2014 Juvenile Salmonid Use of Aquatic Habitats in the Lower Green River

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King County

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2014 Juvenile Salmonid Use of Aquatic Habitats in the Lower Green River

Prepared for:
WRIA 9 Implementation Technical Committee and Watershed Ecosystem Forum

Submitted by:
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Acknowledgements

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1.0 EXECUTIVE SUMMARY

Since the late 1800s, flood control and channelization in the lower Green River subbasin have resulted in a dramatic reduction of habitat for Chinook salmon. In 1999, Green River Chinook Salmon were listed under the Endangered Species Act as threatened. In 2005, the WRIA (Water Resource Inventory Area) 9 Salmon Habitat Plan was created to guide and implement local actions in the Green River watershed to improve habitat conditions and thus support Chinook salmon recovery. A component of this plan is to undertake research, monitoring and adaptive management that will improve implementation of the plan. This report summarizes a monitoring project to help fill in data gaps that were noted during the adoption of the 2005 Salmon Plan.

In 2014, the King County RFMS (River and Floodplain Management Section) of the Water and Land Resources Division conducted the project titled “A Comparison of Aquatic Habitat and Fish Use Among Bioengineered Flood Facilities in the Lower Green River, WA” (further referenced in this report as the “retrospective” project). In conjunction with the retrospective project, WRIA 9 collaborated with RFMS to fund five additional fish sampling sites as a separate project (but part of the overall sampling effort), with the following goals:

- To collect pre-construction fish use data for future restoration projects occurring in the lower Green which will serve as baseline data to measure the success of the projects once completed.
- To better understand how juvenile Chinook are utilizing specific habitat types in the lower Green River to provide information for planning and future project design.

Of the five sites sampled for this project, three were sampled for pre-construction fish monitoring at the Teufel Nursery and Downy Farmstead sites, both of which are designated for upcoming habitat restoration projects. Of the remaining two sites, one was located at the tributary confluence of Mill Creek and the Green River. This type of habitat is unique and historically a much more abundant habitat type in the lower Green, as the majority of tributary confluences are now blocked by flap gates or perching. This site also helped serve as pre-project data for the nearby Leber Homestead project. The final site was located in the Riverview Park Side channel, which was a recently completed habitat project that created an approximately 700-foot-long side channel to the Green River. In addition to data gathered at these five sites, fish sampling data from the overall RFMS project as well as the RFMS Reddington levee setback project were also evaluated to provide comparison.

Overall, mean juvenile Chinook catch (measured in catch per unit effort) was higher in the Riverview side channel than all other WRIA 9 sites (five total) and RFMS retrospective sites (45 total). The Riverview side channel also had consistently high catch during each of the three sampling events, indicating that this type of habitat is providing valuable rearing for juvenile Chinook in the lower Green. The remaining WRIA 9 sites (all prior to restoration) generally had low and/or sporadic juvenile Chinook catch. Pre-project sites and RFMS sites located in riprap armored reaches featured the lowest catch, indicating that this habitat type is providing little or low quality rearing habitat for juvenile Chinook in the lower...
Green. Higher Chinook catch was observed at RFMS sites featuring biorevetments, as well as constructed shallow water habitats at the Reddington levee setback project.

These results demonstrate that when available, juvenile Chinook in the Lower Green will readily utilize off-channel rearing habitats. Juvenile chinook that migrate at a larger size have been found to have a higher survival rate (Jeffres et al. 2008; Unwin 1997; Ruggerone & Weitkamp 2004), and results from Campbell and Claiborne (2017) show that the small fry sized migrants rearing in the Duwamish are surviving at an extremely low rate versus parr migrants that rear to a larger size in the higher quality habitats of the middle Green. While the rearing habitats in the middle Green are of higher quality than the lower Green and provide habitat for Chinook to rear to parr stage, work by Anderson and Topping (2016) showed that the amount of rearing habitat in the middle Green River is limiting the overall production of parr migrants. These findings likely apply to the much more habitat-limited lower Green as well. Therefore, based on the work of Anderson and Topping (2016) and Campbell et al (2017) and the results of this project, we suggest that increasing the amount of high quality rearing habitat for juvenile Chinook to reach parr size in the Lower Green would likely increase adult returns and support salmon recovery in WRIA 9.
2.0 INTRODUCTION

The Lower Green River sub-watershed is located in southwest King County and is composed of dense industrial, commercial, agricultural, and residential land uses (Figure 1). Starting in the 1800s, channel modification of the Lower Green River (river mile 11 to 32) was implemented to limit channel migration and prevent flooding throughout the valley. Currently, there are approximately 28 miles of levees and revetments maintained by the King County Rivers and Floodplain Management Section (RFMS) in the Lower Green River, and many of the remaining unmodified banks of the river are affected by roads or other land uses.

![Figure 1. Vicinity Map of Lower Green River Subbasin (King County 2003)](image)

Changes in land use and river hydromodification have severely reduced and limited salmon habitat throughout the Green River basin. These modifications in the Lower Green River, including the diversion of two rivers, a large flood control dam in the upper watershed, and flood containment levees and revetments have gradually disconnected the floodplain and off-channel habitats (such as sloughs and adjacent wetlands) from the mainstem. With flow management at the dam, the current 100-year flow in the Green River equals a roughly 2-year historic flow (King County Flood Control District 2016). Only about 18% of the historic Lower Green River floodplain area is now connected to the river during a 100-year
flood event, with much of the “connected” floodplain only connected at very high flows (Higgins 2017).

Flow control and channelization have resulted in the dramatic reduction of mainstem winter rearing habitat and a reduction in the quality of summer rearing habitat. It has been shown that most juvenile salmonids rely on low-velocity shallow habitats, and demonstrate preference for those associated with cover (Beechie et al. 2005, Bjornn and Reiser 1991, Fausch 1993; Rosenfeld et al. 2000). Due to these and many other factors, the Chinook salmon (*Oncorhynchus tshawytscha*) population in the Green River has declined from an average of 2339 natural origin spawners between 1968 and 2015, to an average of 962 spawners between 2011 and 2015 (NOAA 2017). With native-origin Chinook throughout Puget Sound at risk for extinction, the National Marine Fisheries Service listed all populations of Puget Sound Chinook salmon (including the Green River Fall Chinook) as threatened species under the Endangered Species Act (ESA) in March, 1999.

In 2014, WRIA 9 partnered with King County’s River and Floodplain Management Section’s (RFMS) project titled “A Comparison of Aquatic Habitat and Fish Use Among Bioengineered Flood Facilities in the Lower Green River, WA” (also known as and further referred to in this report as the “Retrospective” study). This study performed juvenile salmonid sampling in the Green River to study fish use of bioengineered levee and revetment repairs compared to rock-lined control habitats and reference habitats (McCarthy et al. 2016). WRIA 9 added five sites to the RFMS sampling plan with two goals. The first goal was to collect pre-construction data for future restoration projects occurring in this reach, and second, to better understand how juvenile Chinook use certain habitat types in the lower Green River. This report focuses primarily on the additional five WRIA 9 sites sampled in the lower Green River.
3.0 STUDY AREA

There are three separate groups of sites that are either discussed or utilized within this report. The first are the WRIA 9 sites, which include five sites selected by the WRIA 9 Implementation Technical Committee (ITC) and are the primary focus of this report. The second are the RFMS retrospective study sites, which are the sites sampled specifically for the retrospective project and are included because they provide useful comparison and insight to WRIA 9 sites. Finally, the third group is the RFMS Reddington levee setback project sites, which provide additional insight to engineered floodplain habitats. All of these sites were sampled during the spring of 2014 utilizing the same methods, making them well suited for comparison.

3.1 WRIA 9 Sites

A total of five sites were sampled for WRIA 9, which included the mouth of Mill Creek, Riverview side channel, Downey farmstead, and an upstream (U/S) and downstream (D/S) site at old Teufel nursery site (Figure 2). These sites are located between river mile (RM) 19 and 22.8 in the Lower Green River. Data collected at the Teufel and Downey sites are intended to be pre-project data, as both are slated for future habitat restoration projects. The Teufel and Downey sites feature riprap levees, revetments, and biorevetments on one or both sides of the river and have no available off-channel habitat. The site at Mill Creek is located within the confluence of Mill Creek with the Green River, and is intended to provide pre-construction data for the recently completed Leber Homestead backwater project as well as help us better understand the use of tributary mouths by juvenile salmon. The pre-construction data will not be an exact match with the restoration project because the project will create a habitat type that does not currently exist in this area. The site at the Riverview restoration project is a constructed side channel, and is intended to help us understand fish use of this type of constructed habitat (like the future Downey project) and help us understand the importance of side channel habitats for juvenile salmonids in the Lower Green.
3.2 Retrospective Sites

The RFMS Retrospective project identified 15 treatment sites from a list of levee and revetment repairs dated 1983 to 2014. These study sites are located between river mile 12.9 and 32.2 in the Lower Green River, and represent various types of bioengineered repairs (McCarthy et al. 2016). Biorevetments are repairs or construction techniques that utilize strategic large woody debris (LWD) and habitat features incorporated within the traditional riprap revetment construction to reduce the negative impacts of flood control facilities on fish habitat (Appendix A). These 15 treatment sites were then paired with a nearby control site, characterized by rock armoring consistent with pre-1990s construction techniques. When possible, treatment sites were also combined with a nearby
reference site which consisted of an unarmored bank with natural, preferably mature, riparian vegetation. Though labeled as reference sites, it is important to note that these sites were located within primarily armored reaches. This resulted in a total of 13 “triplets,” which consisted of a grouped treatment (biorevetment), control (riprap), and reference (unarmored) site, as well as 3 treatment-control “pairs” for a total of 45 sites. Of these sites, 5 “triplets” (15 sites) within close proximity to the WRIA 9 sites were included in this analysis for comparison.

3.3 Reddington Sites

In addition to the Retrospective project sites, RFMS also added 4 sites at the newly constructed Reddington levee setback to help understand fish use of constructed low velocity habitats (McCarthy et. al. 2014). The 4 sites at Reddington include 1 shallow bench, 2 alcoves located behind rock barbs, and a portion of the reconnected side channel (Figure 3). These sites are also included in WRIA 9 analysis to compare the constructed habitats at Reddington to the WRIA 9 sites. Reddington constructed habitats differ from Retrospective treatment sites in that the constructed habitats are designed off channel habitats associated with the levee setback, while treatment sites for the Retrospective project are biorevetments associated with a repair or mainstem facility.
Figure 3. Reddington sites in comparison to the downstream WRIA 9 sites.
4.0 METHODS

4.1 Sampling Methods

Fish sampling was carried out at night during several discrete sampling events in April and May of 2014 (Table 1). Sites were selected based on their representative habitat type, and 25 meter transects within each habitat were selected for fish sampling. Sampling was performed by electrofishing in a continuous manner, floating downstream along the bank.

Table 1. Sampling dates for WRIA 9 (shaded) and nearby treatment (T), control (C), and reference (R) sites from the Retrospective project

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<tbody>
<tr>
<td>Discharge (cfs)</td>
<td>2900</td>
<td>2310</td>
<td>2330</td>
<td>2310</td>
<td>2540</td>
<td>1410</td>
<td>1260</td>
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<td>Toltul D/S</td>
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<td>x</td>
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<tr>
<td>Tolar D/S</td>
<td>x</td>
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<td>x</td>
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<td>Rivererview</td>
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<td>Mill Creek</td>
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<td>Downy</td>
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<td>26 T</td>
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<td>28 R</td>
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<td>34 T</td>
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<td>36 C</td>
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<tr>
<td>36 R</td>
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<td>42 C</td>
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Fish sampling was conducted using a Smith-Root LR-24 backpack electrofishing unit mounted on a 14-foot Aire Ocelot cataraft. Equipment was maintained and provided by R2 Resource Consultants, Inc. (R2), and fish sampling was completed by a team of two R2 biologists and one King County biologist. The National Marine Fisheries Service electrofishing protocol was followed during all electrofishing (NOAA 2000). For most sites, the unit was set for 420 volts, 30Hz and 15% duty cycle and provided good fish capture while minimizing (or eliminating) fish injury and mortality. For sites with higher than average conductivity (i.e., side channels and tributaries) the voltage was decreased as needed. In general, as the river flow receded over the study period and velocities dropped, samplers were able to shock areas further up under the overhanging vegetation (i.e., willow) cover and inward towards the banks. In circumstances where there were gaps between placed wood and the bank that could not be sampled from the boat, the area was sampled on foot with the backpack shocker.

Shocked and captured fish were immediately removed from the electrical field with a nylon knotless dipnet. Captured fish were mildly sedated in a half-full bucket of water dosed with a small amount (<50mg/L) of MS-222 (Tricaine Methanesulfonate). All fish were identified to species and measured to the nearest millimeter (fork length), with a subset of salmonids weighed to the nearest gram. In some cases a group of small fry were weighed together and an average weight was calculated. All fish marked with adipose or other fin clips were noted on the data sheets. After processing, the fish were placed in a recovery bucket of
fresh water until completely revived, then released back to ambient water near their point of capture.

4.2 Analysis

Potential habitat preference by juvenile Chinook was analyzed for each site at each sampling event using catch per unit effort (CPUE) data for all sites. CPUE is calculated by dividing the number of fish captured at each site by the amount of time in minutes spent actively electrofishing, and was chosen for several reasons. First, CPUE is a semi-quantitative method that requires much less time and fewer personnel to complete than other methods (Crozier and Kennedy 1994). Next, CPUE is less intensive than depletion or multi-pass electrofishing, which allows us to operate within the take limits associated with our NMFS Section 10 collection permit while still allowing for representative sampling between all sites. Also, CPUE was chosen because river environments are difficult to sample, which in turn would make quantitative abundance estimates for many sites extremely difficult. Snorkeling was not used because water clarity in the Green River at this time of year is not conducive to accurate snorkel counts.

Due to the lack of habitat variable data collected for WRIA 9 sites, this analysis is limited to CPUE comparisons and fish specific data. Fork lengths were analyzed to assess potential differences in growth rates among habitat types. Also, CPUE data were compared to discharge data (USGS 12113000 Green River near Auburn, WA) to assess potential effects of discharge on habitat selection by juvenile Chinook.

For the RFMS retrospective sites, a linear regression model was used to relate fish use to aquatic habitat characteristics and to site category, using log (1+CPUE) as the response variable to ensure approximate normality (Zar 2010).

Aquatic habitat variables collected for RFMS retrospective sites included:

- number of wood pieces per 100 m
- number of key wood pieces (>8m long and >0.4m diameter) per 100 m
- percent native vegetation cover
- overhanging vegetative cover (m²/m)
- low velocity (<0.45m/s) area (m²/m)
- average depth
- maximum depth
- average toe slope
- river planiform at the repair site (inside bend, outside bend, or straight reach)
5.0 RESULTS

5.1 WRIA 9 Sites

A total of 93 fish were collected at the five WRIA 9 sites, including Chinook, coho (*Oncorhynchus kisutch*), chum (*Oncorhynchus keta*), pink salmon (*Oncorhynchus gorbuscha*), largescale sucker (*Catostomus macrocheilus*), steelhead/rainbow trout (*Oncorhynchus mykiss*), bluegill (*Lepomis macrochirus*), dace (*Rhinichthys sp.*), and sculpin (*Cottus sp.*). (Table 2). Chinook were the most numerous species encountered, representing 53% of all fish encountered during sampling. Coho were the second most numerous, representing 25% of all fish sampled.

Table 2. Total number of fish captured at each site for all sampling events

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Tufefel D/S</th>
<th>Tufefel U/S</th>
<th>Riverview</th>
<th>Mill Creek</th>
<th>Downy</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Catostomus macrocheilus</em></td>
<td>Largescale Sucker</td>
<td></td>
<td></td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cottus sp.</em></td>
<td>Sculpin sp.</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Lepomis macrochirus</em></td>
<td>Bluegill</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Oncorhynchus gorbuscha</em></td>
<td>Pink salmon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>O. keta</em></td>
<td>Chum salmon</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>O. kisutch</em></td>
<td>Coho salmon</td>
<td></td>
<td>23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>O. mykiss</em></td>
<td>Rainbow/steelhead trout</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>O. tshawytscha</em></td>
<td>Chinook salmon</td>
<td>1</td>
<td>31</td>
<td>8</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td><em>Rhinichthys sp.</em></td>
<td>Dace sp.</td>
<td>2</td>
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</table>

Overall, mean Chinook CPUE (fish/minute) was highest in the Riverview side channel (3.11) over all other nearby sites sampled (Figure 4). This includes all other WRIA 9 sites as well as the nearby retrospective study control (0.83), treatment (1.51), reference (0.65), and constructed Reddington sites (2.40). Of the remaining WRIA 9 sites, mean CPUE was highest for Downy (0.99), followed by Mill Creek (0.51), Teufel U/S (0.09), and finally Teufel D/S (0).
Figure 4. Chinook CPUE across sites. Red dotted lines are mean values, N values are in parenthesis. (** CPUE at constructed Reddington sites are located further upstream and may be influenced by spatial variation)

Overall, mean coho CPUE results were largely inconclusive due to the timing of the sampling in relation to coho rearing. During the sampling period, most coho fry were rearing in tributaries and in the Middle Green, while yearling coho were actively out-migrating. Also, coho hatchery releases from Soos Creek had already occurred. Of the WRIA 9 sites, coho were only found at the Mill Creek mouth. The mean CPUE at Mill Creek (1.78 fish/minute) was higher than the control (0.61), treatment (0.66), reference (0.27), and nearby Reddington sites (0.93) (Figure 5).
Figure 5. Coho CPUE across sites. Red dotted lines are mean values, N values are in parenthesis.

Fork lengths were analyzed to determine if Chinook sampled in off channel habitats (Riverview side channel and Mill Creek) are growing at a higher rate than Chinook sampled in mainstem habitats, which could be indicative of higher quality habitat and/or extended rearing in these habitats within the lower Green. An analysis of covariance (ANCOVA) was performed on fork lengths over time at each of the sampling locations. No differences were observed for growth rates among site categories, and no statistically significant difference was found (though N values were generally low and likely limited statistical power). Other species could not be analyzed due to low catches, or the presence of multiple life stages (e.g., subyearling and yearling coho).

Chinook CPUE data was graphed by site category and discharge to observe any potential changes to off channel versus mainstem habitat selection at varying discharge (Figure 6). Retrospective control (n=15), reference (n=16), and treatment (n=15) sites were included to represent mainstem habitat types available, while the Riverview side channel (n=3) and Mill Creek tributary mouth (n=3) represent off channel habitats. Overall, Chinook CPUE at the Riverview side channel (which had the highest observed CPUE) was highest at low flow (1260 cfs) and lowest at moderate flow (2310 cfs), though appears consistently high over the range of flows. Treatment sites (biorevetments) had the highest CPUE at the 2310–2330 cfs range, with lower values at both higher and lower discharges. Mill Creek, control, and reference sites generally exhibited consistently low CPUE across all flows.
Chinook CPUE was compared to daily Chinook migration out of the Middle Green based on data from the WDFW operated screw trap at RM 34.5 (Topping and Anderson 2015) to observe potential relationships between outmigration and observed catch rates (Figure 7). Chinook migration is extrapolated from actual trap counts, trapping time, and trap efficiency. It is important to note that the trap is located ~11.5 miles upstream from the nearest WRIA 9 site. Overall, it appears that CPUE data loosely tracks outmigration data throughout the season, particularly for Riverview and perhaps Mill Creek.
5.2 RFMS Retrospective and Reddington Sites

The Retrospective study focused on fish use of biorevetments by investigating King County RFMS biorevetment projects, U.S. Army Corps of Engineers (USACE) biorevetment projects, riprap control sites, and unarmored reference sites. The retrospective study also included the collection of aquatic habitat variables to help understand factors influencing fish use of constructed habitats. While the full results and p-values can be found in the original report (McCarthy et al. 2016), the following are highlights from the report that give insight to fish use throughout the Lower Green:

- Habitat conditions at treatment sample sites constructed by the USACE had significantly higher Chinook CPUE than King County RFMS (KC) sites (Figure 8). While there was a relationship seen, the exact reason is not clear and may be a function of the underlying river conditions, differences in sampling efficiency, or construction techniques. The USACE sites were significantly shallower than KC sites, though 6 of the KC sites were located on outside bends (presumably deeper and faster water), while none of the USACE sites were. In addition, the log placement was different between KC and USACE designs, which likely influenced these results (Appendix A).

![Figure 8. Chinook CPUE for retrospective site categories (McCarthy et al. 2016)](image-url)
- Shallow depths (Figure 9) and less overhanging vegetative cover were associated with significantly higher CPUE for young of year Chinook and coho.

Figure 9. Average depth by site category at Retrospective sampling locations

- There was significantly more low velocity habitat at treatment and reference sites versus control sites (Figure 10), and significantly more LWD and key pieces at treatment sites versus both reference and control sites (Figure 11).

Figure 10. Low velocity edge habitat by site category at Retrospective sites
The Reddington Levee setback project was sampled by RFMS in conjunction with the retrospective project to help understand how constructed low velocity habitats were being used by juvenile salmonids (McCarthy et al. 2014). Similar to WRIA 9 sites, these sites were compared to nearby retrospective control and reference sites. Their results showed Chinook CPUE at Reddington sites was significantly greater than both control (P=0.009), and reference sites (P=0.019) (Figure 12).
Figure 12. Mean Chinook CPUE by site category at the Reddington Levee Setback Project
6.0 DISCUSSION

Throughout the past century, changes in land use and hydromodification have severely reduced and limited salmon habitat throughout the Lower Green River. Hydromodification in the form of levees and revetments are known to result in a variety of harmful effects on aquatic conditions and natural processes. This type of armoring disrupts natural channel migration, which prevents the formation and maintenance of valuable habitat including backwaters, side channels, oxbows, overflow channels, and undercut banks (Larsen et al. 2006; Brusven et al. 1986; Schmetterling et al. 2001). Armored banks also tend to increase both sediment and water velocities (Schmetterling et al. 2001), which increases the possibility of streambed coarsening and redd scour. Hardened banks also reduce gravel recruitment from channel migration, increase erosion downstream, and reduce the overall length of stream habitat available for aquatic organisms (Schmetterling et al. 2001; Hayman et al. 1996).

In addition to the effects within the stream, bank armoring also has negative effects on riparian areas. Levees and revetments generally alter riparian areas to the point where little to no woody vegetation grows adjacent to the river. Declines in streamside vegetation can contribute to a loss of large wood recruitment to the river, a reduction in insect prey supply, a reduction in nutrient input from leaf litter, a reduction in shade leading to increased water temperature and reduced dissolved oxygen, and a reduction in overhanging cover for fish (Moring et al. 1985; Beschta and Platts 1986; Ralph et al. 1994; Dykaar and Wigington 2000; Schmetterling et al. 2001).

In conjunction with changes in physical features, research has documented many examples of impacts to juvenile salmonids. Beamer and Henderson (1998) found that juvenile Chinook use of natural edge habitats was over 5 times greater than use of riprap habitats and that summer coho abundance in rootwads averaged 17.9 times higher than that of riprapped banks. Another study by Peters et al. (1998) showed very similar results with salmonid densities being higher at natural sites than at rip-rapped sites. Knudsen and Dilley (1987) found that the abundance of subyearling coho and cutthroat trout reduced at riprap sites in comparison to natural shoreline sites. Bank hardening in general likely changes the distribution and amount of edge habitat from preferred to non-preferred types for juvenile Chinook (Hayman et al. 1996), though measuring effects to juvenile distribution is difficult and not widely studied. It is important to note that these studies looked at direct effects and did not attempt to quantify or account for indirect impacts or cumulative impacts of shoreline armoring, like survival, growth, or changes in population abundance that may just reflect a redistribution of fish.

To help address the lack of habitat associated with typical riprap banks, King County RFMS began repairing damaged levee segments in the early 1990’s by rebuilding the bank with rock and wood at the toe and native vegetation on the slope. This bioengineered technique was viewed as a habitat improvement over traditional riprap-lined slope with little or no native vegetation. The purpose of the RFMS Retrospective project was to determine if bioengineered construction techniques provide improved habitat for juvenile salmonids.
over traditional riprap armoring. The five additional WRIA 9 funded sites build on this by investigating fish use of other available types of habitat in the Lower Green. At some sites, this information will help serve as pre-project data to determine the effectiveness of restoration projects in the Lower Green. In addition, this data will also help us understand how fish utilize other habitat types, which in turn will help guide and support future restoration, adaptive management, and ultimately Chinook recovery under the WRIA 9 Salmon Habitat Plan.

6.1 Teufel and Downey

Teufel, Mill Creek, and Downey are habitat restoration projects and were primarily sampled for pre-project data. Having pre-project data for these sites will help us understand changes in juvenile salmonid habitat use after restoration of these sites occurs, which will then allow us to more fully assess the extent of ecological benefits that the restoration will provide. Currently, both Teufel and Downy sites are located in confined reaches that are characterized by riprap levees, revetments, and biorevetments on one or both sides of the river.

At both the upstream and downstream sites at Teufel, only one single Chinook was captured during sampling. If these results are indicative of the lack of habitat at this site, then we can assume that this site represents a good candidate for restoration as it has the potential for a large increase in available rearing habitat. Although only one Chinook was captured, these sites both featured some amount of overhanging willows that made sampling along the bank difficult, as well as deeper water that likely decreased sampling efficiency. Even with this sampling bias, Chinook CPUE was lower at Teufel sites than similar heavily vegetated control sites. This suggests that even if we are underestimating Chinook numbers at Teufel, the habitat may still be of less value than other similar vegetated riprap control sites.

At the Downey site, a total of 9 Chinook were captured during sampling. While these results are higher than for the Teufel sites, mean Chinook CPUE at Downey was very similar to the riprap control sites. This suggests that while there was Chinook use at Downey, it is likely the habitat is of typical quality for an armored reach. This type of bank hardening in general changes the distribution and amount of edge habitat from preferred to non-preferred types for juvenile Chinook (Hayman et al. 1996).

The armored bank condition throughout the Downey and Teufel reaches are likely limiting juvenile salmon productivity and restoration of the banks and creation of off channel habitats would likely improve the amount and quality of rearing habitat.

6.2 Riverview Side Channel

The site sampled at Riverview was done to assess Chinook use of this type of constructed side channel habitat, as well as help us understand the importance of off-channel habitats for juvenile salmonids in the Lower Green. The Riverview project was completed in 2012, and provides a roughly 700-foot-long side channel along the right bank of the river. Within
the side channel, the left bank was sampled, which was characterized by shallow slow moving water with sandy substrate.

Fish monitoring within the side channel resulted in the highest mean CPUE for Chinook of all the WRIA 9 sites, and higher mean CPUE than the nearby control, treatment, and reference sites. CPUE in the side channel was approximately 3.75 times higher than at nearby control habitats, which are representative of the pre-project riprap conditions at this site. These results are consistent with Beamer and Henderson (1998), which found that juvenile Chinook use of natural edge habitat on the Skagit River was over 5 times greater than use of riprap habitat. The Riverview side channel also had higher mean Chinook CPUE than the constructed off channel alcove habitats at the Reddington project.

The Riverview side channel had high levels of Chinook use throughout all sampling dates and over a range of flows. This is important to note because it shows us that the side channel was able to not only provide quality habitat for juveniles, but it did so over several months and over a broad range of flows (Table 1). Additionally, limited snorkel surveys performed by Oxborrow et al. (2014) documented Chinook use of the Riverview side channel through the end of June. This was the only WRIA 9 site with consistently high CPUE for Chinook, as all other sites had lower or inconsistent CPUE results (Figure 4). While Chinook CPUE appeared to be loosely associated with WDFW screw trap counts, the consistently high CPUE at this site suggests that some fish may be utilizing this habitat for an extended period of time. Also, the CPUE trend found at Riverview appears to follow trends in outmigration at the screw trap occurring 8 to 9 days prior. This lag time could represent a combination of downstream migration to Riverview as well as temporary residence in the side channel, as other sites did not appear to exhibit this lag time. Other sites had low or inconsistent Chinook CPUE, suggesting that these locations may only be providing habitat at specific flows, for specific juvenile life stages, or for out-migrating fish only. These results show that the Riverview side channel provided rearing habitat within the Lower Green, and the low availability of side channel habitat versus other habitat types also suggests that juvenile Chinook may be selecting this habitat disproportionately to its availability.

### 6.3 Mill Creek Tributary Mouth

The habitat sampled at the Mill Creek mouth represents a unique and historically more available habitat type in the Lower Green since most other stream mouths now have flap gates that greatly constrain fish use of non-mainstem habitats. The Mill Creek mouth is a small, naturally incised confluence with deep, slow moving water and steep sand/mud banks. Some LWD was also present near the top of the mouth where Mill Creek entered the confluence area. Fish sampling at this site resulted in fairly low CPUE for Chinook, but had the highest mean coho CPUE observed for all WRIA 9 sites as well as nearby control, treatment, and reference sites. This site also had the highest diversity of the WRIA 9 sites, with 6 species captured during sampling. Compared to the 45 Retrospective sites, Mill Creek was at the 87th percentile for total number of species captured, further showing the value of this habitat for a variety of species. Of the 23 coho captured at this site, 12 were unclipped fry, and 11 were yearlings, most of which (82%) were clipped. Given the high
CPUE of yearling coho, this site may be providing habitat more suitable for larger fish or as temporary refuge for actively out-migrating fish. Also, the close relationship between CPUE and daily migrants at the WDFW smolt trap may further suggest that this site is used for temporary refuge by out-migrating fish.

Fish sampling at this location was difficult and results were likely influenced by a few factors. During sampling, water entering from Mill Creek was turbid and likely reduced capture efficiency. Fish are known be less susceptible to electrofishing in deeper water (Zale et al. 2012), and due to the deeper nature of this site compared to others it is likely that sampling efficiency was reduced. Also, electrofishing is known to select for larger fish as they are more susceptible to electrical fields (Dolan and Miranda 2003), which may have resulted in higher catch rates for yearling coho versus subyearling coho and Chinook. Also, the LWD and vegetation present at the site made it difficult to access some of the shallow marginal habitat, which could have limited capture of subyearling size fish.

### 6.4 RFMS Retrospective and Reddington

The RFMS Retrospective project was implemented to assess fish use of bio-engineered repairs for levees and revetments. The purpose of bio-engineered banks is to use additional features, such as LWD and vegetation, to provide more habitat than typical riprap-only armoring provides. Two types of bio-engineered designs (USACE and King County RFMS) were compared to control sites (riprap-only) and reference sites (unarmored) to compare fish use.

The study found that sites constructed by the USACE had significantly higher Chinook CPUE than those constructed by King County RFMS. Several factors likely influenced this. First, USACE sites were significantly shallower than KC sites. This was partly due to spatial differences, as six of the King County RFMS sites were located on outside bends (which are presumably deeper and faster), while none of the USACE sites were. In addition, the design and orientation of the log placement structures appeared to have an effect on fish use (Appendix A), though this could again be a result of underlying differences (e.g., depths, channel configurations, velocity) between repair sites. At USACE sites, logs are chained end to end parallel to and slightly out from the shore, while King County RFMS repairs embedded wood into the toe of the rock. The two designs interacted differently with the flow of the river. We noticed that the parallel log placement at USACE sites created a shallow depositional area between the wood and the shore that provided a narrow band of habitat that appeared to be preferred by juvenile Chinook. This potential relationship needs to be explored by more in depth future studies.

The study found significantly higher CPUE for subyearling Chinook and coho at the most shallow sites (measured at 3 perpendicular transects within the 25m site). While Chinook were generally found wherever shallow depositional habitats were located regardless of type (treatment, control, or reference), many of the treatment sites provided more of this shallow water habitat than control and reference sites.
Less overhanging vegetative cover was also associated with statistically higher CPUE for young-of-year Chinook and coho. Vegetative cover generally consisted of very thick willows and dogwood that were overhanging the river banks and into the water. This made sampling very difficult, as the vegetation hindered the boat’s ability to sample near the shore. Whenever vegetation prevented sampling near the shore, sampling was forced away from the shore into deeper and faster water, which likely further decreased sampling efficiency as well as potentially forced sampling into less preferred habitat areas. Because of this sampling bias, we cannot be positive there was a true association with reduced cover, or if the cover hindered the ability to successfully sample the shallow and low velocity areas. Further testing with different sampling methods would be needed to determine if this heavy cover is associated with higher salmonid use. The effect of nighttime sampling could also influence this finding, as fish could be utilizing cover during the day and feeding in the open areas at night. R2 (2014) found that during a similar study on the Lower Green, juvenile catch indices were generally greater during nighttime electrofishing when compared to electrofishing conducted in daylight hours.

The study also found significantly more low velocity habitat at treatment and reference sites versus control sites, and significantly more LWD at treatment sites versus both reference and control sites. This reflects the availability of habitat within each type of sites. Control habitats are banks featuring only riprap armoring, which in turn limits their ability to accumulate wood or develop complex habitat features.

Results at the Reddington Levee Setback project showed that Chinook CPUE at constructed habitats was significantly greater than both nearby control and reference sites. The constructed habitats consisted of a shallow bench, 2 alcoves associated with rock barbs, and the outlet to the constructed side channel. Not only do these results show the value of shallow, low velocity habitats for juvenile Chinook in the Lower Green, but the highly engineered nature of these habitats suggests that even atypical and constructed habitats are utilized when available. Juvenile salmonids are known to select for certain types of low velocity habitats throughout their rearing period (Beechie et al. 2005), though these results suggest that shallow low velocity habitats were being used anywhere they are available.

### 6.5 Growth Rate among Sampling Locations

Fork lengths taken for all fish captured at each site were analyzed to determine if differences exist among growth rates, particularly between off channel habitats (Riverview and Mill Creek) versus mainstem. While our data failed to show any statistical difference between sites, growth and survival rates for juvenile Chinook have been found to be higher for floodplain habitats over mainstem (Jeffres et al. 2008; Sommer et al. 2001), indicating higher habitat quality for juvenile Chinook. No obvious patterns were observed, though low catch numbers and inconsistent sampling dates likely reduced the ability to detect a pattern if one existed. If there is in fact no difference between growth rates at various locations in the Lower Green, it could indicate that the sampled habitats are not providing adequate amounts of habitat for juveniles throughout the entire rearing phase. Also, immigration and emigration within off channel sites such as Riverbend could influence growth rate, since at any given time a portion of fish could be rearing while others are
passing through. Further study is needed to answer the question of whether these habitats are providing long-term rearing and higher habitat quality (therefore increased growth rates and presumably higher survival rates).

### 6.6 Additional Sampling Caveats

Sampling bias is a concern with the methods used in this project. The backpack style electrofisher that was used for sampling is better suited to smaller streams, therefore may be underpowered for effective and efficient sampling of the riverine habitats encountered during this project. The large amount of water in comparison to the relatively small electric field likely resulted in reduced catch efficiency versus larger boat electrofishing units. Sampling efficiency also likely changed between habitat types, as some were deeper and offered fish a greater chance to escape compared to shallower habitats. Additionally, sampling effort was often limited by permit restrictions associated with the number of listed Chinook and steelhead that could be handled. Because of these take limits, sampling effort was shortened for the remainder of the reach if high numbers of fish were encountered early at a site. This could unintentionally bias results, as the smaller sample may not reflect the entire site. As mentioned previously, site characteristics may also impede sampling success. Sites with excessive overhanging vegetation limited access to low velocity habitats near the bank, and forced sampling effort into deeper and fast water. Aside from vegetation, river planiform (inside bend, straight, outside bend), may also effect fish use and sampling efficiency. In the future, studies seeking to understand differences in sampling efficiency among different habitat types and how they affect catch rates and results could prove useful.

### 6.7 Watershed-wide comparisons

Previous studies throughout the Green/Duwamish basin have also looked at habitat use and availability for juvenile Chinook. While these studies have generally occurred in the Middle Green or Duwamish, they provide valuable insight to patterns observed in the Lower Green and for the watershed in general.

**Duwamish Studies**

Nelson et al. (2004) found in 2003 during a mark/recapture study that a large amount of Chinook fry (53%) moved downstream from Soos creek to the Duwamish (RM 6.5) within 1–4 days; however, some took as many as 31 days. Our CPUE data could explain some of this variation, as the few locations with high CPUE may be providing adequate habitat for rearing salmonids for longer periods, while the majority of other sites with low CPUE are providing little or poor habitat with most salmonids quickly migrating through. Downstream movement of natural juvenile Chinook may be accelerated even further if they do not find adequate habitat, prey, or if habitats are occupied by other fish (Ruggerone and Weitkamp 2004).

Ruggerone and Jeanes (2004) found that the residency time of marked Chinook salmon in off-channel habitats in the Duwamish declined significantly immediately after the release.
of ~3 million hatchery Chinook salmon. While projects such as Riverbend appear to provide quality off channel habitat, the overall lack of rearing habitat in the Lower Green may be causing crowding and reduce the overall ability of juveniles to rear in these habitats for an extended period of time. Ruggerone and Jeanes (2004) stated that restoration or creation of large habitats is needed in order to have a measurable effect on natural Chinook salmon, which is likely true for both the Duwamish and the Lower Green.

Ruggerone et al. (2006) found that densities of subyearling Chinook and chum were significantly greater inside off-channel restoration sites in the Duwamish (Codiga Cove, RM 8.5) compared with adjacent mainstem areas, likely due to the availability of shallow low velocity habitat. This finding is similar to our results, with the Riverview side channel having higher CPUE than nearby mainstem habitats for juvenile chinook. These off channel features are valuable habitat, especially when little or no mainstem habitat exists due to the channelized nature of the lower Green and Duwamish. Ruggerone and Weitkamp (2004) stated that fry migrants may be more dependent on habitat in the lower Green River and upper Duwamish than fingerling migrants. This finding is also similar to findings in the Middle Green noted by Anderson (2016) that these types of habitats are needed for fry to reside long enough to grow into parr life history types. Compared to mainstem habitats, growth and survival rates for juvenile Chinook have been found to be higher for floodplain habitats (Jeffres et al. 2008; Sommer et al. 2001). While floodplains in the Lower Green have been almost entirely disconnected, off channel habitats may serve a similar function by providing flood refuge and rearing habitat at higher flows, which in turn may result in higher growth rates for juvenile salmonids.

**Lower Green**

R2 Resource Consultants (2014) evaluated how juvenile fish use stream bank edge habitats, including different types of LWD and submerged vegetation, in hydromodified sections of the Lower Green river. The study examined fish use of 10 paired study locations, with each location having a treatment featuring varying amounts of LWD and a riprap control. The study found that Chinook salmon CPUE was significantly greater at treatment locations containing LWD when compared to control locations not containing LWD. Overall, all species and age classes of salmonid CPUE were positively correlated with LWD. Site locations that were comprised of moderate LWD, shallow sloping banks, and little overhead vegetation had greater total salmonid CPUE when compared with simple or complex LWD that had steep sloping banks.

While the focus of the R2 2014 study was to investigate fish use of LWD treatment habitats, the results are similar to those found in this study. In both cases, fish CPUE at treatment sites containing LWD was greater than riprap-only control sites. The finding that LWD in shallow versus deep water is important to note, as water depth greatly influences the usefulness of LWD. Future projects should take into account that placement of habitat features is likely just as important as the feature itself. This study further stresses the importance of shallow water edge habitats for juvenile salmonids in the Lower Green.
Middle Green

R2 Resource Consultants (2006) evaluated juvenile salmon habitat use in low velocity lateral habitats in the Middle Green from 1998–2002 data, as well as habitat availability in both mainstem and side channels over a range of flows. Overall, the report found a reduction in low velocity habitat around 1200 cfs, as well as another reduction in the 500 to 800 cfs range. Both quantity and quality of low flow lateral habitats were impacted by flow, as there was more mainstem habitat at lower flow and more side channel habitat at higher flow. Also at lower flows, there was more unvegetated habitat, whereas at higher flows there was more complex habitat created by interaction with floodplain vegetation. Juvenile Chinook habitat use was greater in lateral mainstem habitats than side channel habitats during the study.

Building on their previous work, R2 evaluated habitat availability data collected in 2010, and related habitat availability to various flows (R2 2013). This effort resulted in similar findings to 2006, with a reduction in off channel habitat as the flow levels dropped to 1200 cfs which became more pronounced as the flows dropped into the 500 to 800 range. Also, side channel disconnection was most pronounced at and below 800 cfs.

In concert with, but a year later than the habitat surveys, Patterson et al. (2015) investigated juvenile salmon use of lateral mainstem habitats as well as side channel habitats throughout the Middle Green. Unlike the 2006 R2 study, this study found that overall, Chinook catch in side channel habitats was comparatively higher than mainstem habitats. When compared to flow, however, Chinook catch in mainstem and side channel habitat types were similar at 1200 cfs and higher in side channel habitats at 2000 cfs. Mainstem margin use appeared to steadily decrease through the sampling period and may have represented fry migrants moving into off-channel habitats or out of the study area. This change corresponded to an April high flow event (~8,000 cfs), during which juveniles may have been forced to find off-channel refuge or move downstream.

Each of the aforementioned projects conducted in the Middle Green, which currently provides the best rearing habitat available for Chinook, provide insight into juvenile Chinook habitat needs for the basin in general. Both the work done by R2 and Patterson et al. shows that Chinook will actively utilize mainstem marginal habitat when available, with the work done by Patterson et al. showing that at higher flows off channel habitats may be necessary to provide refuge. Jeffres et al. (2008) found that juvenile Chinook in mainstem habitats grew rapidly at lower flows, but at high flows there was little growth and high mortality. In the Lower Green, few of the mainstem habitats sampled provided shallow, low velocity marginal habitat. Those that did (some treatment sites and Redington sites) had some of the highest Chinook CPUE observed; however, these catch rates were not consistent throughout the sampling period. Similar to the Middle Green, it is likely that shallow, low velocity mainstem habitats provide high quality and easily accessible habitat, but nearby off channel habitat is needed for refuge at higher flows.
WDFW Screw Trap

The WDFW operated screw trap at RM 34.5 provides outmigrant data for fish produced in the Middle Green, and is currently one of the longest term records of juvenile salmon data in the basin. Topping and Anderson (2015) utilized long-term monitoring data from the screw trap to describe juvenile migration strategies and identify factors affecting freshwater productivity of Chinook. They found that Chinook parr (which are larger than and have a much higher survival rate than fry) production of the Middle Green appears to be density dependent, which would indicate that the number of parr produced is limited by the amount of rearing habitat available in the Middle Green. Fry, on the other hand, appear to be density independent from year to year. They also found higher parr production with a relatively wet spring (>1200 cfs), though fewer parr following high peak flows during incubation and emergence.

Juvenile Chinook are known to have an increased survival rate to adulthood when they leave fresh water at a larger size (Jeffres et al 2008; Unwin 1997; Ruggerone & Weitkamp 2004). If this is the case in the Green River, and the large parr outmigrants are in fact density dependent, then it can be assumed that increasing rearing habitat will directly increase adult returns. Based on our data, the higher CPUE of off channel habitat in the Lower Green suggests that juvenile Chinook are preferentially utilizing this habitat to the extent it’s available. If juvenile Chinook were only utilizing the Lower Green for strictly outmigration, we would assume that catch rates would be similar throughout the sites sampled in the Lower Green, or that catch rates would be inconsistent among all sites as juveniles moved downstream.

6.8 Conclusions

The results of this study, along with findings from other studies, suggest that shallow and slow velocity rearing habitats in the Lower Green are needed to increase the overall capacity of the watershed. The results from the Middle Green and Duwamish show that juveniles will utilize both mainstem and off channel habitats, and likely need both as conditions change throughout the rearing period. Juvenile Chinook depend on these shallow, slow moving margin habitats and off channel areas for rearing as they provide areas for foraging, refuge from high velocities, and areas for predator avoidance (Kerwin 2001, Everest & Chapman 1972; Beechie et al. 2005; Bjornn & Reiser 1991). Draft work by Campbell (WDFW) has indicated that the estuarine (fry migrant) life history types contribution to the adult return in 2015 was extremely low (<1%), further stressing the importance of understanding and enhancing rearing habitats in the Lower Green.

Future projects at Downey Farmstead and Teufel Nursery should aim to restore the greatest possible amount of shallow low velocity habitat along the margins in the mainstem, as well as off channel and floodplain areas that are able to provide habitat throughout the rearing period. R2 (2014) found that many areas with placed wood in the Lower Green were only effective at providing habitat at a specific flow, as high flows would inundate the LWD, and low flows displaced LWD from the water. Future projects should aim to provide LWD that interacts with the waterline at a wide range of flows, especially
higher flows when suitable habitat may be most limited for juveniles. While the majority of available juvenile rearing habitat in the watershed is located in the Middle Green, it is possible that high quality habitat down the migration pathway can help compensate for low upstream habitat quantity and quality (Ruggerone and Weitkamp 2004).

To further understand how fish utilize the Lower Green, annual monitoring should be performed at existing and future restoration projects to show what habitats fish use over the rearing period and at what flows. Additional tagging and tracking of juveniles in the Lower Green could also help us understand how long fish reside in particular areas or habitats, growth rate of fish in various habitats, and the overall survival to adulthood of Lower Green rearing juveniles. Various fish marking methods, including pit tags, micro acoustic tags, and chemical marking could all be effective in providing this information. Data should also be collected over a wider range of flows to understand potential changes in habitat availability and selection as flow changes. For example, further fish sampling at high flows would help us understand habitat availability and use when flows are presumed to be forcing fish out of the system. Also, sampling of tributaries in conjunction with mainstem habitats in the lower Green could help us understand the importance of tributaries for Chinook rearing. Future work should also examine the availability and use of very low velocity habitats (<10-15 cm/s), which are necessary for newly emerged fry (Bjornn and Reiser 1991; Beechie et al. 2005). Currently, King County monitoring protocols define low velocity habitat as water <45 cm/s, which may not capture the availability of lower velocity habitats required for fry. Future fish monitoring work in the Lower Green should also emphasize collection of applicable habitat variables such as depth, substrate, cover, and water velocity to help further understand micro habitat preferences of juvenile salmonids. Future monitoring should also aim to reduce sampling bias by utilizing electrofishing methods that will reduce potential bias (e.g. power standardization), and/or accounting for and correcting potential bias (e.g. capture efficiency coefficient).
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Appendix A: Comparison of King County and Army Corps Bioreventment Construction

Figure A-1. Army Corps repair (left) and King County repairs (right)
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Appendix B: Leber Homestead Fish Monitoring, 2017

Introduction

The Leber Homestead is the site of a salmon habitat project located within the City of Kent near the confluence of Mill Creek with the Lower Green River (Figure 1). The focus of the salmon recovery plan in the Lower Green River is to create relatively static off channel habitats versus restoring habitat forming processes because of the many constraints in the Lower Green subbasin. Thus, it is important to understand if the created habitats are functioning as intended since the habitat will likely not change much over time like restoration projects that work to modify habitat forming processes. The Leber project is the first constructed project of several similar proposed projects creating backwater habitat that will likely be built over the next ten years in the Lower Green River. Given the significant monetary investment in creating these types of habitats, it is important to understand how well these habitats are functioning for juvenile Chinook and if different design approaches are better than others. Leber is also unique in that it is not directly connected to the Green river; rather, it is connected to Mill Creek upstream from its confluence with the Green river. This report summarizes a pilot effort during the spring of 2017 to explore how juvenile Chinook are utilizing the newly constructed project.

Project construction for Leber was completed in late 2016, with planting completed by early 2017. The project involved excavating a large backwater area with a low elevation island in the middle that is connected to Mill Creek approximately 500 feet upstream from its confluence with the Green (Figure 2). Numerous large wood structures were placed in the project area and thousands of native riparian and upland plants were installed. In past years there have been very small and inconsistent observations of Chinook found spawning in the Mill Creek system, but based on the very low numbers and poor Chinook habitat in Mill Creek it is assumed that any Chinook encountered during sampling of the Leber project site originated from the Green River and accessed the site by moving up Mill Creek from the Green River.
Figure 1. Location of Leber project site in Kent (courtesy of www.kentwa.gov)
Figure 2. The Leber Project area, showing the large excavated backwater (sloped and wetted area), log structures, and islands. Prior to construction, the ground elevation was level with the trees to the left and in the background.

Methods

Fish sampling was performed during March of 2017 to determine if juvenile Chinook salmon (*Oncorhynchus tshawytscha*) were utilizing the project area. Sampling was performed over a range of flows throughout the month of March to assess fish utilization over various levels of site inundation.

Fish sampling was performed by a team of 2 trained biologists using a Smith Root LR-20b backpack electrofisher. Electrofishing was performed by wading or walking along the bank carefully and electrofishing a ~2 meter wide swath along the shore, with one biologist electrofishing and one netting. The electrofisher was set to 30 pulses per second frequency, 30% duty cycle, and voltage between 150 and 350 (adjusted based on conductivity). To sample the log structures under higher flow conditions, an 11’ Sotar self-bailing raft was used in conjunction with the backpack electrofisher to allow sampling both around and within the log structures. Electrofishing data was reported as catch per unit effort (CPUE), which is the number of individuals of a particular species captured divided by the seconds spent electrofishing. CPUE was used to compare relative abundance among different habitat units during the sample period. It is important to note that water conditions
changed quite drastically between sampling events, which likely influenced capture efficiency.

A total of four different habitat types were sampled within or adjacent to the project area (Table 1). The majority of sampling occurred in shoreline habitats along the edge of the inundated project area. During the March 2 sampling event (1540 cfs), the Green River was not backwatering into the project area and groundwater was flowing out of the project area into Mill Creek. This created a transitional habitat at the confluence of the project area with Mill Creek that was not present during the next two higher flow sampling events because the project area was backwatered from the Green River with little to no discernable flow out of the project area. Also, on March 2 Mill Creek upstream of the project area was accessible and sampled, but not during subsequent events that were at higher flows. The LWD structures were only sampled on March 30, as they were out of the water on March 2 and almost entirely submerged on March 16.

On March 3, following fish sampling on March 2, physical and chemical water quality parameters were measured in situ and included temperature (°C), pH, DO (mg/L), DO percent saturation (% sat), specific conductance (us/cm), and conductivity (us/cm). The purpose of this sampling was to investigate potential reasons for the fish distribution observed on the prior day. Water quality sampling was performed at 7 points within the Leber project site, as well as one point in Mill Creek.

Table 1. Habitat types and number of units sampled at Leber in 2017 with total electrofishing effort in parenthesis (seconds).

<table>
<thead>
<tr>
<th>Date</th>
<th>Discharge (cfs)</th>
<th>Habitat Units Sampled</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Confluence</td>
</tr>
<tr>
<td>3/2/2017</td>
<td>1540</td>
<td>1 (98)</td>
</tr>
<tr>
<td>3/16/2017</td>
<td>7480</td>
<td></td>
</tr>
<tr>
<td>3/30/2017</td>
<td>4440</td>
<td></td>
</tr>
</tbody>
</table>

Results

Juvenile Chinook were found within the project site during each sampling event (Table 2), with fry being the only life history stage observed. In addition to Chinook, both coho (*Oncorhynchus kisutch*) and chum (*Oncorhynchus keta*) fry were captured as well, though in smaller numbers and more so during the later sampling events. Aside from salmonids, sculpin (*Cottus sp.*), dace (*Rhinichthys sp.*), three-spined stickleback (*Gasterosteus aculeatus*), and an unidentified minnow (*Cyprinidae*) were also found in small numbers.
Table 2. Species encountered and number of fish captured for each sampling event at Leber.

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Number of Fish Captured</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3/2/2017</td>
</tr>
<tr>
<td><em>Oncorhynchus tshawytscha</em></td>
<td>Chinook salmon</td>
<td>63</td>
</tr>
<tr>
<td><em>Oncorhynchus kisutch</em></td>
<td>Coho salmon</td>
<td>2</td>
</tr>
<tr>
<td><em>Oncorhynchus keta</em></td>
<td>Chum salmon</td>
<td>0</td>
</tr>
<tr>
<td><em>Cottus sp.</em></td>
<td>Sculpin</td>
<td>1</td>
</tr>
<tr>
<td><em>Rhinichthys sp.</em></td>
<td>Dace</td>
<td>0</td>
</tr>
<tr>
<td><em>Cyprinidae</em></td>
<td>Unk Minnow</td>
<td>0</td>
</tr>
<tr>
<td><em>Gasterosteus aculeatus</em></td>
<td>Stickleback</td>
<td>1</td>
</tr>
</tbody>
</table>

Juvenile Chinook CPUE was greatest during the first sampling event at the confluence as well as in mainstem Mill Creek upstream of the project (Figure 3). During the other two sampling events, water was backwatered from the Green River into the project area. The amount of wetted area within the project increased greatly between the first sampling event and the next two.

Figure 3. Mean Juvenile Chinook CPUE for each habitat type and sampling event

During the sampling event on March 2 at 1540 cfs, the outlet channel near the confluence was inundated up to the first log structure only, with no water present in the main portion of the project area. At this flow level, the outlet channel was conveying primarily groundwater and was much clearer than Mill Creek. During this sampling event, Chinook were observed only at the transition between groundwater leaving the Leber project site.
and Mill Creek (Figure 4). Chinook were highly concentrated in this area (50 Chinook captured during 98 seconds of effort). Mill Creek upstream of the confluence with the project was also sampled to provide context for the project site. Within Mill Creek, high concentrations of Chinook were also observed in shallow low velocity areas. Though high concentrations of Chinook were observed in the transition area at the mouth of Leber as well as in Mill Creek itself, no Chinook were observed throughout the groundwater fed channel in the Leber project area.

To address potential reasons for the absence of fish within the groundwater fed outlet channel at Leber, water quality parameters were measured the following day. 7 sites were sampled within the project area, with an addition site sampled in Mill Creek (Table 3). Sites “A” through “G” are from upstream to downstream within the Leber site, with site “A” near S 262nd St and the rest following the southwest arm of the project site to the mouth. No sampling was performed in the northeast arm. At the temperatures observed, juvenile Chinook are likely unaffected by the measured DO concentrations, though levels below 7mg/L can induce slight growth and behavioral effects (Chapman 1986). Little difference was observed between Leber and Mill Creek, with the exception of temperature which was ~3.8 degrees warmer in Leber than in Mill Creek.

Table 3. Water quality data collected at Leber on 3/3/2017

<table>
<thead>
<tr>
<th>Location</th>
<th>Site</th>
<th>Temp (C)</th>
<th>PH</th>
<th>ODO (mg/L)</th>
<th>ODO (% sat)</th>
<th>Specific Conductance (us/cm)</th>
<th>Conductivity (us/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leber</td>
<td>a</td>
<td>11.69</td>
<td>6.58</td>
<td>6.88</td>
<td>63.5</td>
<td>415</td>
<td>308.8</td>
</tr>
<tr>
<td>Leber</td>
<td>b</td>
<td>11.54</td>
<td>6.67</td>
<td>9.18</td>
<td>84.2</td>
<td>447.8</td>
<td>332.9</td>
</tr>
<tr>
<td>Leber</td>
<td>c</td>
<td>11.58</td>
<td>6.69</td>
<td>8.42</td>
<td>77.4</td>
<td>505.6</td>
<td>376</td>
</tr>
<tr>
<td>Leber</td>
<td>d</td>
<td>11.45</td>
<td>6.77</td>
<td>8.02</td>
<td>73.7</td>
<td>485.5</td>
<td>359.9</td>
</tr>
<tr>
<td>Leber</td>
<td>e</td>
<td>11.42</td>
<td>6.75</td>
<td>6.97</td>
<td>64.4</td>
<td>461</td>
<td>341.8</td>
</tr>
<tr>
<td>Leber</td>
<td>f</td>
<td>11.52</td>
<td>6.7</td>
<td>7.18</td>
<td>65.9</td>
<td>452.5</td>
<td>336</td>
</tr>
<tr>
<td>Leber</td>
<td>g</td>
<td>11.42</td>
<td>6.68</td>
<td>6.5</td>
<td>59.5</td>
<td>455.6</td>
<td>337.6</td>
</tr>
<tr>
<td>Mill Creek</td>
<td>h</td>
<td>7.6</td>
<td>7.03</td>
<td>8.71</td>
<td>73</td>
<td>179.4</td>
<td>119.8</td>
</tr>
</tbody>
</table>
During the sampling event on March 16 at 7,480 cfs, the entire project area was inundated. At this flow, water from the Green River had backwatered the project area as well as mainstem Mill Creek beyond the project site (Figures 5 & 6). Chinook, coho, and chum salmon fry were observed and sampled along the shoreline throughout the project site. Sampling was performed only along the shore, as the water depth at the LWD structures was too deep to sample effectively.
Figure 5. View of the confluence of the Leber site with Mill Creek on 3/16/2017 at 7480 cfs (looking northwest). Approximate location of the Mill Creek/Leber confluence as observed in Figure 3 highlighted in red circle to show the dramatic increase in wetted area at the site from 3/2 to 3/16.
During the sampling event on March 30 at 4,440 cfs, the main excavated portion of the project site was fully inundated, though at this flow level the LWD structures were more exposed (Figure 7). Chinook, coho, and chum salmon fry were observed and sampled along the shoreline of the project site. Additionally, the LWD structures were sampled from a raft, though the water was fairly deep in the general vicinity of the structures. Based on observations during sampling at the site, all salmonids sampled were located in shallow water <0.5m deep, and none were found around the LWD structures.
Discussion

Given that juvenile Chinook were observed within the project area during all sampling events, the site is performing as both rearing habitat during lower flows as well as refuge habitat at higher flows. During the first event, Chinook were only observed in the transition between Leber and Mill Creek, as well as Mill Creek upstream of the project area. At this transition area, clear groundwater from the site was flowing into the turbid Mill Creek water which is where juvenile Chinook were sampled. Upstream of the confluence within the Leber project area, no Chinook were found. Additional water quality measurements indicated that this is not likely due to water quality issues. It is unclear why Chinook were not found here. It is possible that Chinook were seeking the cover of more turbid water mixing from Mill Creek during daylight hours, and may be using the clear groundwater areas within the project at night. The site had only recently been planted and may not have been providing sufficient prey resources to bring juveniles into the broader site. Also, they could be using this transition area for daytime feeding as potential food drifts downstream. Though unclear for why their spatial distribution was so limited, this finding may not be unusual. During fish sampling performed by King County at the Auburn Narrows restoration site on the Green River, juvenile Chinook were found in much higher numbers.
during the daytime at transition areas between main channels and backwaters than within
the backwaters themselves (C. Gregersen, unpublished data). Significantly higher densities
of juvenile Chinook within transition areas than in adjacent habitats has also been found at
the McElhoe project on the Snoqualmie River (King County 2012), as well as at sites
sampled for the Bear Creek NPDES basin plan (King County 2017). These findings suggest
that transition areas are important to Juvenile Chinook and may naturally concentrate fish.

During sampling on March 16 and March 30, juvenile Chinook, chum, and coho were found
within the Leber project site. Chinook CPUE was much lower during these events than the
first sampling event, though it is important to note a few caveats from sampling during the
latter two events that could bias results. At the low flow level observed during the first
sampling event, far less wetted area was present than during the latter two sampling
events. This likely confined fish to a smaller area, making them easier to capture. During
the latter two sampling events when the project area was backwatered, salmonids were
observed cruising and feeding in schools around the shoreline of the project and no fish
were observed or sampled 1 to 2 meters beyond the shore. This schooling behavior could
result in “hit-or-miss” results while sampling. During the latter two sampling events, the
water was also more turbid which likely reduced visibility and thus netting efficiency.
Though water from Mill Creek was also turbid during the first sampling event, Chinook
were generally confined to small areas which made netting much more efficient. Also, the
water line during the latter two events was against the steeper upper banks of the project
area. This resulted in a narrow margin of shallow habitat, where fish could easily escape to
deeper water when approached by samplers and/or when shocked. Electrofishing
efficiency is greatly reduced in deep and turbid water; therefore the sampling conditions
during the latter two events likely had a much lower sampling efficiency than the first
sampling event.

LWD structures within the project area were only sampled on March 30, and no fish were
observed along the structures. It is important to keep in mind that those habitats can
provide valuable rearing habitat but may only function at a narrow range of flows or for
certain fish at a specific life stage (e.g. yearling coho). Sampling these structures in open
water (especially when deep) is also inherently difficult as electrofishing efficiency is
greatly reduced in deep and turbid water. Sampling the LWD structures and island within
the project at a wider range of flows would be necessary to determine their use by juvenile
salmonids. Sampling should occur at various water levels, especially at levels where the
raised areas and LWD are interacting with the shoreline.

Recommendations

This sampling effort was mostly an initial exploratory effort to verify fish use. While
Chinook use was verified, the sampling effort created new questions. It is recommended
that more in depth fish use and water quality sampling be undertaken at Leber in the
future. Future sampling at Leber should focus on sampling over a broader time period and
repeat sampling over a set range of flows to explore variability in juvenile Chinook use. The
future work should also explore potential reasons (e.g., day vs. night use) and solutions for
the very low use of the larger site during low flow conditions seen during the first sampling
event in 2017. For example, work by Toft & Cordell (2017), suggest that the design of entrances to projects likely influences their use.

In a study on the Cosumnes River, Jeffres et al. (2008) found that growth and survival of juvenile Chinook was higher in floodplain habitats than in the mainstem, which in turn increases overall survival to adulthood (Unwin 1997; Galat and Zweimuller 2001). Comparing condition factor between fish captured in the mainstem versus constructed and natural off channel habitats in the lower Green could help show whether these off channel habitats are providing higher quality rearing habitat than the mainstem. Additionally, a mark recapture study could help show if long term rearing and/or high flow refuge are occurring within the project area. In a larger context, sampling of Leber in conjunction with other tributaries and adjacent mainstem habitats in the Lower Green would help us understand the importance of the different habitat types for juvenile Chinook rearing and high flow refuge in the lower Green.

The Leber project design is unique in that it does not have a direct connection to the mainstem Green River, and fish that utilize the project area must actively enter it via Mill Creek. The fish utilizing the project have likely come from the Green River up Mill Creek, though there have been anecdotal observations of adult Chinook in Mill Creek in the past. It is unclear, however, if fish only enter the system at high flows when Mill Creek/Leber is backwatered from the Green (as observed on March 16 and March 30), or if they travel up Mill Creek at lower flows as well (as observed on March 2). With the relatively low CPUE during the higher flows, additional sampling should explore whether a high flow channel connection directly to the river would provide greater access and use of the site by juvenile Chinook. Based on results from this sampling, the project site may benefit from the addition of a high-flow channel that connects the project area to the river when the full Leber project area becomes inundated. When fully inundated (March 16 and March 30), salmonid relative abundance was generally low and additional access from the river could help more juvenile salmonids utilize the project area. Also, based on what are likely high densities of Chinook found at the transition area between Leber and Mill Creek on March 2, an additional channel could help create more of this “transition” type habitat. A high-flow channel (i.e. activated above 4000 cfs for example), would minimize the width and depth necessary for connection, and if constructed at an angle to the river rather than perpendicular, would minimize the disturbance of trees that provide shade to the river.
References


