Bear Creek Watershed Juvenile Salmon Habitat Use

May 2017

King County

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Prepared for:

King County, Snohomish County, City of Redmond, City of Woodinville, NPDES Permit requirement (Phase I- S5.C.5.c and Phase II- S5.C.4.g), and Washington State Department of Transportation in support of the Bear Creek Watershed-Scale Stormwater Management Plan

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Acknowledgements

The author would like to thank Dan Lantz, Chris Gregersen, Jim Bower, Kate Macneale, Andrew Miller, Steve Brady, and Curtis DeGasperi for help with sample design development, data collection, and data analyses discussion. Special thanks go out to Jeff Burkey for project management of the Bear Creek Watershed-Scale Stormwater Plan as well as supporting King County staff for Plan and habitat use assessment development.

Citation

King County. 2017. Bear Creek Watershed Juvenile Salmon Habitat Use. Prepared by Josh Kubo, Water and Land Resources Division. Seattle, Washington.

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EXECUTIVE SUMMARY

This report summarizes results for juvenile salmon habitat use surveys conducted in the Bear Creek watershed during February to June in 2016. An extensive inventory of habitat conditions throughout the Bear Creek watershed was not conducted in 2016; however, this report does summarize prior assessments of existing habitat conditions and discusses potential salmon habitat restoration and conservation strategies.

Juvenile Salmon Habitat Use

Juvenile Chinook and coho appear to use a variety of habitat types in the Bear Creek watershed with habitat-specific use varying across months and subbasin areas. During late-winter and early-spring (February–March), juvenile Chinook appear to use off-channel, slow water, and non-turbulent habitats such as backwaters, non-turbulent runs, and side-channels. During spring (April–June), juvenile Chinook appear to use various slow and fast water habitats but at lower overall abundances compared to the earlier winter-spring rearing period. Some of these spring habitats included non-turbulent glides, mid-channel scour pools, non-turbulent runs, side-channels, and tributary mouths. Throughout late winter and spring (February–June), juvenile coho appear to use a variety of both slow and fast water habitats.

Existing Habitat Conditions

While Bear Creek has relatively higher quality habitats compared to the greater Sammamish River watershed, habitat degradation has still occurred and has subsequently contributed to the decrease in salmon abundance and productivity. Evaluation of existing habitat conditions in the Bear Creek watershed indicate that factors like altered hydrology, the loss of channel complexity and connectivity, degradation of riparian areas, loss of large wood, and increased sedimentation are associated with degraded instream habitats. Across the Bear Creek watershed, Cottage Lake Creek and Upper Bear Creek have relatively higher levels of watershed function compared to Lower Bear Creek, primarily due to lower percentages of impervious surface, fewer road crossings, and higher levels of riparian forest cover. While Cottage Lake Creek and Upper Bear Creek generally have better instream habitat conditions compared to Lower Bear Creek, factors like pool quality/quantity as well as large wood conditions are consistently degraded throughout all subbasins in the entire Bear Creek watershed.

Salmon Recovery, Restoration, and Conservation Strategies

As highlighted in the WRIA 8 Chinook Salmon Conservation Plan, select reaches in Cottage Lake Creek and Upper Bear Creek are a high priority for habitat protection and restoration. Additionally, the majority of Lower Bear Creek is a high priority for habitat restoration and creation. Relevant strategies may include riparian improvements, off-channel and floodplain habitat connection, instream structures and large wood supplementation, barrier removal, sediment reduction, and beaver management.

Conclusions

Results from this study indicate that a variety of habitat types are needed to support the freshwater life stages of juvenile Chinook and coho salmon in the Bear Creek watershed. This study suggests that as juvenile salmon grow and transition through early life stages, their habitat use and distribution appears to shift. In order to support the continuum of early life stages for juvenile Chinook and coho salmon, a variety of freshwater rearing habitats are needed throughout the Bear Creek watershed. Additionally, analyses indicate that rearing habitat availability is likely limited across the Bear Creek watershed. Since salmon productivity and survival are directly related to the quantity and quality of instream habitats, it is necessary to restore degraded habitats and preserve well-functioning areas. Focusing on preserving and restoring habitat conditions throughout the Bear Creek watershed will help in supporting abundant and productive salmon populations. Findings from this study as well as information summarized from prior assessments will be incorporated into strategies outlined in the Bear Creek Watershed-Scale Stormwater Plan.

1.0 INTRODUCTION

The Bear Creek watershed is an important salmonid bearing system in the greater Sammamish River geographic area. The various streams, lakes, and wetlands in the watershed support several salmonid species including Chinook (*Oncorhynchus tshawytscha*), sockeye (*O. nerka*), coho (*O. kisutch*), kokanee (*O. nerka*), coastal cutthroat (*O. clarki*), and steelhead (*O. mykiss*). Across the Lake Washington/Cedar/Sammamish watershed (WRIA 8), Bear Creek has one of the largest spawning aggregations of Chinook and supports about 90% of the Chinook spawning in the North Lake Washington tributaries (Bear, Little Bear, North, Swamp, Kelsey, Evans, McAleer, Juanita, Thornton, May, and Coal creeks) (Kerwin 2001, WRIA 8 Steering Committee 2005, Berge et al. 2006). Among the salmon species observed in the Bear Creek watershed, sockeye, coho, and Chinook are most numerous. It should be noted that while this report focuses on Bear Creek salmonids, other aquatic species of importance in the Bear Creek watershed include extensive freshwater mussel populations, freshwater sponges, river otters, crayfish, and a diverse community of aquatic insects (Kerwin 2001). The diversity and abundance of these aquatic species in Bear Creek distinguish the watershed as a significant resource in WRIA 8 and King County.

Salmon spawn and rear throughout reaches in the Bear Creek watershed, with the majority of Chinook and sockeye spawning in mainstem channels of Bear and Cottage Lake creeks, and coho spawning in upper reaches of the mainstem and tributaries. Chinook spawning begins in mid-September, peaks around October, and continues through mid-November (Kerwin 2001, Berge et al. 2006). Coho spawning aligns with the onset of fall freshets and generally occurs between November and early December. Sockeye spawning ranges from September through January. Emergence of salmon from spawning nests is dependent on water temperatures but generally begins in January of the year following egg deposition and is typically completed by March. The summer/fall Chinook in WRIA 8 are typically an "ocean-type," meaning that they rear in their natal freshwater environment for one to six months prior to their seaward migration (Kiyohara 2016). Among this ocean-type life-history, juvenile Chinook rearing in Bear Creek tend to migrate either early as fry (February through March) or later as parr (May through June). A major difference in the Lake Washington Basin Chinook from other Puget Sound stocks of Chinook is that all juvenile Chinook leaving Bear Creek enter, rear, and migrate in large lake systems prior to marine entry, as compared to estuarine rearing in other systems (Kerwin 2001). Sockeye migrate to Lake Washington shortly after fry emergence (with lake rearing ranging from 1–3 years) and coho tend to remain in the creek system for a full year prior to lake and seaward migration.

Productivity and overall abundance of Chinook, coho, and sockeye has been much reduced from historic levels (Kerwin 2001, WRIA 8 Steering Committee 2005). Salmonid populations in Bear Creek are part of the WRIA 8 population as well as the Puget Sound ESU (evolutionary significant unit), which are both considered depressed and in decline. Specifically, depressed Puget Sound Chinook populations were subsequently listed as threatened in 1999 under the Endangered Species Act (ESA). Chinook escapement in the

Bear Creek watershed has shown evidence of decline with many of the lowest returns occurring in the last ten years (Berge et al. 2006). The observed decline in salmonids across the Puget Sound has been connected to factors including habitat alterations, hatchery practices, altered flow regimes, ocean survival, climate change, and harvest (Federal Register 1999, Lichatowich 1999, McElhany et al. 2000, ISAB 2002, Tolimieri and Levin 2004). Salmonids in the Bear Creek watershed are at risk in large part due to reduced productivity, abundance, diversity, and spatial distribution attributed to habitat degradation throughout the watershed (WRIA 8 Steering Committee 2005). This degradation includes a loss of habitat diversity (quality and quantity), habitat connectivity, riparian and large wood conditions (quality and quantity), flow conditions, sediment dynamics, channel stability, water quality, and intra- and inter-specific interactions (Kerwin 2001, WRIA 8 Steering Committee 2005).

With small streams providing critical habitat for all freshwater life stages of salmonids (Williams et al. 1975), and since the freshwater phase has the potential to account for over half of the variability in the abundance of returning adult salmon (Bradford 1995), it is important to know the conditions and extents of freshwater habitats in the Bear Creek watershed as well as how salmonids use these habitats. Knowing the habitat type, amount, and optimal environmental conditions for each life stage can provide useful information in understanding freshwater habitat requirements for juvenile salmonids (Rosenfeld 2003).

The purpose of this study was to evaluate juvenile salmonid habitat use in the Bear Creek watershed, summarize prior assessments of existing habitat conditions, and investigate potential restoration and conservation strategies. This assessment will help in understanding how juvenile salmonids use instream habitats in the Bear Creek watershed as well as how habitat use and existing conditions can help to prioritize conservation and recovery strategies.

2.0 METHODS

2.1 Salmonid Habitat Use

2.1.1 Sample Reach Selection

Juvenile salmonid sample reaches in the Bear Creek watershed were selected for each of three subbasin areas including Cottage Lake Creek, Upper Bear Creek, and Lower Bear Creek (Figure 1). While Evans Creek and areas upstream of Cottage Lake flow into the Bear Creek watershed, these areas were not included in this study. Additionally, the portion of Bear Creek below the confluence with Evans Creek was not included. The study area was delineated in this manner to coincide with the area covered by the overall Bear Creek Watershed-Scale planning process.

Within each of the selected subbasin areas, 3 sample reaches were selected within the mainstem channel for a total of 9 sample reaches. Sample reaches were selected based on a combination of Washington Department of Fish and Wildlife (WDFW) salmonid distributions, proximity to Chinook spawning redd distributions, and Salmon Watchers citizen group fish counts. We assumed that our likelihood of observing juvenile salmonids would be greater around reaches with higher adult abundance and spawning activity. Among all of the potential locations, we focused on public ownership parcels for ease of access; however, when public access was not available, private properties were also included. Final study sample reach locations are included in Figure 1.

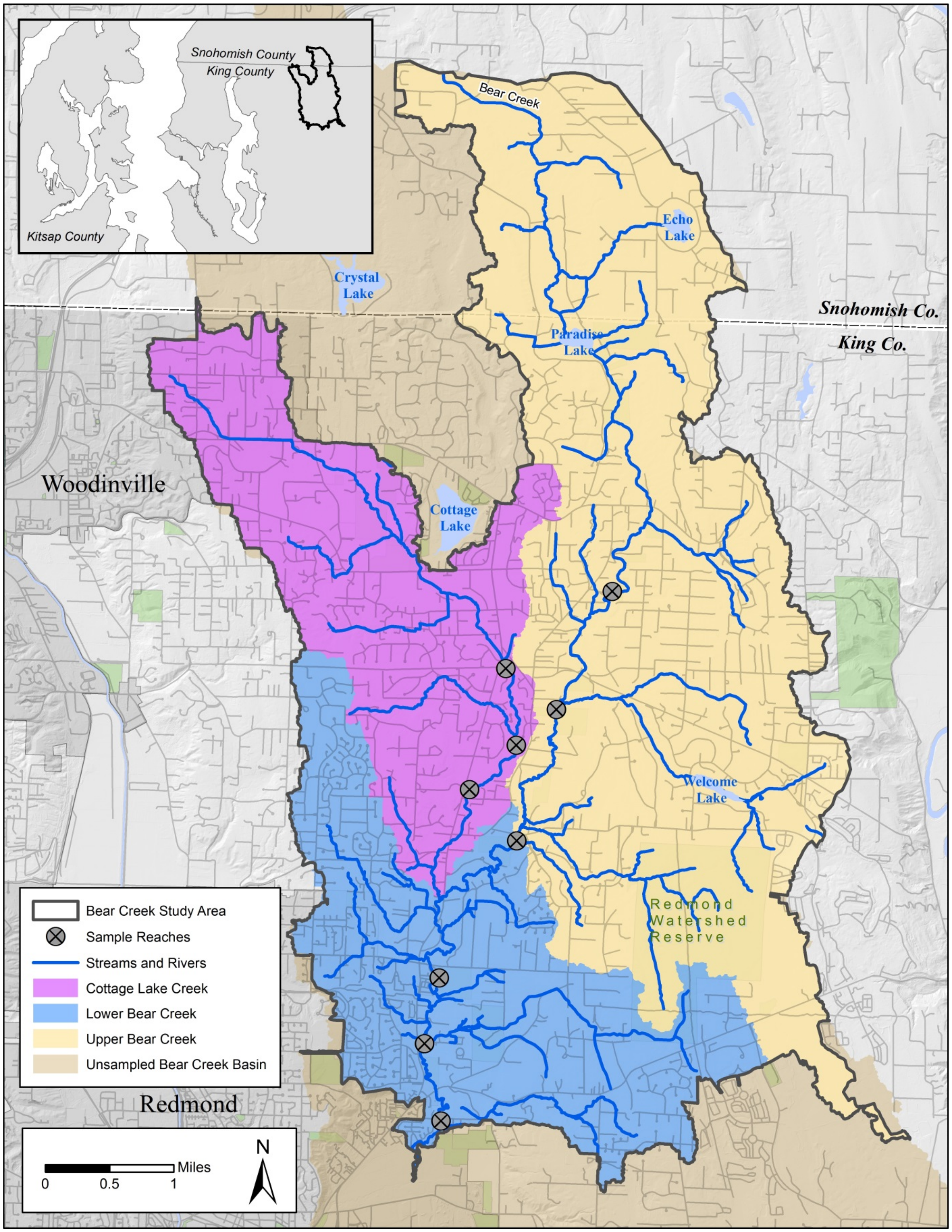

Figure 1. Bear Creek watershed and selected sample reaches. The sampled watershed area does not include the Evans Creek drainage, upstream of the Cottage Lake and Cold Creek confluence, as well as the portion of Bear Creek below the confluence with Evans Creek.

2.1.2 Habitat Mapping and Sample Design

The distribution of juvenile salmonids within stream channel habitats is influenced by a variety of environmental factors including channel hydraulics, water quality, substrate, cover, as well as intra- and inter-specific interactions, food availability, and life stage. Spatial and temporal variations in these habitat characteristics provide an important habitat mosaic shown to be ecologically relevant to salmonids (Bisson et al. 1982, Sullivan 1986, Hawkins et al. 1993). To describe and classify the range of habitat types and environmental factors observed in the Bear Creek watershed, we used the habitat classification described by Hawkins et al. 1993 (Figure 2). Level II–III classifications were used as the primary levels for this study with the addition of two categories not included in the Hawkins et al. (1993) taxonomy: side-channels and tributary mouths.

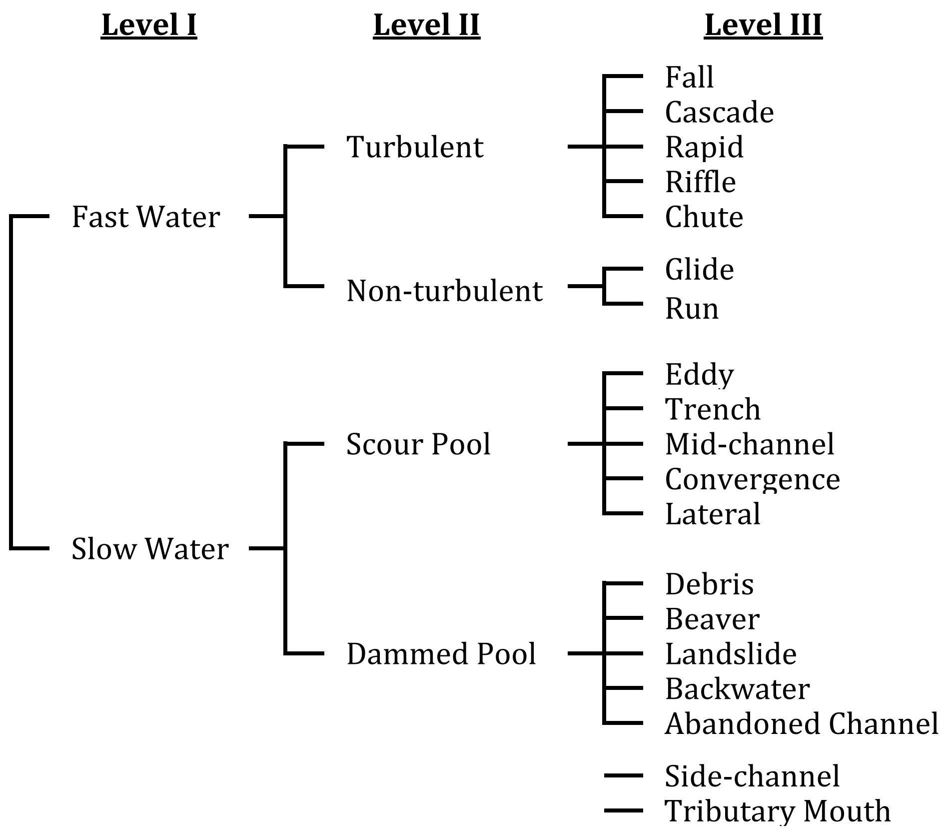

Figure 2. Instream habitat classification modified from Hawkins et al. 1993.

At each selected sample reach, habitats were characterized and mapped along approximately 100 meter during 2016. Since the study was focused on evaluating juvenile salmonid rearing habitats, characterization and mapping efforts were focused on instream habitats during late-winter (February–March) and spring (April–June). Spring flows were considerably lower than winter flows, so we re-evaluated habitat classifications in April to ensure appropriate alignment of habitat types with instream characteristics. While the area extent of several habitat types changed throughout the season at lower flows, only a few habitats were subsequently reclassified (glides and runs were occasionally reclassified as riffles). Mapped habitat types from each sample reach were grouped at the subbasin level to create a set of sample replicates (Table 1). Within each subbasin, two replicates of each habitat type were sampled monthly from February to June for salmonids (Section 2.1.3). Of the two replicates sampled for each habitat type, one was revisited every month and the other was randomly selected from the remaining set of respective habitat replicates. Several habitat types in Lower Bear did not have replicates (due to a paucity of representative habitat types), so only a single sample for each of those habitat types was collected monthly.

Table 1. Instream habitat types and the number of replicates mapped, across each subbasin area in the Bear Creek watershed.

	Habitat replicates in each subbasin area
Cottage Lake Creek (3 sample reaches)	
Backwater	3
Lateral scour pool	6
Debris dammed pool	0
Mid-channel scour pool	4
Non-turbulent glide	3
Non-turbulent run	5
Side-channel	2
Tributary mouth	0
Turbulent riffle	6
Upper Bear Creek (3 sample reaches)	
Backwater	3
Lateral scour pool	4
Debris dammed pool	0
Mid-channel scour pool	6
Non-turbulent glide	0
Non-turbulent run	3
Side-channel	3
Tributary mouth	0
Turbulent riffle	5
Lower Bear Creek (3 sample reaches)	
Backwater	0
Lateral scour pool	0
Debris dammed pool	1
Mid-channel scour pool	1
Non-turbulent glide	12
Non-turbulent run	2
Side-channel	1
Tributary mouth	1
Turbulent riffle	0

2.1.3 Fish Surveys

Within each habitat type, fish assemblages were sampled using a Smith-Root LR-20B® backpack electrofisher system using established protocols (Reynolds and Kolz 2012). Habitat sampling procedures consisted of single-pass electrofishing conducted in an upstream direction during the day. Sampling including a backpack electrofisher operator and 1–2 individuals positioned downstream collecting any stunned fish. Fish and aquatic biota (e.g., frogs, crawfish, etc.) immobilized by the electrical current were netted and placed in recovery buckets. All captured fish were then placed in an anesthetizing water bath of MS-222, identified, measured for length (nearest millimeter), and weighed (nearest gram). After a recovery period, captured fish were released back into the creeks. Stream temperature (°C) and conductivity (µS) were collected at each sample reach at the time of fish sampling.

2.1.4 Data Analyses

The numbers of fish collected were summarized for Cottage, Upper Bear, and Lower Bear subbasin areas. Data analyses focused primarily on juvenile Chinook and coho salmon. Analyses were aimed at determining which habitats juvenile Chinook and coho salmon used for rearing and how these habitat use patterns varied across months and subbasins. Habitat use was evaluated through differences in the relative abundance of fish across each habitat type. Relative abundance was represented as catch per unit effort (CPUE), which was quantified as the number of fish captured in a habitat type standardized by the number of seconds that habitat type was electrofished.

To evaluate explanatory variables potentially driving observed juvenile salmon distributions as well as habitat specific use across months and subbasins, we used classification and regression tree analyses (Breiman et al. 1984). Classification and regression trees (CART) are statistical methods which use recursive partitioning to separate a response variable into groups based on the values of explanatory variables. Response variables can be categorical (classification trees) or numeric (regression trees) and the explanatory variables can be categorical and/or numeric. CART methods represent the structure of the data in a simple and interpretable way and can handle non-parametric datasets and high-level interactions between variables (De'ath and Fabricius 2000, Strobl et al. 2009). Trees are built by first splitting the data based on the predictor variable with the strongest association with the response variable (after testing associations with every predictor variable within the dataset). The process is then applied separately to each partitioned subgroup recursively aiming to differentiate mutually exclusive groups, each of which are as homogeneous as possible. Finally, the tree can be pruned back to the partition level that best fits the data by finding the level where additional splitting does not improve the model fit. This is done by comparing complexity parameter values at each partition and selecting the complexity that has the least cross-validation error. The complexity parameter is similar to a cost statistic which adds a penalty for increasing tree complexity. The final pruned tree represents the model that has the least cross-validation error and best fits the response variable.

In this study, we used regression tree analyses to evaluate if variation in juvenile salmon relative abundance (CPUE) was related to habitat types, months, and subbasins. Regression trees were fitted in R (v3.3.1 www.R-project.org; R Development Core Team 2016) using the 'rpart' library (Therneau 2015). We hypothesized that juvenile salmon relative abundance may be different across subbasins since adult spawning densities are quite different among these areas. Additionally, we hypothesized that juvenile salmon relative abundance and habitat-use may differ across the winter and spring. Flow and temperature changes throughout the winter and spring, and subsequently influence juvenile salmon development, growth, life-stage transition, emigration patterns, and habitat use. However, while flow and temperature data were available for the Bear Creek watershed, parameter values were not measured at the same spatial extent. Specifically, temperature was measured at the habitat-scale and flow was monitored at the watershed scale. Subsequently, in order to evaluate the influence of flow and temperature on juvenile salmon habitat use in Bear Creek, we used month as a binning factor to represent relative differences in flow and temperature. In addition to regression tree analyses, we plotted ranges in catch specific to each subbasin area to supplement regression analyses and to provide additional insight into differences across subbasin habitat types.

2.2 Existing Habitat Conditions

An extensive inventory of habitat conditions throughout the Bear Creek watershed was not conducted in 2016. Rather, habitat conditions in the Bear Creek watershed were summarized from prior assessments that focused on evaluating salmon habitat conditions. While the extent and goals of each assessment were slightly different, we aimed to summarize all of these prior efforts to provide a synthesized understanding of instream habitat conditions across the Bear Creek watershed. For clarification and comparison purposes, the assessments were discussed in the context of watershed and subbasin areas specified in this study (Figure 1). Riparian conditions were documented among most of these assessments; however, minimal discussion is included in this report since detailed analyses and discussion has been completed in King County (2017). The Bear Creek habitat conditions assessments that were reviewed for this report include (summary maps of select assessments can be found in Appendix A–F):

- Bear Creek Basin Current and Future Conditions Analysis (King County, Snohomish County, City of Redmond 1989)
- Bear Creek Basin Plan (King County, Snohomish County, City of Redmond 1990)
- Bear Creek Basin 1994 Annual Report (King County, Snohomish County, City of Redmond, City of Woodinville 1994)
- Bear, Evans, Cottage Lake, and Mackey Creeks Habitat Assessment Technical Memorandum (Entranco 1994)
- Salmon and Steelhead Habitat Limiting Factors Report (Kerwin 2001)
- Bear Creek Habitat Inventory and Assessment (Parametrix 2002)
- Monitoring for Adaptive Management: Status and Trends of Aquatic and Riparian Habitats in the Lake Washington/Cedar/Sammamish Watershed (WRIA 8) (King County 2015)

3.0 RESULTS AND DISCUSSION

3.1 Fish Surveys

A total of 2,146 fish were collected during the study period (February–June) with observations including brook lamprey, Chinook and coho salmon, cutthroat trout, speckled dace, green sunfish, minnow species, peamouth, sculpin species, and three-spine stickleback (Figure 3). Across the observations, cutthroat and sculpin were the predominant fish species collected and the majority of observations across all species were seen in Cottage Lake Creek and Upper Bear Creek. Several other species have been previously documented in the Bear Creek watershed (e.g., sockeye/kokanee salmon, rainbow trout, pink salmon, largescale sucker, largemouth bass, mountain whitefish, bluegill, longnose dace, and pumpkinseed); however, these species were not observed during this 2016 study.

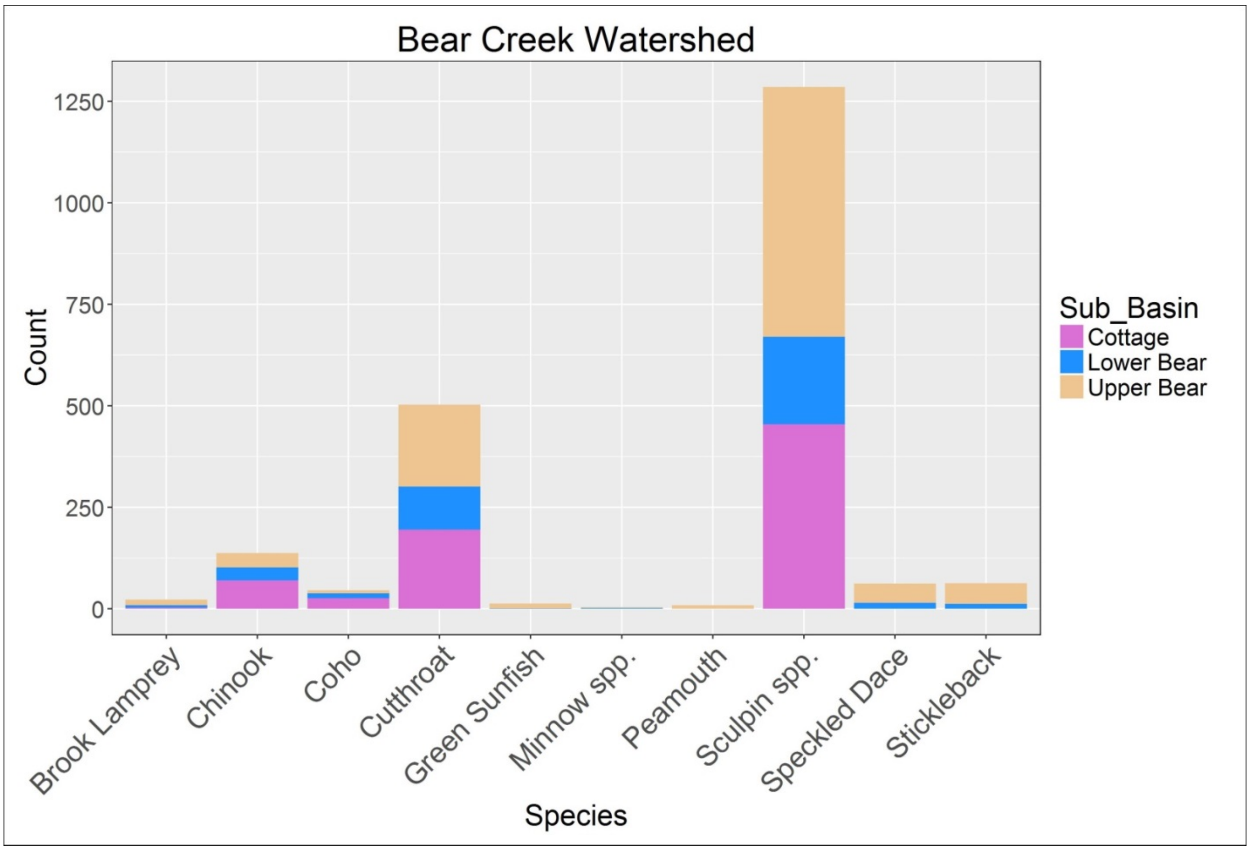

Figure 3. Counts of fish observed in the Bear Creek watershed in 2016.

Among the observed salmonids, cutthroat trout had the highest relative abundance (catch per seconds fished) with the majority of salmonids being observed in the Cottage Lake Creek and Upper Bear Creek subbasins (Figure 4). Juvenile Chinook and coho salmon were almost twice as abundant in Cottage Lake Creek (CPUE = 0.01) compared to Upper and Lower Bear creeks, which had similar lower abundances (CPUE = 0.005 and 0.006, respectively). It is worth noting that the higher abundance of Chinook and coho in Cottage Lake Creek is likely due to relative differences in adult spawner abundances rather than juvenile salmon habitat preference across subbasin areas. For example, WDFW Chinook spawner surveys conducted in the Bear Creek watershed indicate that the majority of Chinook spawning activity occur in the Cottage Lake Creek subbasin.

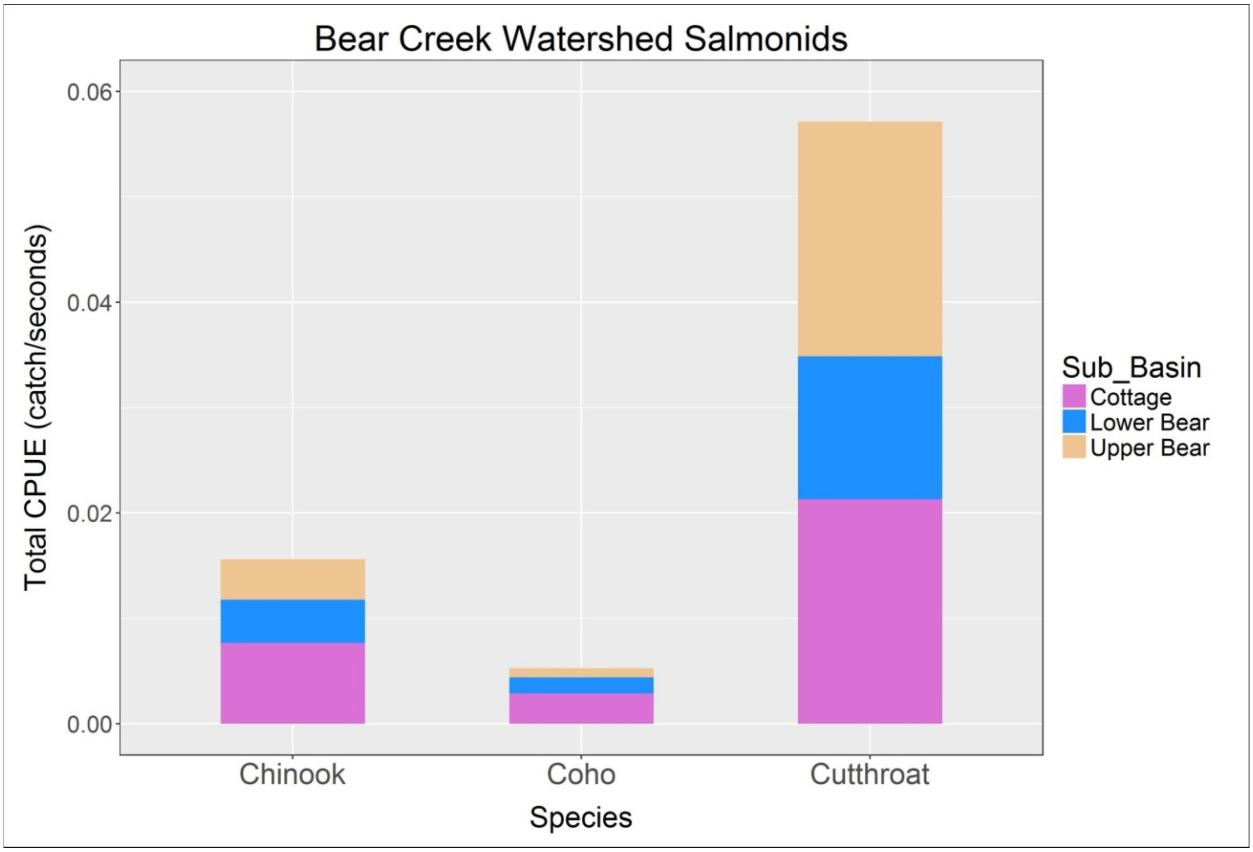

Figure 4. Total catch per unit effort (CPUE) for each salmonid species observed in the Bear Creek watershed during 2016. Total CPUE is the ratio of the number of fish caught per the number of seconds electrofished.

3.2 Juvenile Salmon Habitat Use

3.2.1 Juvenile Chinook Salmon

Regression tree analyses indicated that month, habitat type, and subbasin were significant explanatory variables influencing the observed Chinook CPUE (Figure 5). The final regression tree for juvenile Chinook salmon was pruned at a complexity parameter of 0.013 resulting in 5 splits and 6 final nodes. Month appeared to be the greatest determinant of juvenile Chinook relative abundance (CPUE). Observations across months were split with February, March, and April having greater Chinook CPUE compared to May and June. After month, habitat type was the next determining predictor with greater CPUE from February–April being observed in backwaters, non-turbulent runs, side-channels, and tributary mouths. Among these habitat types, Cottage Lake Creek had higher juvenile Chinook CPUE compared to Upper and Lower Bear Creek. From February–April, lower juvenile Chinook CPUE were observed in debris dammed pools, lateral scour pools, mid-channel scour pools, non-turbulent glides, and turbulent riffles. Among these habitat types, higher juvenile Chinook CPUE was observed in non-turbulent glides, with the greatest CPUE being observed in March. Juvenile Chinook CPUE in May and June were low across all habitat types in Upper and Lower Bear Creek, resulting is no significant tree groupings.

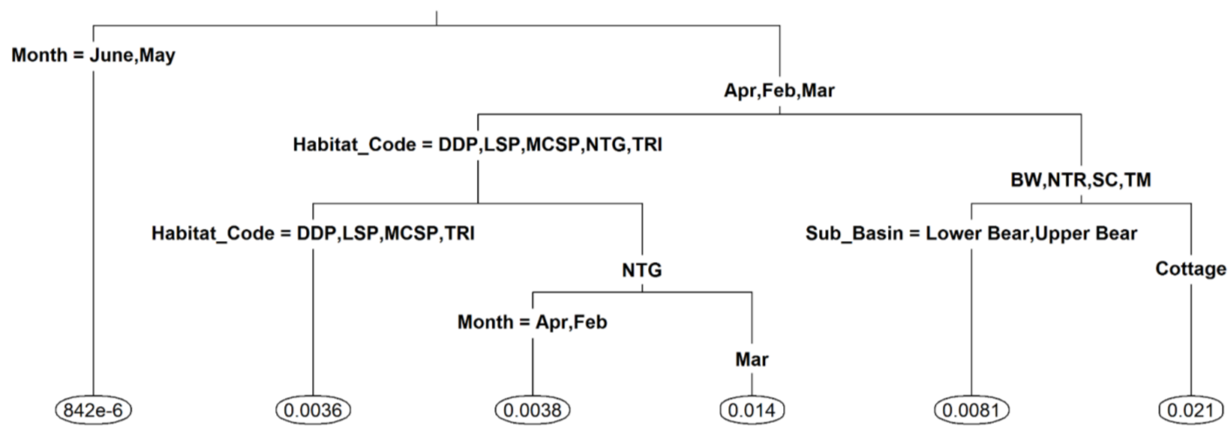

Figure 5. Regression tree plot of Chinook catch per seconds fished (CPUE) based on month, subbasin, and habitat type. Numbers at the final nodes indicate the relative CPUE for that respective group. Tree was pruned to the lowest complexity parameter. Habitat Codes: SC = side-channel; BW = backwater; TM = tributary mouth; DDP = debris dammed pool; LSP = lateral scour pool; MCSP = mid-channel scour pool; NTG = non-turbulent glide; NTR = non-turbulent run; TRI = turbulent riffle.

Since month, habitat-type, and subbasin were significant explanatory variables, it may be useful to subsequently evaluate differences in Chinook CPUE across each subbasin, habitat-type, and month combination. However, consideration of environmental and ecological information across months, suggests that a relative grouping of earlier (late winter–early spring) and later (spring–late spring) periods may best represent Chinook habitat use patterns. For example, flow and temperature observed in the Bear Creek watershed were noticeably different from earlier months (February–March) compared to later months (April–June) (Figure 6 and 7). Since flow and temperature influence instream habitat conditions experienced by juvenile Chinook, it is likely that habitat use patterns shifts with these changing environmental conditions.

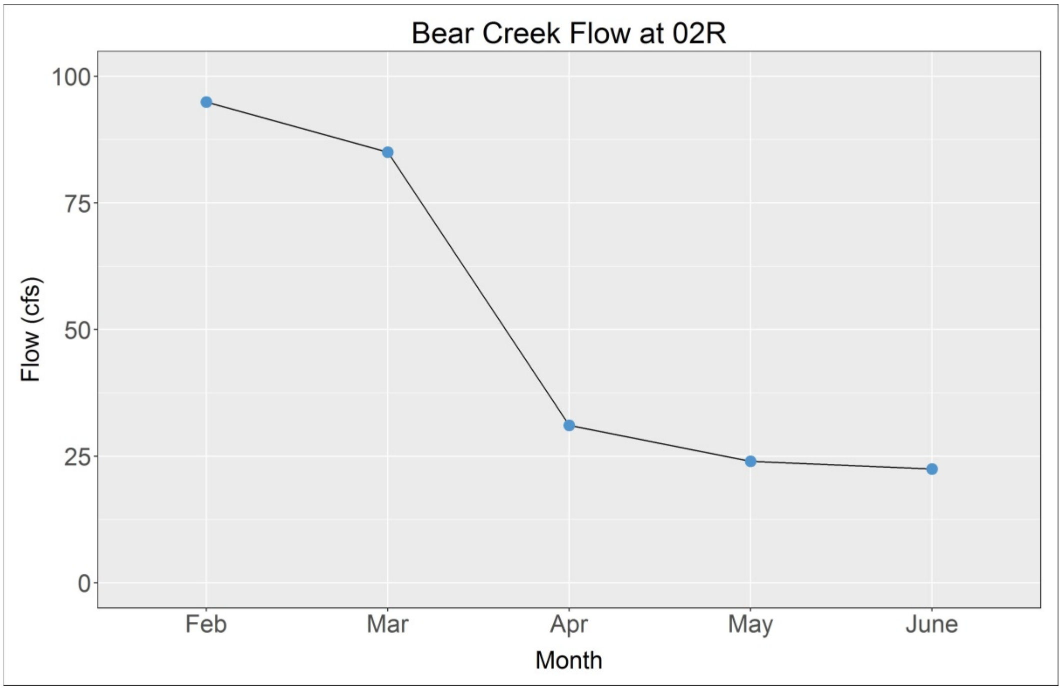

Figure 6. Average flow in Bear Creek at King County Station 02R from February to June in 2016.

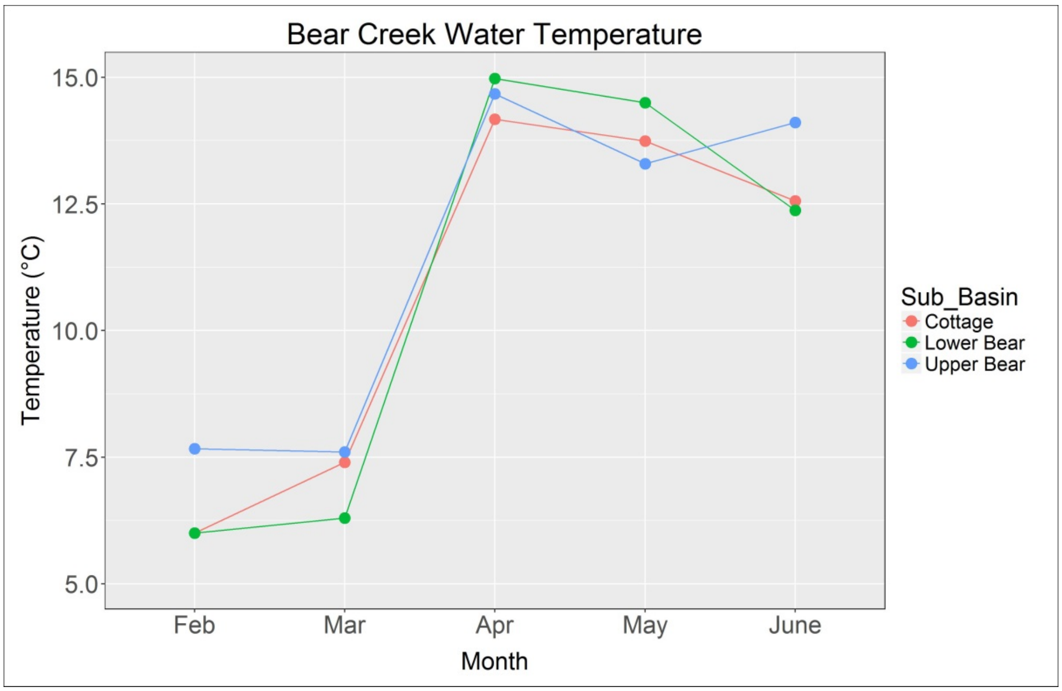

Figure 7. Average monthly water temperature in 2016 observed across habitat types in each Bear Creek subbasin.

Additionally, life-history information specific to juvenile Chinook in the Bear Creek watershed support grouping habitat-use pattern among an earlier and later rearing period. Juvenile salmon outmigrant monitoring conducted by WDFW indicates that two primary juvenile Chinook life-histories are observed in the Bear Creek watershed (Kiyohara 2016). These monitoring efforts show that a cohort of smaller juvenile Chinook (fry) migrate in late winter between February and early April, and a cohort of larger juvenile Chinook (parr) emigrate later in spring from mid-April to the end of June. Our observations support these findings showing that the size distribution of juvenile Chinook increased across months with smaller Chinook observed earlier and larger Chinook observed later in spring (Figure 8). Since salmon foraging, rearing, and growth are related to environmental (e.g., temperature, flow, cover, etc.) and biotic factors (e.g., relative size, food availability, species interaction, etc.), it is likely that Chinook display seasonal shifts in habitat use as factors change. Subsequently, in consideration of these aforementioned environmental and ecological patterns observed in the Bear Creek watershed, we decided to evaluate habitat-use pattern across an early period (February–March) as well as a later period (April–June). This evaluation was done by plotting the ranges in catch observed across subbasins for each of these monthly periods. These analyses would supplement initial regression tree results and allow us to better understand the habitat types used in later months (when juvenile Chinook were larger), which the original regression tree was not able to provide.

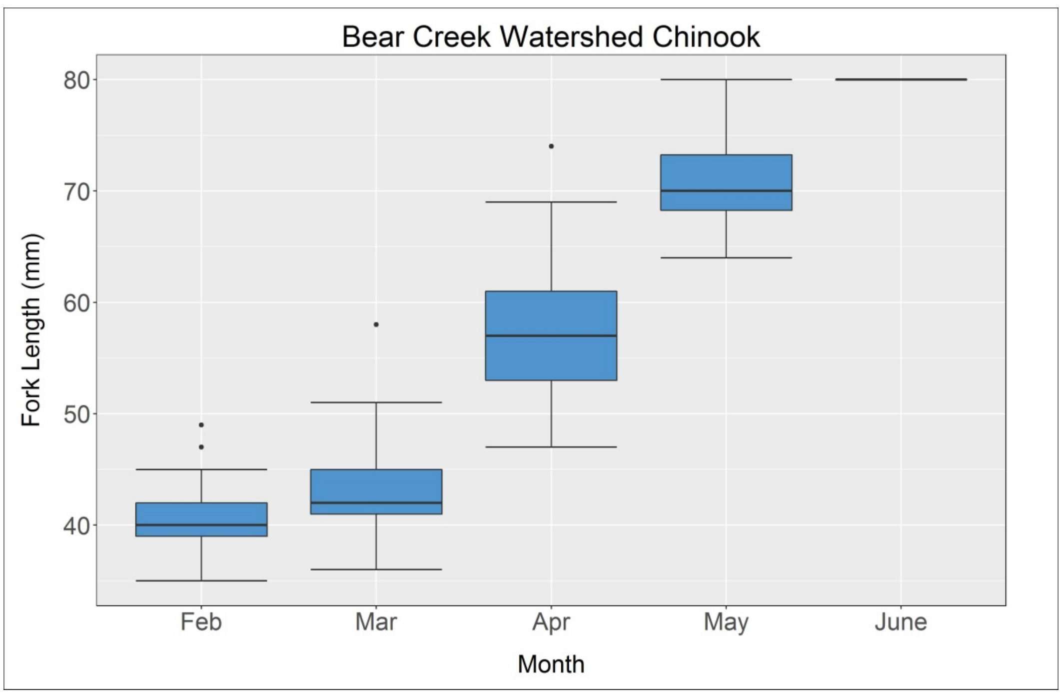

Figure 8. Boxplots of juvenile Chinook fork lengths from February to June 2016 in the Bear Creek watershed. Boxes represent the median and 25% to 75% interquartile range with whiskers denoting the 95% range.

In Cottage Lake Creek during February and March, juvenile Chinook appeared to primarily use side-channels, non-turbulent runs, and backwaters (Figure 9). However, juvenile Chinook were also found in all other available habitat types including turbulent riffles, lateral scour pools, mid-channel scour pools, and non-turbulent glides. The highest relative abundances were observed in side-channel habitats. In Upper Bear Creek during February and March, juvenile Chinook appeared to use backwaters, mid-channel scour pools, non-turbulent runs, turbulent riffles, and lateral scour pools (Figure 10). Highest relative abundances were found in back waters, mid-channel scour pools, and non-turbulent runs. In Lower Bear Creek, juvenile Chinook were found in debris dammed pools, non-turbulent glides, non-turbulent runs, and side-channels (Figure 11). The highest relative abundances were observed in non-turbulent glides.

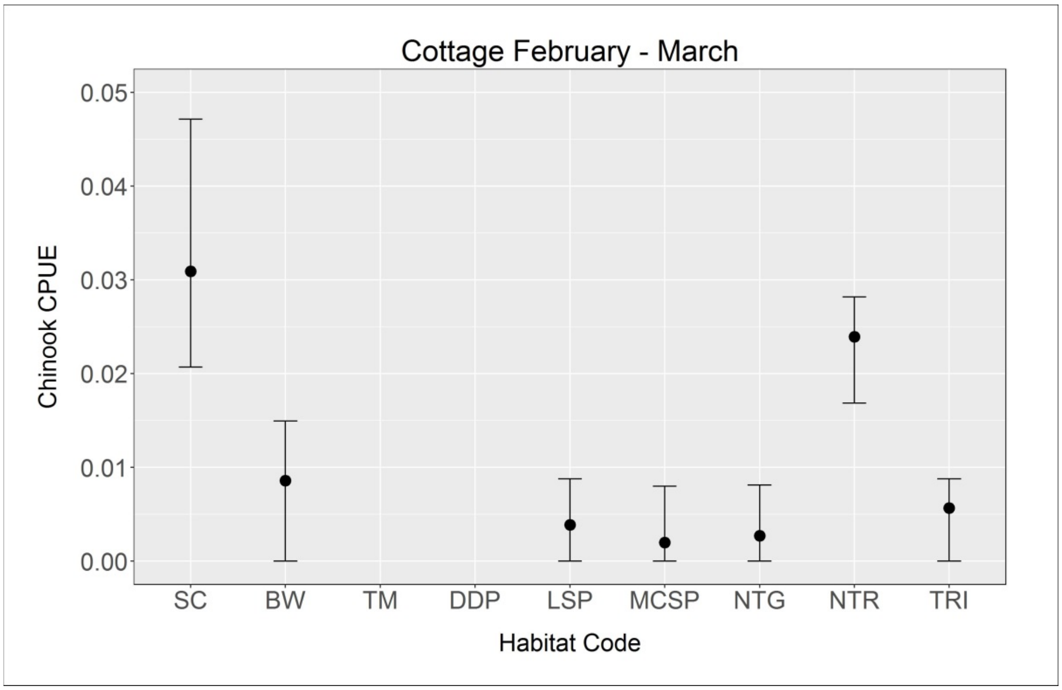

Figure 9. Average Chinook catch per unit effort (CPUE) with max/min whiskers across habitat types in Cottage Lake Creek from February to March. Habitat codes include: SC = side-channel; BW = backwater; TM = tributary mouth; DDP = debris dammed pool; LSP = lateral scour pool; MCSP = mid-channel scour pool; NTG = non-turbulent glide; NTR = non-turbulent run; TRI = turbulent riffle.

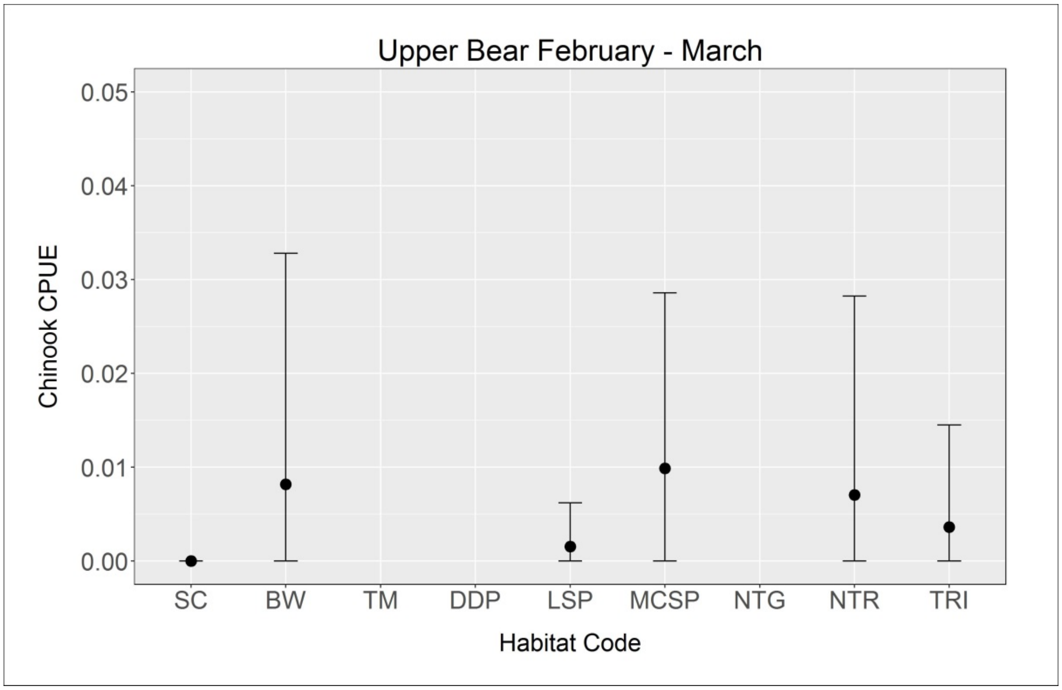

Figure 10. Average Chinook catch per unit effort (CPUE) with max/min whiskers across habitat types in Upper Bear Creek from February to March. Habitat codes include: SC = side-channel; BW = backwater; TM = tributary mouth; DDP = debris dammed pool; LSP = lateral scour pool; MCSP = mid-channel scour pool; NTG = non-turbulent glide; NTR = non-turbulent run; TRI = turbulent riffle.

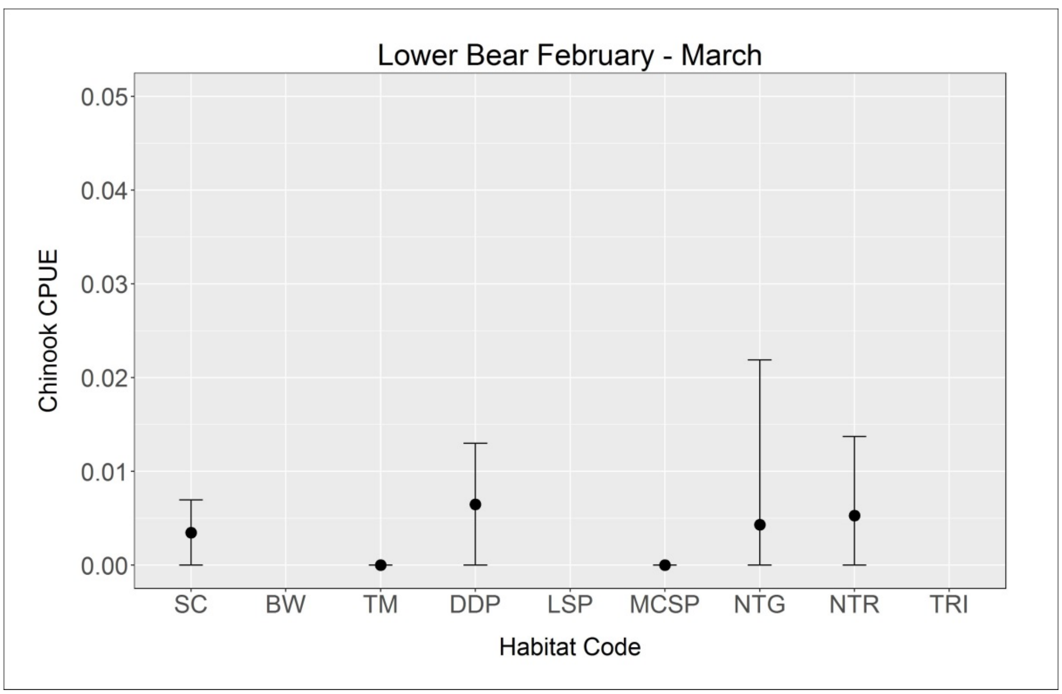

Figure 11. Average Chinook catch per unit effort (CPUE) with max/min whiskers across habitat types in Lower Bear Creek from February to March. Habitat codes include: SC = side-channel; BW = backwater; TM = tributary mouth; DDP = debris dammed pool; LSP = lateral scour pool; MCSP = mid-channel scour pool; NTG = non-turbulent glide; NTR = non-turbulent run; TRI = turbulent riffle.

During the latter spring period (April through June) in Cottage Lake Creek, juvenile Chinook appeared to primarily use non-turbulent glides, mid-channel scour pools, side-channels, non-turbulent runs, and turbulent riffles (Figure 12). The highest relative abundances were found in non-turbulent glides. In Upper Bear Creek, juvenile Chinook appeared to use side-channels, backwaters, mid-channel scour pools, non-turbulent runs, and lateral scour pools (Figure 13). Among these, side-channels appeared to have the highest observed relative abundances. From April through June in Lower Bear Creek, juvenile Chinook were primarily found in tributary mouths, non-turbulent runs, and side-channels (Figure 14). The tributary mouth that was surveyed (Mackey Creek) does not have documented Chinook spawning; however, this location had the highest relative juvenile Chinook abundance in Lower Bear Creek. The high abundance may have been related to prey resources from the tributary as well as low-velocity areas provided upstream of the tributary confluence.

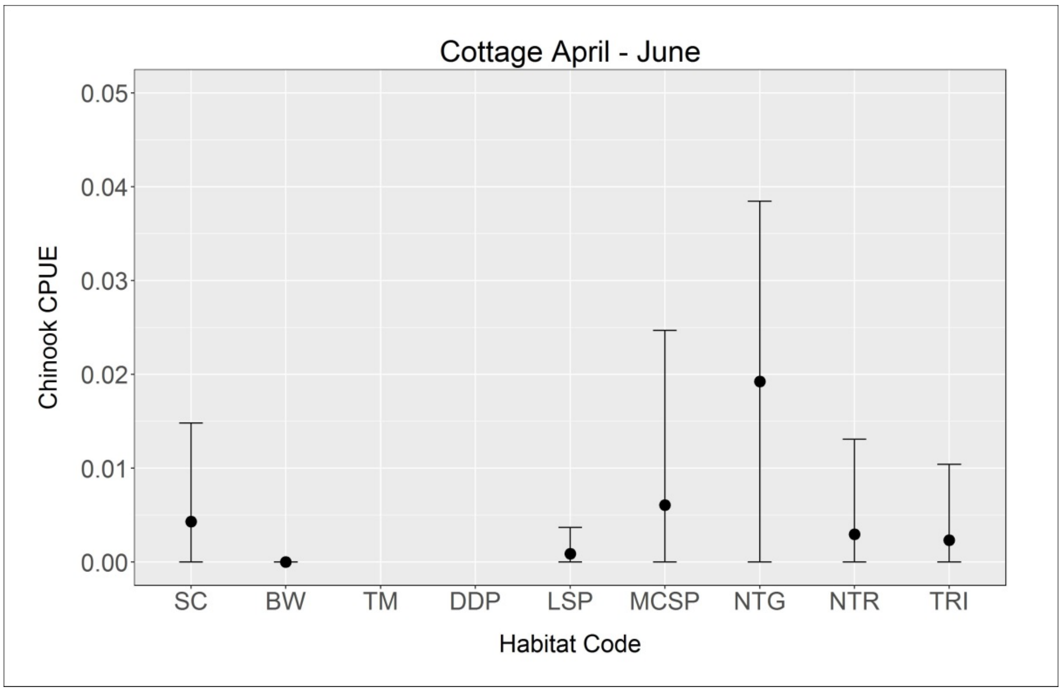

Figure 12. Average Chinook catch per unit effort (CPUE) with max/min whiskers across habitat types in Cottage Lake Creek from April to June. Habitat codes include: SC = side-channel; BW = backwater; TM = tributary mouth; DDP = debris dammed pool; LSP = lateral scour pool; MCSP = mid-channel scour pool; NTG = non-turbulent glide; NTR = non-turbulent run; TRI = turbulent riffle.

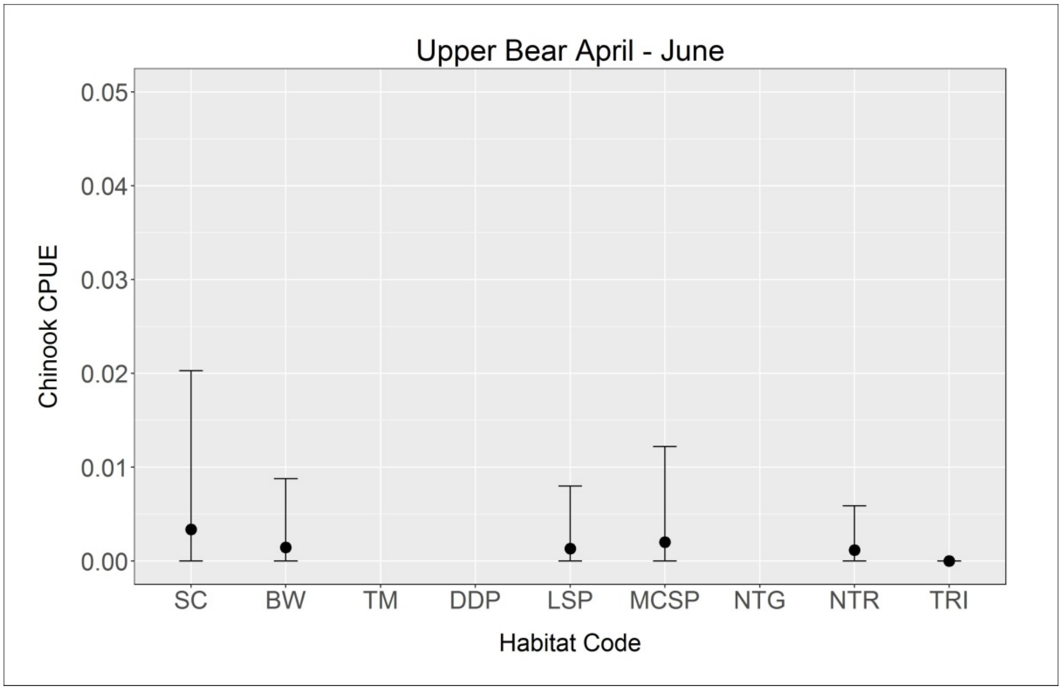

Figure 13. Average Chinook catch per unit effort (CPUE) with max/min whiskers across habitat types in Upper Bear Creek from April to June. Habitat codes include: SC = side-channel; BW = backwater; TM = tributary mouth; DDP = debris dammed pool; LSP = lateral scour pool; MCSP = mid-channel scour pool; NTG = non-turbulent glide; NTR = non-turbulent run; TRI = turbulent riffle.

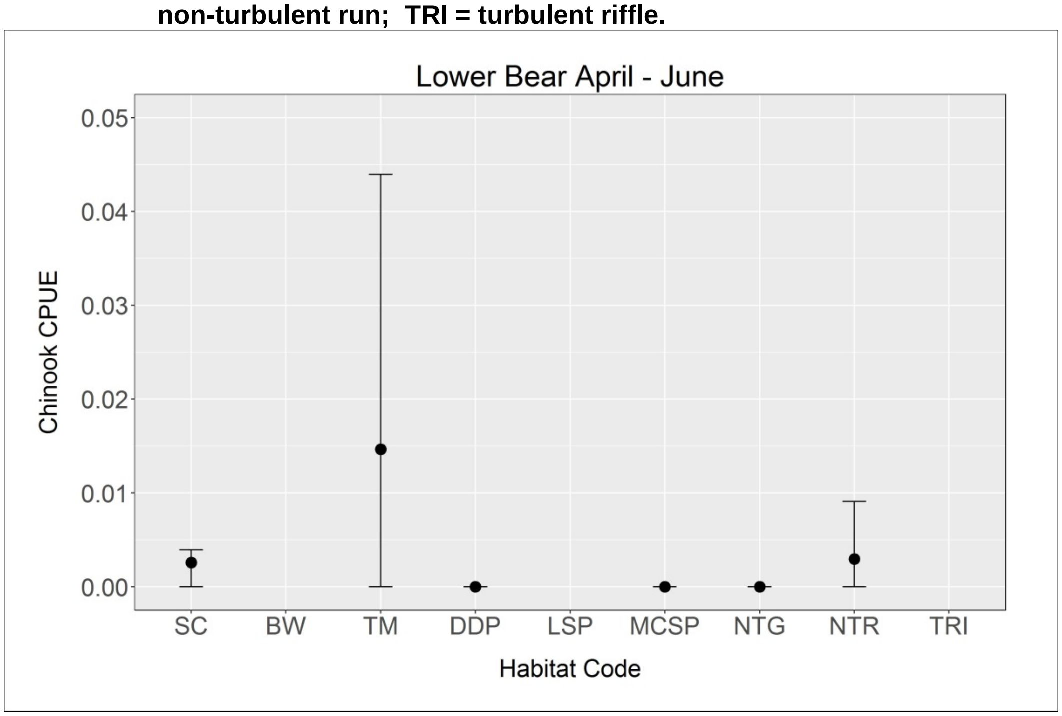

Figure 14. Average Chinook catch per unit effort (CPUE) with max/min whiskers across habitat types in Lower Bear Creek from April to June. Habitat codes include: SC = side-channel; BW = backwater; TM = tributary mouth; DDP = debris dammed pool; LSP = lateral scour pool; MCSP = mid-channel scour pool; NTG = non-turbulent glide; NTR = non-turbulent run; TRI = turbulent riffle.

The regression tree and variation analyses indicate that a suite of habitats were used by juvenile Chinook and this suite of habitats varied across months and subbasin areas. During late winter and the early spring (February–March), juvenile Chinook appear to use a broad variety of habitat types with the highest relative abundances being observed in off-channel, slow water, and non-turbulent habitats. After young salmonids emerge from the gravel nests, juveniles occupy suitable rearing habitats within side sloughs of channels, tributaries, and the outer edges of streams (Kerwin 2001). These low-velocity side margins and off-channel areas are vital for early juvenile rearing providing refuge from higher water velocities as well as areas for foraging opportunities and predator avoidance. Observed use in higher-velocity areas during this early-spring period may indicate that these fish are actively migrating, either as part of a volitional life history strategy or as a consequence of insufficient low-velocity habitat (i.e., displacement).

During spring (April–June), juvenile Chinook appear to use various slow and fast water habitats but at lower abundances compared to earlier winter–spring rearing. As juvenile salmon grow, they move from shallow, low-velocity areas to deeper and faster areas of the stream. These distribution patterns help to optimize foraging opportunities and prey resources. Results from this study indicate that as juvenile Chinook grow their habitat associations' shift with changing biological and behavioral patterns.

While the relative abundance in a given habitat type varied across months and subbasins, juvenile Chinook seemed to occur in most of the available habitat types during both the early and later rearing periods. It should be noted that Lower Bear Creek is very homogeneous and dominated by non-turbulent glides (Table 1, discussed in Section 3.3); however, juvenile Chinook were still found in most available habitat types, when present. For example, while two out the three samples reaches in Lower Bear were almost entirely non-turbulent glides, one reach located just downstream of 116th St near Juel Park had several habitat types (e.g., side channel, mid-channel scour pool, debris-dammed pool, non-turbulent run). Among Lower Bear Creek, the majority of the juvenile Chinook were observed in this sample reach.

The presence of juvenile Chinook across the diverse suite of available habitat types throughout the winter and spring indicates that a variety of habitat types are needed to support the freshwater stages of juvenile Chinook life-histories. Alternatively, these patterns may indicate that the quantity of optimal habitats is insufficient, thereby forcing Chinook into less optimal habitat.

3.2.2 Juvenile Coho Salmon

The final regression tree for juvenile coho salmon did not show any specific groupings once it was pruned to a complexity parameter of 0.12 (lowest cross-validation error). However, additional variation analyses across months and subbasins provided some insight into which habitats coho salmon were observed in. It should be noted that we observed relatively fewer juvenile coho compared to Chinook (as discussed in Section 3.1), which may influence the power of observed coho habitat use patterns. However, lower juvenile coho abundances observed in 2016 were likely representative for Bear Creek, in that juvenile salmon outmigrant monitoring conducted by the WDFW indicated that 2016 had the lowest coho production over the last 15 years (Kiyohara 2017). Similar to Chinook salmon, we decided to evaluate habitat-specific use for coho based on observed life-history strategies. Coho salmon in Bear Creek display two primary life-histories including a sub-yearling cohort (hatched during the present year) as well as a yearling cohort (hatched during the previous year and remained in riverine habitats for the past year). Sub-yearling coho, known as nomads, have been shown to emigrate to estuarine and nearshore habitats (Chapman 1962, Koski 2009); however, the majority of coho emigration occurs at the yearling smolt stage. The emigration timing of this yearling cohort tends to occur from April to June (Kiyohara 2016). We observed both sub-yearling and yearling coho in the Bear Creek watershed. The fork-length distribution across months in this study indicated that yearling coho were generally observed around February to March and the sub-yearling cohort were primarily observed from April to June (Figure 15). Subsequently, we decided to evaluate habitat-use for yearling coho during an early period (February–March) and for sub-yearling coho during a later period (April–June).

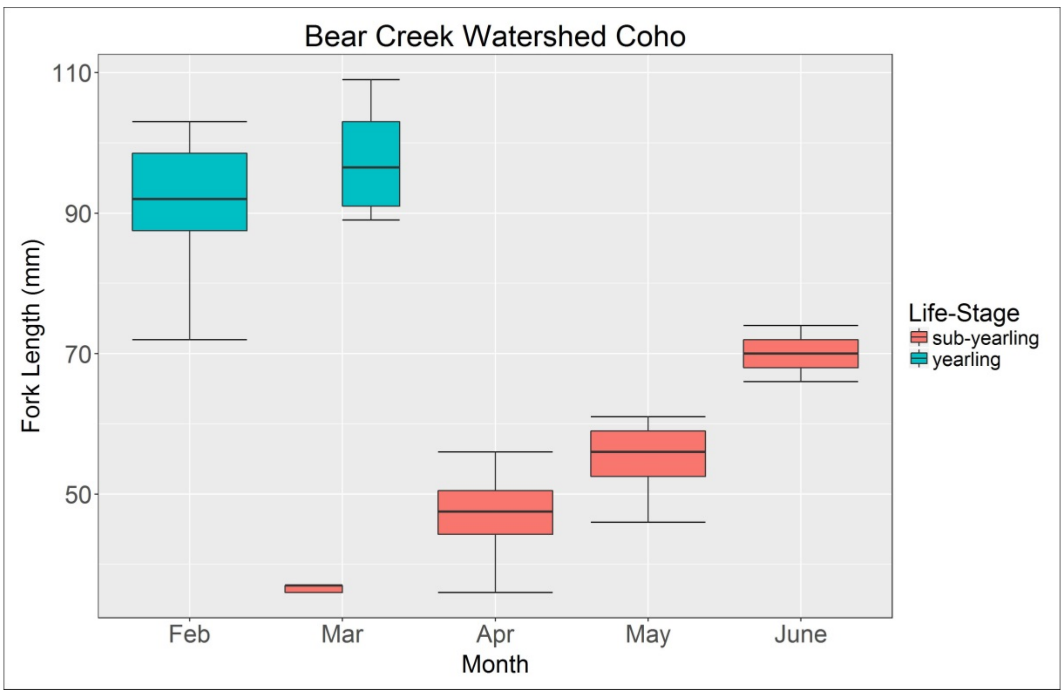

Figure 15. Boxplots of sub-yearing and yearling coho fork lenghs from February to June in the Bear Creek watershed. Boxes represent the median with 25% and 75% interquartile range with whiskers denoting the 95% range.

Yearling coho during February and March used a variety of habitat types and were primarily found in Cottage Lake Creek as well as Upper Bear Creek. In Cottage Lake Creek, yearling coho were found in all available habitat types with the highest relative abundances observed in backwaters, non-turbulent runs, lateral scour pools, and mid-channel scour pools (Figure 16). In Upper Bear Creek, yearling coho were found in backwaters, turbulent riffles, lateral scour pools, and side-channels (Figure 17). Among these habitat types, the highest relative abundances were found in backwaters. In Lower Bear, yearling coho were only found in non-turbulent glides (Figure 18).

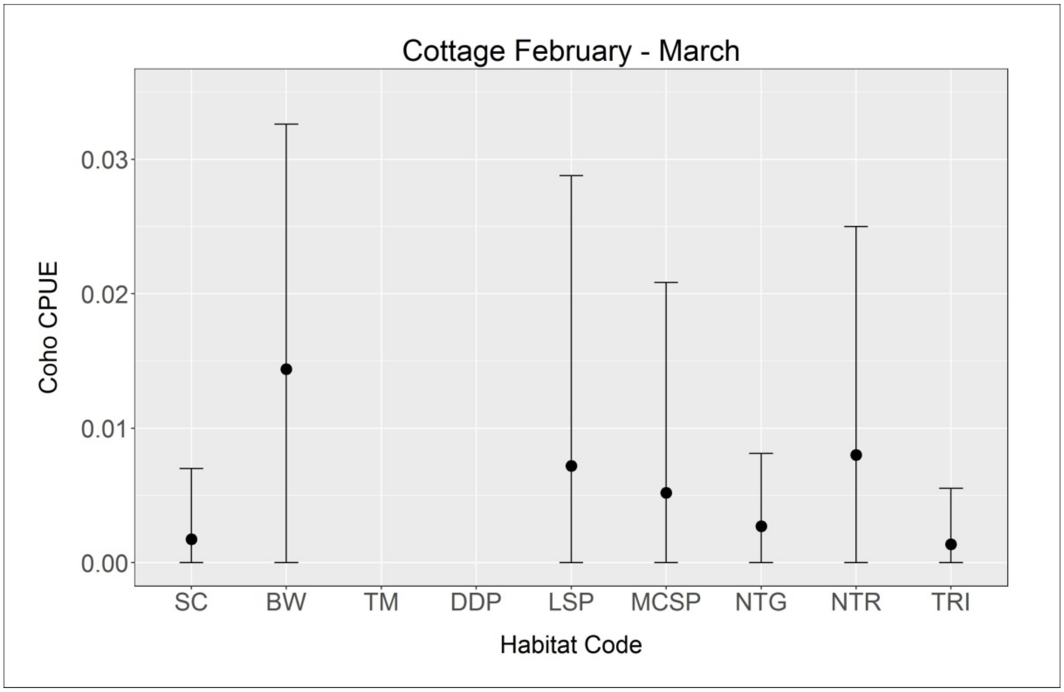

Figure 16. Average yearling coho catch per unit effort (CPUE) with max/min whiskers across habitat types in Cottage Lake Creek from February to March. Habitat codes include: SC = side-channel; BW = backwater; TM = tributary mouth; DDP = debris dammed pool; LSP = lateral scour pool; MCSP = mid-channel scour pool; NTG = non-turbulent glide; NTR = non-turbulent run; TRI = turbulent riffle.

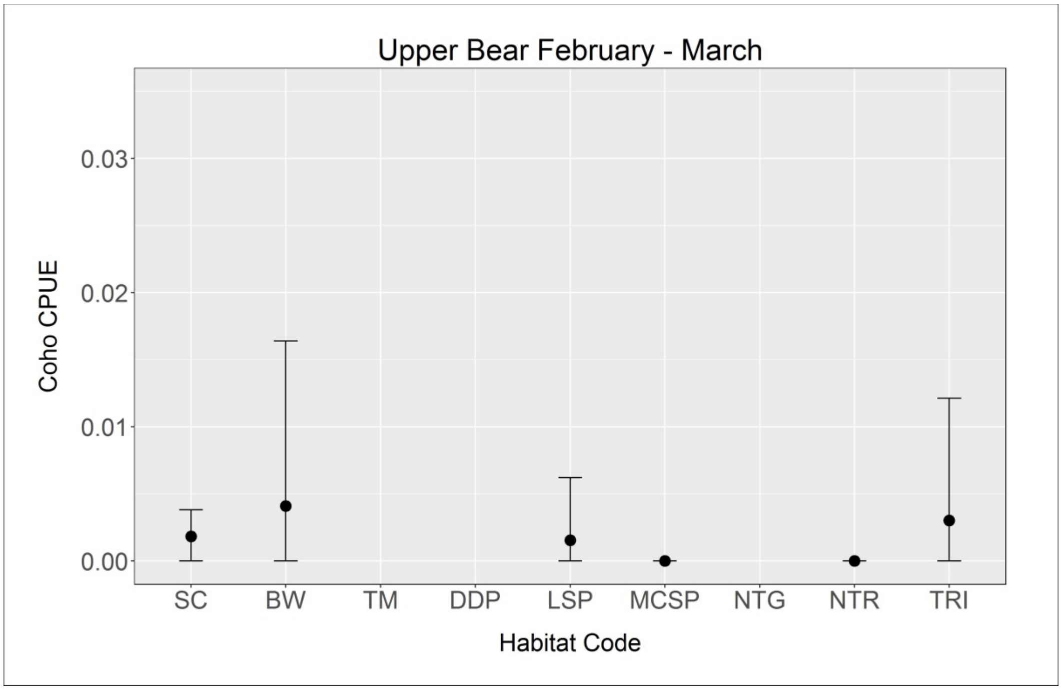

Figure 17. Average yearling coho catch per unit effort (CPUE) with max/min whiskers across habitat types in Upper Bear Creek from February to March. Habitat codes include: SC = side-channel; BW = backwater; TM = tributary mouth; DDP = debris dammed pool; LSP = lateral scour pool; MCSP = mid-channel scour pool; NTG = non-turbulent glide; NTR = non-turbulent run; TRI = turbulent riffle.

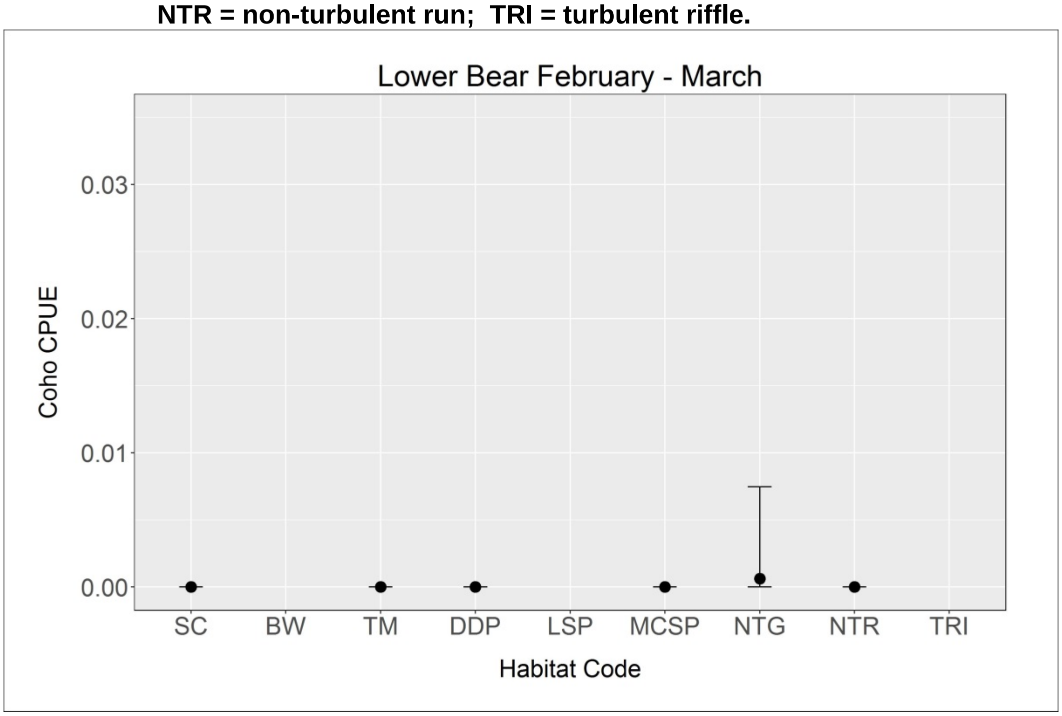

Figure 18. Average yearling coho catch per unit effort (CPUE) with max/min whiskers across habitat types in Lower Bear Creek from February to March. Habitat codes include: SC = side-channel; BW = backwater; TM = tributary mouth; DDP = debris dammed pool; LSP = lateral scour pool; MCSP = mid-channel scour pool; NTG = non-turbulent glide; NTR = non-turbulent run; TRI = turbulent riffle.

Sub-yearling coho from April to June were primarily found in Cottage Lake Creek as well as Lower Bear Creek. In Cottage Lake Creek during April-June, sub-yearling coho were found in backwaters, turbulent riffles, mid-channel scour pools, side-channels, and non-turbulent runs (Figure 19). Among these habitats, the highest relative abundances were observed in backwaters. In Upper Bear Creek from April to June, sub-yearling coho were found in low abundances and only in side-channels and turbulent riffles (Figure 20). In Lower Bear Creek, sub-yearling coho were found in tributary mouths, side-channels, non-turbulent glides, and non-turbulent runs (Figure 21). The highest relative abundances were observed in the tributary mouth of Mackey Creek.

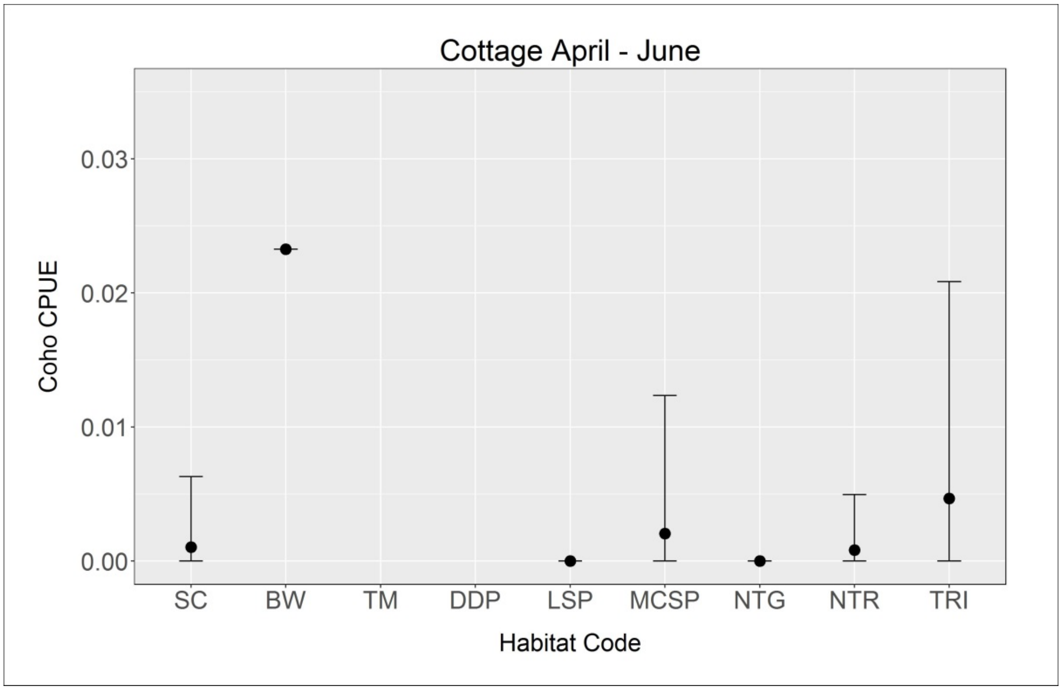

Figure 19. Average sub-yearling coho catch per unit effort (CPUE) with max/min whiskers across habitat types in Cottage Lake Creek from April to June. Habitat codes include: SC = side-channel; BW = backwater; TM = tributary mouth; DDP = debris dammed pool; LSP = lateral scour pool; MCSP = mid-channel scour pool; NTG = non-turbulent glide; NTR = non-turbulent run; TRI = turbulent riffle.

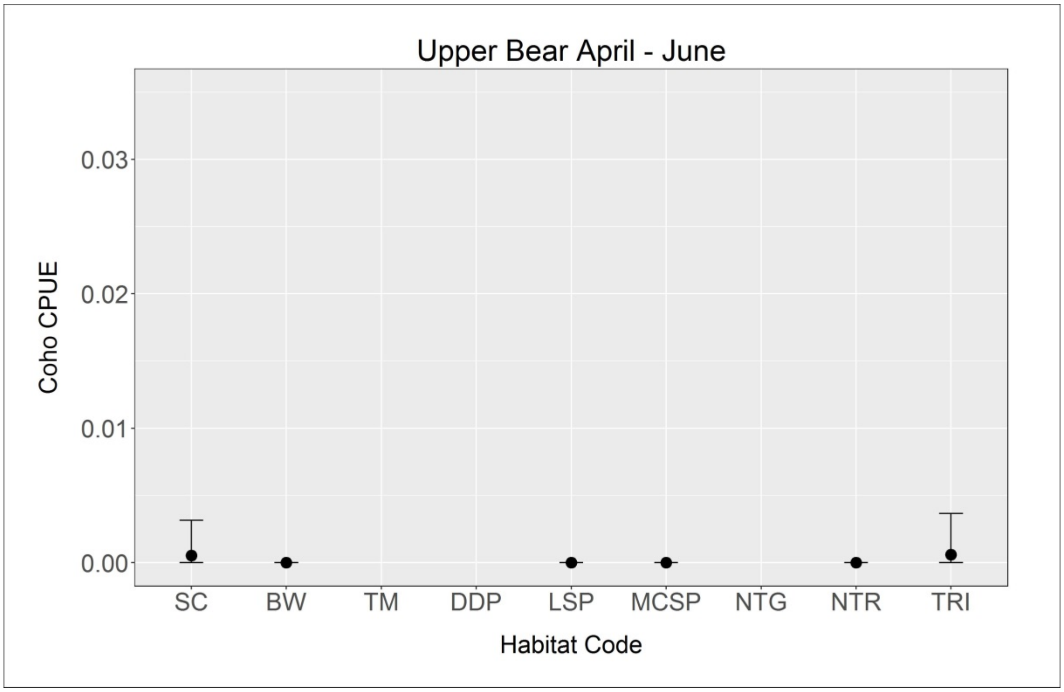

Figure 20. Average sub-yearling coho catch per unit effort (CPUE) with max/min whiskers across habitat types in Upper Bear Creek from April to June. Habitat codes include: SC = side-channel; BW = backwater; TM = tributary mouth; DDP = debris dammed pool; LSP = lateral scour pool; MCSP = mid-channel scour pool; NTG = non-turbulent glide; NTR = non-turbulent run; TRI = turbulent riffle.

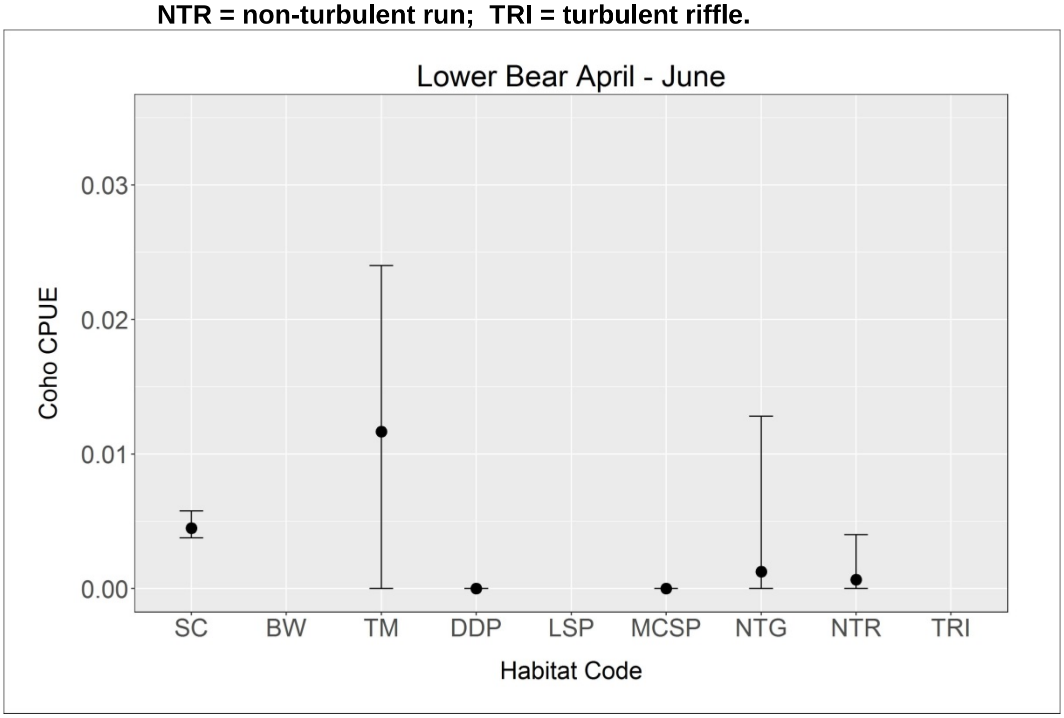

Figure 21. Average sub-yearling coho catch per unit effort (CPUE) with max/min whiskers across habitat types in Lower Bear Creek from April till June. Habitat codes include: SC = side-channel; BW = backwater; TM = tributary mouth; DDP = debris dammed pool; LSP = lateral scour pool; MCSP = mid-channel scour pool; NTG = non-turbulent glide; NTR = non-turbulent run; TRI = turbulent riffle.

Variation analyses indicate that a suite of habitats were used by yearling and sub-yearling coho. During late-winter and the early-spring (February–March), juvenile yearling coho appear to use several habitat types with the highest relative abundances being observed in both slow and fast water habitats. Since yearling coho are generally larger than most juvenile salmon during this period, it may be possible that these yearling coho are able to use a broader range of slow and fast water habitats for foraging and rearing opportunities. During spring (April–June), sub-yearling coho appear to use various slow and fast water habitats and were found in relatively lower abundances compared to yearling coho. Similar to juvenile Chinook, results from this study indicate that a variety of habitat types are needed to support the freshwater stages of juvenile coho life-histories. Additionally, results from this study support that as juvenile coho grow their habitat associations' shift with changing biological and behavioral patterns.

3.3 Existing Habitat Conditions

Instream habitat requirements for salmonids include physical features (e.g., habitat areas, wood and instream cover, substrate, riparian vegetation), environmental conditions (e.g., flow, temperature), as well as biological factors (e.g., predation, competition, food resources) (Roni et al. 2014). These attributes govern habitat quality and quantity which influence the growth and survival of juvenile salmonids. At the watershed scale, juvenile salmonids occupy and move throughout mainstem, tributary, and floodplain habitats (Quinn and Petersen 1996, Kahler et al. 2001, Jeffres et al. 2008). At the reach and site level, optimal salmonid habitats are related to slow water for refuge and rearing, specific temperature regimes for development and metabolic needs, woody debris and available cover for predator avoidance, and habitats with adequate food resources (Everest and Chapman 1972, Hillman et al. 1987, Sommer et al. 2001, Rosenfeld et al. 2005, Jeffres et al. 2008). The following sections discuss existing habitat conditions in the Bear Creek watershed as they relate to these aforementioned habitat requirements.

3.3.1 Bear Creek Watershed

The Bear Creek watershed is a core area for Chinook use and has relatively higher levels of watershed function compared to much of WRIA 8 (Lake Washington/Cedar/Sammamish watershed). However, instream habitats within Bear Creek are still degraded compared to well-functioning and unmanaged forested basins. Factors like altered hydrology, the loss of channel complexity and connectivity, degradation of riparian areas, loss of large wood, and increased sedimentation appear to be associated with the decline of naturally produced salmonids in the Bear Creek watershed (Kerwin 2001, WRIA 8 Steering Committee 2005). Additionally, associated factors including increased water temperatures during the summer months, loss of shoreline complexity, instream barriers, and introduced fish and plant species likely contribute to salmonid decline. Across the Bear Creek watershed, Cottage Lake Creek and Upper Bear Creek have relatively higher levels of watershed function compared to Lower Bear, primarily due to lower percentages of impervious surface, fewer road crossings, and higher levels of forest cover and riparian forest (WRIA 8 Steering Committee 2005). Habitat mapping efforts from this 2016 assessment support these observations, showing that the diversity of habitat types and frequency of each habitat type was relatively greater in Cottage Lake Creek and Upper Bear Creek, compared to Lower Bear Creek (Table 1, Section 2.2).

The hydrology of the Bear Creek watershed has been altered primarily due to land conversion from historic forests and wetlands to grass and impervious surfaces (King County 2000). This altered hydrology influences factors like recharge and infiltration, storm-flow volume and run-off rates, and the intensity and frequency of instream high flow events. Changes in these hydrologic responses has subsequently resulted in decreased habitat quality and quantity by influencing bank erosion, instream scour, wood residence time, and juvenile salmonid displacement (King County et al. 1989).

Within the Bear Creek watershed, the loss of channel complexity and connectivity is associated with channelization, the removal of large woody debris, clearing of the riparian corridor, and disconnection with floodplain and off-channel areas. Floodplain connectivity in Bear Creek has been impacted by confinement, channelization, and road crossings (Entranco 1994, King County 2000). Floodplain area has been significantly decreased due to the conversion of floodplain and riparian areas to residential and commercial development. The conversion of the floodplain and riparian areas has subsequently reduced the complexity and diversity of habits in the Bear Creek watershed (King County 2000). Decreased connectivity to floodplain and off-channel areas has resulted in decreased quantity and quality of refuge and low-velocity rearing habitats available for juvenile salmonids. The lack of sufficient rearing habitat results in a diminished ability to provide food resources as well as refuge from predators and higher velocity flows.

Instream habitat complexity in Bear Creek is limited due to a lack of large wood as well as poor pool quality and quantity (King County et al. 1994, Parametrix 2002). Large wood present in Bear Creek tends to be small in volume and low in frequency, with Lower and Upper Bear creeks having considerably less large wood than Cottage Lake Creek (King County et al. 1989). When compared to wood volumes in well-functioning and unmanaged forested basins (e.g., Fox and Bolton 2007), the Bear Creek watershed has considerably lower wood volumes. For example, WRIA 8 status and trends monitoring conducted from 2010–2013 concluded that stream wood volume conditions in the Bear Creek Watershed were generally poor ($<28m^3/100m$) when compared to criteria outlined in Fox and Bolton (2007). Removal of large wood from the stream reduces hydraulic diversity and alters sediment dynamics, decreasing the complexity and heterogeneity of available habitats (Maser et al. 1988, King County et al. 1989). Large wood maintains the hydraulic stability of critical instream habitat features, especially pools (Bilby and Ward 1991), and dissipates hydraulic energy during peak flows providing high-flow refuge for salmonids (Bilby 1984). Additionally, large wood provides excellent cover and habitat diversity for salmonids (Harmon et al. 1986). Across several previous assessments in Bear Creek, reduced pool quality and quantity has largely been attributed to the lack of large wood and riparian vegetation in the system (King County et al. 1989, King County et al. 1994, Parametrix 2002). Degraded pool conditions have been consistently documented across Bear Creek and reduced pool diversity has been found throughout all primary subbasin areas (King County et al. 1989, King County et al. 1994, Parametrix 2002). These degraded pool conditions result in limited foraging and rearing habitats for juvenile salmonids as well reduced holding habitats for returning adults.

Many fish barriers have been documented in the Bear Creek watershed, primarily in smaller streams in the upper reaches (inventory/locations of barriers not included in this report). Documented passage barriers include culverts, dams, weirs, high velocity stream flows, beaver dams, and choking vegetation. The extent to which these barriers influence salmonids in Bear Creek is not fully documented; however, it is likely that juvenile and adult life-history stages among many salmonids are influenced by these barriers.

3.3.2 Cottage Lake Creek

Cottage Lake Creek subbasin instream habitats were characterized as relatively moderate to higher quality in 1989 (King County et al. 1989). When evaluated again in 1994, Cottage Lake Creek had higher quality habitat compared to Lower Bear with the greatest instream habitat diversity found in reaches around NE 143rd Pl –194th Ave NE (Entranco 1994). However, there were still several reaches in Cottage Lake Creek which displayed a lack of instream habitat diversity (Entranco 1994, King County et al. 1994). Habitat mapping efforts from this 2016 assessment indicate that habitat diversity and frequency were relatively similar in Cottage Lake Creek and Upper Bear Creek (Table 1, Section 2.1.2), especially when compared with Lower Bear Creek. Cottage Lake Creek generally has greater numbers and volumes of large wood compared to Upper and Lower Bear creeks (King County et al. 1989, 1994). However, when evaluated in 2001 and compared to properly functioning conditions (i.e., conditions of watershed habitat-forming processes necessary for long-term salmonid survival; as described by the National Marine Fisheries Service), wood volume and frequency were consistently below criteria (Parametrix 2002). Much of the wood observed in Cottage Lake Creek in 2001 was smaller in size (<24'' diameter, <50' length) and infrequent (<80 pieces/mile).

When re-evaluated in 2010–2013 as part of WRIA 8 Status and Trends Monitoring and compared to criteria outlined in Fox and Bolton (2007), wood volumes observed in Cottage Lake Creek varied from good (>99m^3/100m) to poor (<28m^3/100m) with most years ranking as fair-poor. Pool quality in Cottage Lake Creek is generally at risk (few pools >1m deep) or not at properly functioning conditions (no pools >1m deep) (Parametrix 2002). Pool quantities (adequate number of pools per mile) are generally around properly functioning conditions from NE 128th St to 194th Ave NE; however, as previously mentioned; most of the pools in Cottage Lake Creek are of poor quality. Urban encroachment (residential landscaping; land and stream clearing) was identified as a significant habitat pressure with bank erosion and instability sporadically occurring in the Cottage Lake Creek subbasin (Entranco 1994). However, the extent and frequency of bank erosion and instability in Cottage Lake Creek is less than that observed in Lower Bear Creek.

3.3.3 Upper Bear Creek

Within the Upper Bear Creek subbasin, habitats were characterized as higher quality compared to Cottage and Lower Bear creeks back in 1989 (King County et al. 1989). However, while habitat quality tends to be higher in Upper Bear Creek, when evaluated in 2001, several reaches were characterized as having large wood frequencies below properly functioning conditions (Parametrix 2002). Similar to Cottage Lake Creek, much of the large wood found in Upper Bear Creek during 2001 was consistently smaller in size (<24'' diameter, <50' length) and infrequent (<80 pieces/mile). When re-evaluated in 2010–2013 as part of WRIA 8 Status and Trends Monitoring and compared to criteria outlined in Fox and Bolton (2007), reaches in Upper Bear consistently ranked fair in wood volume (≧28 and ≦99m^3/100m). Pool quality and quantity in Upper Bear was characterized as below properly functioning conditions in 2001; however, select reaches from NE 133rd St up to the Tolt pipeline trail were observed to have pool quality/quantity within properly functioning conditions (Parametrix 2002). As previously mentioned, habitat mapping efforts from 2016 indicate that habitat diversity and frequency were relatively similar in Upper Bear and Cottage Lake creeks (Table 1, Section 2.1.2).

3.3.4 Lower Bear Creek

Lower Bear Creek was characterized as having generally low to moderate quality instream habitats back in 1989 (King County et al. 1989). When re-evaluated in 1994, much of Lower Bear Creek was documented to be uniform and homogeneous with low large wood presence (Entranco 1994). A lack of instream habitat diversity is common in Lower Bear, with reaches generally having many wide, shallow areas as well as lower pool frequency. Habitat mapping efforts from this 2016 assessment support these observations showing that the diversity and frequency of habitat types were considerably lower in Lower Bear Creek compared to Cottage and Upper Bear creeks (Table 1, Section 2.1.2). For example, while 6 habitat types were mapped in Lower Bear, the vast majority of Lower Bear was classified as non-turbulent glides. Across the three sample reaches mapped in Lower Bear, two of the three were almost entirely non-turbulent glides and the majority of habitat diversity observed at the third reach was related to a fallen tree which had altered instream channel dynamics. Much of the lack of instream habitat diversity has been attributed to past dredging, clearing of the riparian corridor, and low wood presence.

When evaluated in 2010–2013 as part of WRIA 8 Status and Trends Monitoring and compared to criteria outlined in Fox and Bolton (2007), Lower Bear Creek consistently had poor wood volume conditions (<28m^3/100m). When present, much of the wood found in Lower Bear was infrequent and smaller in size. Lower Bear has many scour sites with bank erosion and instability occurring throughout the area (Entranco 1994). Eroding banks are common in Lower Bear Creek and appear to be caused by removal of large wood and riparian vegetation (Entranco 1994). Much of Lower Bear is a meandering check-mark channel (high stress channels with high outside bank and low point bars on the inside bank) (Entranco 1994). This channel type tends to be very susceptible to erosion when bank vegetation and large wood is removed. Additionally, high-flow bank erosion increases the amount of fine sediments that reduce the quality of spawning gravels and fill in pools which reduce rearing space (King County et al. 1989). Lower Bear is considered to have only a moderate level of watershed function, due primarily to increased impervious surface and stormwater flow volumes, decreased large wood volumes, along with reductions in forest and riparian cover (WRIA 8 Steering Committee 2005).

3.4 Salmon Recovery, Restoration, and Conservation Strategies

Salmonids depend on various habitat types throughout their life cycle to support individual survival as well as population sustainability (Bjornn and Reiser 1991, Roni et al. 2014). The suite of habitats and associated environmental conditions experienced throughout their life cycle subsequently influence the abundance, productivity, distribution, and diversity of salmonid populations (McElhany et al. 2000). The quantity, quality, and connectivity of these habitats are thus inherently critical to salmonid survival and productivity (Roni et al. 2014). Since factors that influence growth and rearing in freshwater habitats have the potential to influence survival at later stages (Holtby et al. 1990, Quinn and Peterson 1996, Connor and Tiffan 2012), it is critical to protect, restore, and monitor these freshwater habitats.

Critical salmon freshwater life stages in Bear Creek are negatively impacted due to the degradation of habitat diversity (quality and quantity), habitat connectivity, riparian and large wood (quality and quantity), flow conditions, sediment dynamics, channel stability, water quality, and intra- and inter-specific interactions (WRIA 8 Steering Committee 2005). Supporting productive and abundant salmon populations subsequently requires high quality habitats for freshwater rearing, refuge from flows and predators, abundant prey resources, as well as favorable water quality and temperature conditions. Critical life stages are sustained by protecting areas where these attributes are closer to well-functioning conditions as well as actively restoring reaches where conditions are degraded. Additionally, consideration of habitat-use patterns, as highlighted in this study, helps in emphasizing the habitat needs of salmonids throughout their freshwater residence.

Results from this study indicate that a suite of habitat types are used by juvenile salmon in the Bear Creek watershed and this suite of habitats vary across months and subbasins. These patterns indicate that different habitat types are utilized at different times of the year as juvenile salmon grow and environmental conditions change. Salmonids in Bear Creek appear to need a variety of slower water habitats early in the year which provide refuge from high flows and predators as well as foraging areas ideal for salmonid fry rearing. As the season progresses and the juvenile fish grow, the suite of utilized habitat types appear to broaden as foraging opportunities increase across available habitat types. Overall habitat availability throughout the Bear Creek watershed also appears to be important, since the majority of habitat types were consistently occupied by juvenile salmonids. Habitat complexity and connectivity is inherently related to well-functioning riverine, floodplain, and riparian processes. Supporting these processes through protection and restoration promotes the variety of habitats critical to juvenile salmonids in the Bear Creek watershed.

While this study provides information about habitat-specific use by juvenile salmon, when developing effective salmon conservation strategies, it's also important to consider inter-annual variability among adult productivity and juvenile life history strategies. Adult spawning and juvenile outmigrant monitoring data collected by WDFW indicate that average Chinook productivity (juveniles/female spawner) has been increasing in the Bear Creek watershed (Figure 22). While these patterns suggest an increase in juvenile production from 2001–2016, it's important to consider the demographics of these juveniles to understand potential rearing habitat limitations. For example, in recent years (2013–2016) there appears to be a greater proportion of emigrating juvenile Chinook displaying a fry-migrant life history (i.e., leaving earlier in the spring at smaller sizes)(Figure 23). Since productivity in Bear Creek has been increasing, but a larger proportion of the produced juveniles are displaying an early migrant life-history, it may be possible that there is limited in-stream rearing habitat capacity. If habitat availability and connectivity is limiting, then as more juveniles are produced, a greater proportion may subsequently leave as fry-migrants.

As discussed in Section 3.2.1, juvenile Chinook in Bear Creek display two life-histories and juveniles that remain in the system for an extended period (parr) are larger in size and emigrate later in spring. The relative size of these juveniles affects growth and survival by decreasing vulnerability to predators as well as increasing the size range of available prey resources. The size and migration timing of juvenile salmon through freshwater and marine habitats subsequently influences survival to adulthood (Zabel and Achord 2004, Scheuerell 2005, Scheuerell et al. 2009, Duffy and Beauchamp 2011, Evans et. al. 2014). Consideration of habitat specific use observed in 2016 in addition to inter-annual demographic trends highlight the need to support a variety of rearing habitats as well as increase overall rearing habitat availability. In order to support and conserve Bear Creek salmonids, it will be important to address these instream rearing habitats needs.

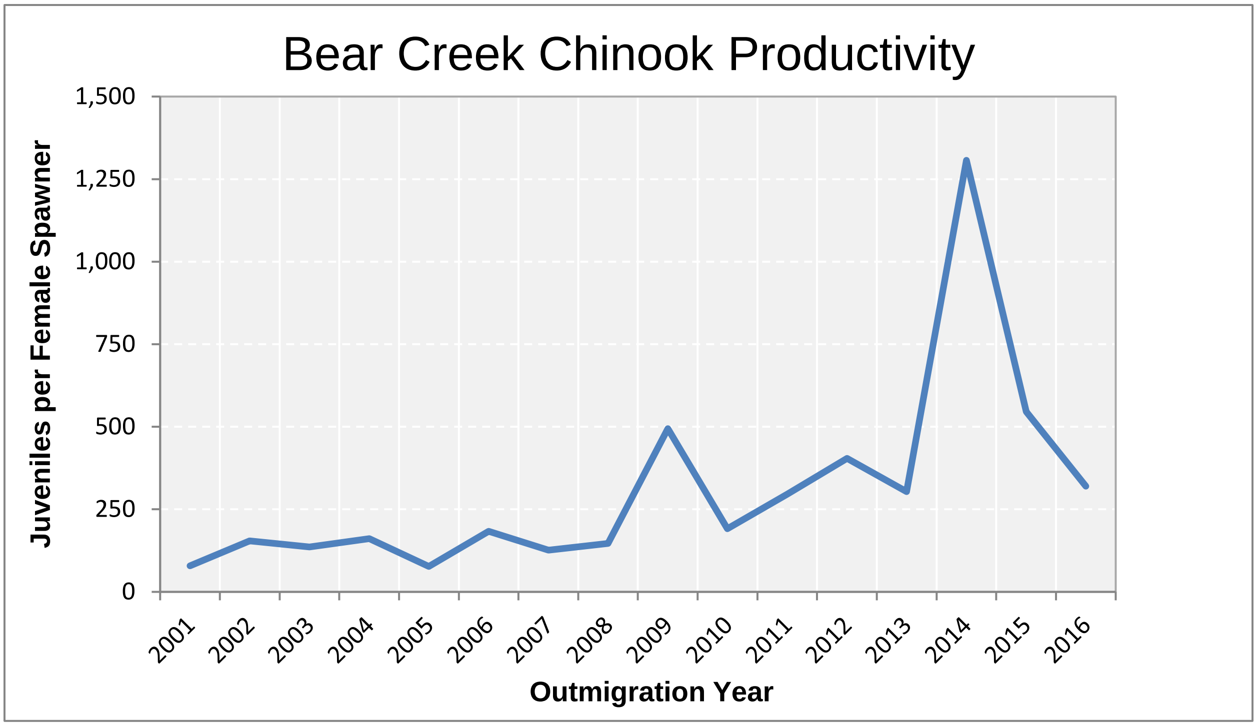

Figure 22. Bear Creek watershed Chinook productivity (juveniles per female spawner). Data provided by WDFW.

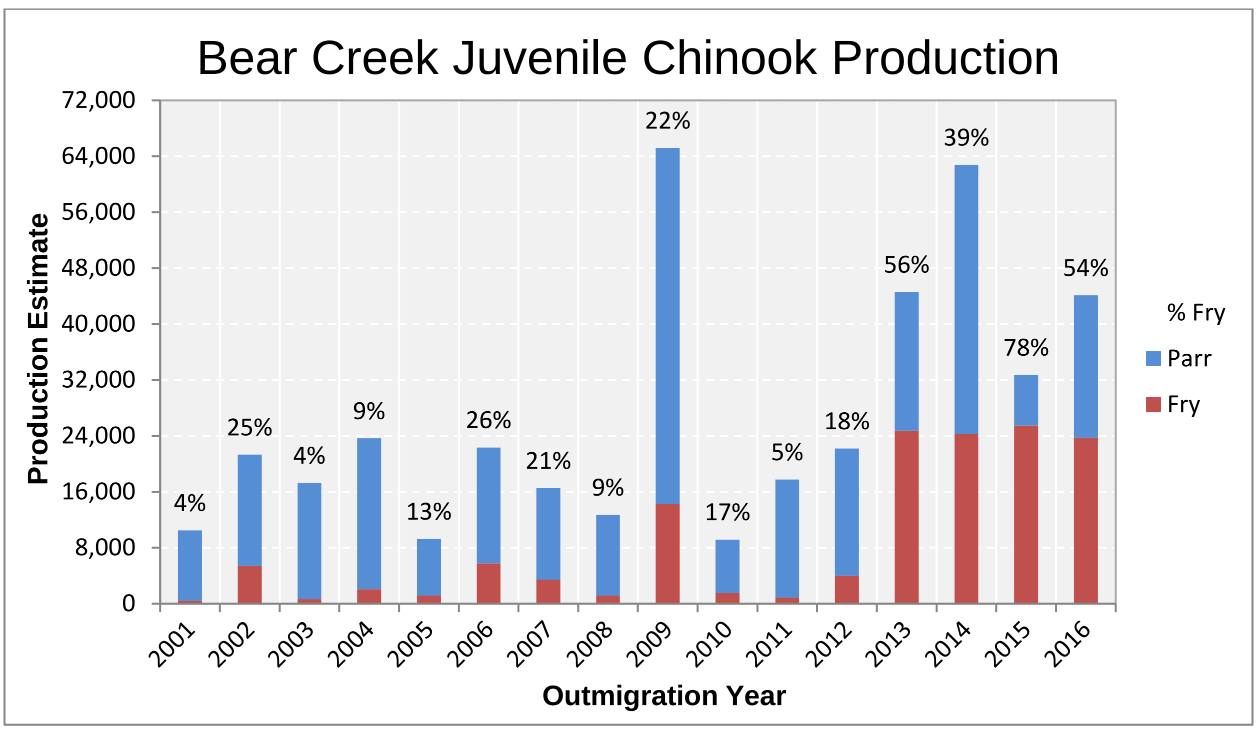

Figure 23. Bear Creek watershed juvenile Chinook fry and parr production estimates. Data provided by WDFW.

As specified in the WRIA 8 Chinook Salmon Conservation plan, areas with high-quality habitat forming features (e.g., LWD, riparia, channel connectivity) should be protected for critical salmon life stages. In Upper Bear Creek, areas that are prioritized high for habitat protection include reaches upstream of NE 160th St to Paradise Lake, reaches between NE 141st St and the Tolt Pipeline Trail, and reaches from the confluence with Cottage Lake Creek to NE 133rd St. In Cottage Lake Creek, areas that are prioritized high for habitat protection include reaches from NE 130th St up to the Tolt Pipeline Park Trail. Across Lower Bear Creek, reaches are relatively equally prioritized for habitat protection. Across all of these reaches, protection should focus on headwaters, wetlands, and sources of groundwater as well as areas with higher quality riparian and instream conditions (WRIA 8 Steering Committee). Protection strategies may include continued or further implementation of land-use policies that protect critical areas such as regulatory mechanisms (e.g., comprehensive plans, critical areas ordinance, shoreline programs, zoning regulations, storm water management, reduction of development impacts, etc.), conservation easements and transfers/purchase of development rights, water rights and instream flow protection, best management practices and voluntary measures, as well as other strategies.

The restoration and enhancement of habitat-forming processes is also critical to support salmon productivity and abundance. In Upper Bear Creek, reaches from the confluence with Cottage Lake Creek to the Tolt Pipeline Trail are prioritized high for habitat restoration. In Cottage Lake Creek, reaches from the Tolt Pipeline Trail to Cottage Lake are prioritized high for habitat restoration. Almost all of Lower Bear Creek downstream from the confluence with Cottage Lake Creek is prioritized high for habitat restoration. Restoration strategies across these reaches should focus on habitat quality/quantity, habitat diversity, habitat connectivity, as well as decreasing the pressures which degrade habitats. Restoration strategies may include riparian improvements, off-channel and floodplain habitat connection or reconnection, instream structures and large wood supplementation, barrier removal, sediment reduction, and beaver management.

Riparian improvements such as plantings and removal of invasive species may reduce peak water temperatures, provide sources of cover and large wood recruitment, improve water quality, and improve channel stability. Off-channel and floodplain connection will support habitat heterogeneity and provide areas of low velocity for foraging, rearing, and predator avoidance as well as refugia from high flow events. With most of Bear Creek showing low wood frequencies and volumes, the supplementation and addition of wood and wood structures is likely necessary throughout the watershed. Instream structures and large wood will help provide instream cover and promote channel complexity supporting habitat diversity and connectivity. Barrier removal may include culvert replacement, obstruction removal, as well as road crossing improvements. Strategies for sediment reduction as well as decrease erosion and bank instability may include improving stormwater management practices, instream wood addition, and riparian corridor enhancement. Beaver management strategies will help in supporting wetland and instream habitat diversity as well as promoting well-functioning watershed conditions.

4.0 CONCLUSIONS

Bear Creek is an important stream resource in King County and the Sammamish River watershed supporting a diversity of fish and wildlife species. Bear Creek provides productive instream habitats which support several salmonid populations, including ESA-listed Chinook salmon. While Bear Creek has relatively higher quality habitats compared to the greater Sammamish River watershed, habitat degradation has still occurred and has subsequently contributed to the decrease in salmon abundance and productivity. Since freshwater habitats support critical life stages for salmonids and contribute to the survival and abundance of returning adults, it is important to protect, restore, and monitor these freshwater habitats. Specifically, information on the conditions of freshwater habitats in the watershed as well as how juvenile salmonids use these habitats can help inform salmon conservation and recovery strategies. Subsequently, this study aimed to evaluate juvenile salmonid habitat use in the Bear Creek watershed, summarize prior assessments of existing habitat conditions, and discuss potential restoration and conservation strategies.

Results from this study indicate that month, habitat type, and subbasin are significant factors influencing juvenile salmon abundance and distribution. Juvenile Chinook and coho appear to use several habitat types with habitat-specific use varying across month and subbasin area. Habitat use and distribution appears to shift with changing biological and behavioral patterns. During late-winter and the early-spring (February–March), juvenile Chinook appear to use several habitat types with the highest relative abundances being observed in off-channel, slow water, and non-turbulent habitats. During spring (April–June), juvenile Chinook appear to use various slow and fast water habitats but at lower abundances compared to earlier winter-spring rearing. Similar to Chinook, juvenile coho appear to use several habitat types with the highest relative abundances being observed in both slow and fast water habitats during early spring (February–March) as well as in late spring (April–June). While the timing of habitat-specific use varies by salmon species, results from this study indicate that as juvenile salmon grow and transition through early life stages, their habitat use and distribution appears to shift. In order to support the continuum of early life stages for juvenile Chinook and coho salmon, a variety of freshwater rearing habitats are needed throughout the Bear Creek watershed.

Within the Bear Creek watershed, factors like altered hydrology, the loss of channel complexity and connectivity, degradation of riparian areas, loss of large wood, and increased sedimentation appear to be associated with the decline of naturally produced salmonids. Across the Bear Creek watershed, Cottage Lake Creek and Upper Bear Creek have relatively higher levels of watershed function compared to Lower Bear Creek primarily due to lower percentages of impervious surface, fewer road crossings, and higher levels of forest cover and riparian forest. While Cottage Lake Creek and Upper Bear Creek generally have better instream habitat conditions compared to Lower Bear Creek, factors like pool quality/quantity as well as large wood conditions are consistently degraded throughout all subbasin areas. Much of the degraded instream habitat appears to be related to a lack of large woody debris in the system.

Salmonid productivity and survival in Bear Creek are likely to be related to the quantity and quality of instream habitats. Supporting productive and abundant salmon populations subsequently requires high quality habitats for freshwater rearing, refuge from flow and predators, abundant prey resources, as well as favorable water quality and temperature conditions. Habitat-specific use patterns observed in this study, as well as inter-annual demographic trends documented from WDFW monitoring indicate that a variety of rearing habitats are needed to support juvenile salmon, that rearing habitat availability may be limited, and that current conditions are insufficient to recover threatened populations.

Evaluation of existing conditions indicate that select reaches of Cottage Lake Creek and Upper Bear Creek are prioritized high for protection and restoration, and the majority of Lower Bear Creek is prioritized high for habitat restoration and creation. Relevant strategies may include riparian improvements, off-channel and floodplain habitat connection, instream structures and large wood supplementation, barrier removal, sediment reduction, and beaver management. Focusing on preserving and restoring habitat conditions in the Bear Creek watershed will help in supporting abundant and productive salmonid populations.

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6.0 APPENDICES

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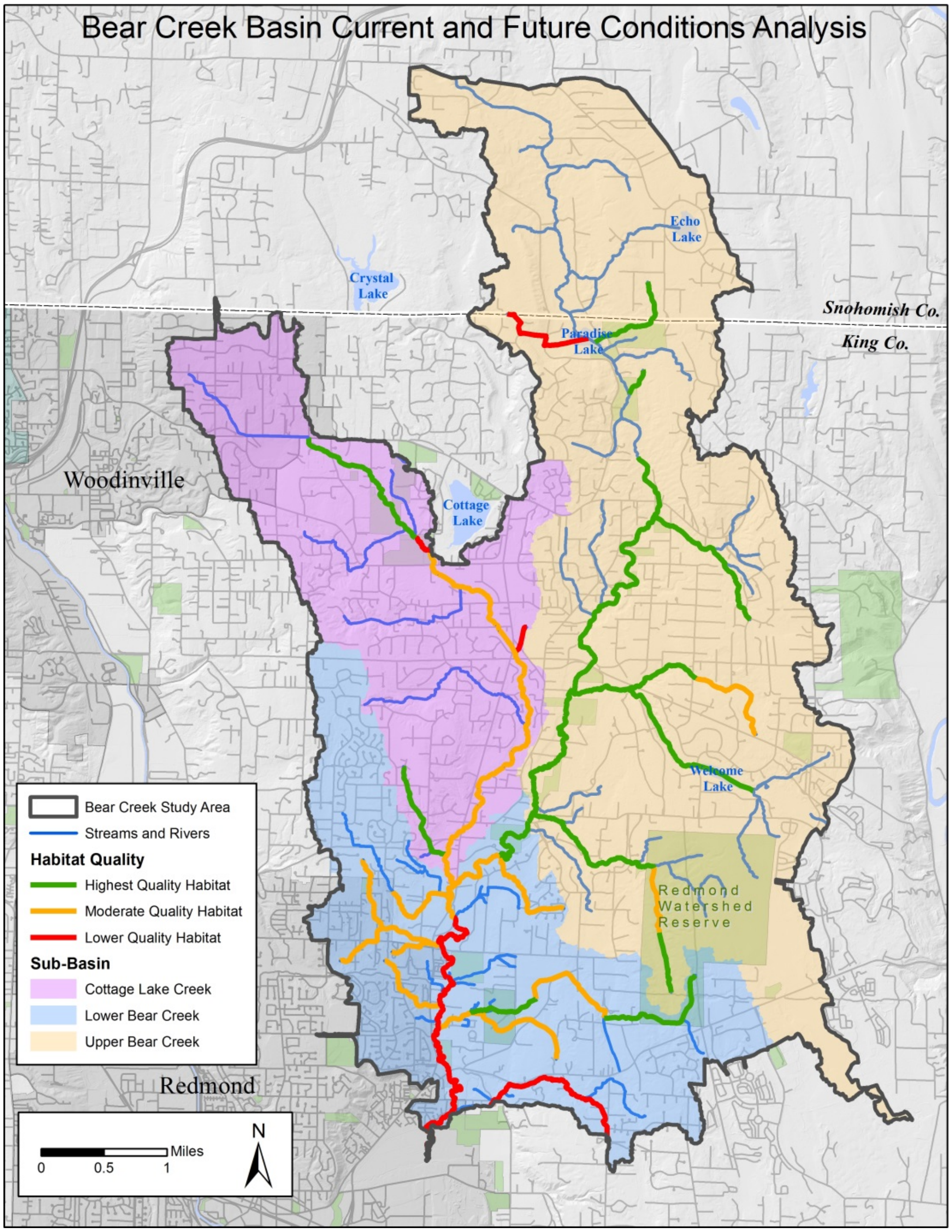
Appendix A: Bear Creek Current and Future Conditions Analyses (King County, Snohomish County, City of Redmond, 1989).



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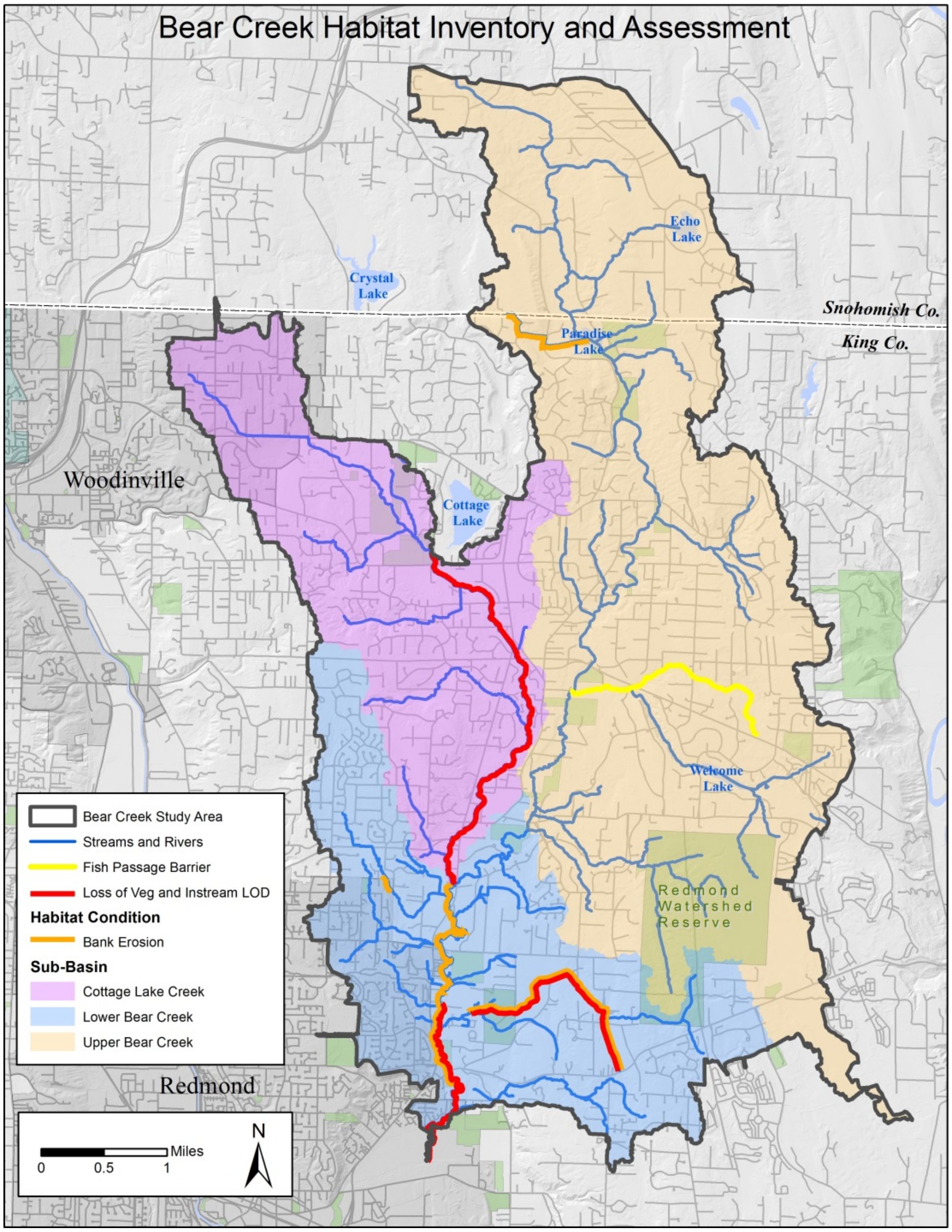
Appendix B: Bear Creek Basin 1994 Annual Report (King County, Snohomish County, City of Redmond, City of Woodinville, 1994). Veg = Vegetation and LOD = Large Organic Debris.



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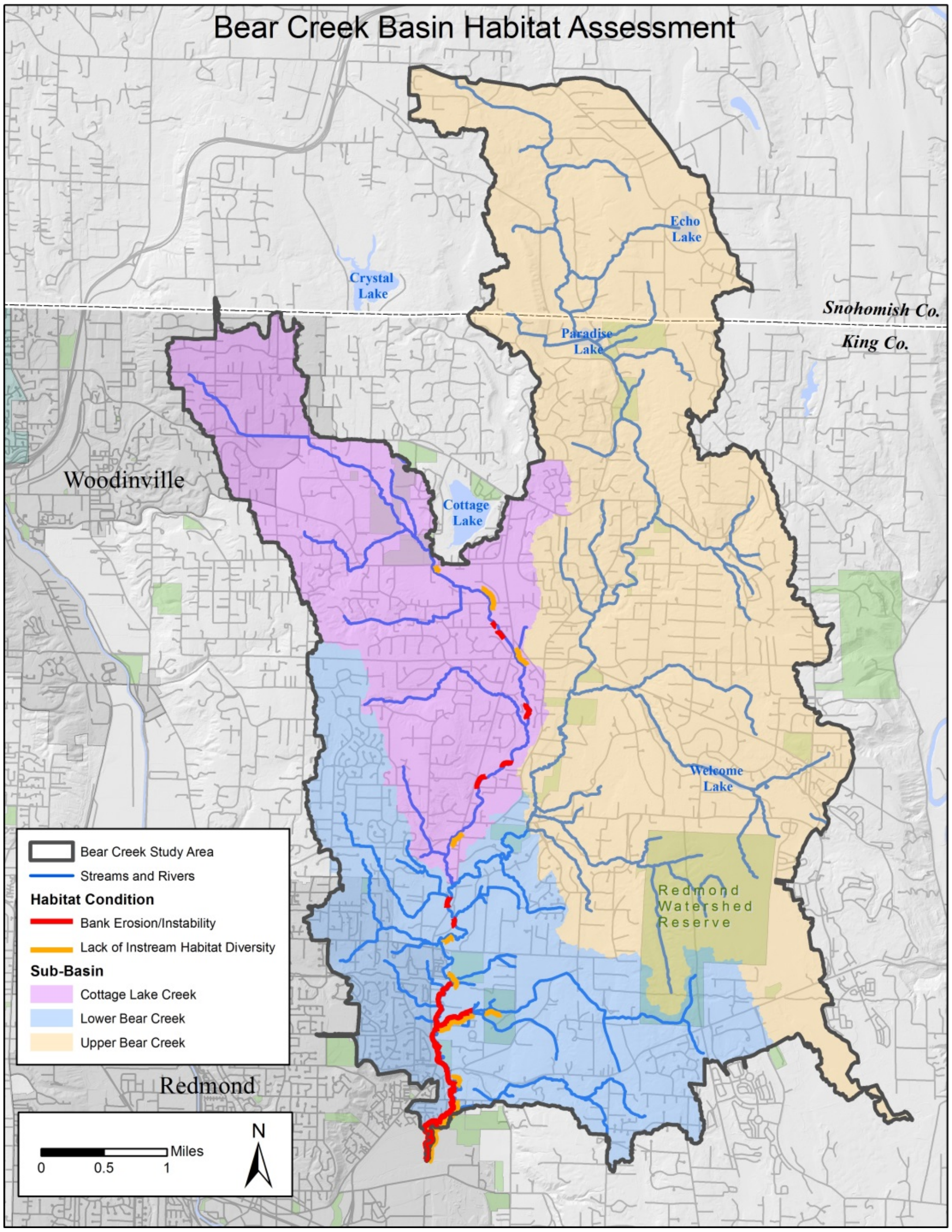
Appendix C: Bear, Evans, Cottage Lake, and Mackey Creeks Habitat Assessment Technical Memorandum (Entranco 1994).



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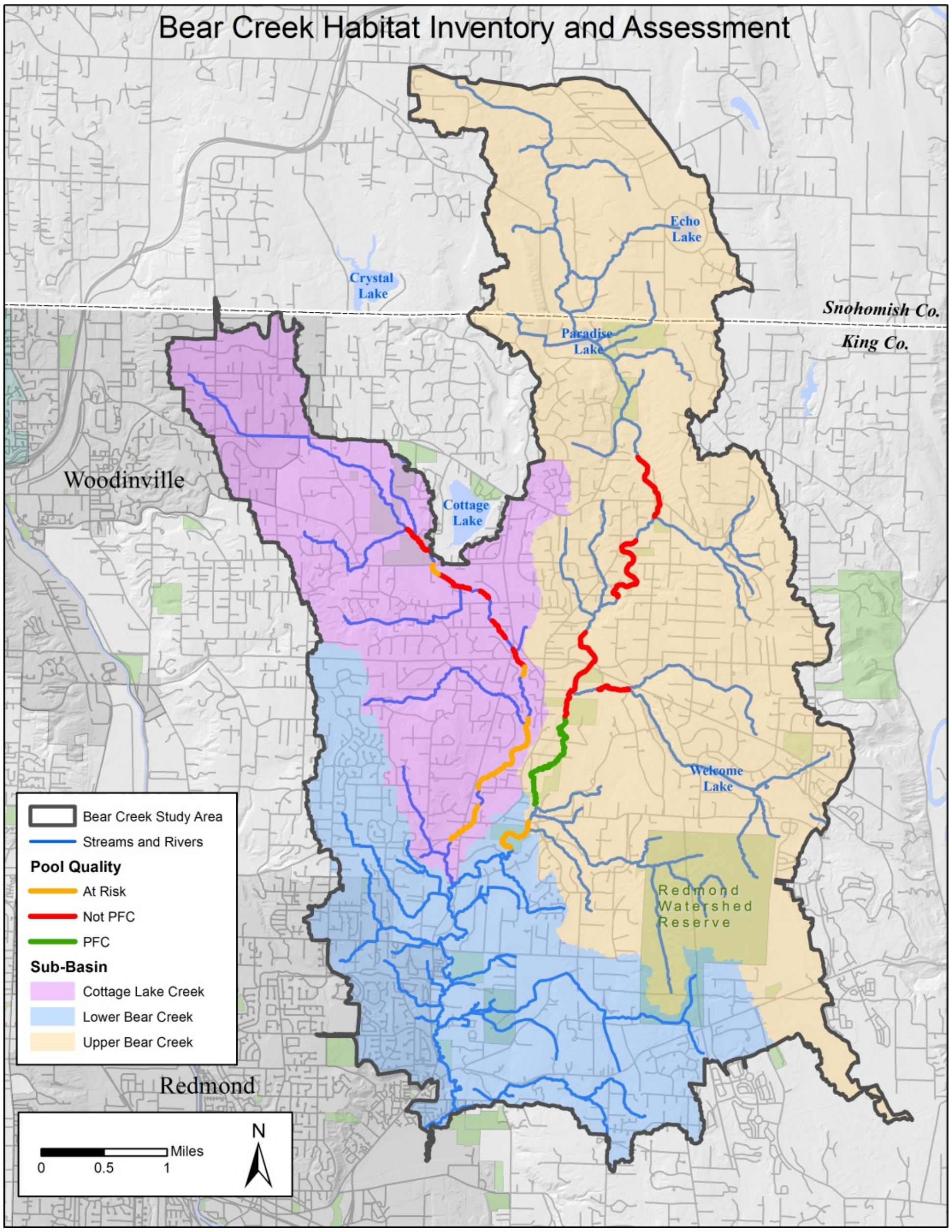
Appendix D: Bear Creek Habitat Inventory and Assessment – Pool Quality (Parametrix, 2002). PFC = Properly Functioning Conditions (as described by the National Marine Fisheries Service).



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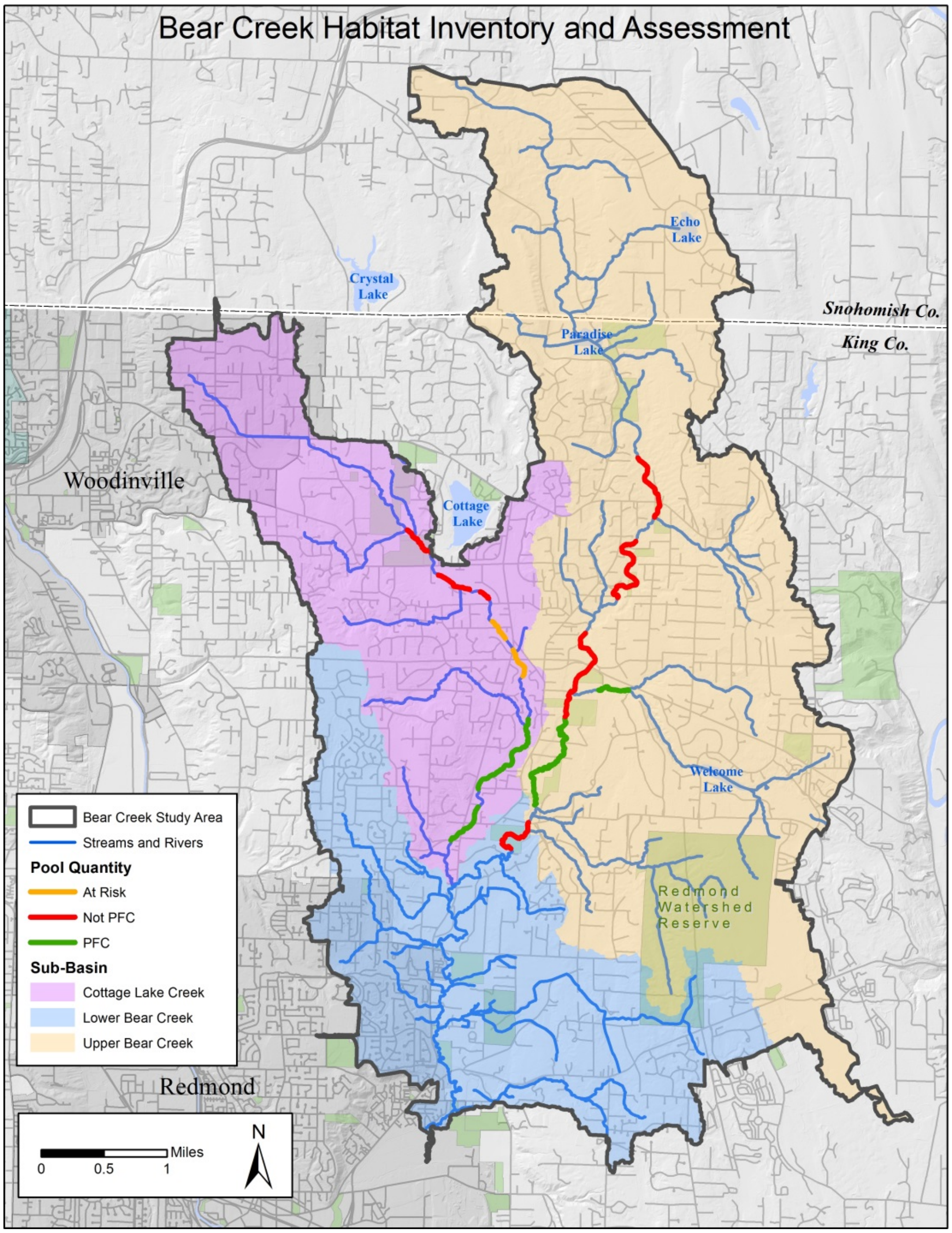
Appendix E: Bear Creek Habitat Inventory and Assessment – Pool Quantity (Parametrix, 2002). PFC = Properly Functioning Conditions (as described by the National Marine Fisheries Service).



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Appendix F: Bear Creek Habitat Inventory and Assessment – Large Wood Frequency (Parametrix, 2002). PFC = Properly Functioning Conditions (as described by the National Marine Fisheries Service).