CHAPTER 2

Characterization of the Utilization of Agricultural Waterways by Salmonid Fishes

2.1 Introduction to Salmonid Density Hypothesis (Goal 1)

Although there is little published information on salmonid use of small watercourses associated with agricultural areas in King County's riverine floodplains and on the Enumclaw Plateau, waterways within these areas are used by various salmonid species (Berge 2002). As was presented in Chapter 1, the overall objective of this entire study was to determine effective and economical means to maintain agricultural watercourses, while protecting fish habitat as described in the Sampling and Analysis Plan developed by Washington State University and the University of Washington (2006) and approved by KCDNRP. In support of that mission, the goal of this Chapter is to determine if the County's agricultural watercourses serve as habitat for Chinook (*Oncorhynchus tshawytscha*) and other salmonids and, if so, to determine what habitat functions are provided in these watercourses. With the assistance of KCDNRP staff, the following research hypothesis was posed in relation to this study component:

> Salmonid density (as indexed by catch rate) within agricultural waterways does not vary temporally, spatially, or in relation to physical factors (specifically water source or surrounding vegetation).

Broad characterization of all species encountered are included in this report however, this study component was intended to focus on use of agricultural waterways by salmonid species, particularly Chinook salmon (*Oncorhynchus tshawytscha*) listed as Threatened under the Endangered Species Act (Federal Register 56, March 24, 1999: 14308-14328). Multiple races of Chinook salmon (spring, summer, and fall) occur within the research area. Although the majority exhibit an ocean-type life history with subyearling outmigration (Myers et al. 1998), approximately one third of the White River spring run (Myers et al. 1998) and the Snoqualmie River fall run (Williams et al. 1975; Washington Department of Fish and Wildlife 1995; 1997) exhibit stream-type life histories with yearling outmigrants. The proportion of yearling outmigrants in these populations varies substantially from year to year and may be environmentally rather than genetically determined (Myers et al. 1998).

Although juvenile Chinook salmon had previously been collected within the study area, insufficient data existed to adequately determine spatial and temporal distributions (Ken Carrasco, KCDNRP, personal communication with Tom Cichosz, September 28, 2001). Permit restrictions on the handling/collection of Chinook salmon (up to eight individuals per year) prohibited any direct assessment of their use of agricultural waterways during the early stages of this study (2002-2003). Subsequent permit modifications helped to address this constraint for the 2004-2006 sampling periods although numbers of Chinook salmon encountered remained relatively low and inconsistent through subsequent sampling events.

Coho salmon (*O. kisutch*) were commonly collected from the agricultural waterways studied, and coho and Chinook salmon share many general life history characteristics and habitat preferences. Juveniles of both species illustrate similar preferences in temperature (Bell 1991; Bjornn and Reiser 1991) and other habitat characteristics including use of depth, cover, and velocity (Bjornn and Reiser 1991; Raleigh et al. 1986; Thompson 1972). Seasonal variations in rearing habitat use are also expected to be relatively similar between the two species (Meehan and Bjornn 1991; Hillman et al. 1987; Tschaplinski and Hartman 1983).

However, differences do exist between life histories and habitat preferences of juvenile Chinook and coho salmon. Chinook salmon do not use off-channel areas to the same extent as coho, and particularly not off-channel ponds that are similar in function to agricultural watercourses (Hans Berge, KCDNRP, personal communication with Tom Cichosz, June 20, 2005) having very limited water velocity, soft substrates, and common occurrence of rooted vegetation. Emergence of juvenile Chinook salmon from spawning gravels in Puget Sound streams is generally earlier than that of coho salmon (February versus March/early April; Williams et al. 1975; Grette and Salo 1986). Additionally, as a single race, coho salmon throughout the study area exhibit a more consistent life history than the multiple races of Chinook salmon. Juvenile coho salmon typically spend 18 months in freshwater before outmigrating as yearlings with peak outmigration occurring between late April and mid May (Weitkamp et al. 1995). This report discusses findings within the context of both similarities and differences in life histories of these two salmonid species, and makes recommendations applicable to both species while maintaining an emphasis toward listed Chinook salmon.

Bull trout use of mainstream rivers in King County which are receiving waters of some certain agricultural watercourses is thought to occur, making their occurrence in agricultural waterways a possibility. Such use of agricultural waterways by bull trout however had not been documented prior to this study, and no bull trout were encountered during this study. Bull trout are therefore not addressed in this report.

Definitive statements about the relationship between land use activities in the agricultural lowlands and fish habitat were not previously available due to a lack of data, and this report represents a significant increase in the knowledge about salmonid habitat utilization in low-gradient agricultural watercourses (Berge 2002). Knowledge gained from this study has the potential to be incorporated into a Habitat Conservation Plan (HCP) submitted by King County under the authority of Section 10(a)(1)(B) of the federal Endangered Species Act (ESA) for agricultural practices in water bodies that constitute critical habitat for listed species as defined by the Act. Additionally, the information garnered from this study will enable King County staff, to make decisions relating to allocation of resources as well as to establish work priorities in the county's agricultural areas. Furthermore, the study findings can be shared with other government partners in the region in order to develop and implement programs that address salmonid use of floodplain habitats, and aid in their understanding of effective BMPs for routine maintenance of agricultural drainage channels.

2.2 Study Area

This study was conducted in waterways in or near King County's Agricultural Production Districts (APDs), which are composed of approximately 40,600 acres (16,430 hectares) zoned for agricultural use (Figure 2-1). Approximately 483 kilometers (300 miles) of watercourses, excluding the mainstems (and braids) of the major rivers, flow through King County's five APDs (Lower Green River, Upper Green River, Enumclaw, Sammamish, and Snoqualmie). The APDs are located almost exclusively on the floodplains of major rivers, with the exception of the Enumclaw Plateau APD. However, agricultural activities in the Enumclaw Plateau APD occur on similar extremely flat land, and often affect channels and riparian zones with similar characteristics to those on the valley floors surrounding large rivers. Sampling for this study took place in waterways throughout the Snoqualmie (Figure 2-2, Figure 2-3, Figure 2-4, Figure 2-5 and Figure 2-6), Enumclaw (Figure 2-7 and Figure 2-8) and Lower Green River (Figure 2-9) APDs at locations believed to be representative of those found throughout the county's five APDs.

Over time, many floodplain areas within these APDs have become subject to more frequent and prolonged flooding and as a result extended conditions of saturated soils. Accumulation of fine sediments and invasive grasses such as reed canarygrass (*Phalaris aundinaceae*, RCG) in agricultural drainage networks has added to this dilemma, and leads to repeated flooding. These recurrent and persistent conditions are of greater concern to agricultural landowners than are major floods that occasionally inundate extensive valley floor areas. Both the livestock and the horticultural sectors of the agricultural industry have routinely removed sediment and vegetation from agricultural watercourses to alleviate chronic flooding of their lands over the last 150 years. Even crops normally thought of as needing wet soil, such as blueberries, do not thrive in such highly saturated soils. Yet, the customary method of maintaining watercourses by dredging is contrary to some of the current fish habitat protection, mitigation, and in some instances restoration requirements. Anecdotal reports from various areas within King County indicate that the need for regular maintenance of agricultural drainage channels has increased in recent decades due to increased runoff from urban and suburban development on the slopes above many of the farming areas.

In 1979, the voters of King County passed an initiative protecting farmland through the purchase of development rights. This initiative provided for a bond to establish the King County Farmland Preservation Program (FPP), which purchases the development rights associated with livestock and horticultural farmlands to protect them from development. Many of the properties in this study are enrolled in the FPP. The interest of King County to preserve farmlands within it's boundaries requires development of policies and procedures to facilitate economically viable agriculture while at the same time complying with requirements of the Endangered Species Act (ESA). One aim of this study is to enhance the amount of information available regarding use of agricultural waterways by salmonid listed under the ESA (as well as those not listed) to better allow farming and fisheries to co-exist on these properties.

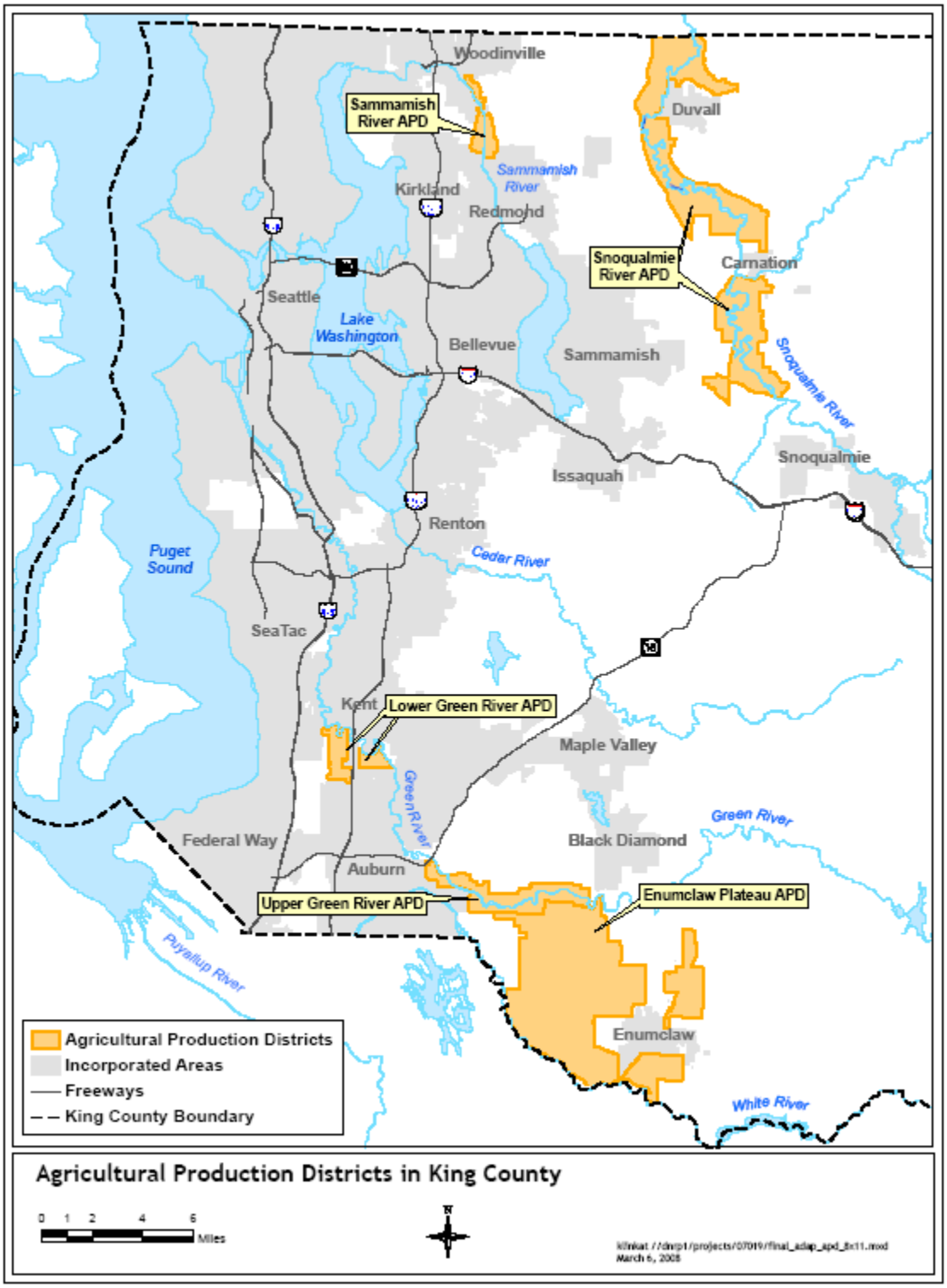

Figure 2-1. Agricultural Production Districts and incorporated areas within King County.

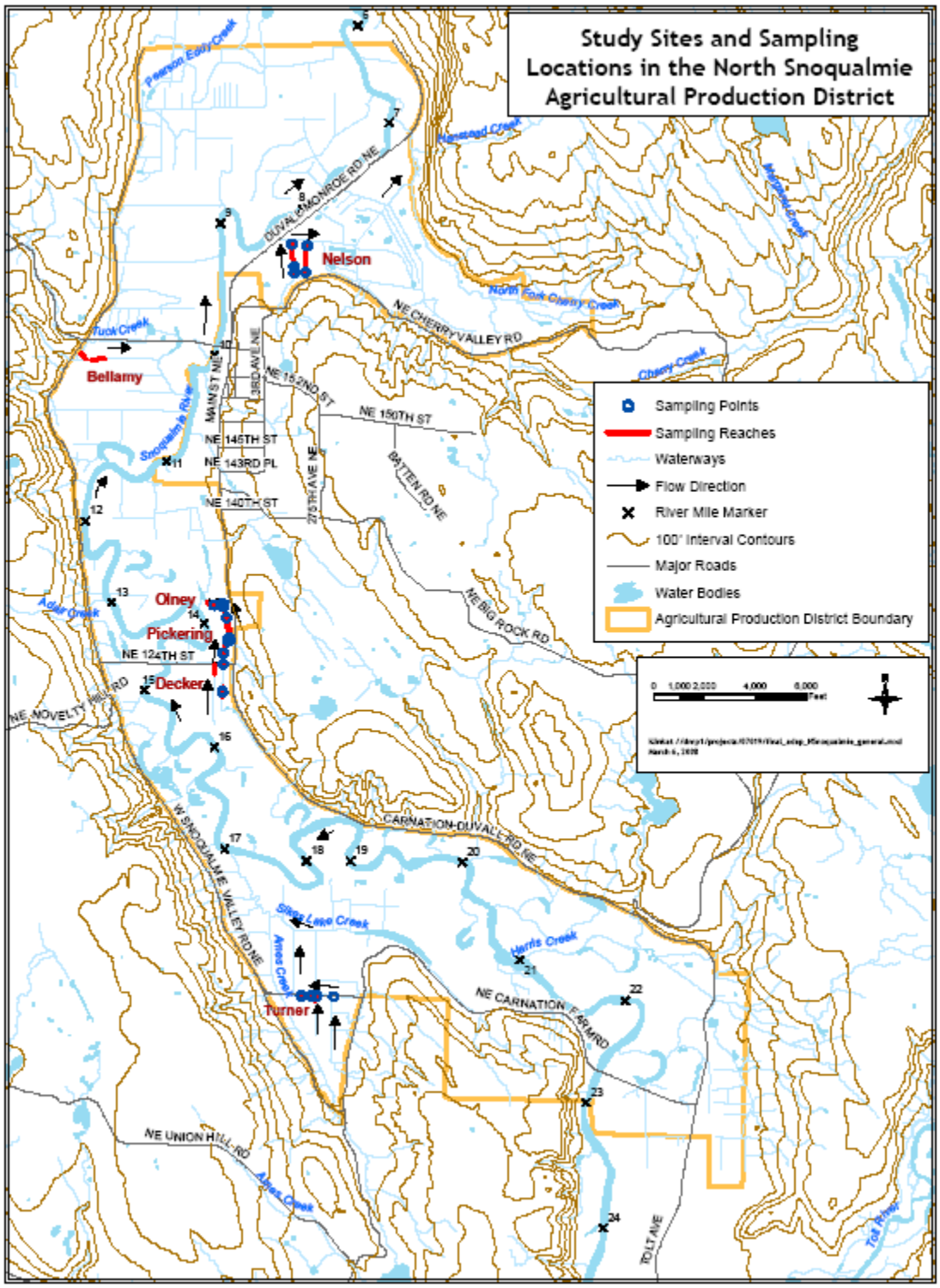

Figure 2-2. Overview of study sites and sampling locations in the North Snoqualmie Agricultural Production District.

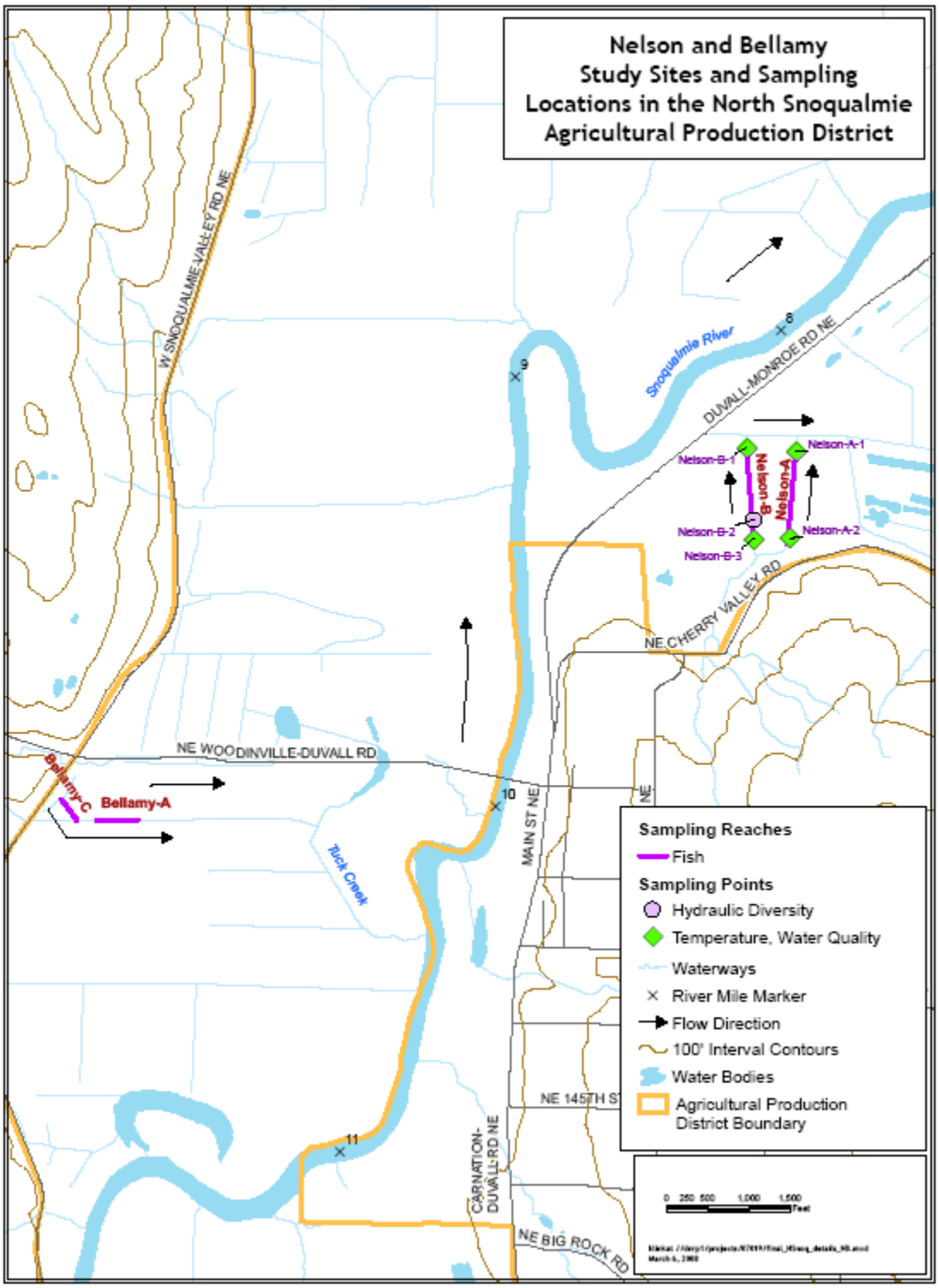

Figure 2-3. Detail of study sites and sampling locations in the northern portions of the North Snoqualmie Agricultural Production District.

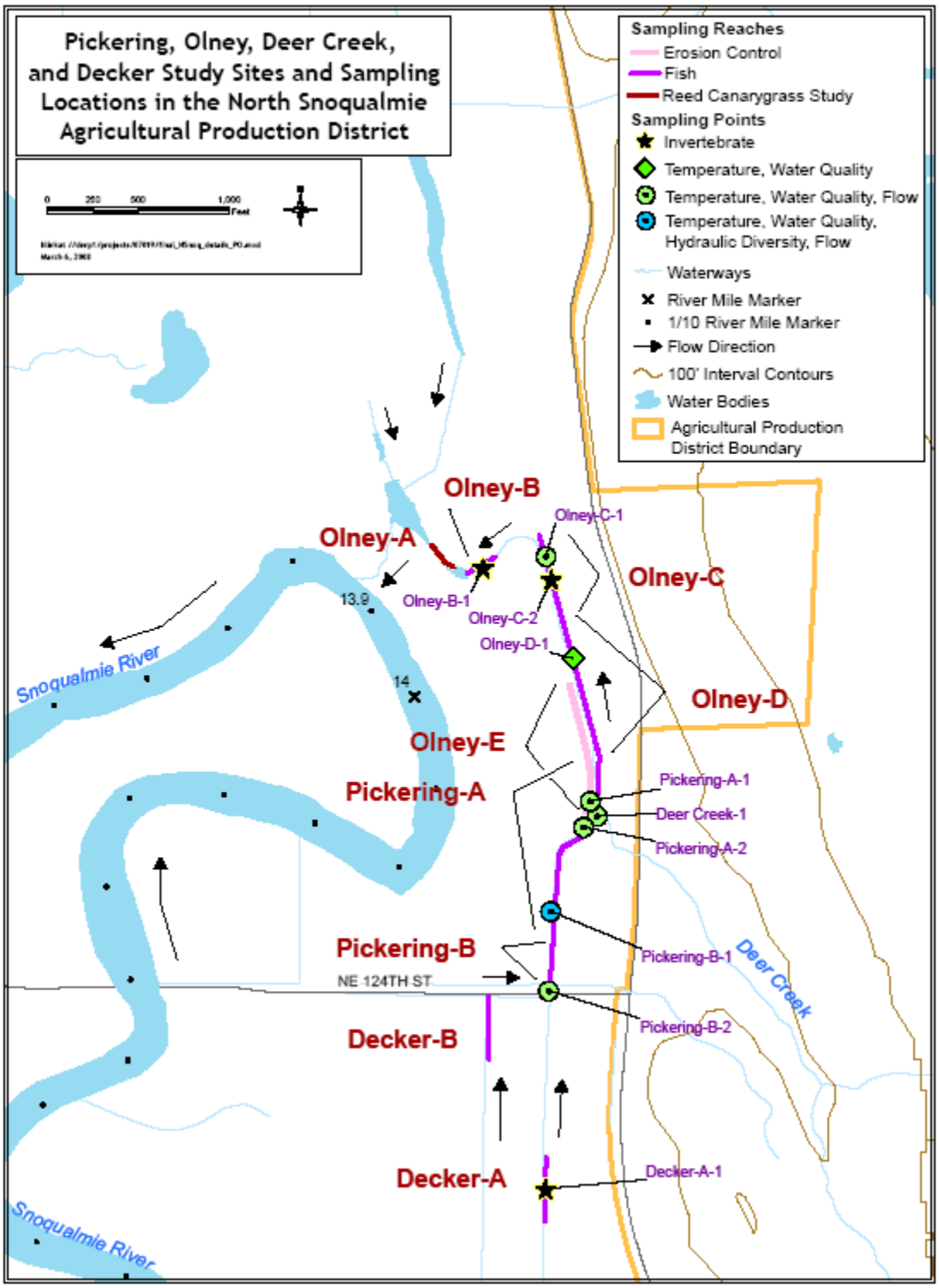

Figure 2-4. Detail of study sites and sampling locations in the central portions of the North Snoqualmie Agricultural Production District.

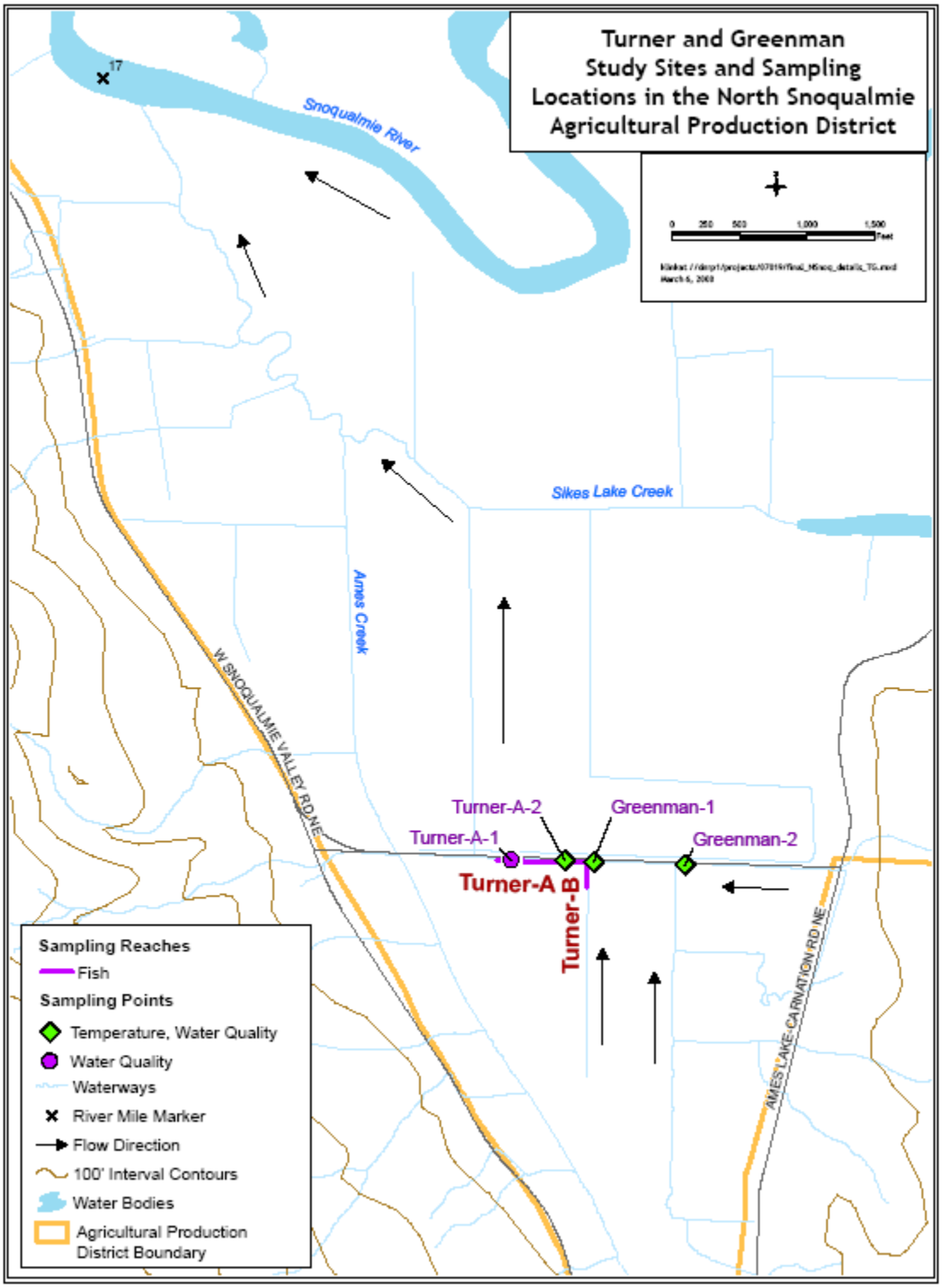

Figure 2-5. Detail of study sites and sampling locations in the southern portions of the North Snoqualmie Agricultural Production District.

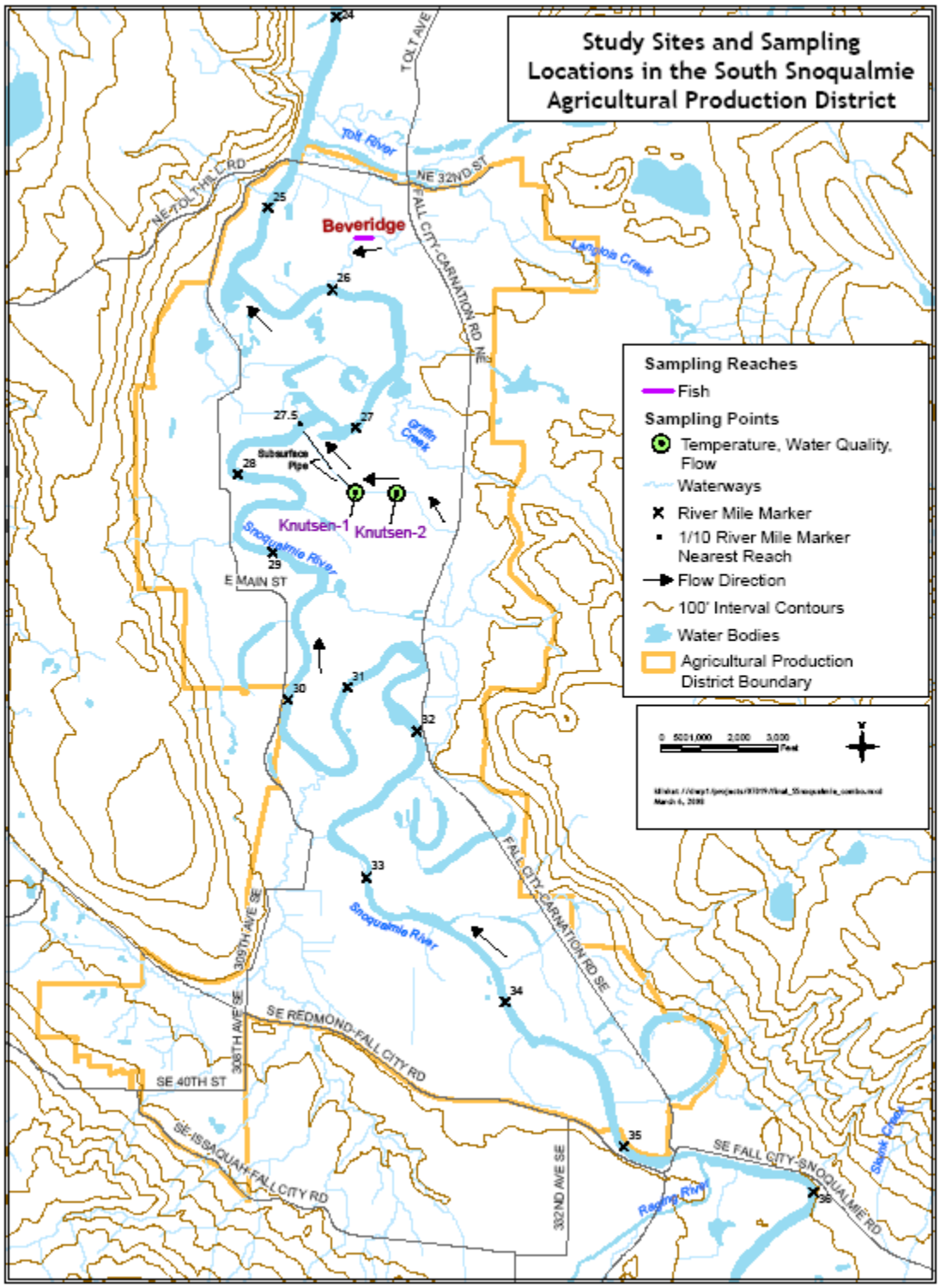

Figure 2-6. Detail of study sites and sampling locations in the South Snoqualmie Agricultural Production District.

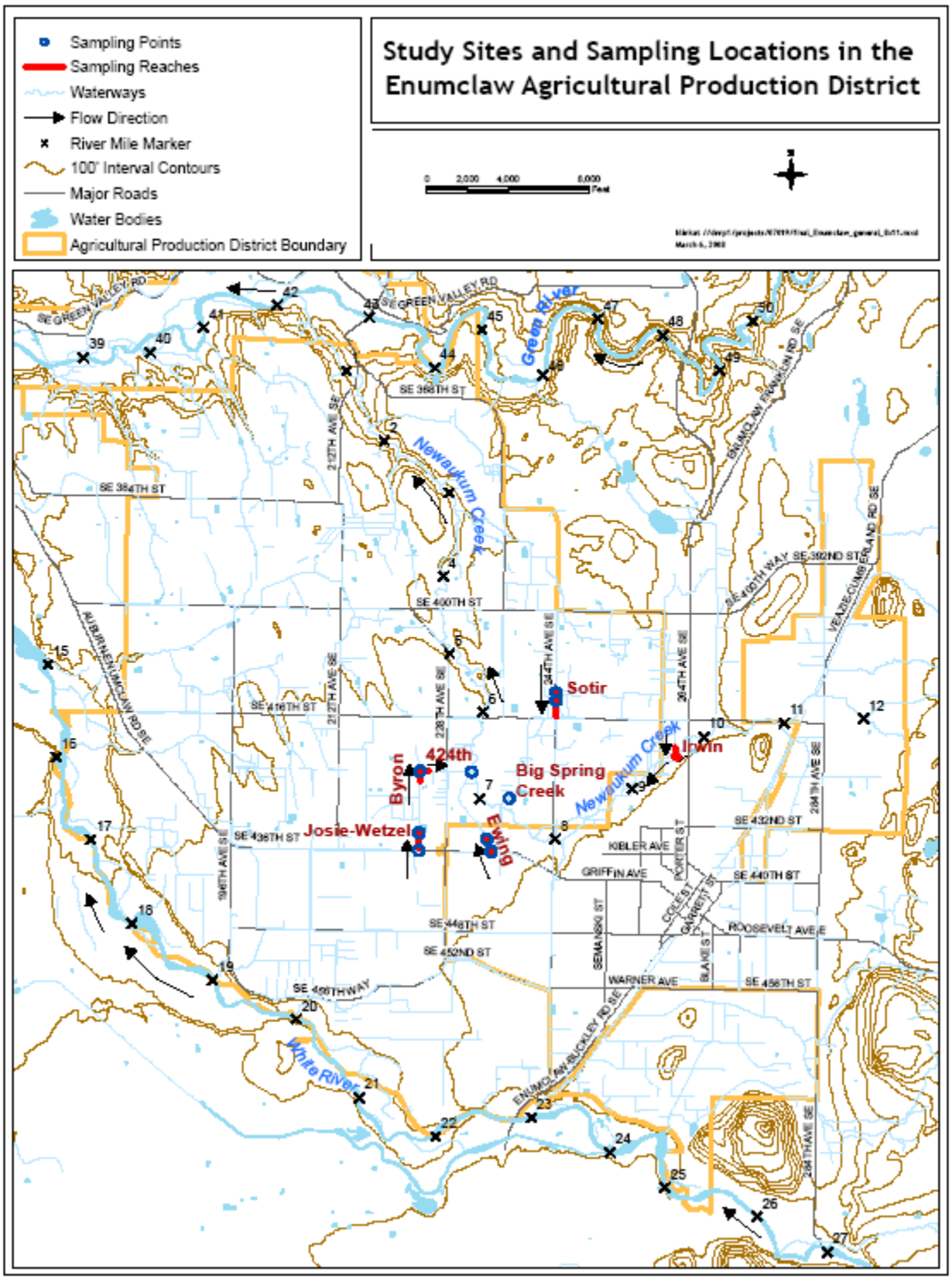

Figure 2-7. Overview of study sites and sampling locations in the Enumclaw Agricultural Production District.

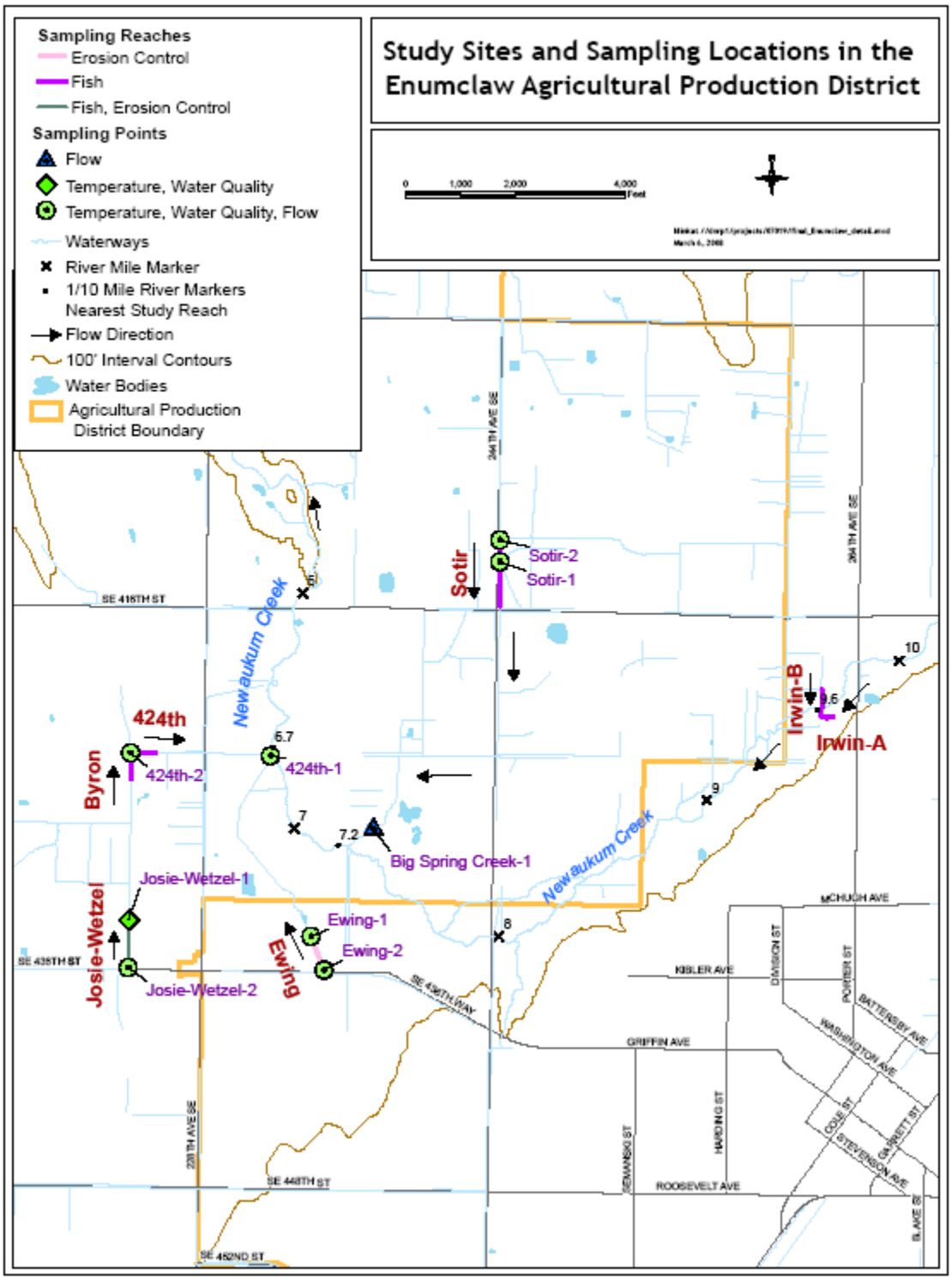

Figure 2-8. Detail of study sites and sampling locations in the Enumclaw Agricultural Production District.

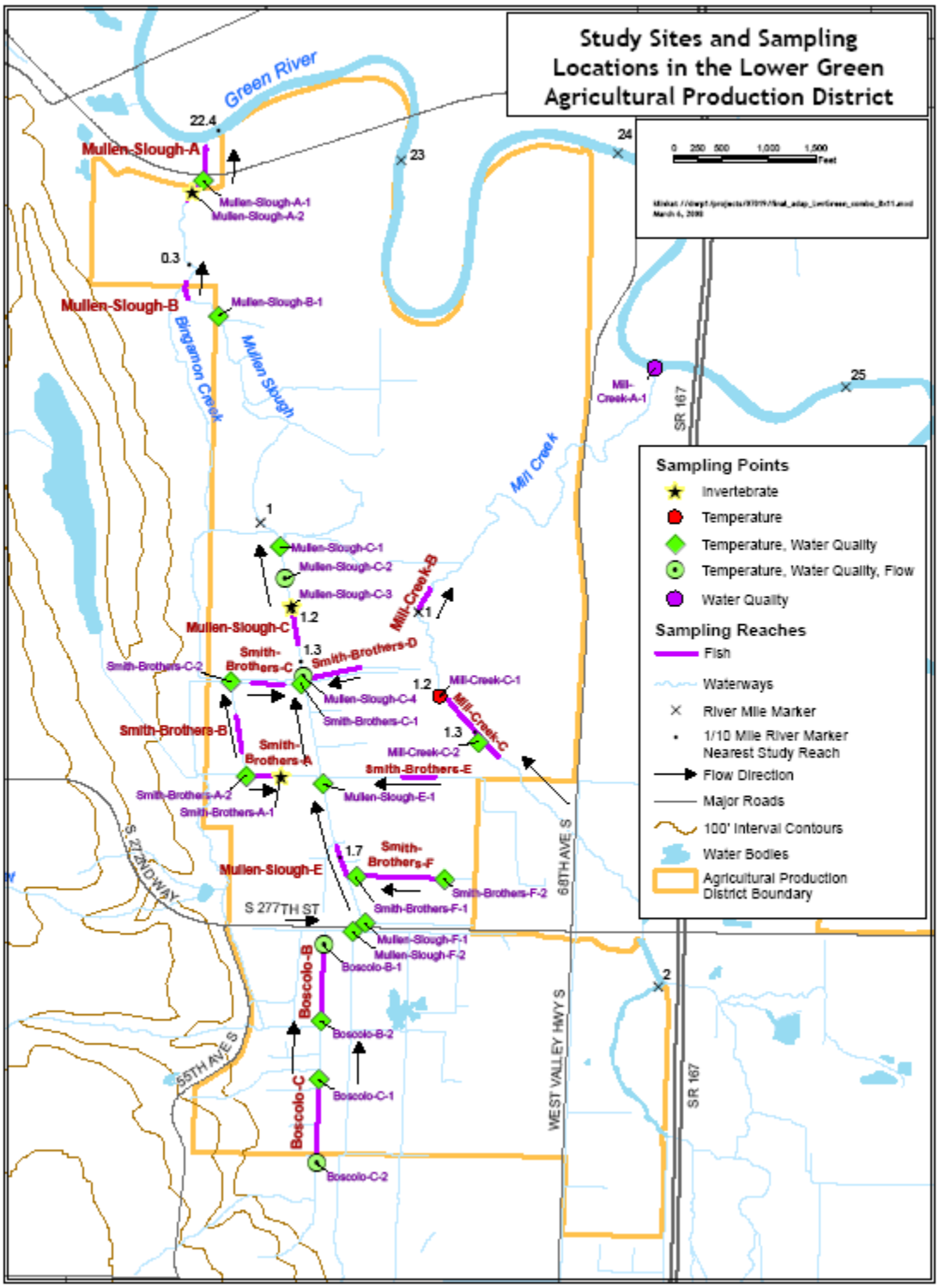

Figure 2-9. Study sites and sampling locations in the Lower Green Agricultural Production District.

2.3 Methods

2.3.1 Site Selection

Initial site selections were conducted in consultation with King County staff, willing landowners, and site visits. Vegetative condition and flow source were both considered during site selection. Vegetative condition was defined by the dominant vegetation surrounding the sampling reach and was classified as:

1. Reed Canarygrass (RCG).
2. Natural (a mixture of herbaceous vegetation including trees with no or limited RCG influence).
3. Mixed Vegetation (includes both herbaceous vegetation and a moderate to abundant RCG influence).

Flow categories were defined as:

1. Natural Flow – Typically found within natural waterway systems (may be channelized) where flows originate from hillsides, springs, or other natural sources of water.
2. Drainage Flow – Typically found within constructed channels with their origin in the agricultural area itself (originating from that site or another farm) and conveying primarily groundwater seepage (including that from drain tiles) and seasonal flood waters that would otherwise have moved as overland flow.
3. Mixed Flow – A mixture of natural and drainage flow. This is the most common classification observed within the King County APDs.

Although it was impossible to define and categorize the complete network of all watercourses throughout the APDs, it is believed that the selected study sites represent a stratified sample of watercourses with various flow and vegetative conditions represented in proportion to their occurrence. This assumption is based on examination of existing data and aerial photos, consultation with KCDNRP staff, and extensive site visits.

2.3.2 Fish Collection

Fish data collected seasonally (January/February, April, July and October) from the fall of 2002 through the spring of 2006 were analyzed for this study component. Fish were collected by electrofishing according to endangered species protocols defined by the National Marine Fisheries Service (2000). Fish were anesthetized using MS-222 prior to handling, and allowed to recover prior to their subsequent release. Length (mm) and wet weight (to nearest 0.5g) were recorded for the majority of individuals collected. In most cases, length and weight data were obtained from all fish collected. However, in cases when the numbers of fish collected were substantial enough to result in fish being retained for extended periods during data recording (e.g. resulting in undue stress to fish), length and weight information were collected only from a representative sample of each fish species captured.

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.

2.3.3 Fish Biology

For the most commonly collected salmonid species, definition of life stages was done using professional judgment of fisheries experts in conjunction with length frequency histograms. For anadromous coho and Chinook salmon, sub-adult and adult life stages were easily distinguished from juveniles due to the size of individuals observed. No aging of fish based upon hard body parts was conducted during this study however, the assigning of ages based on length frequency histograms is a common alternative to the much more time consuming process of direct aging by scales or other hard structures (Ney 1993). This methodology allowed for general characterization of the utilization of agricultural waterways by various juvenile age classes, however, without age verification using hard structures, this approach did not allow for reliable statistical analysis of age-specific data.

For rarely collected salmonid species (e.g. chum salmon (*O. keta*) and rainbow trout (*O. mykiss*)) assessment of age or life history stages based on length frequency histograms was not possible. Any discussion of life stages for these species is therefore based solely on professional judgment.

Life history characteristics of coastal cutthroat trout (*O. clarki*) were not evaluated during this study. The life history of coastal cutthroat trout may be the most diverse of any Pacific salmonid, with populations showing great diversity in size and age at maturity as well as a mixture of anadromous and resident population components (Johnson *et al*. 1999). Assessment of life history types and stages of coastal cutthroat trout would have required extensive and detailed assessment of hard body parts which was not conducted during this study.

Weekly instantaneous growth rate of salmonid species was estimated based on the change in average length of fish observed between quarterly sampling events and the number of weeks between sampling events. Since quarterly sampling events typically occurred across a period of 3-4 days, an intermediate sampling date for each event was used in calculation of instantaneous growth rates. The number of weeks was defined using these intermediate sampling dates and instantaneous growth rate (G) was estimated as:

$$G = \frac{\ln(L_2) - \ln(L_1)}{t} \qquad (2.1)$$

where *ln* is the symbol for natural logarithm, L_1 and L_2 are the average length (mm) of fish at sample time 1 and sample time 2 respectively, and t is the time in weeks between sampling times 1 and 2.

2.3.4 Data Analysis

Collected data included many observations of zero catch which could not be statistically assessed in conjunction with non-zero catch data. Consequently the data was divided into two subsets (zero and non-zero data), and processing and data analysis steps were unique for each subset. Comparison of zero and non-zero catch data across various conditions allowed us to evaluate the likelihood that salmonids would be found in or associated with various habitat conditions. Statistical analysis of non-zero catch data allowed us to assess differences in the expected abundance within habitat conditions where salmonids were found. Similar but separate data analysis was performed for Chinook salmon, coho salmon, and all salmonids combined. All statistical analyses were conducted using SAS software (SAS Institute 2006) with a selected alpha level of 0.10.

Zero and non-zero catch per unit of effort (CPUE) data were summarized across treatment effects as the percent of observations within each treatment being evaluated (e.g. flow or habitat category). A chi-square test of homogeneity was conducted to evaluate if zero and non-zero values were similarly distributed across treatment groups. If the percentage of zero data within any treatment group was found to be particularly high or low, an avoidance or association (respectively) with that treatment by salmonids could be inferred.

For non-zero catch data, the CPUE observed at each site during each sampling event (season) was used for statistical analyses. Doing so removed any effects of variable length of sampling reaches and/or variable sampling time spent within a given reach. For the purpose of analyses, 100 seconds of shocking time was considered a standard unit of effort.

Analysis of variance (ANOVA) was used to evaluate differences in mean catch rates across factors or treatments of interest (season, surrounding habitat type, flow type, and distance from mouth of watercourse system; Table 2-1). Due to the unbalanced design[1] of the study, the General Linear Model procedure (PROC GLM command in SAS) was used to perform all analysis of variance tests. Evaluation of differences in mean catch rates relied upon test statistics derived using the Type III sums of squares, also due to the unbalanced nature of the study design. The ANOVA model evaluated was:

$$\text{Log (CPUE)} = SN + FT + HT + DWM \qquad (2.2)$$

where *SN* represents season [winter, spring, summer, fall], *FT* is flow type [natural, drainage, mixed], *HT* is habitat type [natural, RCG, mixed], and *DWM* is the distance from waterway mouth.

Distance of each site from the mouth of the waterway was not included in the original contractual study design, but was thought to be potentially important in explaining catch rates based on professional judgment and observations made during sampling. Distances were

[1] The term 'unbalanced design' refers to the fact that unequal numbers of samples were obtained in the various treatment groups across sampling events. This is due to a variety of factors such as sites being added or deleted from the study, high water levels precluding sampling some sites in some seasons, etc. This situation does not negatively impact the study, but does require additional consideration during data analyses.

estimated using available GIS layers of the drainage networks, and then classified into half-mile groups (Table 2-1).

Interaction terms (e.g. Season x Habitat) were intentionally excluded from the statistical model. The high incidence of zero catch data observed during this study, and the resultant need to separate zero from non-zero catch data for analysis, led to sample sizes being insufficient to statistically evaluate interaction terms.

The assumption of normality of treatment means was evaluated via a post-ANOVA assessment using 'PROC Univariate Normal' commands in SAS. Since only one mean existed for each treatment, normality of model residuals was examined rather than the raw data. Residuals of untransformed CPUE data were found to be non-normally distributed (Shapiro Wilk statistic, $p<0.0001$[2]). Logarithmic transformation of CPUE data resulted in normalized means for Chinook salmon, coho salmon and for all salmonids combined (Shapiro Wilk statistic, $p>0.6$) and this transformation was therefore used for all analyses of non-zero catch data.

The raw data supporting these analyses are extensive and therefore could not be included with this document. All data has been supplied to KCDNRP in electronic format.

Table 2-1. Factor levels evaluated for their influence on salmonid catch rates using ANOVA.

Factor	**Options**
Season	Winter (Jan. or Feb.) Spring (April) Summer (July) Fall (October)
Surrounding Habitat Type	Reed Canarygrass (RCG) Natural Vegetation Mixed Vegetation
Flow Type	Natural Drainage Mixed
Distance Class (from mouth of agricultural waterway)	<0.5 miles 0.5-1.0 miles 1.0-1.5 miles 1.5-2.0 miles

[2] Shapiro Wilk statistic tests the hypothesis that the data is normally distributed. If the resultant p-value is small (e.g. <0.05) the hypothesis is rejected and the data are considered to be non-normally distributed. If the resultant p-value is relatively large (e.g. >0.25), the hypothesis is not rejected and the data are considered to be normally distributed. As the p-value increases, so does the relative certainty of data normality.

2.4 Results

2.4.1 Species Characterizations

Twenty one fish taxa were collected in quarterly electrofishing surveys throughout the life of this project, accounting for over 5,300 individuals. A summary by species and year is presented in Table 2-2. The most commonly encountered species were coho salmon and three spine sticklebacks (*Gasterosteus aculeatus*). Six taxa were collected in all years of the study: Lamprey (Petromyzontidae), coho salmon, cutthroat trout, suckers (*Catostomus* spp.), three spine sticklebacks and sculpin (*Cottus* spp.). Chinook salmon were collected in all years sampled except 2002 when only one quarterly sampling event took place (October 2002) limiting the likelihood of their capture in that calendar year relative to others sampled.

Five salmonid taxa were collected during the life of this project: coho, Chinook, and chum salmon, and cutthroat and rainbow trout/steelhead (Table 2-2). Of the 255 sampling events (site/date combinations) conducted between October, 2002 and April, 2006, salmonid species were collected during 147 events which equates to 58% of the time (Table 2-3). Of salmonid species collected, coho salmon were encountered most frequently (127 events). Chinook salmon and cutthroat trout were commonly encountered (in 36 and 44 events, respectively), whereas chum salmon and rainbow trout/steelhead were encountered only rarely (1 and 3 events, respectively).

Collectively, nearly 2,600 salmonids were collected during this study. Numbers of each species collected followed a similar trend to their frequency of encounter, with coho salmon accounting for the vast majority (88 percent, 2,275 individuals) of the salmonid catch. Table 2-4 illustrates that Chinook salmon and cutthroat trout accounted for approximately 7 and 4 percent, respectively, of the total salmonid catch (189 and 108 individuals, respectively) whereas rainbow trout/steelhead (6) and chum salmon (3) were encountered only in minimal numbers during this study.

Table 2-2. Summary of fish and other taxa collected by electrofishing during 2002-2006 quarterly monitoring surveys of agricultural watercourses within King County APDs.

Common Name	**Scientific Name**	**2002**	**2003**	**2004**	**2005**	**2006**	**Total**
Lamprey	Petromyzontidae	14	23	32	11	84	**164**
Chinook Salmon[2]	*Oncorhynchus kisutch*	--	8	119	57	5	**189**
Coho Salmon	*Oncorhynchus tshawytscha*	278	757	501	722	17	**2,275**
Chum Salmon	*Oncorhynchus keta*	--	--	2		--	**2**
Cutthroat Trout	*Oncorhynchus clarki clarki*	20	41	18	26	3	**108**
Rainbow Trout	*Oncorhynchus mykiss*	--	--	2	4	--	**6**
Salmonid-Unidentified	Salmonidae	--	--			3	**3**
Dace	*Rhinichthys* spp.	--	--	8		--	**8**
Longnose Dace	*Rhinichthys cataractae*	--	3			--	**3**
Peamouth	*Mylocheilus caurinus*	--	--	254	13	--	**267**
Northern Pikeminnow	*Ptychocheilus oregonensis*	--	16	15	1	--	**32**
Sucker	*Catostomus* spp.	30	12	58	7	4	**111**
Bullhead	*Ictalurus* spp.	--	444	11	5	2	**462**
Three Spine Stickleback	*Gasterosteus aculeatus*	159	--	322	498	166	**1,145**
Centrarchidae	Centrarchidae	--	--		2	--	**2**
Largemouth Bass	*Micropterus salmoides*	--	--	10		--	**10**
Pumpkinseed Sunfish	*Lepomis gibbosus*	2	51	85	29	--	**167**
Black Crappie	*Pomoxis nigromaculatus*	--	1			--	**1**
Green Sunfish	*Lepomis cyanellus*	--	5	10	9	--	**24**
Lepomis spp.	*Lepomis* spp.	--	5	1		--	**6**
Cottus spp.	*Cottus* spp.	32	120	63	45	16	**276**
Total Count –Fish		**535**	**1,486**	**1,543**	**1,452**	**300**	**5,316**
Non-Fish Species							
Dicamptodon spp.	*Dicamptodon* spp.	--	18	10	6	--	**34**

Table 2-3. Summary of seasonal fish collections between October, 2002 and April, 2006. Shading represents that sampling occurred; '**S**' indicate salmonids were collected; 'x' indicates that only non-salmonid fishes were collected.

Site Name	APD	Vegetative Class	Flow Class	'02	2003				2004				2005				2006	
				Oct	Feb	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Feb	Apr
424th[1]	Enum	Cleaned	Mixed	--	--	--	--	--	--	--	--	--	--	--	--	**S**	--	--
Byron	Enum	Natural	Mixed	--	--	**S**		--	**S**	**S**	x	x			x	--	--	--
Irwin-A	Enum	Mixed	Natural	**S**	**S**	**S**	--	--	--	--	--	--	--	--	--	--	--	--
Irwin-B	Enum	Mixed	Drainage	**S**	**S**	**S**	**S**	**S**	x	**S**	**S**	**S**	**S**	**S**	**S**	--	--	--
Josie-Wetzel[2]	Enum	Cleaned	Mix	--	--	--	--	--	--	--	--						--	--
Sotir	Enum	Natural	Mixed	**S**	**S**	**S**	**S**	x	**S**	x	**S**	**S**	**S**	**S**	**S**	--	--	--
Boscolo-B[3]	Lgreen	Mixed	Mixed	x	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Boscolo-C[3]	Lgreen	Mixed	Mixed	x	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mill-Ck-B	Lgreen	Mixed	Natural	**S**	--	**S**	**S**	**S**	--	**S**	**S**	--	--	--	--	--	--	--
Mill-Ck-C	Lgreen	Grass	Natural	**S**	--	**S**	**S**	**S**	--	**S**	**S**	--	--	--	--	--	--	--
Mullen-Slough-A	Lgreen	Natural	Mixed	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	--	--	--
Mullen-Slough-B	Lgreen	Mixed / Cleaned[5]	Mixed	x	**S**		--	x	**S**				**S**	**S**	x	**S**	**S**	x
Mullen-Slough-C	Lgreen	Grass / Cleaned[5]	Mixed	**S**	**S**	**S**	x	x	x							x	x	x
Mullen-Slough-E	Lgreen	Grass / Cleaned[5]	Mixed	**S**	x	x	x	x			x				x	x	x	x
Smith-Bros-A	Lgreen	Mixed / Cleaned[5]	Natural	**S**	**S**	**S**	x	x	**S**	**S**	**S**	**S**	**S**	**S**	x	x	x	x
Smith-Bros-B	Lgreen	Grass / Cleaned[5]	Natural	**S**	**S**	**S**	x	x	x	x					x	x	x	x
Smith-Bros-C	Lgreen	Grass / Cleaned[5]	Mixed	**S**	**S**	**S**			--		--	--	--	--	x	x	x	x
Smith-Bros-E	Lgreen	Grass / Cleaned[5]	Drainage	x					--			--	--	--	--	--	--	--
Smith-Bros-F	Lgreen	Natural	Drainage	--		--	--	--	--	--	--	--	--	--	--	--	--	--
Bellamy-C	Nsnoq	Mixed	Mixed	--	--	--	--	--	--	--	--	--	--	--	--	**S**	--	--
Bellamy-A	Nsnoq	Mixed	Natural	--	--	--	--	--	--	--	--	--	--	--	--	**S**	--	--
Beveridge	Nsnoq	Grass	Natural	--	--	--	--	--	--	--	--	--	**S**	**S**	--	--	--	--
Decker-A	Nsnoq	Mixed	Natural	**S**	**S**	**S**	**S**	x	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	--	x
Decker-B	Nsnoq	Grass	Drainage		--			x	x				x	x		--	--	--
Nelson-A	Nsnoq	Grass	Drainage	--	--	x	--	--	**S**	x	--	--	--	--	--	--	--	--
Nelson-B	Nsnoq	Grass	Natural	--	--	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	--	--
Olney-C	Nsnoq	Natural	Mixed	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
Olney-D	Nsnoq	Cleaned	Mixed	--	--	--	--	--	--	--	--	**S**	**S**	--	**S**	**S**	x	**S**
Pickering[5]	Nsnoq	Grass	Mixed	**S**	**S**	**S**	x	x	**S**	**S**	x	--	--	--	--	--	--	--
Pickering-A[5]	Nsnoq	Cleaned	Mixed	--	--	--	--	--	--	--	--	**S**	**S**	**S**	x	x	**S**	
Pickering-B[5]	Nsnoq	Cleaned	Mixed	--	--	--	--	--	--	--	--	**S**	**S**	**S**		x	**S**	**S**
Turner A/B	Nsnoq	Mixed	Mixed	--	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	--	--	--

1 Site was surveyed at the request of KCDNRP after maintenance activities occurred. Since no pre-maintenance data was collected at this site, it has been excluded from data analyses.
2 Site was incorporated at the request of KCDNRP after maintenance activities occurred. Since no fish were collected, it has been excluded from data analyses.
3 Sites on Boscolo property were sampled at the project outset only to validate past findings that salmonids were not present at these sites; All sites have been excluded from data analyses.
4 Reach had a probable blockage (culvert) at the mouth; following multiple sampling events without fish collection, the site was removed from further study (including data analyses).
5 Vegetative designations changed following cleaning activities conducted in 2005 between the spring and summer sampling events. At the Pickering site, two sub-reaches were created following maintenance activities, one of which had LWD installed (Pickering-B) and one of which did not (Pickering-A).

Table 2-4. Seasonal summary of electrofishing effort and salmonid catch.

Year / Season (Month)	Shock Effort (seconds)	Coho Salmon	Chinook Salmon	Chum Salmon	Cutthroat Trout	Rainbow/ Steelhead Trout	Unid. Salmonid	Total Salmonids
2002								
Fall (Oct.)	11,130	278	.	.	20	.	.	298
2003								
Winter (Feb.)	10,106	240	3	.	12	.	.	255
Spring (Apr.)	12,039	202	5	.	16	.	.	223
Summer (July)	7,996	199	.	.	8	.	.	207
Fall (Oct.)	9,628	116	.	.	5	.	.	121
2004								
Winter (Jan.)	9,301	78	1	.	2	2	.	83
Spring (Apr.)	10,997	119	66	2	6	.	.	191
Summer (July)	8,402	195	1	.	6	.	.	202
Fall (Oct.)	8,210	109	51	.	4	.	.	164
2005								
Winter (Jan.)	9,112	71	30	.	7	1	.	109
Spring (Apr.)	8,027	209	16	.	8	3	.	236
Summer (July)	8,377	276	3	.	10	.	.	289
Fall (Oct.)	5,985	166	8	.	1	.	.	175
2006								
Winter (Feb.)	5,184	8	5	.	2	.	.	13
Spring (Apr.)	4,018	9	.	.	1	.	3	13
Totals	**128,512**	**2,275**	**189**	**2**	**108**	**6**	**3**	**2,581**

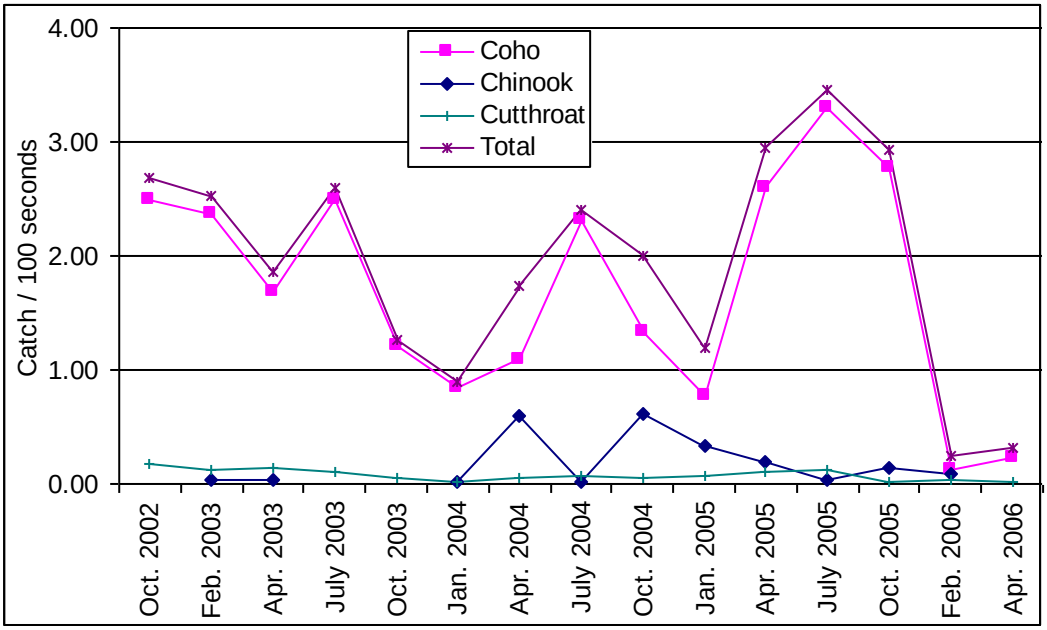

Figure 2-10. Seasonal CPUE[3] of commonly collected salmonid species.

Salmonid catch rates showed a distinct seasonal influence throughout the life of this study with catch rates lowest in winter and greatest during summer sampling events (Figure 2-10). This trend is driven by the abundance of coho salmon, with no distinct seasonality observed in catch rates of other commonly collected salmonids (Figure 2-10). However, from 2003 through 2006, summer catch rates were typically 2.5-3 times greater than those of the preceding or following winters. Catch rates during intermediate periods (spring and fall sampling) showed no distinct similarity to either summer or winter catch rates during this study. During 2004, spring and fall catch rates were relatively high and most resembled those of the intermediate summer. During 2003, spring and fall catch rates of coho salmon were relatively low and most resembled those of adjacent winter samples; during these same spring and fall (2003) samples, the highest catch rates of Chinook salmon observed throughout the study period were observed, leading to overall salmonid catch rates most resembling that of the intermediate summer period. During 2003, spring catch rates were relatively high whereas those in fall were relatively low, showing no clear relation to either higher summer or lower winter catch rates.

[3] Values presented in this graph represent total seasonal catch divided by total season effort (see Table 2-4) and include both zero and non-zero catch data.

2.4.2 Age and Growth of Key Salmonids

2.4.2.1 Coho Salmon

Agricultural waterways within King County provide rearing habitat for both age 0+ and 1+ coho, although the presence of various age classes varies by season (Table 2-5 and Appendix 2-A). During winter sampling, only age 1+ coho salmon were encountered; during summer and fall sampling, only age 0+ coho salmon were encountered. For winter, summer and fall sampling periods, this seasonal distinction of age classes remained consistent throughout all years of this study.

Spring sampling showed the presence of multiple age classes of juvenile coho salmon in agricultural waterways although the age classes present varied considerably between years (Table 2-5). Both age 0+ and 1+ coho salmon were encountered during spring sampling in 2003 and 2005. The relative abundance of the two year classes differed between these years however, with age 1+ fish most abundant during spring 2003 and age 0+ fish most abundant during spring 2005. During spring sampling in 2004, only age 0+ coho salmon were encountered. In contrast, during spring of 2006, only age 1+ coho salmon were collected (Table 2-5).

Juvenile coho salmon appear to spend slightly more than one year in agricultural waterways and grow approximately 60mm in length during their observed residence time (Table 2-6 and Figure 2-11). When first encountered at age 0+ in spring surveys, juvenile coho salmon captured ranged from 45.5mm (2003 cohort) to 52.7mm (2004 cohort) in length, with an average size of 48.6mm. As age 1+ pre-smolts, coho salmon collected during spring surveys ranged from 106.6mm (2002 cohort) to 117.7mm (2004 cohort) with an average size throughout the study of 109.7mm. Seasonal and annual average lengths are presented in Table 2-6.

Table 2-5. Numbers of coho salmon collected by age and season from agricultural waterways in King County.

	Apparent Ages	**2002**	**2003**	**2004**	**2005**	**2006**
Winter (Jan/Feb)	0+	--	0	0	0	0
	1+	--	240	78	71	8
Spring (April)	0+	--	76	119	127	0
	1+	--	126	0	48	4
Summer (July)	0+	--	199	195	276	--
	1+	--	0	0	0	--
Fall (October)	0+	278	116	109	166	--
	1+	0	0	0	0	--

Table 2-6. Seasonal, age specific average length of various cohorts of coho salmon collected from agricultural waterways within King County.

	Year Class				Weighted
Period (age)	**2002 YC**	**2003 YC**	**2004 YC**	**2005 YC**	**Avg.**
Spring (0+)	--	45.5	52.7	46.7	48.6
Summer (0+)	--	69.8	71.8	60.3	66.5
Fall (0+)	--	80.8	86.8	78.4	81.5
Winter (1+)	86.1	88.9	95.3	108.1[a]	88.7
Spring (1+)	106.6	--	117.7	111.0[a]	109.7

a - Average size is based on low numbers of fish (see Table 2-5).

Growth rates of juvenile coho salmon found within agricultural waterways varied markedly with season (Table 2-7 and Figure 2-11). Average inter-seasonal weekly instantaneous growth rate was greatest for age 0+ fish between the spring and summer sampling periods (0.026); the observed weekly growth rate during this period was approximately 35% greater than that in any other inter-seasonal period, and more than 400% of the lowest inter-seasonal growth rate observed (0.005, Fall-Winter period). Coho salmon exhibited intermediate and relatively similar growth rates during the Summer-Fall and Winter-Spring growth periods (0.014 and 0.019, respectively).

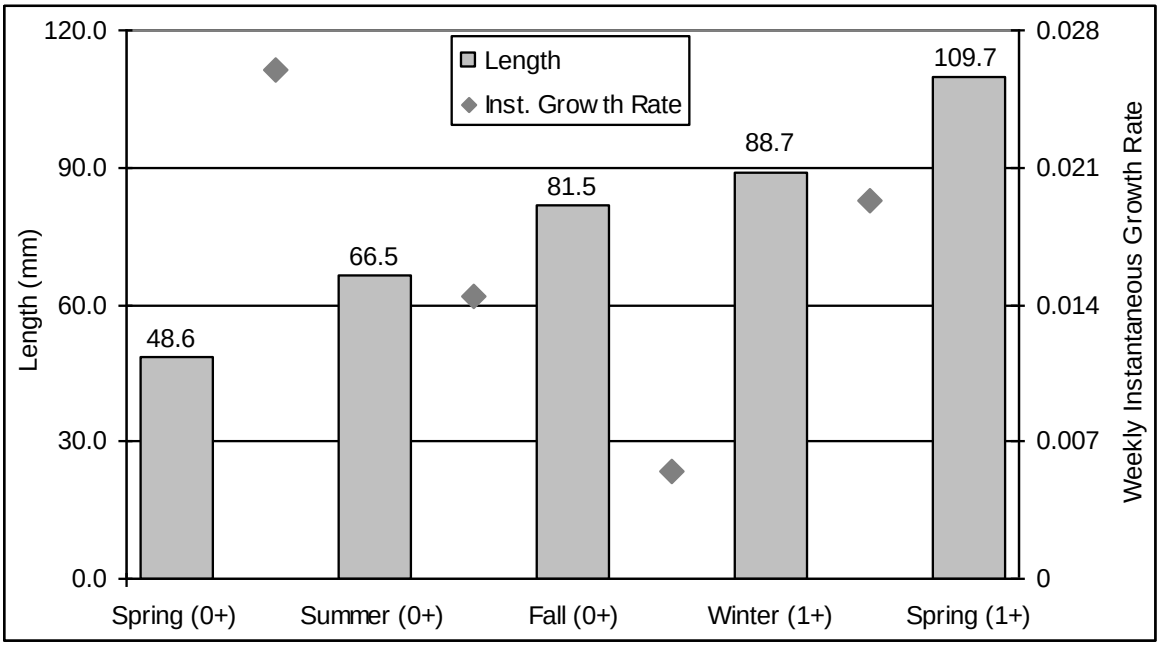

Figure 2-11. Comparison of seasonal weighted average length and inter-seasonal weekly instantaneous growth rates of coho salmon collected from agricultural waterways within King County.

Although greatest during the Spring-Summer period, weekly instantaneous growth rate was also most variable between cohorts during this period, ranging from 0.019 (2005 year class) to 0.036 (2003 year class) with a calculated coefficient of variation (CV) of 0.31 (Table 2-7). Juvenile coho growth rates during the Summer-Fall growth period showed a similar degree of variability (CV=0.27), whereas growth rates appeared markedly more stable amongst cohorts during the Fall-Winter and Winter-Spring periods (CV=0.04 and 0.02, respectively).

Table 2-7. Seasonal, age specific weekly instantaneous growth rates of various cohorts of coho salmon collected from agricultural waterways within King County.

	Year Class				**Weighted Avg.[a]**	**Coef. of Variation**
Growth Period (age)	**2002 YC**	**2003 YC**	**2004 YC**	**2005 YC**		
Spring-Summer (0+)	--	0.036	0.028	0.019	0.026	0.31
Summer-Fall (0+)	--	0.011	0.013	0.019	0.014	0.27
Fall-Winter (0/1+)	--	0.007	0.007	NC[b]	0.005	0.04
Winter-Spring (1+)	0.021	--	0.021	NC	0.019	0.02

a – Weighted average growth is based on change in weighted average lengths presented in Table 2-6.
b - NC =Not calculated due to limited numbers of individuals collected (<10). These individuals are included in calculation of the associated weighted average but not the Coefficient of Variation.

2.4.2.2 Chinook Salmon

Agricultural waterways within King County provide rearing habitat for both age 0+ and 1+ Chinook salmon, although the presence of various age classes varied by season (Table 2-8 and Appendix 2-B). Winter and spring sampling showed the presence of both age classes of juvenile Chinook salmon while in summer and fall samples, only age 0+ Chinook salmon were observed (Table 2-8).

Juvenile Chinook salmon rearing within agricultural waterways were found to do so for slightly more than fifteen months. The newest year class (age 0+) of Chinook salmon was typically first encountered during winter sampling in late January or early February[4] and could be traced through the spring of the following year (Table 2-8). Juvenile Chinook salmon begin to utilize agricultural waterways for rearing by the time they are 50mm in length (Table 2-9). At the end of their first year in these waterways, the juvenile Chinook salmon grew to approximately 117mm in total length and reached approximately 129mm on average as pre-smolts the following spring (Table 2-9).

[4] Age 0+ Chinook salmon were encountered during winter 2003 and 2005 in surveys conducted on February 2-6, 2003 and January 24-29, 2005, respectively. During 2004, winter surveys were conducted approximately 2 weeks earlier (January 12-15), and no age 0+ Chinook salmon were encountered. Winter surveys conducted during 2006 were (February 24-25) were less extensive than those in previous winters, and no age 0+ Chinook were encountered.

Table 2-8. Numbers of Chinook salmon collected by age and season from agricultural waterways in King County.

Season	Apparent Ages	2003	2004	2005	2006
Winter	0+	3	0	21	0
	1+	0	1	9	5
Spring	0+	2	8	1	0
	1+	3	58	15	0
Summer	0+	0	1	3	--
	1+	0	0	0	--
Fall	0+	0	51	8	--
	1+	0	0	0	--

Table 2-9. Seasonal, age specific average length of various cohorts of Chinook salmon collected from agricultural waterways within King County.

	Year Class				Weighted
Period (age)	2002 YC	2003 YC	2004 YC	2005 YC	Avg.
Winter (0+)	--	50.0[a]	--	45.1	45.7
Spring (0+)	--	66.5[a]	84.8[b]	56.0[a]	78.9[b]
Summer (0+)	--	--	112.0[a]	86.3[a]	92.7[a]
Fall (0+)	--	--	113.7	116.6[b]	114.1
Winter (1+)	--	--	105.4[b]	118.2[a]	116.9[b]
Spring (1+)	142.7[a]	128.8	126.7	--	128.9

a = Average length is based on less than 8 individuals.
b = Average length is based on 8-14 individuals.

Estimated growth rates[5] of juvenile Chinook salmon found within agricultural waterways varied markedly with season (Table 2-10 and Figure 2-12) although estimates of average sizes used to calculate growth were often based on small numbers of individuals and may be subject to error (See Table 2-8 and Table 2-9). Growth was fastest during the Winter-Spring period of the fishes first year of life. The estimated weekly instantaneous growth during this period (0.047) was

[5]Although juvenile Chinook growth rates are suspected to vary by river system (Hans Berge, KCDNRP, personal communication with Tom Cichosz, date unknown) and therefore potentially by APD, such differences were not apparent from length frequency histograms compiled during this study with the possible exception of April, 2004 (Appendix 2-B). Due to a lack of evidence for differential growth between APDs and relatively low numbers of juvenile Chinook salmon collected overall, comparative assessment of growth was limited to season and year class.

more than three times greater than that estimated for any other inter-seasonal period (Table 2-10). Estimates of weekly instantaneous growth of Chinook salmon during the spring-summer (0.013) and summer-fall (0.015) sampling periods were similar, and intermediate to those estimated for other inter-seasonal periods. Estimated growth of juvenile Chinook salmon was least during the Fall-Winter period (0.002), and growth appears to increase again between winter and spring (0.009) as fish approach the pre-smolt life stage.

Table 2-10. Seasonal, age specific estimates of weekly instantaneous growth of various cohorts of Chinook salmon collected from agricultural waterways within King County.

	Year Class				**Weighted Avg.[a]**	**Coef. of Variation**
Growth Period (age)	**2002 YC**	**2003 YC**	**2004 YC**	**2005 YC**		
Winter-Spring (0+)	--	0.029	--	0.021	0.047	0.11
Spring-Summer (0+)	--	--	0.025	0.033	0.013	0.40
Summer-Fall (0+)	--	--	0.001	0.021	0.015	0.97
Fall-Winter (0/1+)	--	--	NC[b]	0.001	0.002	N/A
Winter-Spring (1+)	--	--	0.018	--	0.009	N/A

a – Weighted Average growth is based on change in weighted average lengths presented in Table 2-9.
b - NC = Not calculable due to limited numbers of individuals collected during winter 2004; the resultant growth estimate was negative.

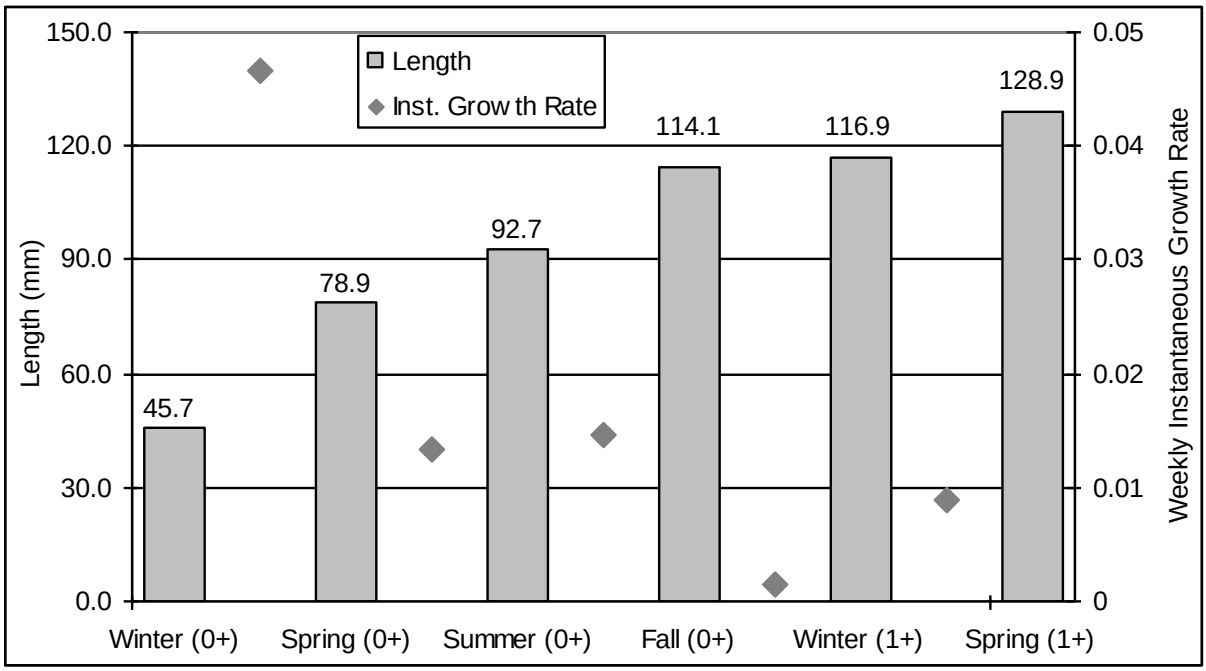

Figure 2-12. Comparison of seasonal weighted average length and inter-seasonal weekly instantaneous growth rates of juvenile Chinook salmon collected from agricultural waterways within King County.

2.4.3 Temporal, Spatial, and Habitat Distribution of Key Salmonids

2.4.3.1 General Characterization

Most habitats available within agricultural waterways are commonly utilized by all juvenile life history stages of coho salmon. Juvenile coho salmon utilize agricultural waterways as parr shortly after their emergence from spawning gravels (total length <55mm), as well as for spring, summer, fall and overwinter rearing (Table 2-11). Coho salmon continued to rear within the agricultural waterways until shortly before their expected outmigration to the ocean, as evidenced by their broad distribution across available habitats in the pre-smolt stage as age 1+ fish collected during spring monitoring.

Illustrating the importance of agricultural waterways to juvenile coho salmon, all juvenile life stages were collected from each of the habitat configurations evaluated with only two exceptions (Table 2-11). Juvenile coho salmon were not found in a limited sample[6] of recently cleaned (of vegetation) waterways with predominantly natural flows. Additionally, juvenile coho salmon were found to utilize waterways with predominantly RCG vegetation coupled with drainage flows only on a single occasion in which a number of individuals (14) were found overwintering in a waterway with those conditions (Nelson-A, January 2004; refer to Table 2-3).

Juvenile Chinook salmon utilize agricultural waterways as parr shortly after their emergence from spawning gravels (total length <55mm), as well as for spring, summer, fall and overwinter rearing (Table 2-11). Most habitats available within agricultural waterways were utilized by 2-3 juvenile life history stages of Chinook salmon, although few habitat conditions had observed utilization by all four life history stages evaluated. Recently emergent and overwintering juveniles however were observed in fewer habitat configurations than those rearing from spring through fall or as age 1+ pre-smolts.

No juvenile Chinook salmon were collected from waterways dominated by drainage flows during this study (Table 2-11). In RCG dominated vegetation, more life history stages of juvenile Chinook salmon were found in waterways dominated by natural flows (all four life stages) than those dominated by mixed flow conditions (spring-fall and pre-smolt rearing only). The same was not true of mixed vegetation sites in which both mixed and natural flow conditions had only spring-fall rearing (including pre-smolt rearing). Under a natural vegetative regime only mixed flow conditions were evaluated and all juvenile life history stages of Chinook salmon were encountered under these conditions. In waterways with banks/channels recently cleaned of vegetation, juvenile Chinook salmon were not encountered during limited sampling; more extensive sampling was conducted in recently cleaned waterways with mixed flow conditions and juvenile Chinook salmon were collected as recent emergent fry and during spring, summer, fall and overwinter rearing stages.

[6] Evaluation of this habitat configuration involved only two sites (Smith-Bros-A and Smith-Bros-B) located on adjacent and connected waterways. Each site was sampled during 4 seasonal sampling events following cleaning of vegetation from the channels.

Table 2-11. Summary of habitat and flow conditions where various juvenile life stages of Chinook and coho salmon were observed in quarterly monitoring surveys.

Habitat Character[a]		**Parr**			**Presmolt**
Vegetation	**Flow**	**Recently Emerged fry (<55mm)**	**Spring-Fall Rearing**	**Overwinter**	**Rearing (Age 1+ in April)**
Reed Canarygrass	Natural	Chinook, Coho	Chinook, Coho	Chinook, Coho	Chinook, Coho
	Drainage	--	--	Coho	--
	Mixed	Coho	Chinook, Coho	Coho	Chinook, Coho
Mixed	Natural	Coho	Chinook, Coho	Coho	Chinook, Coho
	Drainage	Coho	Coho	Coho	Coho
	Mixed	Coho	Chinook, Coho	Coho	Chinook, Coho
Natural	Natural	NI[b]	NI	NI	NI
	Drainage	NI	NI	NI	NI
	Mixed	Chinook, Coho	Chinook, Coho	Chinook, Coho	Chinook, Coho
Cleaned[c]	Natural	--	--	--	--
	Drainage	NI	NI	NI	NI
	Mixed	Chinook, Coho	Chinook, Coho	Chinook, Coho	Coho

a - Refer to Table 2-3 for summary of sites monitored, and habitat conditions and frequency of salmonid capture at each site.
b - No Information (NI) collected in these habitat configurations; use of these habitats by juvenile anadromous salmon is unknown.
c - Extent of recently cleaned waterways available in this study was limited; Those with predominantly natural flow were limited to 2 sites evaluated through 4 seasons.

2.4.3.2 Statistical Characterization

Zero Versus Non-Zero Catch Data
Salmonids, as indicated by total catch, were encountered in all seasons, distance classes, and habitat and flow conditions evaluated during this study. However, differences in their likelihood of encounter were observed across all of these factors. Moreover, the distribution of non-zero catch data differed significantly from that of zero catch data across season, distance class, vegetative habitat type and flow type (Chi square test, $p<0.10$; Figure 2-13). Chi square evaluation allows for evaluation of differences in distributions across all classes of a variable (e.g. season or habitat type) but does not allow for pairwise comparisons within classes (e.g. zero versus non-zero catch during summer). Consequently, interpretation of intra-class differences is subjective.

Based on our sampling, salmonids are most likely to be encountered during the winter and spring seasons and least likely to be encountered during the summer season (Figure 2-13). During fall sampling, salmonids were found to have an approximately equal likelihood of being encountered (non-zero catch rate) or not (zero catch rate).

Salmonids were far more likely to be encountered in close proximity (≤0.5 miles) to the mouth of the drainage (Figure 2-13). Encounters (36) also outnumbered non-encounters (33) between 0.5 and 1.0 miles upstream of the mouth of the drainage systems although the difference was far less pronounced. In contrast, non-encounters outnumbered encounters in reaches more than one mile above the mouth of the drainage system. This difference was more pronounced for sites from 1-1.5 miles upstream than for sites 1.5-2 miles upstream of the mouth.

Across vegetative regimes, salmonids were likely to be collected in natural or mixed vegetative habitats and unlikely to be collected from RCG habitats or waterways recently cleaned of vegetation (Figure 2-13). The discrepancy in encounter versus non-encounter rates was similar in RCG dominated habitats (18:32) and recently cleaned habitats (32:64).

Salmonids were far more likely to be collected from waterways with a natural flow regime (49 of 73 events) than from those dominated by drainage flows (12 of 39 events). Sampling in mixed flow regimes resulted in salmonids being encountered more often than not (83 of 150 events) although not by a wide margin (Figure 2-13).

Coho salmon were encountered in all seasons, distance classes, and habitat and flow conditions evaluated during this study although differences in their likelihood of encounter were observed across most of these factors. For coho salmon, the distribution of non-zero catch data differed significantly from that of zero catch data across distance class, vegetative habitat type and flow type (Chi square test, $p<0.10$), but did not differ significantly across seasons (Chi square test, $p>0.38$; Figure 2-14).

Similar to the trend noted for all salmonids combined, coho salmon were far more likely to be encountered in close proximity (≤0.5 miles) to the mouth of the drainage (Figure 2-14). Encounters were outnumbered by non-encounters at all distance classes exceeding one half mile upstream of the mouth of the drainage systems. The discrepancy between the numbers of encounters (non-zero catch) and non-encounters (zero catch) increased with increased distance.

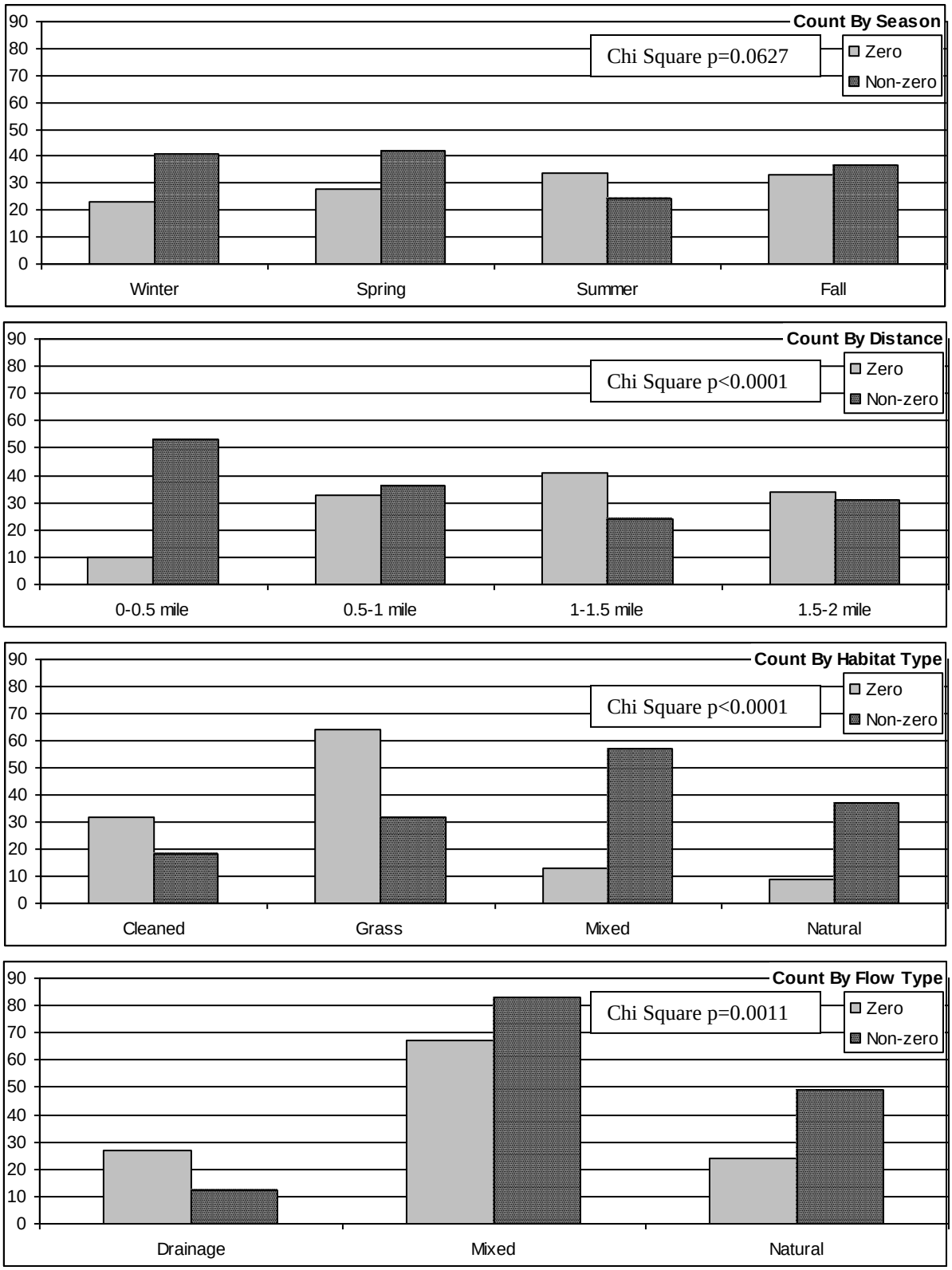

Figure 2-13. Count of total salmonid zero and non-zero catch observations by season, distance, habitat, and flow type.

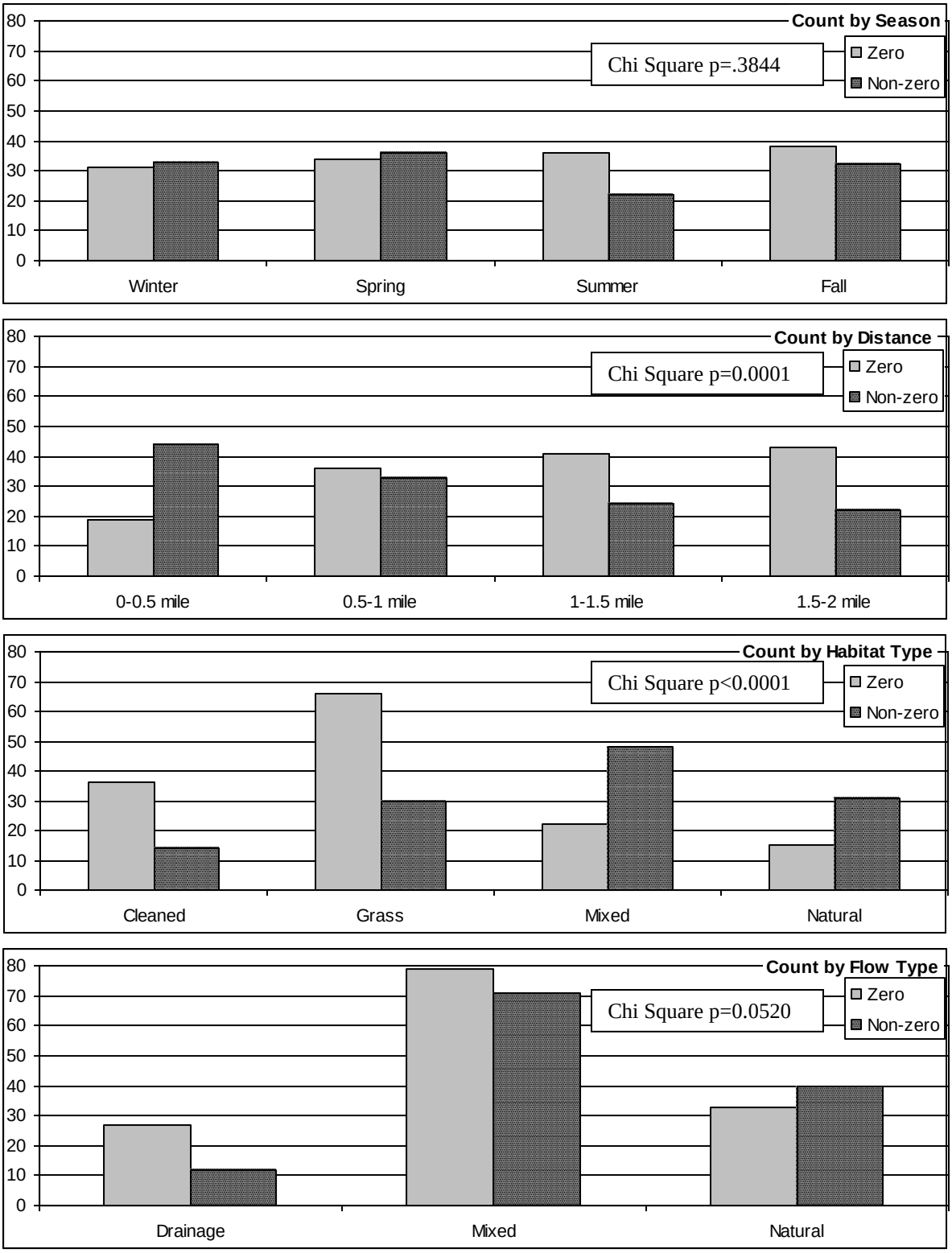

Figure 2-14. Count of coho salmon zero and non-zero catch observations by season, distance, habitat, and flow type.

Coho salmon were very likely to be collected in natural or mixed vegetative habitats and unlikely to be collected from RCG habitats or waterways recently cleaned of vegetation (Figure 2-14). This is similar to the trend noted for all salmonids combined.

With respect to flow type, coho salmon were least likely to be collected from waterways dominated by drainage flow, where the number of non-encounters (27) outnumbered encounters (12) substantially (Figure 2-14). In channels with predominantly mixed flow, coho salmon were encountered less often than not (71 of 150 events) although by only a narrow margin. Natural flow was the only flow condition in which coho salmon encounters (40) outnumbered non-encounters (33) although this did not appear to be a substantial difference.

Chinook salmon were encountered in all seasons, distance classes, and habitat conditions evaluated during this study; they were encountered from only two of three flow regimes sampled during this study (mixed and natural, not drainage flow; Figure 2-15). Chinook salmon zero and non-zero catch distributions varied significantly across season, distance class, vegetative habitat type and flow type (Chi square test, $p<0.10$; Figure 2-15). In general, Chinook salmon were less likely to be encountered than either coho salmon or salmonids (as evidenced by lower number of non-zero catch observations) across all seasons, distance classes and habitat or flow regimes (Figure 2-15, Figure 2-13 and Figure 2-14, respectively).

Although uncommonly collected throughout the study, Chinook salmon were most frequently encountered during spring and winter samples, and least frequently encountered during summer sampling (Figure 2-15). Chinook salmon were most commonly encountered in reaches nearer the mouth of the drainage system in which they were located, and appeared to exhibit an affinity for natural vegetative habitats and an avoidance of RCG dominated habitats. Chinook salmon were not collected from waterways dominated by drainage flows, and showed no apparent affinity nor avoidance of those sites dominated by either mixed or natural flow regimes. These patterns are similar to those observed for both coho salmon and total salmonid catch statistics.

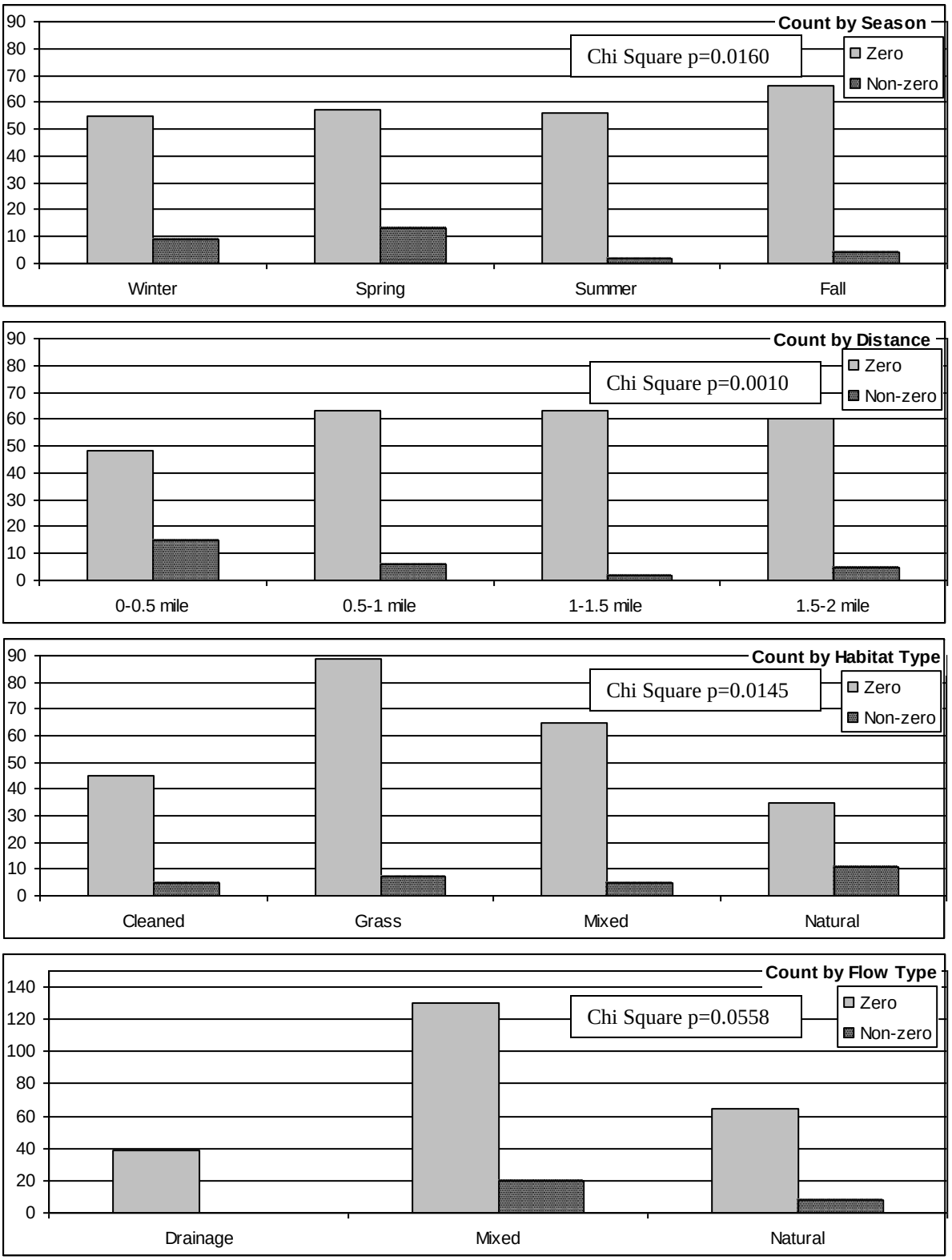

Figure 2-15. Count of Chinook salmon zero and non-zero catch observations by season, distance, habitat, and flow type.

Non-Zero Catch Data

When considering non-zero catch data for all salmonids combined, the overall model evaluating effects of temporal, spatial and physical habitat factors on salmonid catch rate was significant ($p<0.01$; Table 2-12). Vegetative habitat class and distance from the mouth of the drainage system were highly significant ($p<0.01$) in describing total salmonid non-zero catch rates. Season was also significant in predicting total salmonid non-zero catch rate ($p=0.0868$), but was less descriptive than vegetative habitat or distance class in doing so. Flow class was not significant in describing total salmonid non-zero catch rate ($p>0.77$).

Table 2-12. ANOVA results for evaluations related to combined salmonid catch.

Source	DF	Sum of Squares	Mean Square	F-Value	Prob > F
Model	11	7.703	0.700	2.49	**0.0073**
Error	132	37.189	0.282		
Corrected Total	143	44.892			
Individual Factors[a]					
Season	3	1.892	0.631	2.24	**0.0868**
Flow Class	2	0.142	0.071	0.25	0.7782
Veg. Habitat Class	3	3.576	1.192	4.23	**0.0068**
Distance Class	3	3.783	1.261	4.48	**0.0050**

a – For individual factors, Type III sum of squares are presented.

Pairwise comparisons indicate that summer non-zero catch rates of all salmonids combined were significantly greater than those observed during winter sampling ($p=0.0839$; Table 2-13; Figure 2-16). Seasonally, no other pairwise comparisons were statistically relevant ($p>0.22$) when comparing non-zero catch rates of all salmonids combined. Observed total salmonid catch rate was greater in RCG dominated habitats than in cleaned ($p=0.0059$) or mixed ($p=0.042$) vegetative habitats. Non-zero catch rates in RCG dominated habitats were not significantly different than those observed in sites dominated by natural vegetation, and there was no statistical difference in non-zero catch rates between natural, mixed, or cleaned vegetative habitats ($p>0.20$ for all comparisons). Pairwise comparisons of distance classes found that when encountered, total salmonid catch rate was significantly ($p<0.1$) lower from 1-1.5 miles above the mouth of the drainage system than in any of the other three distance classes evaluated (0-0.5, 0.5-1, and 1.5-2 miles).

The overall model evaluating effects of temporal, spatial and physical habitat factors on coho salmon non-zero catch rates was significant ($p<0.01$; Table 2-14). Season and distance from the mouth of the drainage system were significant ($p<0.01$ and $p=0.0519$, respectively) in describing non-zero catch rates of coho salmon. In contrast to the model for combined salmonid catch, vegetative habitat was not a significant factor in describing coho salmon catch rates ($p>0.14$). Similarly to the model for combined salmonid catch, flow class was not significant in describing non-zero catch rates of coho salmon in agricultural waterways ($p>0.68$).

Table 2-13. Summary of significant (p≤0.10) Tukey Kramer post-hoc evaluations for factors significant in describing catch rates of all salmonids and coho salmon.

	All Salmonids Combined			Coho Salmon	
Factor	**Sig. Comparison**	**p-value**		**Sig. Comparison**	**p-value**
Season	Summer > Winter	0.0839		Summer > Winter	0.0380
Vegetative Habitat	RCG > Cleaned	0.0059		None	---
	RCG > Mixed	0.0420			
Distance Class	0-0.5 > 1.0-1.5 miles	0.0029		0-0.5 > 1.0-1.5 miles	0.0082
	0.5-1.0 > 1.0-1.5 miles	0.0892		1.5-2.0 > 1.0-1.5 miles	0.0055
	1.5-2.0 > 1.0-1.5 miles	0.0396			

Table 2-14. ANOVA results for evaluations related to coho salmon.

Source	DF	Sum of Squares	Mean Square	F-Value	Prob > F
Model	11	7.979	0.725	2.55	**0.0065**
Error	111	31.591	0.285		
Corrected Total	122	39.569			
Individual Factors[a]					
Season	3	2.268	0.756	2.66	**0.0519**
Flow Class	2	0.218	0.109	0.38	0.6826
Veg. Habitat Class	3	1.568	0.523	1.84	0.1448
Distance Class	3	4.348	1.449	5.09	**0.0024**

a – For individual factors, Type III sum of squares are presented.

Pairwise comparisons indicate that, when encountered, summer catch rates of coho salmon combined were significantly greater than those observed during winter sampling (p=0.0380; Table 2-13; Figure 2-16). Seasonally, no other pairwise comparisons were statistically relevant (p>0.22) when comparing non-zero catch rates of coho salmon. Pairwise comparisons of distance classes found that non-zero catch rates for coho salmon were significantly (p<0.1) lower from 1-1.5 miles above the mouth of the drainage system than in reaches 0-0.5 and 1.5-2.0 miles above the mouth of the drainage system.

Catch rates of Chinook salmon within King County's agricultural waterways were not significantly described by ANOVA procedures (p>0.55; Table 2-15). The most relevant term for predicting catch rate of Chinook salmon within the model was 'Flow Class' (p~0.22), however the species was collected from only two of three flow conditions evaluated during this study (natural and mixed flow; refer to Table 2-11). Mean non-zero catch rates of Chinook salmon across season, distance class, vegetative habitat, and flow type are presented in Figure 2-16.

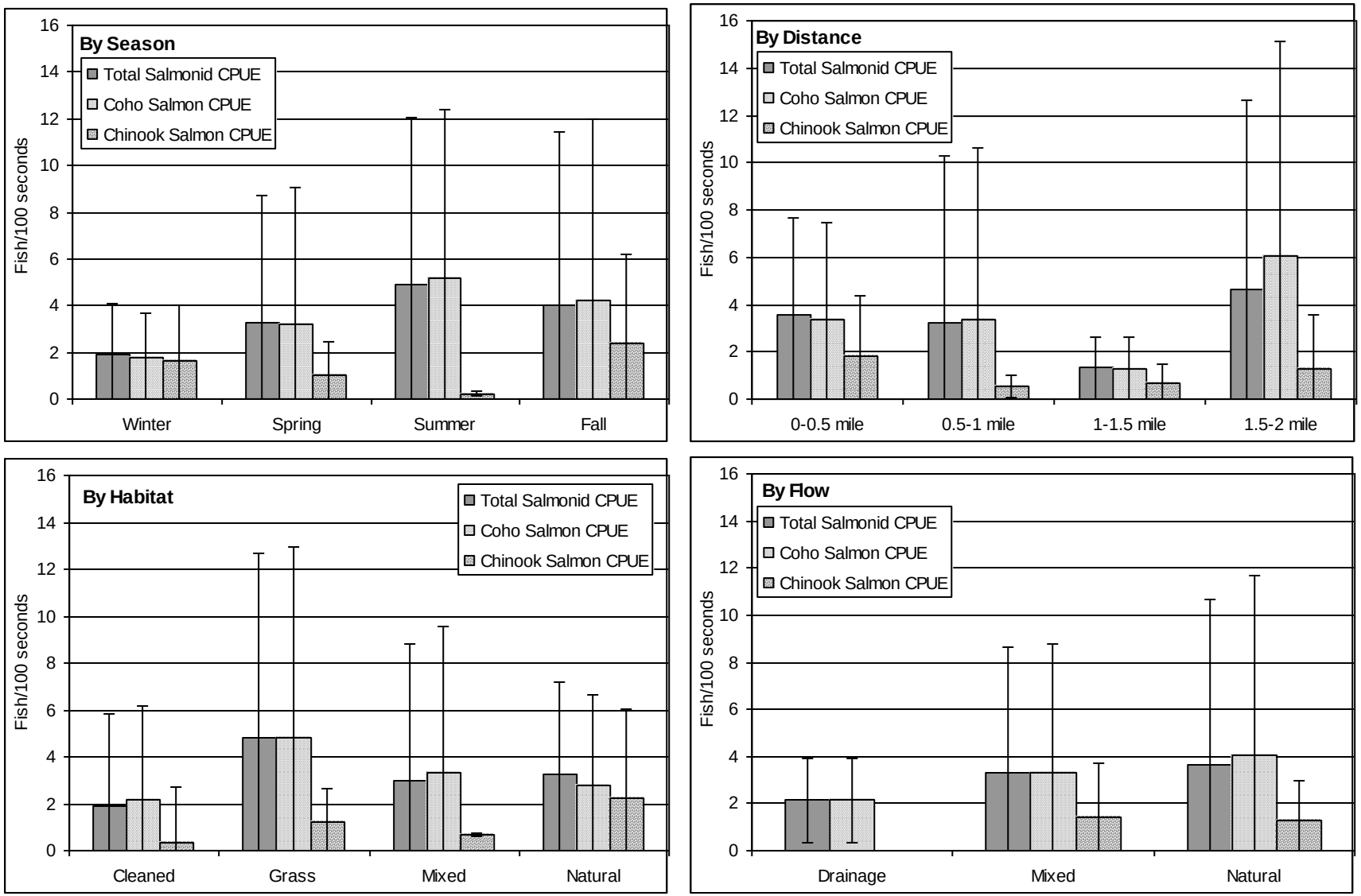

Figure 2-16. Depiction of mean non-zero CPUE for combined salmonids, coho salmon and Chinook salmon across seasons, distance classes, vegetative habitats and flow classes. Error bars are ± one standard deviation.

Table 2-15. ANOVA results for evaluations related to Chinook salmon.

Source	DF	Sum of Squares	Mean Square	F-Value	Prob > F
Model	10	2.843	0.284	0.90	0.5560
Error	17	5.394	0.317		
Corrected Total	27	8.237			
Individual Factors[a]					
Season	3	0.863	0.288	0.91	0.4585
Flow Class	1	0.519	0.519	1.64	0.2180
Veg. Habitat Class	3	0.871	0.290	0.91	0.4547
Distance Class	3	0.386	0.129	0.41	0.7509

a – For individual factors, Type III sum of squares are presented.

2.5 Discussion

2.5.1 Life History Characteristics

Five species of salmonids were found to utilize agricultural waterways within King County during the life of this study including coho, Chinook and chum salmon, rainbow trout/steelhead and cutthroat trout. Coho salmon were by far the most commonly and abundantly collected species with nearly 2,600 individuals collected over fifteen seasonal surveys conducted between October, 2002 and April, 2006. Although far less abundant (108 individuals), cutthroat trout were the only other salmonid species collected during each of fifteen seasonal surveys conducted as part of this study. However, due to the complexity of the cutthroat trout life history (Johnson *et al*. 1999) no effort was made to assess their use of agricultural waterways in detail. Chum salmon and rainbow trout/steelhead were rarely observed during this study suggesting a limited importance of agricultural waterways to these species. Due to limited encounters, no attempt was made to evaluate life history characteristics of chum salmon or rainbow trout/steelhead utilizing agricultural waterways.

Based on adult observations, salmon are not believed to spawn in agricultural waterways on a regular basis. It is believed that adult salmon occasionally explore or stray into these waterways seeking spawning habitat although the heavily silted condition of most agricultural waterways would preclude their ability to spawn successfully. Spawning habitat requirements described by Bjornn and Reiser (1991) support the idea that most agricultural waterways do not likely support spawning of Chinook or coho salmon. Agricultural channels are commonly too small to allow typical redd development, and velocity and substrate characteristics are typically very divergent from that of preferred habitats (Thompson 1972; Reiser and White 1981; Smith 1973). Adult salmon may find suitable spawning habitats in select agricultural waterways that contain gravel substrates in at least some reaches (e.g. Mill Creek; Figure 2-9) or in steeper channels upstream of agricultural areas which may result in their having suitable substrate conditions.

Potential salmonid spawners were observed in agricultural waterways only on limited occasion during this study. During site selection procedures in 2002 two adult Chinook salmon were observed migrating through Mill Creek, a channelized natural waterway in the Lower Green River APD. In fall of 2002 a partially decomposed carcass of an adult Chinook salmon was found on the bank of Mill Creek. The carcass was found high on the bank and appeared to have been deposited in that location by an animal making the exact origin of the carcass uncertain. Based on the proximity of surrounding waterways however, it was believed to have died in Mill Creek prior to being moved up the bank by animals. During January, 2005 surveys a carcass of an apparent jack coho salmon[7] was found on the banks of a channelized natural waterway on the Pickering property in the North Snoqualmie APD. On the same date, odors at nearby sampling sites suggested additional salmonid carcasses (2-3) may have been decomposing along the same waterway although none could be found among the heavy RCG cover. Carcass(es) found or smelled during January, 2005 were in relatively close proximity to Deer Creek, a higher gradient natural tributary to the agricultural waterway being sampled; Spawning of coho salmon had

[7] Carcass decomposition made definite identification impractical. The individual was approximately 17" total length with redish tint to skin on lower half of body and some black spotting on the back. Fin ray counts were not possible.

previously been observed in Deer Creek (Hans Berge, KCDNRP personal communication with Tom Cichosz, February 2005).

It is important to note that cutthroat trout have very different spawning requirements than salmon with regard to preferred depth, velocity and substrate size (Bjornn and Reiser 1991). These differences suggest that regular or relatively widespread spawning of cutthroat trout is more likely than that of other salmonid species in agricultural waterways. However, observations of habitat conditions during this study (particularly the heavy siltation of channels and lack of underlying gravel in most cases) suggest that suitable spawning areas for cutthroat trout are also likely limited to select reaches in agricultural waterways and/or steeper channels upstream of agricultural areas which have higher velocity and presence of suitable spawning substrates.

Cutthroat trout were commonly collected during this study and found to be relatively widely distributed in agricultural waterways. The fact that the species was commonly collected and widely distributed illustrates that agricultural waterways do provide important habitats for cutthroat trout. However, due to relatively limited numbers collected, detailed evaluation of their use of agricultural waterways was impractical.

Of species and life stages closely evaluated during this study, agricultural waterways within King County are most important to juvenile coho and Chinook salmon. Agricultural waterways provide important habitat for rearing of age 0+ and 1+ Chinook and coho salmon and are utilized by both species throughout their juvenile life histories from shortly after emergence to the pre-smolt stage prior to their outmigration to salt water. Juvenile coho and Chinook salmon were both encountered in all four seasons monitored, and multiple age classes (0+ and 1+) of both species were encountered.

Our findings indicate that Chinook salmon enter the agricultural waterways at age 0+ earlier (late January/early February) than coho salmon, and utilize these waterways for a longer period of time than coho salmon (15 versus 12+ months, respectively). Emergence of juvenile Chinook salmon from spawning gravels in Puget Sound streams is generally completed earlier than that of coho salmon (February versus March/early April; Williams et al. 1975; Grette and Salo 1986). Age 0+ Chinook salmon appeared to enter the agricultural waterways in late January/early February based on surveys conducted during that period; Surveys conducted in mid January in some years did not find age 0+ Chinook salmon to be present. In contrast, age 0+ coho salmon were first encountered during April sampling in all years (except 2006 when sampling was limited and no age 0+ coho were collected).

The entry timing of both coho and Chinook salmon and their mean size at first encounter suggests that both species entered agricultural waterways and were first captured very shortly after emergence. The average size of age 0+ Chinook salmon encountered in King County's agricultural waterways during late January/early February was 45.7 mm total length. Chinook typically emerge from the gravels approximately 42-44mm total length (Connor 1998; Triton Environmental Consultants Ltd. 2001; Ramseyer 1995). Cramer and Martin (1978 cited in Brun 2003) considered the date after which Chinook fry fork length exceeded 45mm (51mm TL; Ramseyer 1995) to indicate the completion of emergence. The average size of age 0+ coho salmon encountered in King County's agricultural waterways during April was 48.6 mm total

length. Koski (1966) found coho emergence to occur at 38-39 mm fork length in a coastal Oregon stream (equivalent to 41-42mm total length; Ramseyer 1995).

Trends of length and weight of a fish cohort throughout life usually show an early period of rapid growth and a subsequent period of more gradual increase (Van Den Avyle 1993). Although only juvenile fish were considered during this study, this trend was generally observed for both Chinook and coho salmon collected from agricultural waterways.

Instantaneous growth of juvenile coho and Chinook salmon in agricultural waterways followed a similar pattern across seasons. Estimated instantaneous growth of both species were greatest during their first season in the agricultural waterways (winter-spring for Chinook; spring-summer for coho), and both species exhibited minimum growth rates between fall and winter sampling periods. Instantaneous growth of both species increased again for age 1+ fish between winter and spring sampling beginning their second year of residence in the agricultural waterways.

Estimates of instantaneous growth for Chinook salmon should be utilized with some caution. The number of individuals utilized to estimate growth for individual cohorts between seasons was commonly less than ten, and resultant estimates may be skewed based on the occurrence of even one or two fish being particularly 'large' or 'small' within the sample.

The size of coho and Chinook pre-smolts (age 1+ in spring) observed rearing in agricultural waterways is consistent with published reports for pre-smolts throughout the Puget Sound area, suggesting that growth of juvenile salmon rearing in agricultural waterways is consistent with that observed in other rearing habitats throughout the Puget Sound area. According to Weitkamp et al. (1995), peak outmigration of juvenile coho salmon from Puget Sound waterways typically occurs between late April and mid May, with smolts ranging from approximately 90-124mm fork length (97-134mm total length; Ramseyer 1995). Our study results found an average total length of approximately 110mm for age 1+ coho salmon collected during April sampling. Myers et al. (1998) reported that yearling Chinook salmon from the area typically outmigrated at 73-134mm fork length (83-152mm total length; Ramseyer 1995). Chinook salmon observed in agricultural waterways during this study had an average total length of approximately 129mm.

2.5.2 Temporal, Spatial, Habitat and Flow Distribution of Key Salmonids

Data analysis techniques used to evaluate temporal, spatial and habitat related distributions of salmonids in agricultural waterways allowed for both evaluation of changes in the frequency of encounter as well as changes in the relative abundance (as CPUE) of salmonids when they are encountered. The Chi-square analyses used to compare zero and non-zero catch data provide information about the likelihood that salmonids will be found to utilize agricultural waterways of a given character; ANOVA results provide information about differences in the relative abundance of salmonids if and when they are found to be present in the agricultural waterways. This two-pronged statistical analysis approach is important to understanding the significance of agricultural waterways to salmonids since a habitat area that is seldom used but, when used, supports large numbers of fish could potentially be considered of equal importance to another site which is frequently used but by small numbers of salmonids. Table 2-16 summarizes

findings of both Chi-square and ANOVA analyses conducted for total salmonid catch, coho salmon, and Chinook salmon.

When using Chi-square analysis across seasons, insight is gained about the breadth of a species distribution during that season since the analysis compares the numbers of sites where a species was encountered to the numbers where the same species was not encountered. In contrast, results of Chi-square analyses across distance, habitat or flow classes can be interpreted to imply an affinity for or avoidance of a particular condition. As an example, coho salmon were encountered far more frequently than not from mixed vegetative habitats and encountered far less frequently than not from RCG dominated habitats, suggesting an affinity for mixed vegetative habitats and an avoidance of RCG habitats.

Table 2-16. Comparison of findings from Chi-square and ANOVA analyses for coho salmon, Chinook salmon, and all salmonids combined.

	Chi Square Analysis Zero Vs. Non-Zero Catch Statistics[1]	**ANOVA Analysis Non-Zero Catch Statistics**
Total Salmonids		
Season	+ Winter, Spring - Summer	Summer > Winter
Distance	+ 0-0.5 miles -1.0-1.5 miles	0-0.5 > 1-1.5 miles 0.5-1 > 1-1.5 miles 1.5-2 > 1-1.5 miles
Habitat (veg.)	+ Natural, Mixed - RCG, Cleaned	RCG>Cleaned, Mixed
Flow	+ Natural, Mixed - Drainage	No Significant Differences
Coho Salmon		
Season	No Significant Difference	Summer > Winter
Distance	+ 0-0.5 miles -1.0-1.5 miles and 1.5-2 miles	0-0.5 > 1.0-1.5 miles 1.5-2.0 > 1.0-1.5 miles
Habitat (veg.)	+ Natural, Mixed - RCG, Cleaned	No Significant Differences
Flow	- Drainage	No Significant Differences
Chinook Salmon		
Season	+ Winter, Spring - Summer	No Significant Differences
Distance	+ 0-0.5 miles	No Significant Differences
Habitat (veg.)	+ Natural - RCG	No Significant Differences
Flow	- Drainage	No Significant Differences

1 '+' and '-' indicate an apparent affinity for or avoidance of the factor, respectively.

Coho salmon at all juvenile life history stages were found to utilize agricultural waterways across a wider range of seasons and habitat conditions (vegetation and flow classes) than juvenile Chinook salmon. The abundant presence of coho salmon in virtually all habitat conditions sampled during all seasons suggests a life history strategy that relies on agricultural waterways as rearing habitat for extended periods.

In contrast, Chinook salmon appeared most likely to utilize agricultural waterways for spring-fall rearing; Juvenile Chinook salmon were uncommonly encountered in agricultural waterways during winter sampling, suggesting that they may utilize agricultural waterways much more selectively than coho salmon. It has been shown that if non-winter rearing habitats are not suitable for winter rearing, juvenile salmon may migrate to larger river systems to overwinter (Bjornn 1978; Bjornn and Mallet 1964).

2.5.2.1 Temporal

Based on Chi-square analysis, salmonids in general (total salmonid catch) are most widely distributed throughout agricultural waterways during winter and spring seasons and most narrowly distributed during summer. When encountered however, the relative abundance of salmonids followed an inverse trend, with summer catch rates being significantly greater than winter catch rates (Table 2-16). Similar seasonal observations were made for coho salmon. Although not statistically significant, coho salmon were most narrowly distributed during summer sampling; when encountered however, catch rates of coho salmon were significantly greater during summer than during winter.

Temporal variations in total salmonid and coho distributions and abundance are probably tied to seasonal variations in water quality throughout the agricultural waterways, although immigration and emigration timing of anadromous species from the agricultural waterways may partially explain seasonal trends in salmonid distribution. Coho salmon make up the majority of the total salmonid catch and therefore have a strong influence on trends observed for total salmonids. For coho salmon, winter and spring samples include age 1+ fish which have been in the agricultural waterways for as much as 9-10 months and, as such, have had substantial time to migrate throughout the drainage system. In addition, observations made at the time of fish collection indicated that water temperature is generally reduced and dissolved oxygen levels generally increased during winter, potentially making agricultural waterways more suitable for widespread salmonid rearing. Summer samples represent only age 0+ fish which would have been in the drainage system for approximately 3 months (presumably ample time to migrate throughout the drainage systems), but which are subject to reduced water quality conditions including probable increased temperature and decreased dissolved oxygen. The limited distribution of coho during summer is probably tied to reduced water quality, with fish localizing to areas of suitable conditions for summer rearing. To the degree that localized habitat conditions impact water quality (e.g. potentially increased BOD in areas heavily dominated by RCG or other in channel vegetation), they may also impact the seasonal distribution of salmonids in agricultural waterways.

Like other salmonids, Chinook salmon utilizing agricultural waterways were most widely distributed during winter and spring and most narrowly distributed during summer. In contrast to what was observed for other salmonids, catch rates of Chinook salmon where encountered

were notably lower in summer sampling events than in other seasons (although this was not statistically significant; refer to Figure 2-16).

Based on these data continued adherence to King County public rule 21A-24 sub-sections 374 and 375 regarding the timing of maintenance activities and fish removal prior to such activity (King County DDES 2001) is warranted. Although present within agricultural waterways during the timelines delineated in that rule, salmonids are less widely distributed than at other times of the year thereby minimizing the likelihood of encountering or disturbing salmonids during maintenance activities. However, when found during this same timeframe, salmonids appear to be more densely grouped indicating the need to conduct pre-maintenance fish removal activities to ensure that impacts to salmonids, when present, are minimized.

2.5.2.2 Spatial

For coho salmon and total salmonid evaluations the distance that a sampling site was upstream from the mouth of the drainage system which contained it was a significant factor in describing both the likelihood of encountering salmonids as well as the abundance of salmonids which were encountered. For Chinook salmon, distance was significant in defining the likelihood of encountering the species, but was not significant in determining the abundance encountered if present. Logically and in all cases, the likelihood of encountering salmonids was greatest for sites nearest to the mouth of the drainage system (0-0.5 miles) and for coho salmon the likelihood of encounter decreased directly with increased distance upstream. The likelihood of encountering salmonids however did not appear to decrease directly with increased distance upstream for either Chinook salmon or total salmonid evaluations.

Evaluation of catch rates of both combined salmonids and coho salmon across distance classes also showed an unexpected pattern, with catch rates typically lowest within one of the intermediate distance classes evaluated (1-1.5 miles upstream). Catch rates for both combined salmonid and coho salmon were significantly greater in the furthest upstream distance class (1.5-2.0 miles) than in the aforementioned distance class.

The unexpected and somewhat anomalous results for evaluations of the impacts of distance on salmonid encounter and catch rates suggests that there is an interaction of distance with other variables which is driving the statistical relevance of this factor in our analyses. Since the study design did not allow for evaluation of interactions amongst variables of interest, further study is warranted to better delineate the impact of upstream distance on salmonid distribution and catch rates in agricultural waterways.

When considering all salmonids combined, the inclusion of cutthroat trout probably contributed to this irregularity since cutthroat trout (either anadromous or resident) are likely associated to some degree with higher gradient tributaries to agricultural waterways which are typically found further upstream in the drainage systems. For Chinook salmon this irregularity suggests a possible interaction between distance and habitat factors which could not be assessed during this study.

2.5.2.3 Habitat Characteristics

In terms of frequency of use, salmonids (Chinook, coho and all combined) show a preference for natural vegetative regimes and an apparent avoidance of RCG dominated habitats within agricultural waterways. For coho and combined salmonids, a preference for mixed vegetative habitats and avoidance of habitats recently cleaned of vegetation were also noted.

When considering only those sites where fish were encountered, combined salmonid densities (catch rates) in RCG dominated habitats were significantly greater than in recently cleaned or mixed vegetative habitats. Although not statistically significant, this same pattern of catch rates was observed for coho salmon. When encountered, Chinook salmon catch rates exhibited a slightly different pattern with highest catch rates observed in areas dominated by a natural vegetative regime, and lowest catch rates observed in recently cleaned habitats; however, the observed differences in catch rates of Chinook salmon across habitat types was not statistically significant.

These demonstrated patterns of habitat use or avoidance by salmonids are important when considering in-channel activities that may impact salmonids if and when they are present. Encroachment by RCG into agricultural waterways which inhibits flow and may increase the frequency and/or duration of flooding events is one of the primary reasons why landowners seek to perform maintenance activities within King County's agricultural areas. Based on the apparent avoidance of RCG dominated habitats by salmonids, maintenance activities aimed at RCG removal, coupled with appropriate mitigation activities, may result in more preferred habitats being made available to salmonids in these areas. It is important to note that there is an apparent avoidance of 'cleaned' (recently maintained) habitats by some salmonids suggesting that maintenance activities may have a negative impact on habitat conditions in agricultural waterways. However, the researchers believe that, given the apparent negative impact of maintenance activities to salmonids, removal of RCG from agricultural waterways remains the preferred alternative for long term benefits to salmonid populations in these systems for the following reasons:

1. Effects of RCG encroachment into agricultural channels may have broader scale impacts than maintenance activities. Very high RCG densities may inhibit immigration and emigration to/from upstream areas as well as the area directly impacted by RCG. In contrast, any negative habitat effects of maintenance activities are believed to remain localized to the project area itself.
2. The potential negative impacts of 'cleaned' habitats can be mitigated for through vegetation plantings and introduction of temporary cover into channels to shorten and/or minimize any negative impacts to salmonids.
3. The potential negative impacts of 'cleaned' habitats are relatively short-lived, lasting only until surrounding and/or in-channel vegetation can be re-established. In contrast, once established, the negative impact of RCG encroachment is a relatively permanent impact affecting salmonid populations.
4. Based on the relatively small extent of most maintenance projects (<0.5 waterway miles) conducted in King County, the researchers believe that the mobility of salmonids will allow them to easily access other more preferred habitat areas within the same drainage system until positive impacts of mitigation measures are realized.

Based on these data continued adherence to King County public rule 21A-24 sub-section 383 (King County DDES 2001) regarding habitat mitigation following maintenance activities is warranted. Mitigation measures should attempt to minimize re-establishment of RCG, resulting in establishment of mixed or natural vegetative regimes preferred by salmonids. This would likely be most effectively accomplished with measures described in subsections 383(b) and 383(c).

With regard to in channel habitat and cover, King County should consider the cost effectiveness of measures described in subsection 383(a) regarding installation of in-channel structures (King County DDES 2001). Subsection 383(b) calls for plantings to provide cover and shade to the ditch or stream "during the first planting season after maintenance or at another time no later than one year after completion of maintenance" thereby implying a very short term function of any installed structures intended to do the same. Based on the apparent short term function and relatively high cost of structures to be installed, King County might consider various alternatives to this strategy including evaluation of more temporary and less costly alternatives to provide short term cover following maintenance, or installation of structures only to waterways where those measures described in subsection 383(b) would not be expected to provide substantive shade or cover within the proposed timeframe.

Also based on these data, continued adherence to King County public rule 21A-24 sub-section 375 regarding fish removal prior to such activity (King County DDES 2001) is warranted. This practice should continue to occur in all habitat configurations prior to scheduled maintenance activities. Although less likely to be found in RCG dominated habitats than other habitats, salmonids appear to be more densely grouped in RCG habitats when found. This indicates that even though difficult, fish removal activities are necessary to ensure that impacts to salmonids, when present, are minimized.

2.5.2.4 Flow Characteristics

Flow regime was not found to significantly influence the catch rates of Chinook or coho salmon or all salmonids combined within agricultural waterways. The importance of flow regimes to salmonids in agricultural waterways appears to be reflected in their frequency of use of various flow regimes rather than the density of fish encountered.

In terms of frequency of use, salmonids (all combined) appear to prefer waterways with natural or mixed flow regimes while avoiding those dominated by drainage flows. For individual species (Chinook or coho salmon) the avoidance of channels dominated by drainage flow was evident although no notable preference for other flow types was evident. Cutthroat trout are the primary species encountered other than Chinook or coho salmon and probably drive the differences in apparent preference or avoidance of various flow regimes between all salmonids combined and individual species. Field observations suggest that channels dominated by drainage flows tend to be smaller in size and have lower velocities than channels with different flow regimes. Cutthroat trout found in agricultural waterways are frequently larger than other species observed, and size of fish is often directly related to the size of channel (Bjornn and Reiser 1991; Allen 1969) and focal velocity (Smith and Li 1983) preferred by salmonids, potentially explaining the apparent affinity of mixed or natural flow regimes for all salmonids combined.

2.6 Conclusions and Recommendations

Results of this study suggest that in relation to the tested hypothesis, salmonid density (as indexed by capture frequency and/or catch rates) does vary temporally, spatially, and in relation to physical factors such as surrounding vegetative regime and flow type in King County's agricultural waterways. Specifics of that variation differ by species considered and have previously been described in detail. However, general trends can be summarized as follows:

1. Temporally, salmonids tend to be least widely distributed but more concentrated during the summer period, and most widely (but less densely) distributed during the winter and/or spring periods.

2. Spatially, salmonids tend to be found more frequently and in greater abundance in close proximity to the mouth of the drainage system in which they are collected. However, catch frequency and catch rates do not appear to decline directly with increased distance from the mouth. Findings suggest that there is an interaction of distance with other variables which is driving the statistical relevance of this factor in our analyses.

3. Salmonids in agricultural waterways appear to avoid both habitats dominated by RCG and those which have been recently cleaned/maintained, and appear to prefer habitats with a mixed or natural vegetative regime.

4. Salmonids appear to avoid channels in which flows are dominated by drainage flow and lack at least some component of natural flow. It remains somewhat unclear however if such apparent avoidance is driven solely by flow source(s) or if variations in physical factors such as channel size and flow velocity are responsible for this finding.

5. Findings of this study directly support the continued application of King County public rule 21A-24 sub-sections 374, 375, and 383(b) regarding maintenance timing, fish removal prior to, and mitigation planting activities following maintenance activity (King County DDES 2001). Additionally, installation of short term cover following maintenance activities (consistent with subsection 383(a) of the public rule) appears warranted based on findings of this study although the cost effectiveness of measures currently described in that subsection is unclear.

Based on the findings of this study component, recommendations for future work can be summarized as follows:

1. Comparison of growth characteristics of salmonids in agricultural waterways relative to those in natal or other types of rearing waters should be considered. Inquiry for salmonid growth data from other areas in the Puget Sound area during this study did not locate any such data for comparison. These comparisons would be valuable to help further define the relative importance of agricultural waterways as salmonid habitat in King County.

2. King County should evaluate their desire or need to assess variations in salmonid use and life history characteristics between APDs. This study was designed to assess salmonid use and life history characteristics in agricultural areas as a whole and did not consider potential differences between individual APDs. Data from this study does provide baseline data suitable to aide in determining the need for such a study, and/or clarifying design considerations of any such future study.

3. Further study should be considered to more clearly define the importance of distance (above the waterway mouth) on salmonid use of agricultural waterways, including the potential interaction of distance with other habitat variables (e.g. surrounding vegetative regime, distance of waterway mouth to known spawning areas). Since the current study design did not allow for evaluation of such interactions, and because interpretation of significant findings regarding distance as it relates to salmonid distribution and use of agricultural waterways was unclear, further study is warranted to more clearly define the importance of distance on salmonid distribution and catch rates in agricultural waterways.

4. It is recommended that King County independently assess the cost effectiveness of measures currently described in public rule 21A-24, sub-section 383(a), as less permanent and costly structures may meet the intended needs until such time as the benefits of activities undertaken as part of subsection 383(b) are realized.

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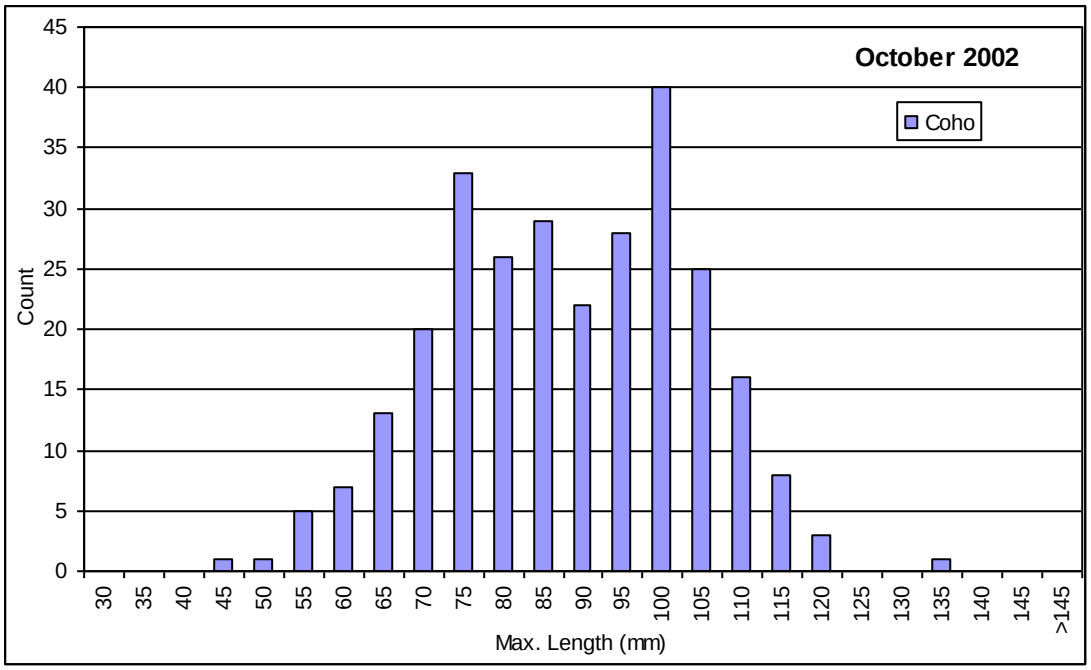
Appendix 2-A: Coho Salmon Seasonal Length Frequency Graphs

Notes:

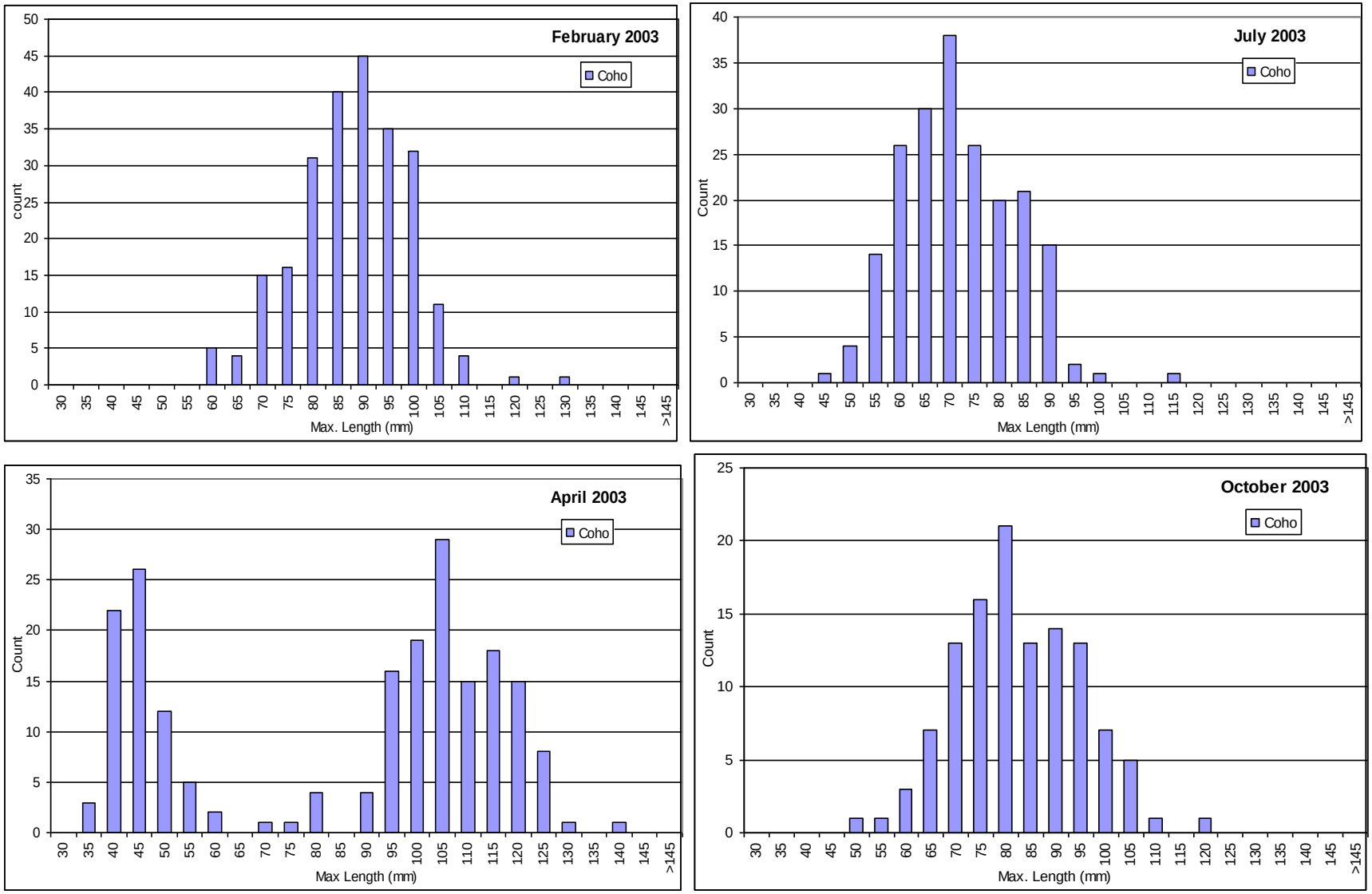
1. Of nearly 2,300 coho salmon collected during this study, fewer than 5 were identified as being of hatchery origin. Due to their minimal numbers, hatchery reared coho salmon are not given separate consideration in the following length frequency histograms (All coho salmon are considered in concert, regardless of origin).
2. Length frequency histograms include all measured coho salmon. In some instances not all fish were measured; numbers of fish represented in histograms therefore may not coincide with capture numbers presented elsewhere in this report.
3. All yearling coho salmon were assumed to outmigrate from the system prior to summer sampling, consistent with life histories described by Weitkamp et al. (1995). All coho salmon collected in summer and fall samples are therefore assumed to be age 0+.

Appendix 2-A 1. Summary of length breaks used to distinguish age classes of coho salmon from length frequency histograms.

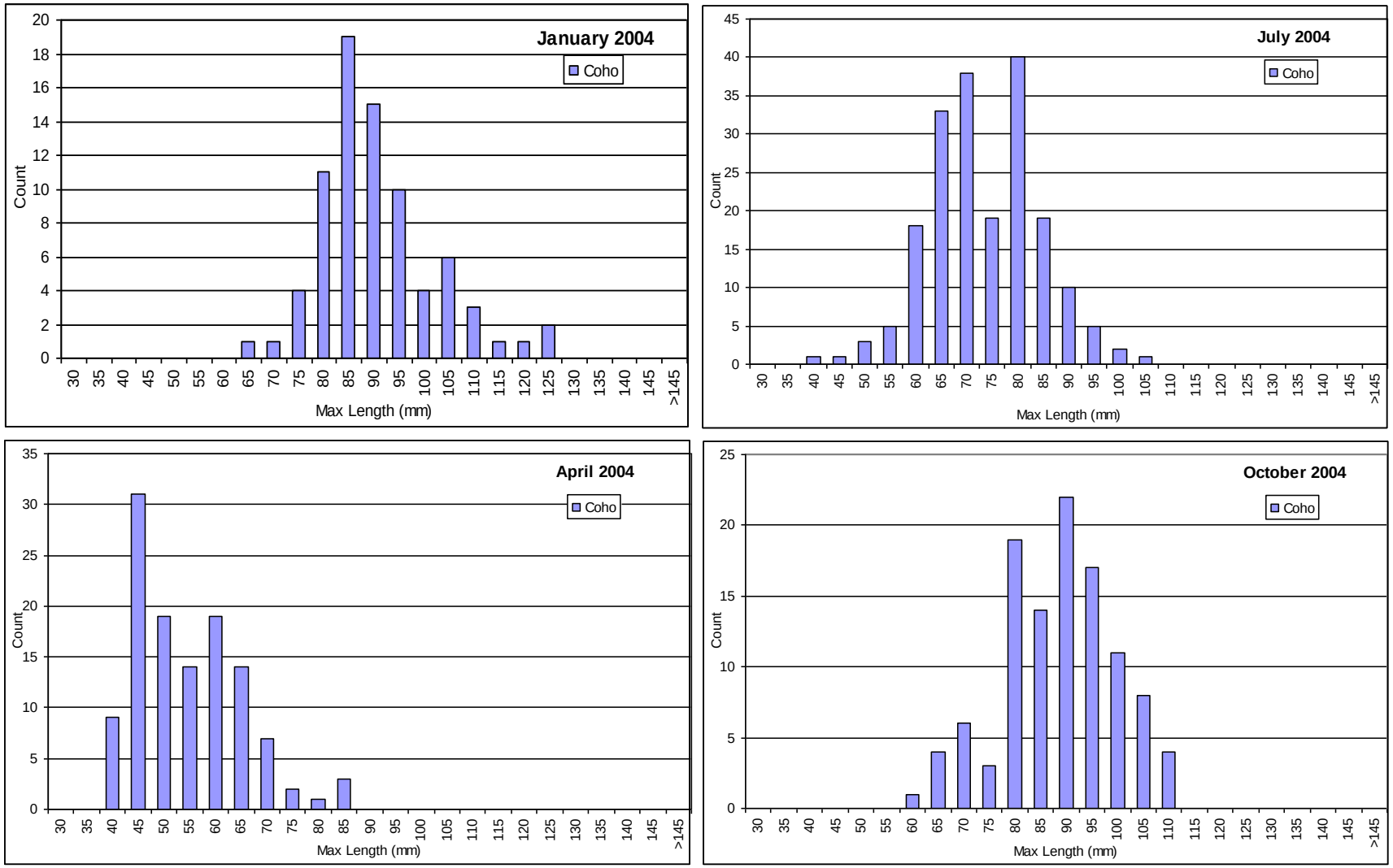
Year	Age	Winter	Spring	Summer	Fall
2002	0				All
	1				--
2003	0	--	<85	All	All
	1	All	>85	--	--
2004	0	--	All	All	All
	1	All	--	--	--
2005	0	--	<90	All	All
	1	All	>90	--	--
2006	0	--	--		
	1	All	All		



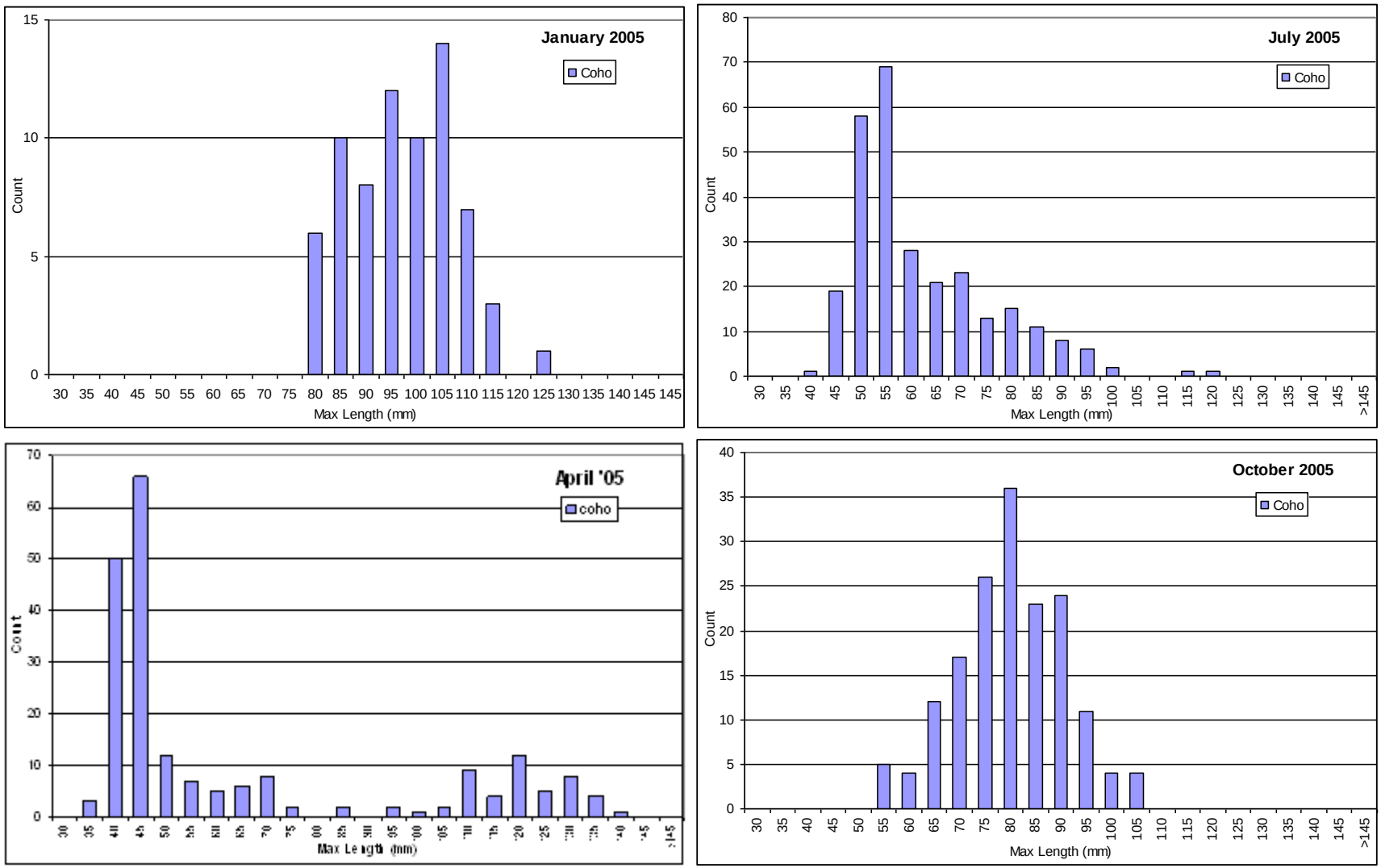
Appendix 2-A 2. Length frequency histogram of coho salmon collected during October, 2002.



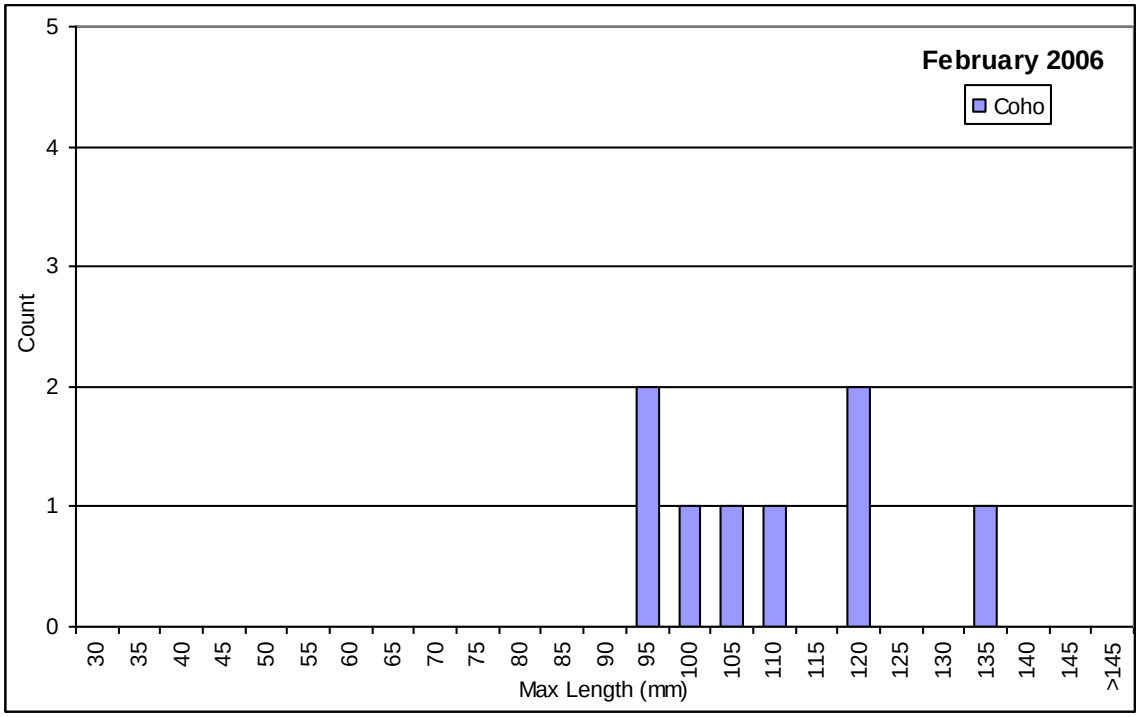
Appendix 2-A 3. Length frequency histogram of coho salmon collected during seasonal surveys in 2003.

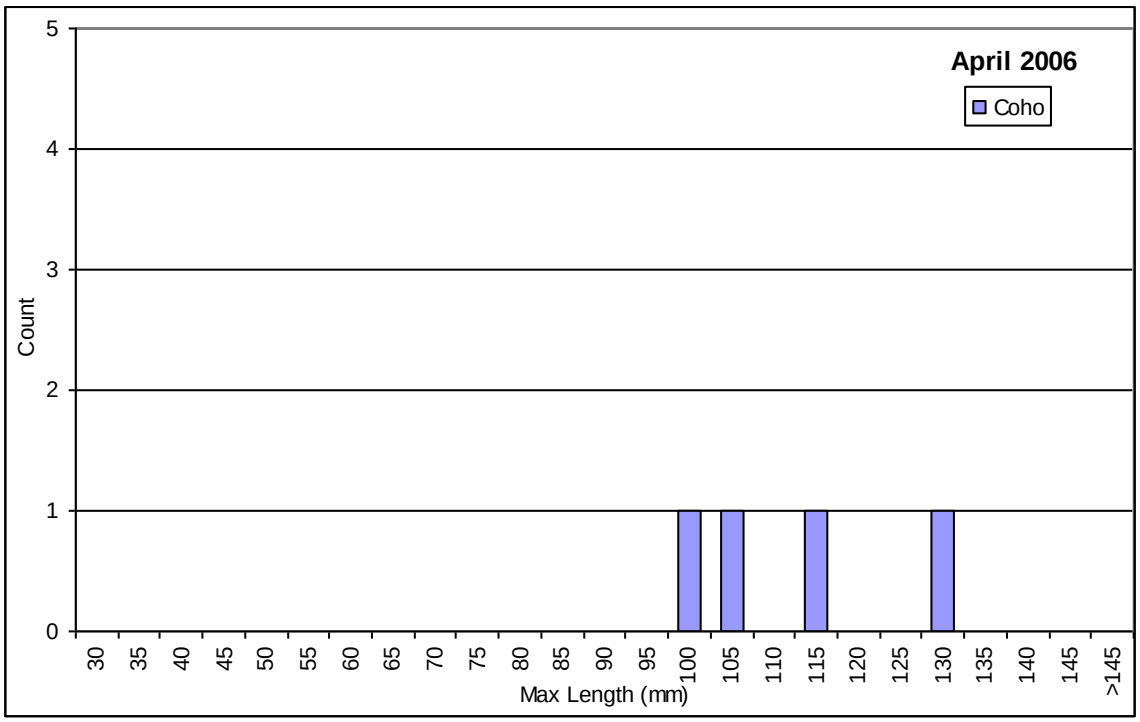


Appendix 2-A 4. Length frequency histogram of coho salmon collected during seasonal surveys in 2004.



Appendix 2-A 5. Length frequency histogram of coho salmon collected during seasonal surveys in 2005.





Appendix 2-A 6. Length frequency histogram of coho salmon collected during seasonal surveys in 2006.

Appendix 2-B: Chinook Salmon Seasonal Length Frequency Graphs.

Notes:

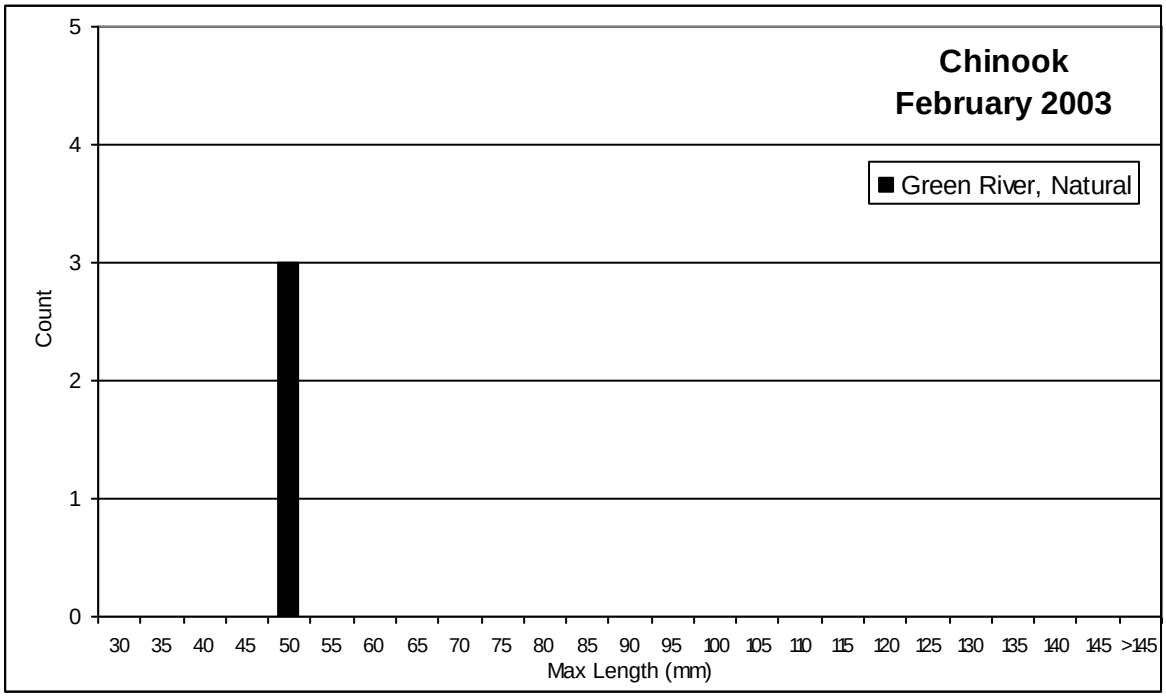
1. No Chinook salmon were collected during October 2002, July 2003, October 2003 or April 2006 surveys; no length frequency graphs are presented for these sampling periods.
2. Discussions with local biologists suggested the potential for different growth rates of juvenile Chinook salmon in the Snoqualmie and Green River watersheds; Differences in size at age between hatchery and naturally produced fish of the same species are known to be common. Length frequency histograms for Chinook salmon therefore separate fish according to APD/watershed area from which they were collected (Lower Green, Snoqualmie or Enumclaw) and origin (Natural or Hatchery).
3. All Chinook salmon captured are represented in the length frequency graphs. If a group (e.g. Snoqualmie, Natural) is not represented on the graph legend, then no individuals within that group were collected during that sampling period.
4. All yearling Chinook salmon were assumed to outmigrate from the system prior to summer sampling, consistent with life histories described by Kope et al. (1998). All Chinook salmon collected in summer and fall samples are therefore assumed to be age 0+.

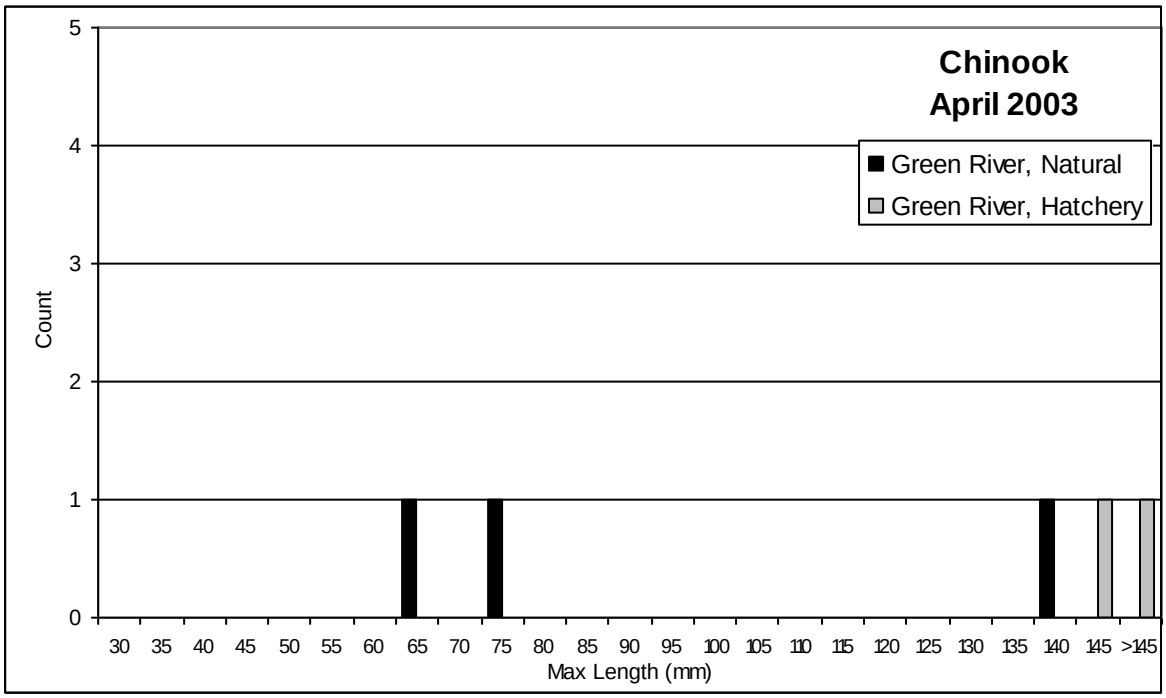
Appendix 2-B 1. Summary of length breaks used to distinguish age classes of Chinook salmon collected from the Snoqualmie River drainage.

Year	Age	Winter	Spring	Summer	Fall
2002	0				--
	1				--
2003	0	--	--	--	--
	1	--	--	--	--
2004	0	--	--	All	All
	1	--	All	--	--
2005	0	<50	<65	--	--
	1	>85	>110	--	--
2006	0	--	--		
	1	--	--		

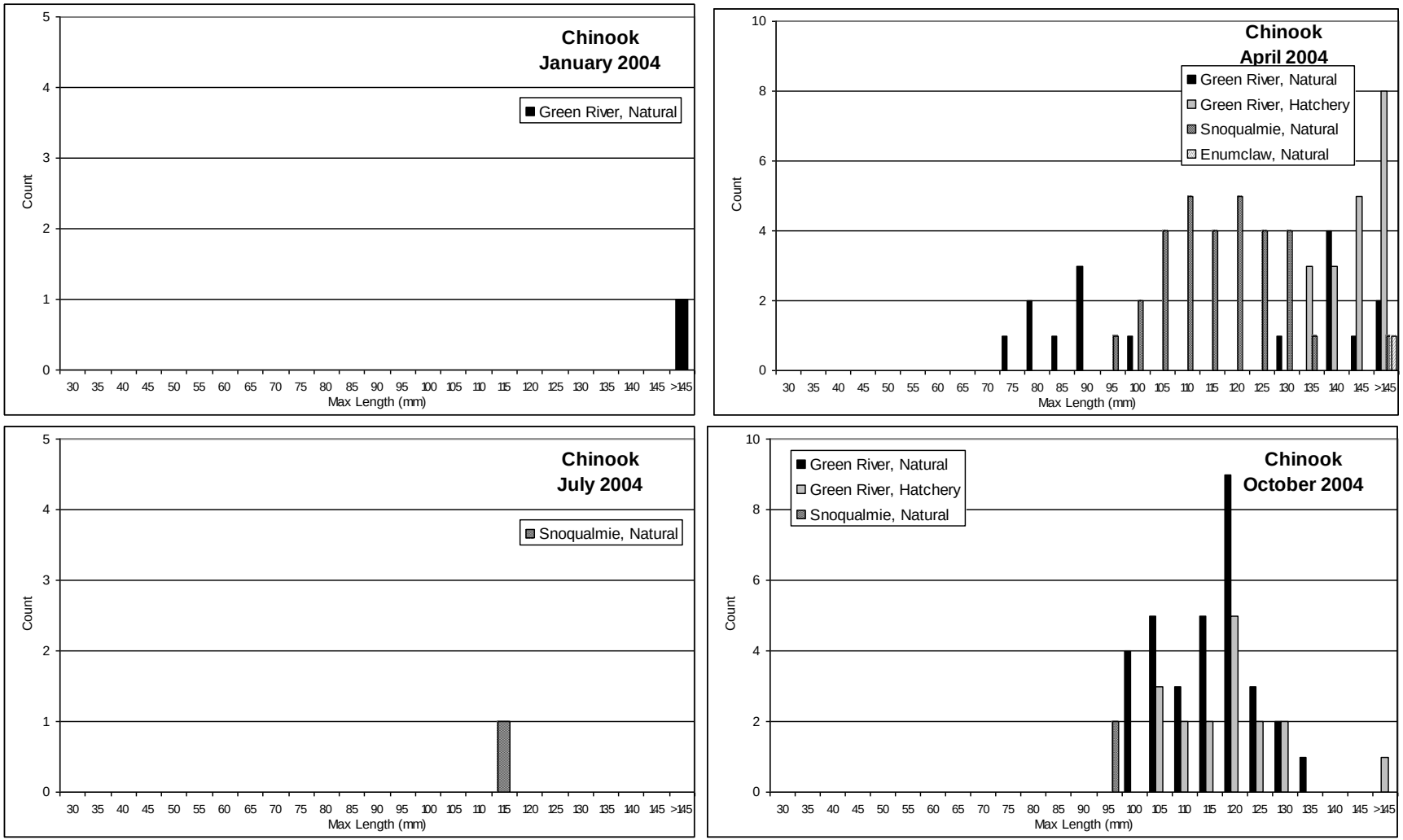
Appendix 2-B 2. Summary of length breaks used to distinguish age classes of Chinook salmon collected from the Green River drainage.

Year	Age	Winter	Spring	Summer	Fall
2002	0				--
	1				--
2003	0	All	<80	--	--
	1	--	>135	--	--
2004	0	--	<105	--	All
	1	All	>125	--	--
2005	0	All	--	All	All
	1	--	All	--	--
2006	0	--	--		
	1	All	All		

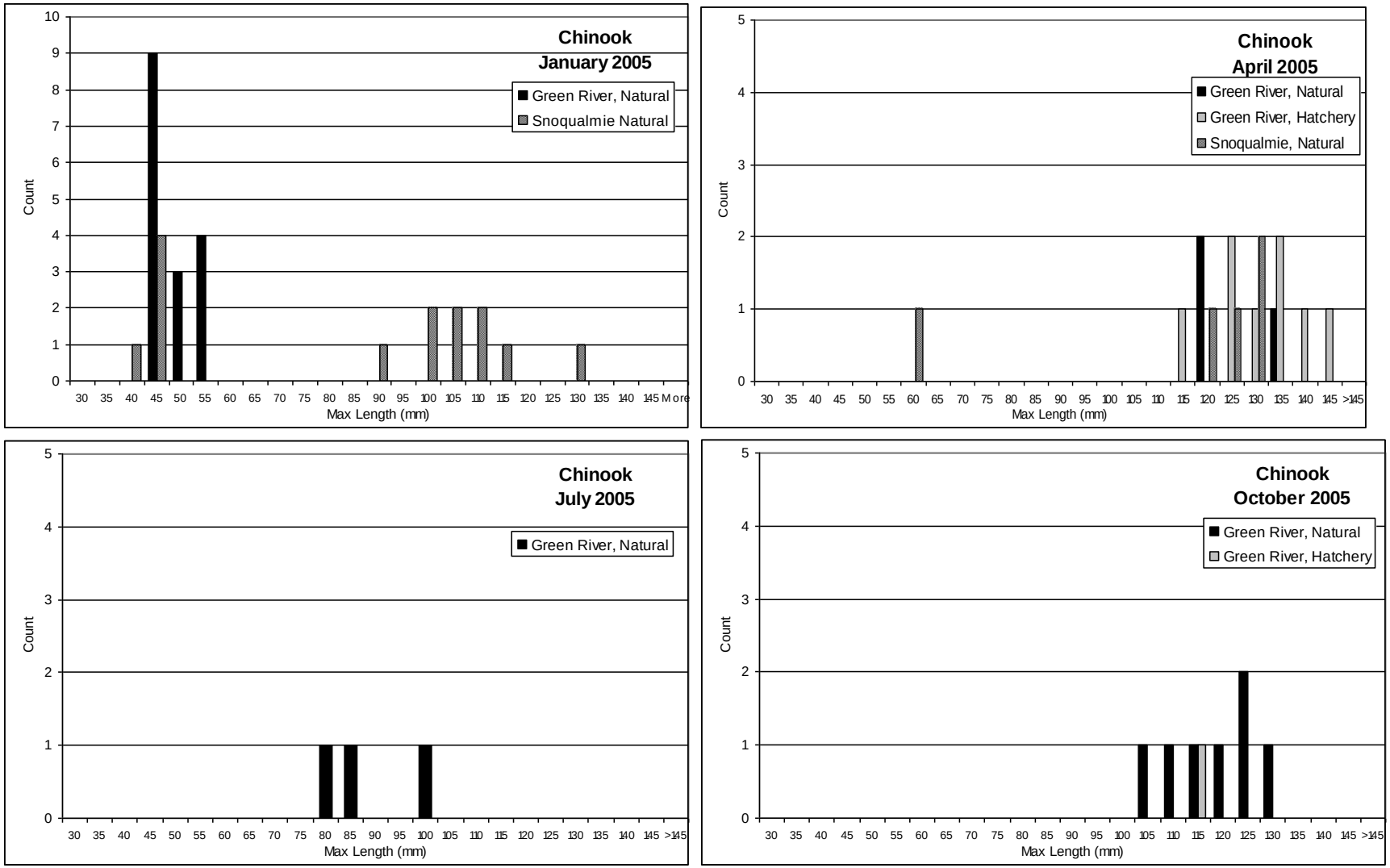




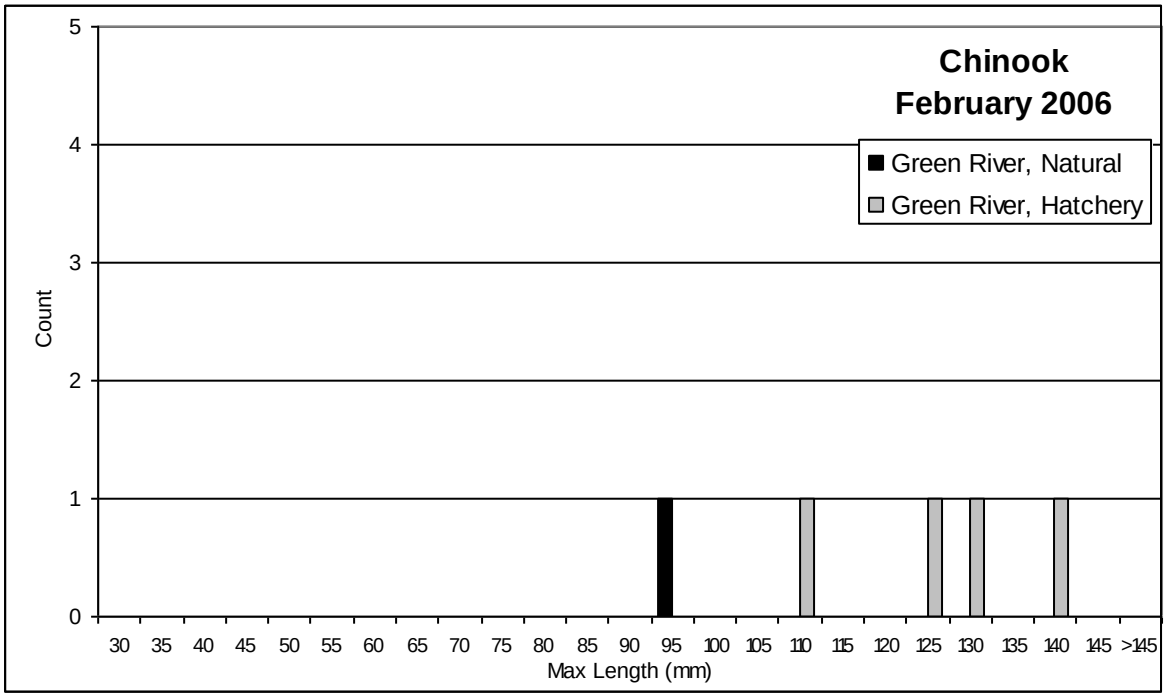
Appendix 2-B 3. Length frequency histogram of Chinook salmon collected during seasonal surveys in 2003.



Appendix 2-B 4. Length frequency histogram of Chinook salmon collected during seasonal surveys in 2004.



Appendix 2-B 5. Length frequency histogram of Chinook salmon collected during seasonal surveys in 2005.



Appendix 2-B 6. Length frequency histogram of Chinook salmon collected during seasonal surveys in 2006.