CHAPTER 5

Determining if Salmonid Distribution in Agricultural Watercourses is Preferentially Associated with Woody Debris

5.1 Introduction to Woody Debris Use by Salmonids (Goal 4)

The specific roles of woody debris in low gradient, agricultural waterways may differ from those in natural streams, and has not been as thoroughly investigated to date. A literature review located no pertinent prior investigations and findings regarding the role of woody debris in agricultural or other small, low-gradient (<1%) channel systems similar to those within the King County APDs. The goal of this study component was to determine if salmonid distribution is preferentially associated with woody debris. With the assistance of KCDNRP staff, the following research hypothesis was posed in relation to this study component:

1. There is no difference in salmonid density between segments of agricultural waterways with and without large woody debris in configurations typically installed by KCDNRP.

Waterways within King County's APDs are most commonly either highly modified (e.g. channelized) natural waterways or artificially constructed to facilitate drainage. The majority of waterways within the APDs have existed and been maintained in this condition for an extended period (e.g. >50 years). Discussions with property owners suggests that prior to the introduction of current regulations, most waterways were maintained/cleared of vegetation every 2-5 years and have therefore long lacked the complexity of natural drainage systems due to historic maintenance activities.

King County DNRP has established Best Management Practices (BMPs) to be considered and/or implemented in sensitive areas including agricultural waterways used by salmonids (King County DDES 2001). This ordinance requires that consideration be given to the utilization of large or small woody debris (LWD or SWD, respectively) as mitigation for removal of in-channel cover and complexity during maintenance activities.

The impacts of large woody debris (LWD) on habitat and cover for salmonids has been widely investigated and reported on (see Andrus et al. 1988, Hicks et al. 1991, Reeves et al. 1991 and Roni 2002 for general overview and literature reviews). LWD in streams has been shown to affect physical stream processes (Bisson et al. 1987; Keller and Swanson 1979), formation of pools (Beechie and Sibley 1997; Bilby and Ward 1991) and other habitat factors (Bilby and Bisson 1998), nutrient cycling (Aumen et al. 1990; Krankina et al. 1999), local macroinvertebrate communities (Carlson et al. 1990), and a variety of fluvial processes (Keller and Swanson 1979) including sediment transport (Malanson and Butler 1990) and storage

(Nakamura and Swanson 1993), all of which impact the overall quantity and quality of related salmonid habitats.

Increases in anadromous and non-anadromous fishes after addition of LWD have been demonstrated through several studies and are often cited widely as justification for enhancement projects (e.g. Bisson et al 1987). However, many published and unpublished studies have demonstrated no impact or even negative impacts of LWD on fish populations (e.g. Hall and Baker 1982). The effectiveness of LWD in providing the desired effects depends on many factors including velocity distributions and sediment transport characteristics of the stream, habitat connectivity, and watershed condition. For example, LWD will provide greater hydraulic diversity in streams with high velocity and bedload. Further, in heavily degraded watersheds the influence of basin disturbance on channel processes will often overwhelmed any potential benefits of LWD (Larson et al. 2001).

5.2 Study Area

A single site was used to evaluate differences in fish abundance between two sub-reaches, one with LWD installed and one without LWD installed. The sub-reach with LWD installed was immediately adjacent to, and upstream of, the sub-reach with no LWD installed (Figure 5-1). The two sub-reaches were each approximately 76 meters (250 feet) in length and the assumption was made that fish could move freely across that distance and between adjacent sub-reaches; any difference in fish CPUE between the two sub-reaches would therefore be taken as illustrative of habitat (LWD) preference or avoidance.

A large (>5’ diameter) corrugated steel culvert pipe was installed during maintenance of the study site which essentially divided the downstream (no-LWD) sub-reach in half. This culvert was not thought to impact study results as it replaced a similar but smaller culvert pipe that had previously been in place at the study site. Prior to agricultural watercourse maintenance activities (and installation of LWD and the modified culvert), quarterly monitoring surveys indicated regular use and accessibility of the upstream-most sub-reach by salmonids. Since the modified culvert was larger and of more modern design, it’s presence is not believed to have impacted the results of this study.

Other mitigation actions taken at the same sites included hydroseeding with ryegrass and planting of willow and dogwood stakes. Neither of the additional mitigation actions was thought to impact results of this study because 1) they were consistent across both study reaches and 2) the willow and dogwood stakes showed only limited growth between being planted and the end of the study period.

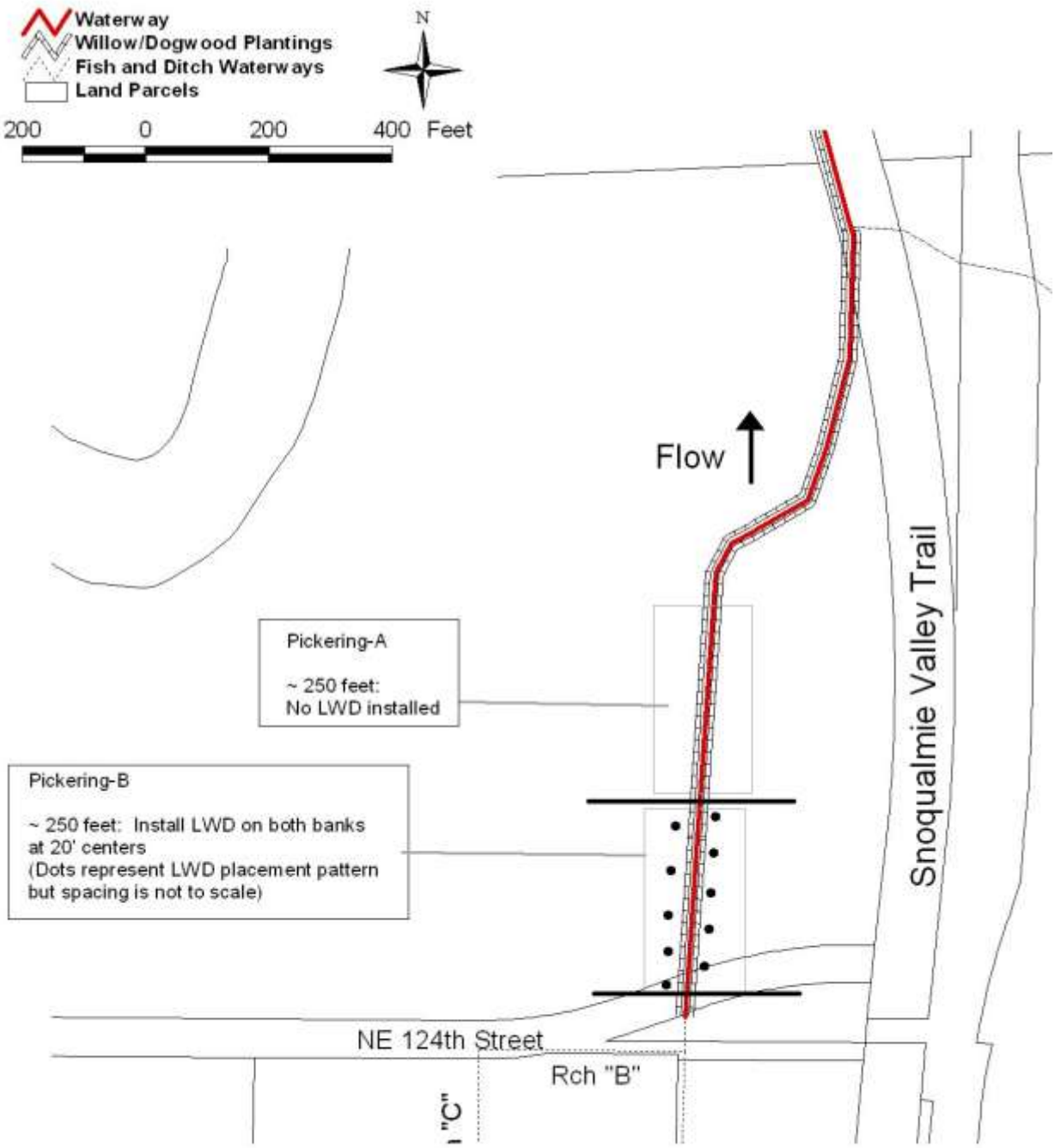

Figure 5-1. Schematic of study site used to assess salmonid preference of LWD.

5.3 Methods

5.3.1 Site Selection

Initial site selections for this study were conducted in consultation with King County staff and site visits. The following criteria were used to evaluate/select site(s) for this study component:

1. The waterway(s) needed to be scheduled and permitted for maintenance during the study period so that LWD treatment(s) could be installed;
2. The waterway(s) scheduled for maintenance needed to be 150 meters or more in length so that two sub-reaches could be established along it's length which were ecologically similar (same size, shape, discharge, vegetative cover, etc.);
3. If a single waterway >150m in length was not available, two shorter waterways on the same property that were ecologically similar to one another could be used.
4. The landowner, KCDNRP, the permitting agencies and the WSU research team needed to reach agreement that a proposed site was suitable and permittable for use in this study component.

From the frame of sites available, a single location was deemed both suitable and available to address this study goal (see Figure 5-1). Researchers and KCDNRP staff attempted but were unable to locate additional reaches that could be used in this study component given the previously stated criteria.

5.3.2 Data Collection

For this study component, fish data were collected seasonally (January/February, April, July and October) from the fall of 2004 through the spring of 2006. Fish were collected by electrofishing according to protocols defined by the National Marine Fisheries Service (2000). Length (mm) and wet weight (to nearest 0.5 g) were recorded for all individuals collected. During each seasonal site visit, a single pass electrofishing sample was conducted in each of two sub-reaches (with LWD installed and without LWD installed). The downstream sub-reach (without LWD) was electrofished in two portions upstream and downstream of a culvert that existed within the sub-reach; no sampling was conducted within the culvert itself.

Assessment of salmonid origin (hatchery or natural) was made upon the time of capture and noted on field sheets. Fish origin was determined according to the presence (natural) or absence (hatchery) of the adipose fin.

5.3.3 Data Analysis

Investigations to address this project goal and its related hypothesis were done by comparing salmonid CPUE in separate reaches of the 'Pickering' agricultural watercourse with (Pickering-B) and without installed LWD (Pickering-A; Figure 5-1). This approach allowed for direct comparison of reaches with and without wood while controlling for additional sources of variation (e.g. channel size, discharge or temperature).

Seven quarterly sampling events occurred following maintenance of both study reaches and installation of LWD in one study reach (Fall, 2004 through Spring, 2006). Due to the limited number of seasonal samples available for this evaluation, no attempt was made to evaluate seasonal differences in the use of LWD by salmonids.

Statistical evaluation of differences in CPUE between the reaches with and without installed LWD was done via a one tailed, paired T-test for equality of means, with each of the seven sampling events providing a paired sample of the two treatments (LWD or no LWD). The null hypothesis tested was that the mean difference in catch rates between sub-reaches with and without installed LWD was zero; the alternative hypothesis was that mean catch rates differed between sub-reaches with and without LWD installed. Separate analyses were performed for Chinook salmon, coho salmon, and all salmonids captured. T-tests were performed with the 'Analysis Toolpak' associated with Microsoft Excel software.

5.4 Results

Few salmonid fishes were encountered during seven monitoring events following installation of the study design in the selected waterway (Table 5-1). Salmonid species were encountered during only five of seven quarterly monitoring surveys conducted, and when encountered, fewer than 25 salmonids (average 7.2) were collected from each treatment sub-reach. Of the five sampling events when salmonids were encountered, only four had salmonids collected from both sub-reaches (with and without LWD; Figure 5-2) during the same monitoring event.

Table 5-1. Summary of salmonid catch and CPUE for study reaches with and without LWD installed.

		2004	2005				2006	
		Fall	**Winter**	**Spring**	**Summer**	**Fall**	**Winter**	**Spring**
Number of fish collected								
Chinook	Wood	0	2	1	0	0	0	0
	No Wood	0	0	0	0	0	0	0
Coho	Wood	9	0	20	0	0	4	2
	No Wood	3	1	20	0	0	1	0
Total	Wood	9	2	21	0	0	4	2
	No Wood	3	1	22[1]	0	0	1	0
Catch Per Unit Effort (Fish/100 Seconds)								
Chinook	Wood	0	0.331	0.124	0	0	0	0
	No Wood	0	0	0	0	0	0	0
Coho	Wood	1.848	0	2.488	0	0	0.723	0.667
	No Wood	0.589	0.2364	4.049	0	0	0.173	0
Total[1]	Wood	1.848	0.331	2.61	0	0	0.723	0.667
	No Wood	0.589	0.236	4.45	0	0	0.173	0

1 Includes two cutthroat trout.

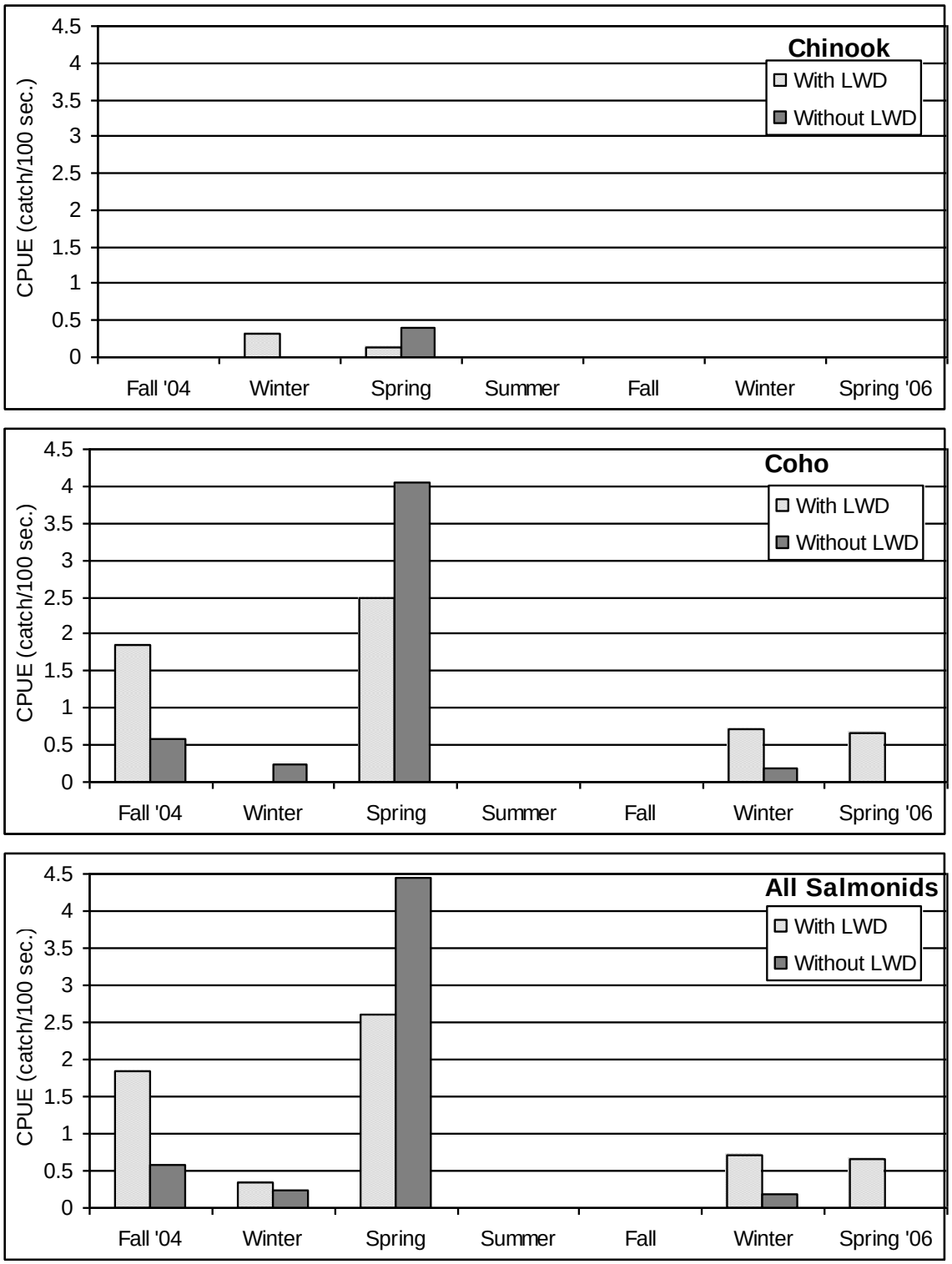

Figure 5-2. Comparison of CPUE of Chinook (top), coho (middle and all salmonids (bottom) captured from comparable reaches with and without LWD installed.

Juvenile coho salmon were more frequently collected than were juvenile Chinook salmon. Respectively, these species were encountered during five and two surveys accounting for totals of 60 and 3 individuals across all surveys (Table 5-1). Juvenile Chinook salmon were encountered only from the sub-reach with LWD installed during the winter (2) and spring (1) of 2005. Of the five surveys when juvenile coho salmon were encountered, they were collected from both sub-reaches during three events (Fall, 2004; Spring, 2005 and Winter, 2006); during Winter, 2005 and Spring, 2006 surveys coho salmon were collected only from the sub-reach without LWD and with LWD, respectively.

Catch rates for juvenile coho salmon were typically greater than those observed for juvenile Chinook salmon (Table 5-1 and Figure 5-2). When encountered, catch rates of coho salmon ranged from 0.17 to 4.05 fish/100 seconds of shock time (Table 5-1). In the sub-reach with LWD installed, coho catch rate averaged 0.818 fish/100 seconds of shock time across all monitoring events. In the sub-reach without LWD installed, coho catch rate averaged 0.721 fish/100 seconds of shock time across all monitoring events. When encountered, catch rates of Chinook salmon in the sub-reach with LWD installed ranged from 0.124 to 0.331 fish/100 seconds of shock time (Table 5-1), averaging 0.065 fish/100 seconds of shock time across all monitoring events; No Chinook salmon were collected from the sub-reach without installed LWD during this study.

Differences in catch rate between sub-reaches varied by sampling event. During spring, 2005, catch rates of both Chinook and coho salmon were greatest in the sub-reach without LWD installed (Figure 5-2). During fall, 2004 and the winters of both 2005 and 2006, catch rates of both Chinook and coho salmon were greatest in the sub-reach with LWD installed. During spring, 2006, salmonids (coho only) were collected from the sub-reach with LWD installed, but not from the corresponding sub-reach without LWD.

Statistically, no significant difference ($\alpha = 0.10$) in catch rates was noted between sub-reaches with and without LWD installed for Chinook or coho salmon or for all salmonids combined (Table 5-2). The mean difference in catch rates between sub-reaches with and without LWD was lowest and statistically most relevant (0.065 fish/100 seconds of electrofishing; $p=0.111$) for Chinook salmon, although the observed count in both sub-reaches was most frequently zero (Table 5-1). For coho salmon, the mean difference in catch rates between sub-reaches with and without LWD installed was 0.097 fish/100 seconds of electrofishing and was not statistically relevant ($p=0.392$). When all salmonids were considered simultaneously, the mean difference in catch rate (0.104 fish/100 seconds of electrofishing) and the corresponding statistical relevance ($p=0.393$) were similar to that observed for coho salmon which made up the majority of the salmonid catch.

Table 5-2. Results of paired T-tests performed to evaluate differences in catch rates of salmonid species between sub-reaches with and without LWD installed.

Species	n	Mean difference (LWD – No LWD)	T-statistic (calculated)	T-statistic (Critical)	*p*-value
Chinook	7	0.065	1.365	1.439	0.111
Coho	7	0.097	0.288	1.439	0.392
All Salmonids	7	0.104	0.283	1.439	0.393

5.5 Discussion

Based on this study, it is largely unclear if salmonid distribution in agricultural waterways is preferentially associated with installed LWD. Although statistical analyses indicate that no significant differences exist ($p > 0.10$) between salmonid abundance in reaches with and without LWD installed, numerous factors contribute to uncertainty of the statistical results:

1. Statistical power of the evaluation is limited due to small sample sizes (n=7) and low catch rates of salmonids encountered (including frequent zero values) during the study.
2. When salmonids were encountered, catch rates were commonly greatest in the sub-reach with LWD suggesting that preference for LWD amongst salmonids may exist but not have been statistically detectable given the study constraints.
3. Having only a single sampling site available for this evaluation limits the practicality of generalizing results to other agricultural waterways within King County.

The power of the statistical assessment of differences in catch rates between sub-reaches with and without installed LWD was limited in this study. Power is the probability that the statistical test will identify a treatment's effect if it actually exists, and is a function of the selected α level for statistical tests, the effect size of the treatment, and the sample size of the groups (Hair et al. 1995). Although relationships among α, sample size, effect size and power are quite complicated (Hair et al. 1995), power of analyses for Chinook, coho, and all salmonids combined were all estimated to be less than 0.20 (Lenth 2006).

Power of statistical tests is directly related to the selected α level for the test. Alternatively, as α becomes more restrictive (is decreased), power decreases (Hair et al. 1995). For this reason a somewhat conservative α level (0.10) was selected for tests related to this analysis in an attempt to maximize power while providing an acceptable Type I error rate (α) for the experiment.

The probability of achieving statistical significance is based, in part, on the effect size or magnitude of the effect of interest (e.g. the difference of means between two groups; Hair et al. 1995). Logically, as effect size increases that effect is more likely to be found, thereby increasing the power of the associated statistical analysis. The mean difference in catch rates

between sub-reaches with and without installed LWD were typically small (<0.10 for Chinook and coho salmon; refer to Table 5-2) in part due to the relatively common occurrence of zero catch during this study (refer to Figure 5-2).

The limited catch rates (including frequent zero values) observed in the sampled sub-reaches were not predictable and may have been related to any number of uncontrollable outside factors. Between the summer and fall, 2005 sampling events, a beaver dam approximately 6 feet in height was constructed downstream of the study site and may have inhibited movement of salmonids into and out of the study area. Variations in water quality due to maintenance activities, backwater conditions created by the beaver dam, and/or vegetative regrowth in the channel over time may have contributed to sporadic salmonid catch rates observed.

In this study, sample sizes were logistically limited by the number of quarterly samples (7) that could be drawn following installation of the treatments in the waterway. More frequent sampling to increase sample sizes for this test was not practical. In part, logistic constraints associated with the larger overall project limited the practicality of additional sampling to increase sample sizes related to this single project goal. More importantly, since substantial intra-seasonal movements are not typically expected from rearing salmonids, more frequent sampling may have negated the necessary independence of sampling events required for valid statistical analyses.

It should be noted that during the first monitoring event following installation of LWD (Fall, 2004), the LWD was not actively interacting with the wetted channel width. Due to the limited sample sizes, this data was retained and used in data analysis since the root-balls associated with the individual wood pieces were in close proximity to the wetted width and likely provided some level of differential cover (e.g. shade) than existed in the sub-reach without LWD. Following the initial sampling event, LWD was repositioned so that it interacted directly with the channel although the degree to which this was true varied over time as water levels varied and LWD was further repositioned by water level fluctuations. The level of variation observed in the interaction of LWD with the wetted channel width during this study is believed to be typical and representative of interactions expected in other channels of similar design throughout King County's APDs.

Data gathered during this study suggests that preference for LWD amongst salmonids may exist but was not statistically detectable given the study constraints. Salmonid catch rate in the sub-reach with LWD was commonly greater than that in the sub-reach without LWD installed (Refer to Figure 5-2). When considering all salmonids combined, this was the case in four of five sampling periods in which salmonids were collected. The primary exception to this was observed during the spring of 2005 when catch rates of Chinook, coho, and all salmonids combined were each greatest in the sub-reach without LWD. During the winter of 2005, coho salmon were collected only from the sub-reach without LWD although Chinook salmon were collected only from the sub-reach containing installed LWD; when all salmonids are considered, catch rate during winter 2005 sampling was greatest in the sub-reach containing installed LWD.

It is unclear what impact, if any, the density of LWD installed for this study may have had on the study outcome. In this instance, LWD was spaced every 6 meters (20') along each bank of the

channel. The study goal was to evaluate the impact of LWD "in configurations typically installed by KCDNRP"; this wording was necessary because the density and configuration of LWD deemed appropriate by KCDNRP can vary based on project budgets and funding as well as site specific characteristics such as size and discharge of the channel, and the number and types of other mitigation activities performed at that site. It is possible that the effect of LWD on salmonid density in agricultural waterways may relate (directly or otherwise) to the density of LWD installed. Over time and following scheduled maintenance activities, as LWD is installed in differing densities in additional waterways, subsequent monitoring data should be utilized to investigate if such an effect exists and to determine if criteria for LWD density can be developed.

5.6 Conclusions and Recommendations

Based on this study, we could not disprove the research hypothesis related to this project goal. We therefore conclude that there was no difference in salmonid density observed between segments with and without installed large woody debris at the single research site evaluated. However, since only a single research site was available for this study, the following cautions and recommendations are relevant based upon our results:

1. Having only a single sampling site available for this evaluation[1] limits the practicality of generalizing observed results or trends to other agricultural waterways within King County. Any attempts to apply these findings to other waterways throughout the County should be limited to those waterways of similar character to the site studied.
2. Results presented in this report should not be taken as definitive regarding the utility of LWD to juvenile salmonids rearing in agricultural waterways, but rather as preliminary results with which a broader, more detailed study might be designed.
3. Further study at additional sites, particularly sites where salmonids are more abundant, may provide a clearer picture of the potential preference of LWD by juvenile salmonids rearing in low gradient agricultural waterways. Any future studies should consider using a paired design similar to that used in this study to minimize effects of other environmental factors on results. Additionally, consideration should be given to the potential utility of stocking fish into the study reach to increase catch rates during the study while taking into account potential differences in behavior of natural versus hatchery produced fish.
4. To the degree practical, any future assessments of the impact of LWD on salmonid density in agricultural waterways should evaluate differing densities of LWD in the channels evaluated. Practicality of such a study may largely be based on (1) the number of sites available (given that each LWD density evaluated would optimally be installed at more than one site), and (2) the expanded cost of installing LWD in higher densities than were used in this study.

[1] The utility of numerous other site which had previously had LWD installed was considered but all were deemed inappropriate for this study. Other sites typically had no control/comparative reach without LWD available, multiple treatments installed (e.g. LWD and plantings) and/or had had treatments installed for an extended period prior to this study. Over time sediment was found to buildup around LWD, mitigation plantings showed substantial growth, and/or substantial encroachment of RCG and/or other aquatic vegetation into the reach had occurred. Given these conditions, our ability to separate the impact of LWD from other treatments and conditions would have been minimal. The single site utilized for this study was designed to minimize such external influences since the only substantive difference between study and control reaches was the presence or absence of LWD and the impact of other mitigation treatments during the study period (e.g. new willow plantings) was believed to be negligible.

5.7 References

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