	6	59
39	5	3	2	0	0	10
40	0	0	0	0	0	0
41	0	0	0	0	0	0

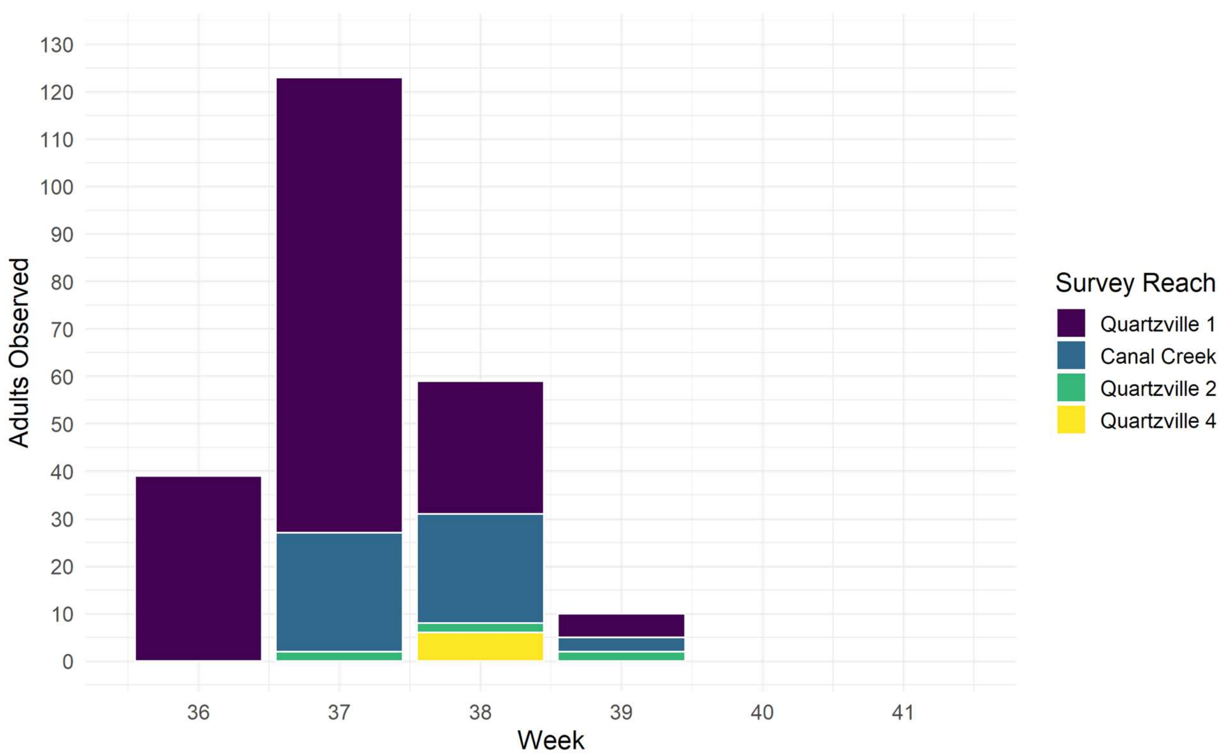

Figure 3. Number of live Chinook salmon adults observed during surveys by statistical week and survey reach.

Redds

A total of 27 Chinook salmon redds were observed this season (Table 5). A similar pattern was observed between adult and redd construction, with the majority of redds occurred within the Quartzville 1 and Canal Creek reaches (n = 23; 85%; Figure 4). Redd construction began in week 37, peaked during week 38 and was completed by week 39 (Figure 5).

Table 5. Observed redds by week and survey reach.

Reach	Week						total redds
	36	37	38	39	40	41	
Quartzville 1	0	0	9	5	0	0	14
Canal Creek	NA	3	6	0	0	0	9
Quartzville 2	NA	0	1	1	0	0	2
Quartzville 3	NA	0	0	0	0	0	0
Quartzville 4	NA	0	2	0	0	0	2

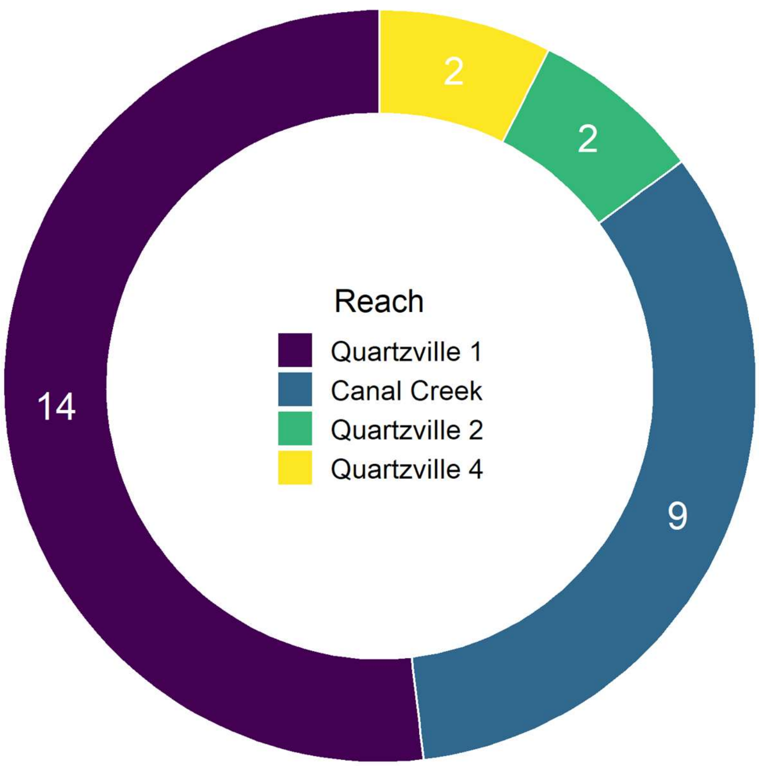

Figure 4. Total number of Chinook salmon redds observed by survey reach.

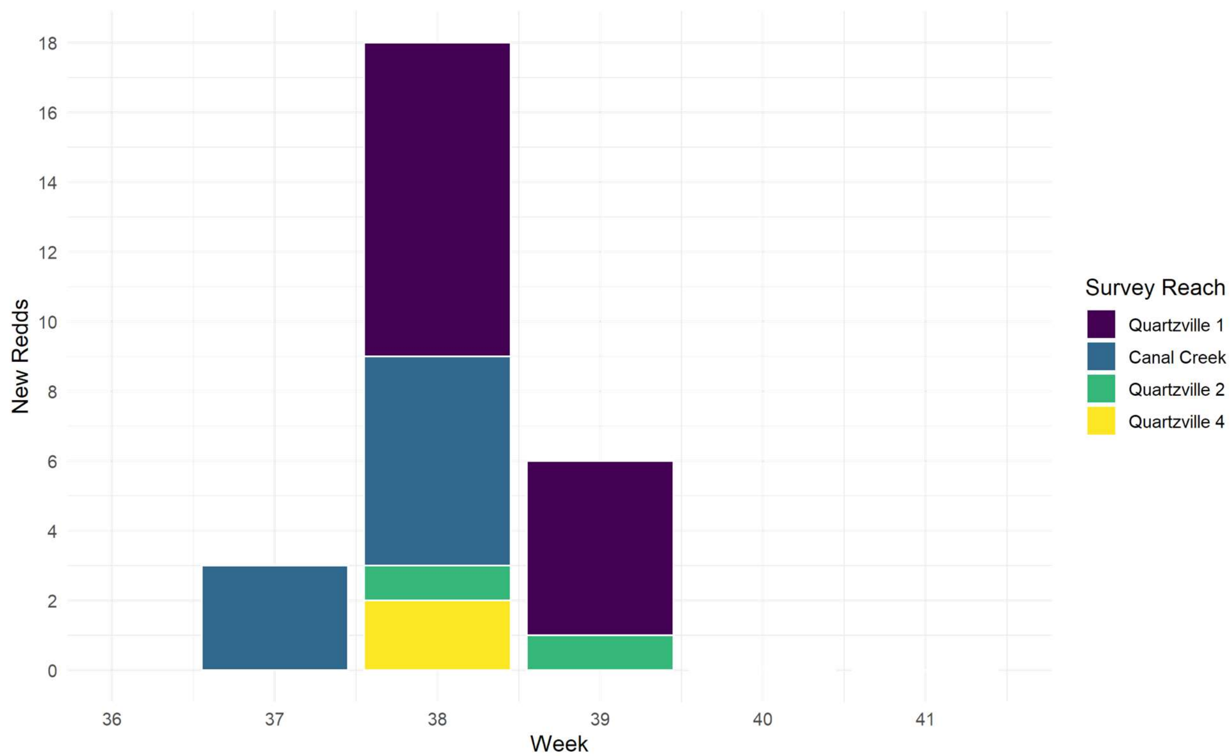

Figure 5. Number of Chinook salmon redds observed by statistical week and survey reach.

In addition to enumerating redds, we collected metrics describing the dimensions of the redds, the dominant size of substrate used in their construction, and the average depth of water at the redd. Mean water depth ranged from 0.18 – 0.31 meters, redd area ranged from 0.77 – 2.19 square meters, and mean dominant substrate size ranged from 80 – 180 millimeters (Table 3).

Table 6. Redd number by reach, with mean water depth, redd area, and substrate size, by survey reach.

Reach	Redds (n)	Mean Water Depth (m)	Mean Redd Area (m²)	Mean Substrate Size (mm)
Quartzville 1	14	0.24	0.77	152
Canal Creek	9	0.18	0.78	180
Quartzville 2	2	0.3	0.84	175
Quartzville 3	0	-	-	-
Quartzville 4	2	0.31	2.19	80

Carcasses

A total of 74 Chinook salmon carcasses were recovered this season (37% of total fish released; Table 7). The largest proportion of carcasses were recovered within the Quartzville 1 reach (Figure 6). Carcass recovery peaked during week 38 and declined steadily through the end of the sampling season (Figure 7). Carcasses recovered were nearly equal with a total of 36 females and 34 males (four carcasses were scavenged so severely that we were unable to identify sex; Table 8). Sex ratio varied between reaches and was skewed toward females in Quartzville 1 and skewed toward males in Quartzville 2 (Table 9).

Table 7. Observed carcasses by week and survey reach.

Reach	Week 36	37	38	39	40	41	Total
Quartzville 1	0	0	26	12	10	0	48
Canal Creek	NA	0	1	9	4	0	14
Quartzville 2	NA	0	4	3	1	2	10
Quartzville 3	NA	1	0	0	0	0	1
Quartzville 4	NA	0	0	1	0	0	1

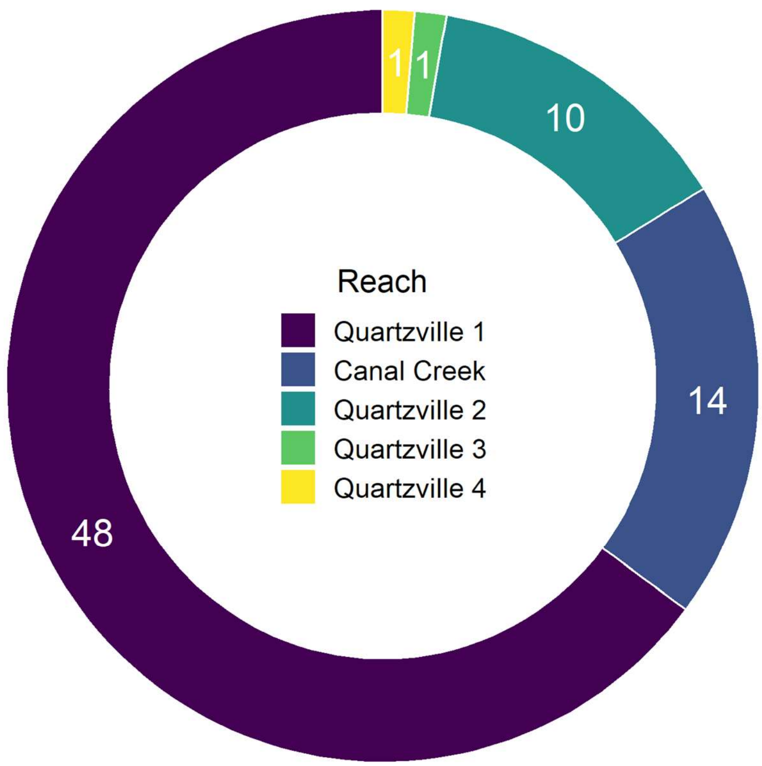

Figure 6. Total number of carcasses observed by reach.dsa

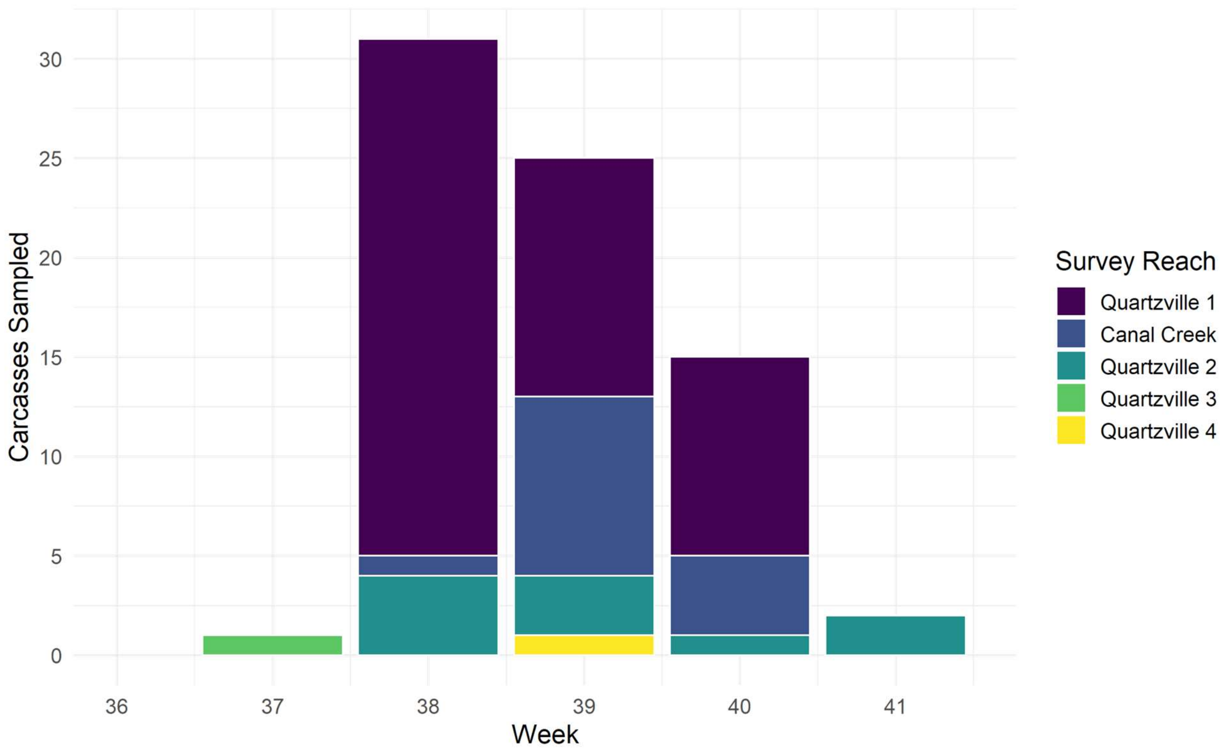

Figure 7. Number of carcasses observed by statistical week and reach.

Table 8. Carcasses by sex. Heavily scavenged carcasses were assigned a value of "unknown."

Carcass Sex	Total
Female	36
Male	34
Unknown	4

Table 9. Carcass fork length by survey reach and sex.

			Carcass fork length (mm)		
Reach	Sex	n	minimum	mean	maximum
Quartzville 1	Female	28	637	733	810
Quartzville 1	Male	19	595	742	890
Canal Creek	Female	6	645	698	732
Canal Creek	Male	6	659	700	750
Quartzville 2	Female	2	680	700	720
Quartzville 2	Male	7	633	742	820
Quartzville 3	Male	1	700	700	700
Quartzville 4	Male	1	704	704	704

Fork lengths ranged from 637 – 810 millimeters and from 595 – 890 millimeters for females and males, respectively (Table 9). Across reaches, carcasses recovered in Quartzville 1 had the greatest average fork length (733 mm, Table 9). Of the 36 female carcasses examined, only four had at least 50 percent of their eggs remaining resulting in a female pre-spawn mortality estimate of approximately 11 percent (Table 10).

We recovered a single carcass in Quartzville 3 with a blue floy tag, indicating either a) that it was a fish that had been released into the Middle Santiam River, moved back downstream to Green Peter, then ascended into Quartzville Creek or b) it received the wrong-colored tag and was mis-released into Quartzville Creek. This carcass was the very first carcass we recovered during the season, was not "fresh", and was the only carcass recovered in Quartzville 3 during the entire season. While we cannot rule out that it may have been mis-tagged, we believe that the preponderance of evidence suggests that this fish strayed from the Middle Santiam. We did not find any unmarked adfluvial Chinook salmon carcasses.

Table 10. Estimated pre-spawn mortality for female Chinook salmon.

Egg Retention %	Yes	No	Pre-spawn mortality %
> 50	4	32	11.1

Spawning Habitat

We surveyed the available spawning habitat on Quartzville 1, Quartzville 2, and Canal Creek. We estimate that, depending on flows, these three reaches contain enough suitable substrate patches to support the creation of 61 – 66 spring Chinook salmon redds (Table 11).

Table 11. Estimated area of suitable spawning substrate for spring Chinook salmon and the number of redds that could be supported, by study reach.

	Spawning Area m²			Redds (n)		
Reach	25th Percentile	Mean	75th Percentile	25th Percentile	Mean	75th Percentile
Quartzville 1	354	372	372	25	26	26
Canal Creek	387	440	458	26	29	30
Quartzville 2	143	143	143	10	10	10

Additional Observations

We made several additional notable observations throughout the survey period. First, the amount of preferred spawning habitat in Quartzville Creek is very limited. The stream is dominated by large cobble, boulders, and bedrock with very few pockets of spawning sized substrate on the margins. The small patches of suitable substrate that exist throughout Quartzville Creek and Canal Creek are interspersed with habitat that is in extremely poor condition, with very little large wood to provide bed stability and sequester spawning sized gravel. Second, recreational use was common, even late in the season, with tens if not hundreds of people observed using the area for swimming, boating, fishing, camping, etc., on any given day. On more than one occasion, our survey crew overheard people talking about trying to capture the adult fish. We also observed numerous river otters and mink and estimate that approximately 20% of our carcasses showed signs of scavenging. Third, we observed that 26% of the recovered carcasses were missing their floy tags. Fourth, hatchery rainbow trout were abundant and were observed in high densities, particularly in pools and are likely predatory on any juvenile Chinook that survive to become fry. Lastly, kokanee salmon *O. nerka* were observed spawning in Quartzville reaches 2 – 4 in relatively high densities where smaller substrate was available.

Discussion

Historical reports suggest that Middle Santiam sub-basin was once responsible for 51% of the entire production of UWR Chinook salmon in the greater South Santiam Basin (Mattson 1948). The Middle Santiam sub-basin represents approximately 33% of the total area of the South Santiam Basin, having a disproportionally importance for providing high densities of quality UWR Chinook salmon spawning and rearing habitat for the entire Upper Willamette Valley. This potential highlights the importance of reconnecting and potentially restoring these habitats for the recovery of UWR Chinook salmon.

Additional historical information provided by Parkhurst et al. (1950) suggests that the Middle Santiam River itself represented 83% of the spawning potential for spring Chinook salmon in the basin compared to only 17% in Quartzville Creek. The observations that we made during this year align with the historical perspective provided by Parkhurst et al.; currently, available spawning and rearing habitat in Quartzville Creek appears limited and productivity is likely only a fraction of that in the Middle Santiam.

There are a number of constraints facing the UWR Chinook salmon reintroduction in Quartzville Creek. Spawning habitat is limited by barriers and a legacy of habitat degradation, predation by rainbow trout is likely detrimental, and anecdotal reports of poaching all contribute to the difficulty in reestablishing UWR Chinook salmon in Quartzville Creek. Green Peter and Foster dams represent barriers to both upstream and downstream migration and have a negative impact on survival of downstream migrants. The Middle Santiam basin above Green Peter dam was stocked with juvenile spring Chinook salmon from 1968 -1986. The stocking effort was discontinued because downstream passage was so bad that managers determined the effort was no longer worthwhile (USFS 2002). Improving downstream passage through Green Peter Dam will be a key objective if this reintroduction effort is to succeed. We observed high densities of rainbow trout during their surveys, and Quartzville Creek is projected to receive 21,000 additional hatchery rainbow trout in 2023. These hatchery trout will compete for resources and prey upon juvenile salmon that survive to become fry. Harvest, whether directed or from poaching will continue to reduce the success of reintroduction of UWR Chinook to Quartzville Creek.

In order to be successful in reintroducing spring Chinook upstream of Green Peter Reservoir, it is important to evaluate the habitat capacity for spawning and rearing, identify constraints in survival (e.g., predation in the river and reservoir, migration pathways), and factors that will influence the success of the reintroduction of adults such as methods of reintroduction (location, timing, escapement goals, etc.) will be essential in reestablishing a population of spring Chinook in Quartzville Creek.

References

Blumm, M. C. 2002. Sacrificing the Salmon: A legal and policy history of the decline of the Columbia River salmon. Beverly Hills, FL: Book World Publications.

Bradford, M. J. and J. R. Irvine. 2000. Land use, fishing, climate change and the decline of Thompson River, British Columbia, coho salmon. Can. J. Fish. Aquat. Sci. 57: 13-16.

Crawford, B., T.R. Mosey, and D.H. Johnson. 2007. Carcass Counts. Pages 59-86 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.

Good, T. P., R. S. Waples, and P. Adams (editors). 2005. Updated status of federally listed Seuss of West Coast salmon and steelhead. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-66, 598 p.

Gallagher, S.P. and C.M. Gallagher. 2005. Discrimination of Chinook salmon, coho salmon, and steelhead redds and evaluation of the use of redd data for estimating escapement in several unregulated streams in Northern California. North American Journal of Fisheries Management. 25:284-300.

Gallagher, S.P., P.K. Hahn, 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.

Goodman, D. 2005. Selection equilibrium for hatchery and wild spawning fitness in integrated breeding programs. Can. J. Fish. Aquat. Sci. 62: 374-389.

Gregory, S. V., and P. A. Bisson. 1997. Degradation and loss of anadromous salmonid habitat in the Pacific Northwest. pp 277-314 in D. J. Stouder, P. A. Bisson, and R. J. Naiman, editors. Pacific salmon and their ecosystems. Chapman and Hall, New York.

Huntington, C. W.; W. Nehlsen; J. Bowers. 1996. A survey of healthy native stocks of anadromous salmonids in the Pacific Northwest and California. Fisheries. 21(3): 6-15.

INPFC (International North Pacific Fisheries Commission). 1963. Annual Report, 1961. Vancouver, B. C.

Koo, T. S. Y. 1962. Age designation in salmon. pp. 37-48 in T. S. Y. Koo, ed., Studies of Alaska red salmon. University of Washington Press, Seattle.

Lichatowich, J. A. 1999. Salmon without rivers: a history of the Pacific Salmon crisis. Island Press, Washington, D. C. 333 pp.

Mcintosh, B.A., S.E. Clarke, and J.R. Sedell. 1990. Bureau of Fisheries Stream Habitat Surveys, Willamette River Basin, Summary report 1934-1942. Bonneville Power Administration, Division of Fish and Wildlife, Project No. 89-104. 492 pp.

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

Nehlsen, W., J.E. Williams, and J.A. Lichatowich. 1991. "Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington." Fisheries. 16(2): 4-21.

Romer, J.D., and Monzyk, F.R. 2014. Adfluvial life history in spring Chinook salmon from Quartzville Creek, Oregon. North American Journal of Fisheries Management. 34(5): 885-891.