Timing, abundance, and population characteristics of spawning Chinook salmon in the Cedar/Sammamish Watershed

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INTRODUCTION

In the Pacific Northwest, Pacific salmon (*Oncorhynchus spp.*) are an important economic, biological, and cultural resource that embodies the values of the region. Habitat degradation and fragmentation coupled with harvest and hatchery practices has led to an acute decline in the abundance of Pacific salmon, culminating in several listings under the ESA (U.S. Endangered Species Act) (Nehlsen et al. 1991; Huntington et al. 1996; Gregory and Bisson 1997; Myers et al. 1998; Lichatowich 1999; Bradford and Irvine 2000; Blumm 2002). In response to this precipitous decline, the National Marine Fisheries Service (now NOAA Fisheries) identified over 50 ESUs (Evolutionarily Significant Units) for salmon and steelhead throughout the Pacific Northwest (California, Washington, Oregon, and Idaho) to evaluate individual populations that are reproductively isolated from adjacent ESU's and represent an important segment of the evolutionary legacy of the species (Good et al. 2005). As a result of population declines, nearly half of the ESU's identified are now listed under the ESA as *threatened* or *endangered*. For example, seventeen ESU's are identified for Chinook (*O. tshawytscha*), and nine of those are listed as *endangered* or *threatened* (Good et al. 2005).

The Puget Sound summer/fall Chinook salmon ESU was listed as threatened in 1999 under the ESA (Federal Register 1999). In turn, federal, state, local, and tribal governments and citizens have engaged in salmon recovery planning to develop watershed specific recovery strategies for Chinook within the Puget Sound ESU. The goals of these efforts are to implement scientifically-based recovery plans that will result in the recovery (de-listing) of Chinook salmon stocks within the Puget Sound ESU, which includes 23 independent populations (PSTRT 2003).

There are several large watersheds within the Puget Sound ESU, including the Cedar/Sammamish (Figure 1). Three large, naturally spawning groups of fall Chinook salmon exist in the watershed: Cedar River, Bear Creek, and Issaquah Creek (WRIA 8 2005). Recent work suggests that there has been genetic exchange between these three spawning aggregations (Marshall 2000; Warheit and Bettles 2005). The results of pairwise FST comparisons in the work of Warheit and Bettles (2005) suggest that there may be two populations of Chinook salmon in the Cedar/Sammamish watershed, the Sammamish (Bear Creek and Issaquah Basins) and Cedar River populations (Warheit and Bettles 2005). The Cedar River and Bear Creek populations are considered largely of natural origin, while the Issaquah Creek stock is of known hatchery origin (PSTRT 2003; WRIA 8 2005). Two hatcheries are operated within the watershed, one at Portage Bay operated by the UW (University of Washington), and the other on Issaquah Creek operated by the WDFW (Washington Department of Fish and Wildlife). Prior to this study, little was known about the run timing, abundance, population characteristics (i.e. pre-spawning mortality, age of maturity), and proportion of hatchery strays on the spawning grounds in the Cedar/Sammamish watershed.

Since the 1970s, annual Chinook spawning surveys have been conducted throughout the Cedar/Sammamish watershed in an attempt to quantify natural escapement on the spawning grounds. We have observed a decline in the abundance of naturally spawning Chinook in the watershed since the 1980s, while the numbers of returning adults to the Issaquah and UW hatcheries have increased (Figure 2). Since 1998, King County and the WDFW have collected critical information on Chinook salmon throughout the watershed in collaboration with staff from the Muckleshoot Indian Tribe and Seattle Public Utilities (Carrasco et al. 1999; Burton et al. 2006).

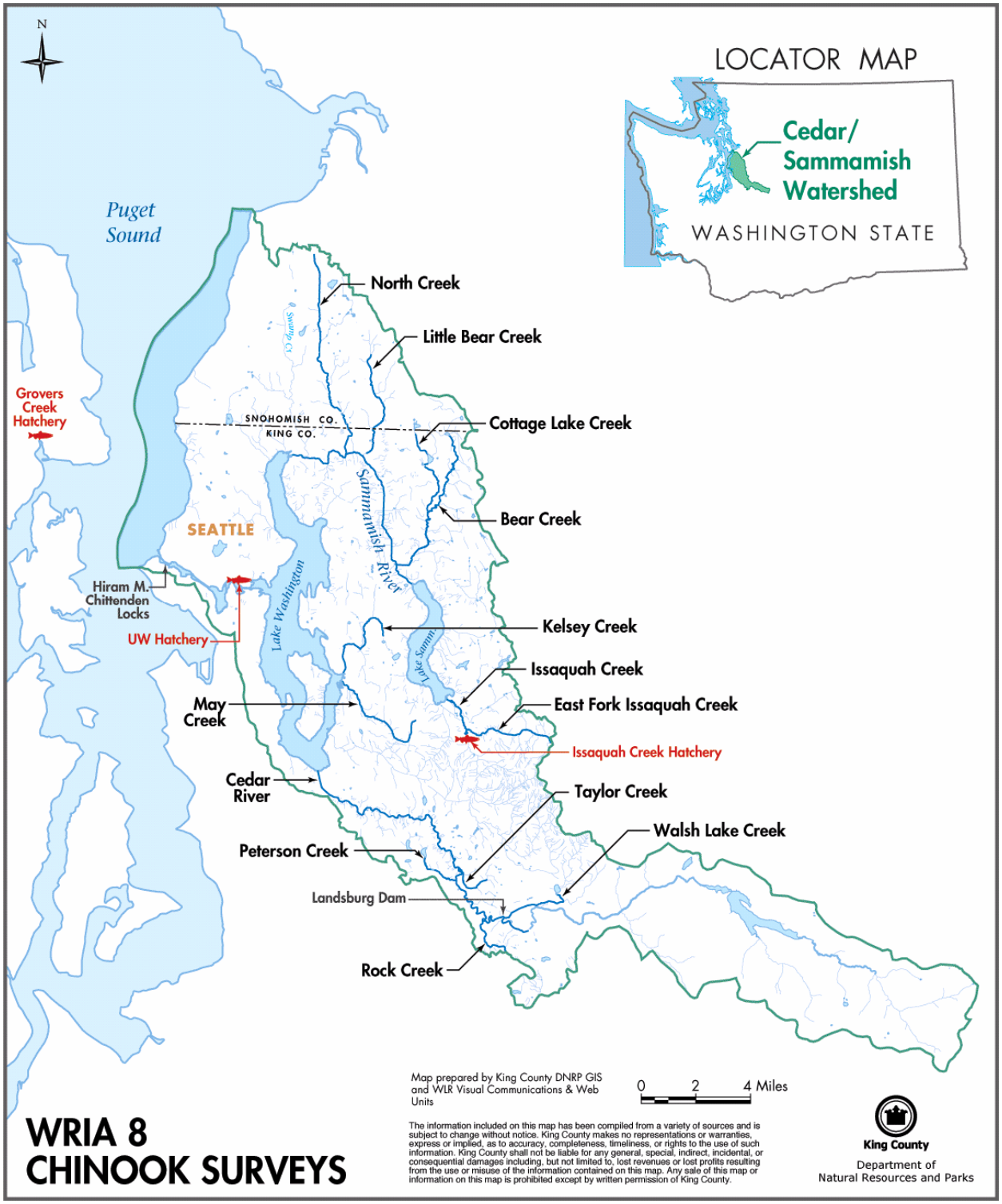

Figure 1. Map of Cedar/Sammamish Watershed and nearby Chinook hatchery facilities.

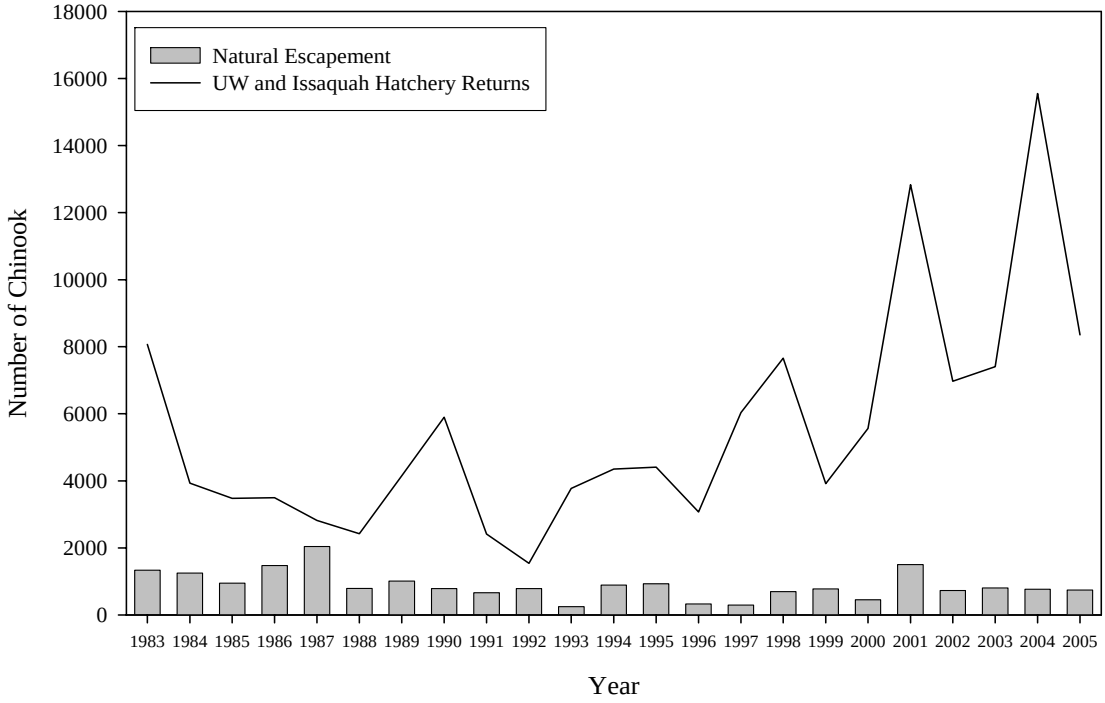

Figure 2. Natural spawning ground escapement from the Bear Creek and Cedar River Basins and hatchery returns to the Cedar/Sammamish Watershed (1983-2005).

The purpose of this document is to provide a summary of data collected from adult Chinook salmon on the natural spawning grounds in the Cedar/Sammamish watershed during 2003 through 2005. These data are useful in characterizing the spawning populations and understanding important factors that may affect the productivity and persistence of Chinook salmon throughout the entire Puget Sound ESU and are part of a larger monitoring effort to evaluate the long term status and trends of Chinook populations in the Cedar/Sammamish watershed (WRIA 8 2005).

STUDY AREA

The Cedar/Sammamish watershed (Water Resource Inventory Area 8) drains a catchment of 1,572 km^2 and includes all of the water that drains to Puget Sound via the Hiram M. Chittenden Locks (Figure 1). There are two major rivers within the watershed, the Cedar and Sammamish Rivers. The Cedar River is approximately 93 km long (to Chester Morse Lake) and has a mean annual flow of 19.9 m^3/s (cubic meters per second). In comparison, the Sammamish River is approximately 23 km long and has a mean annual flow of 10.4 m^3/s. The Cedar River originates in the Cascade Mountains and drains into the south end of Lake Washington. In contrast, the Sammamish River originates from an epilimnetic outlet of Lake Sammamish and flows into the north end of Lake Washington. Lake Washington waters then drain through the Hiram M. Chittenden Locks and enter Puget Sound at Salmon Bay (Figure 1). Latest population estimates suggest that the Cedar/Sammamish watershed is home to approximately 1.4 million people (Kerwin 2001; C. Naito, Puget Sound Regional Council, unpublished data). Sockeye

salmon (*O. nerka*) are the most abundant anadromous salmonid in the watershed, followed by coho (*O. kisutch*), Chinook, and steelhead (*O. mykiss*), and occasional use by pink (*O. gorbuscha*) and chum (*O. keta*). The watershed is also home to several indigenous resident salmonids including kokanee salmon (*O. nerka*), cutthroat (*O. clarki*) and rainbow (*O. mykiss*) trout, bull trout (*Salvelinus confluentus*), and mountain (*Prosopium williamsoni*) and pygmy (*P. coulteri*) whitefish. Chinook salmon typically migrate into the watershed in June, peak in August, and continue through the month of September (Figure 3).

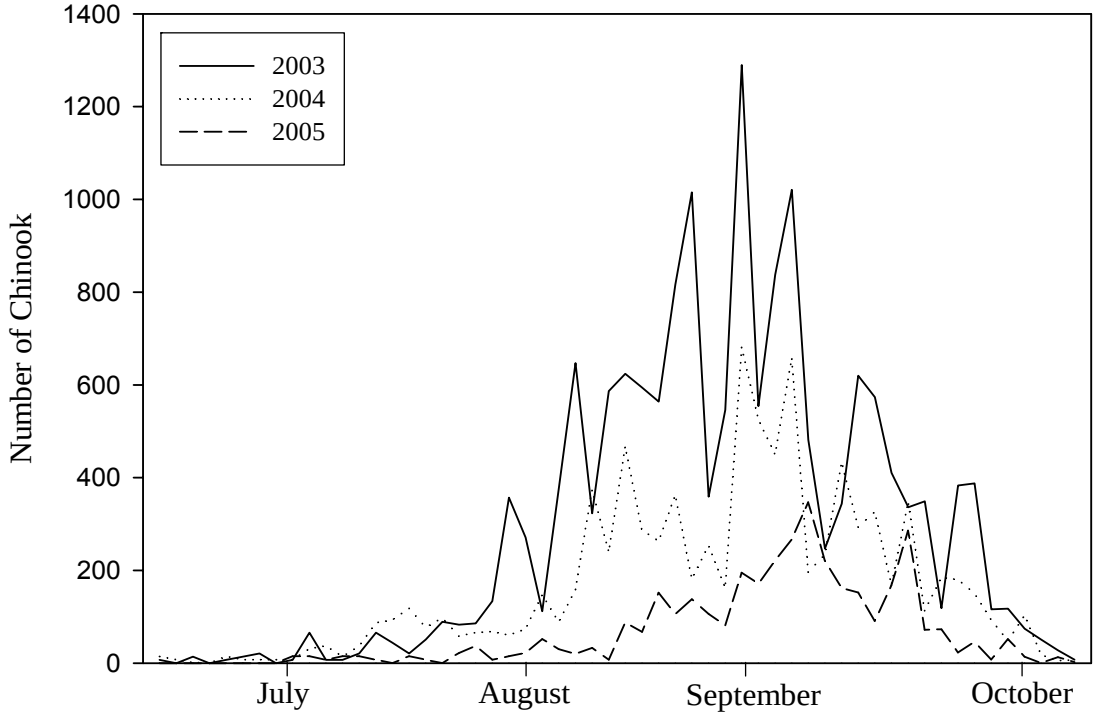

Figure 3. Counts of Chinook salmon entering freshwater at the Hiram M. Chittenden Locks (2003-2005).

Tributaries of the Sammamish River that consistently have Chinook spawning activity include North, Little Bear, and Bear Creek Basins (Figure 4). Of these tributaries, only the Bear Creek Basin has a relatively large spawning aggregation of Chinook from year to year (Carrasco et al. 1999; WRIA 8 2005). Bear Creek is the largest tributary of the Sammamish River and enters at RKM (river kilometer) 19.8 and contributes a mean annual flow of 2.216 m^3/s. Cottage Lake Creek is the largest tributary of Bear Creek entering at RKM 8.7 and contributing a mean annual flow of 0.48 m^3/s. Spawning ground surveys have been conducted in Bear and Cottage Lake Creeks since 1982, and the index spawning ground escapement goal for the Bear Creek Basin is 350 Chinook, which was last met in 2001. Excluding Issaquah Creek, Cottage Lake Creek has the highest density of Chinook spawning in the entire Cedar/Sammamish watershed.

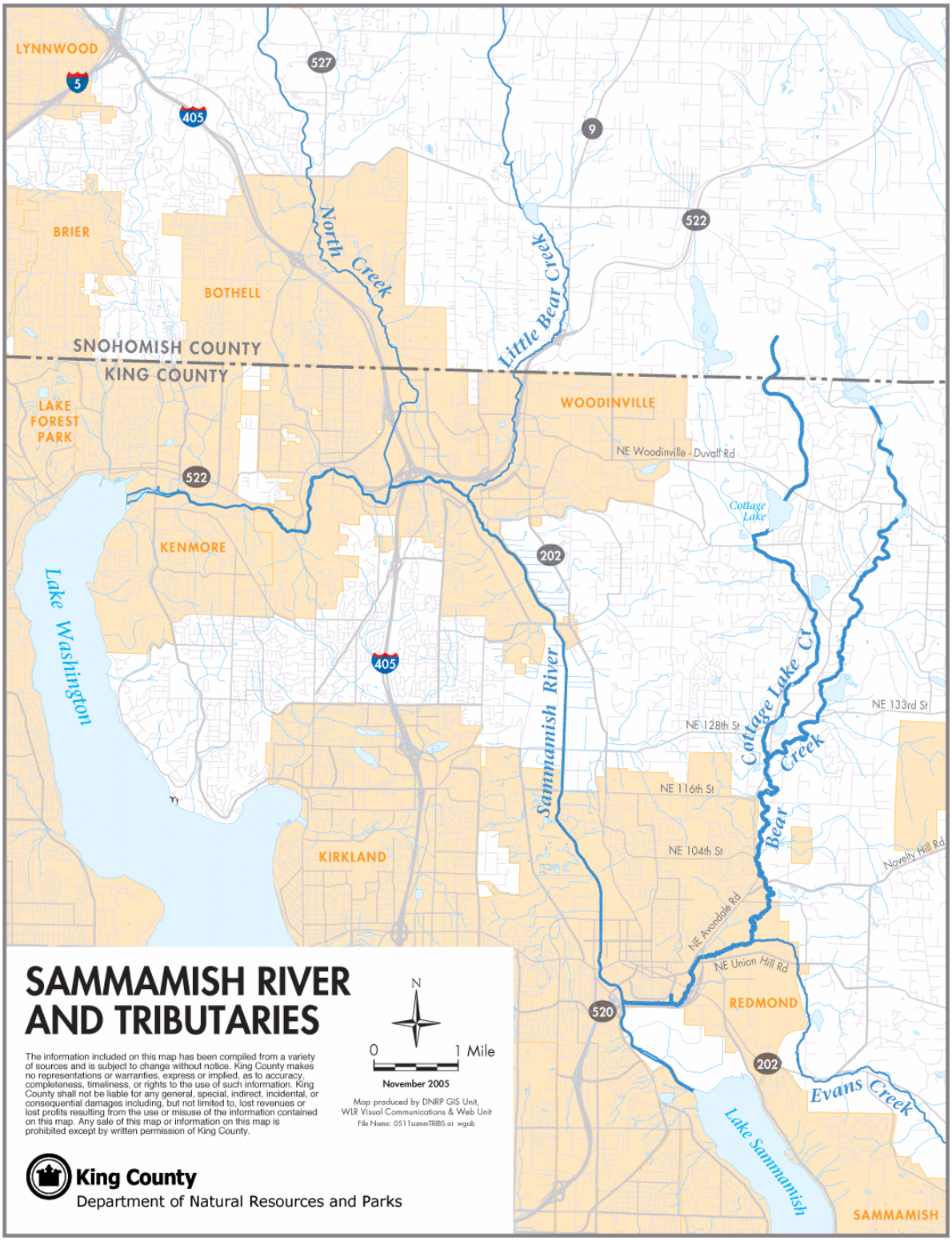

Figure 4. Map of Bear Creek Basin and Sammamish River tributaries surveyed in 2003-2005.

Issaquah Creek is the largest tributary of Lake Sammamish, with a mean annual flow of 3.71 m^3/s. Issaquah Creek enters Lake Sammamish at the south end adjacent to Lake Sammamish State Park (Figure 5). The East Fork of Issaquah Creek contributes a mean annual flow of 0.63 m^3/s and enters Issaquah Creek at RKM 4.7.

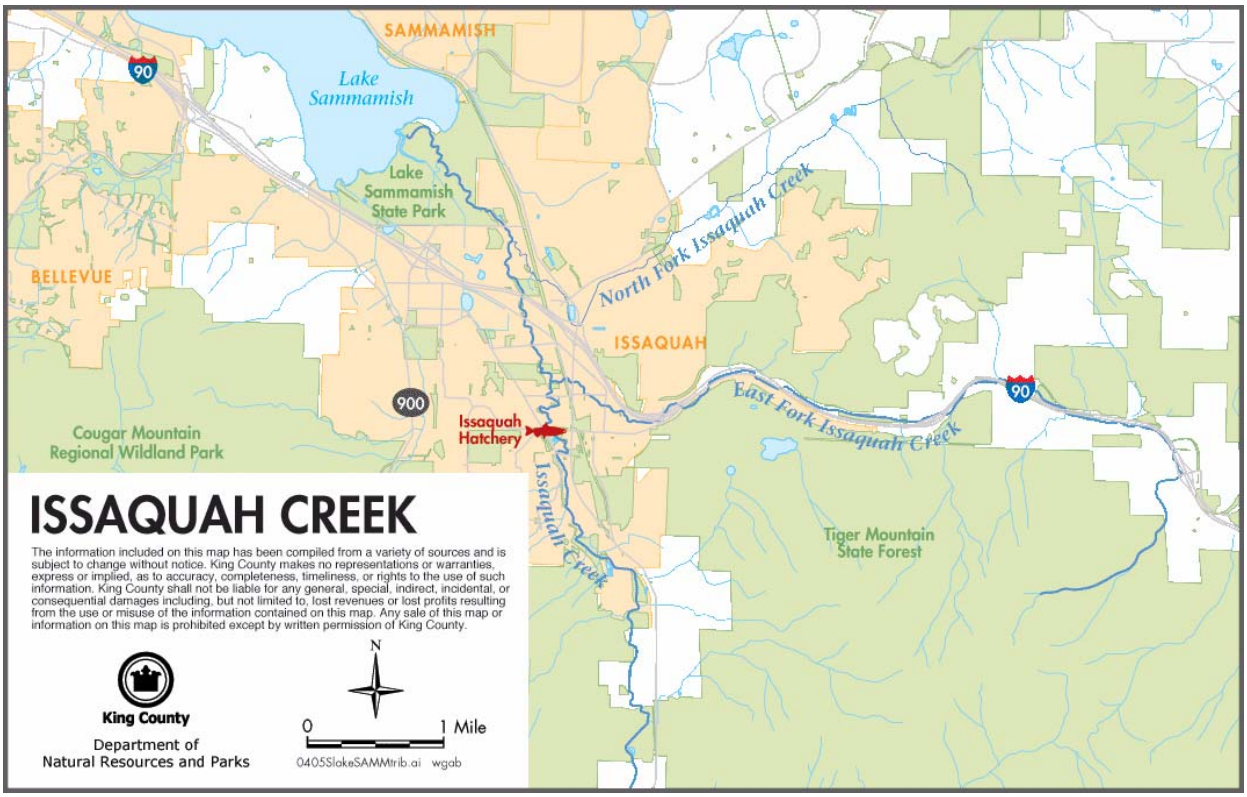

Figure 5. Map of the lower Issaquah Creek Basin.

The Issaquah Creek Hatchery is located at RKM 5.8 and has released Chinook into the watershed since 1936. In recent years, approximately two million Chinook smolts have been released from the hatchery each year, and starting with the 1999 broodyear, almost all of the smolts released have been marked externally with an adipose fin clip (Table 1). Beginning in broodyear 2002, eight to ten percent of the Chinook released from the Issaquah Creek Hatchery have been also marked with a CWT (coded wire tag; Table 1). The average number of adult Chinook spawned at the Issaquah Creek Hatchery from 1994 to 2005 is 2,471 with a standard deviation of 752 fish. Surplus fish that arrive at the Issaquah Creek hatchery are allowed to spawn naturally, and as a consequence, Issaquah Creek has significant natural production of Chinook juveniles (Seiler et al. 2003).

Table 1. Hatchery releases of Chinook salmon corresponding to CWT (coded wire tag) recoveries on the spawning grounds in the Lake Washington Watershed in 2003-2005.

Hatchery	Broodyear	CWT releases	Percent CWT	Adipose clip only	Total Unmarked	Total Released	CWT's recovered
Issaquah	1998	0	0	0	2,172,100	2,172,100	NA
Portage	1998	118,419	100.0	0	0	118,419	2
Grover's	1998	198,868	12.0	60,509	1,392,324	1,651,701	2
Cowlitz	1998	524,253	12.3	3,731,923	0	4,256,176	0
Issaquah	1999	0	0	1,446,258	76,119	1,522,377	NA
Portage	1999	0	0	160,018	0	160,018	NA
Grover's	1999	361,668	42.1	19,457	477,571	858,696	2
Cowlitz	1999	6,810	0.1	5,382,129	0	5,388,939	0
Issaquah	2000	0	0	2,053,605	141,168	2,194,773	NA
Portage	2000	165,800	99.7	0	474	166,274	35
Grover's	2000	412,977	91.3	25,211	13,914	452,102	5
Gobin	2000	165,278	11.6	24,863	1,229,859	1,420,000	0
Cowlitz	2000	1,143,070	99.2	9,452	0	1,152,522	1
Issaquah	2001	0	0	1,837,300	24,200	1,861,500	NA
Portage	2001	0	0	180,937	0	180,937	NA
Grover's	2001	408,253	60.8	260,184	2,987	671,424	6
Gobin	2001	183,594	13.7	10,083	1,142,093	1,335,770	0
Cowlitz	2001	548,231	9.7	805	5,094,139	5,643,175	0
Issaquah	2002	201,587	9.0	2,017,888	18,317	2,237,792	8
Portage	2002	107,589	34.8	201,698	0	309,287	2
Grover's	2002	393,940	96.9	360	12,289	406,589	6
Gobin	2002	153,354	10.7	35,917	1,249,387	1,438,658	1
Cowlitz	2002	582,210	10.4	4,337	5,011,963	5,598,510	0
Issaquah	2003	200,081	8.7	2,010,064	80,460	2,290,605	3
Portage	2003	92,523	40.2	137,668	138	230,329	0
Grover's	2003	317,450	81.2	50,151	23,336	390,937	0
Gobin	2003	177,501	9.4	13,851	1,696,345	1,887,697	0
Cowlitz	2003	967,227	16.7	24,174	4,812,416	5,803,817	0

The Cedar River is the largest tributary of Lake Washington and has the highest natural spawning ground escapement of Chinook in the watershed (not including Issaquah Creek). Chinook generally spawn in the mainstem with some additional spawning occurring in the four largest tributaries of the Cedar River below Landsburg Dam, including: Peterson, Rock, Taylor, and Walsh Lake Creeks (Figure 6). The annual spawning ground index escapement goal for the Cedar River is 1,200 Chinook, and this goal has not been met since 1987. From 1901 until

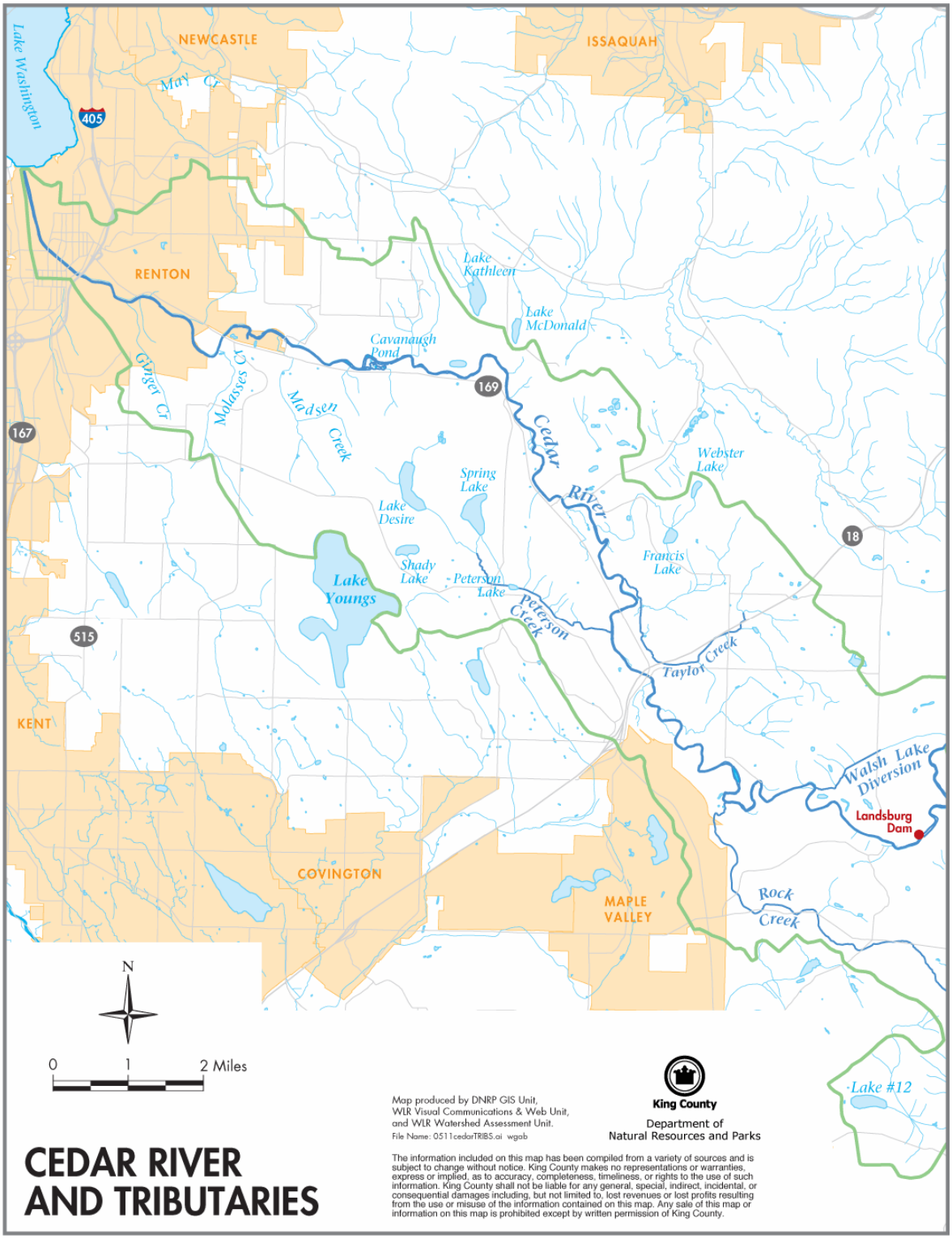

Figure 6. Map of the Cedar River Basin, below Landsburg Dam.

2003, Chinook salmon were confined to the lower 35.2 RKMs of habitat below the Landsburg Dam. Beginning in September 2003, fish passage above Landsburg Dam was provided for all species except sockeye by Seattle Public Utilities, allowing access to an additional 11.9 RKMs of mainstem habitat (Burton et al. 2006).

In addition to the core populations, small spawning aggregations of Chinook have been observed in a number of streams throughout the basin. Of these, only Kelsey Creek and May Creek are used on an annual basis with an average of less than 50 individual Chinook in each of these streams per year.

The UW Hatchery at Portage Bay has been releasing Chinook salmon since 1949. In recent years, an average of approximately 180,000 Chinook juveniles have been released from the UW Hatchery on an annual basis, although that number has varied from year to year depending upon particular research projects. In contrast to the Issaquah Creek Hatchery, the purposes of the UW facility are education and research. Since broodyear 1998, almost 100 percent of the Chinook released from the UW Hatchery have been marked externally with an adipose fin clip (Table 1). Since 1996, a large percentage of the fish released from the UW Hatchery have also been marked internally with a CWT, including the 2000 broodyear, where 100 percent of the Chinook released had both an adipose fin clip and a CWT (Table 1). Since 2000, only hatchery origin fish (as evidenced by an adipose fin clip) have been used for broodstock at the UW Hatchery. From 1994 to 2005 the mean escapement of Chinook to the UW hatchery was 1,855 with a standard deviation of 641 fish.

METHODS

Weekly live fish counts were conducted on the spawning grounds to calculate spawning ground escapement estimates for Issaquah Creek, Bear Creek, and Cedar River Basins in 2003, 2004, and 2005. Mainstem Cedar River surveys were conducted by inflatable raft, and in all other streams, foot surveys were used. Polarized sunglasses were worn by surveyors to increase visibility, and all live and dead fish were recorded. When possible, streams were walked downstream to increase sampling effectiveness as described by Ames (1982). Attempts were made during surveys to avoid disturbance of fish on redds. Surveys were not conducted if water conditions were dangerously high or fast, or if turbidity impaired visual detection of fish. Conditions permitting, the entire stream was sampled on each survey date.

Spawning ground escapements can be calculated using the live count data. Live counts are combined for a stream system and plotted by date on the x axis, and the number of live fish observed on the y axis. The first step is to calculate $\mathbf{F}$ (fish days):

$$\mathrm{F}_{t+1} = \left(\frac{C_t + C_{t+1}}{2} \right) \bullet \left(J_{t+1} - J_t \right) \qquad \text{(Equation 1)}$$

where $\mathbf{C}_t$ is the live count for the first survey, $\mathbf{C}_{t+1}$ is the live count of the second survey, $\mathbf{J}_t$ and $\mathbf{J}_{t+1}$ corresponds to the Julian Day of each of the live counts, respectively, and α represents the initial survey date. The AUC (area under the curve index escapement; Ames 1984; Perrin and Irvine 1990) is then defined as:

$$AUC = \frac{\sum_{t}^{t_F} \mathrm{F}}{\mathrm{V}} \qquad \text{(Equation 2)}$$

where $\mathbf{F}$ represents fish days, $\mathbf{V}$ is the number of days a fish is susceptible to being counted by surveyors, and t_F represents the last survey date. The escapement goal set in the Bear Creek and Cedar River Basins is based upon the AUC index escapement estimate. For Chinook salmon in the watershed, we assume $\mathbf{V}$ to be 10 days. By summing the fish days and dividing by the visibility life we generate a spawning ground escapement for the entire survey period. This method requires a survey with no live fish observed on the first and last date on the curve (i.e. the endpoints of the curve must be zero). It is also important that surveys are complete for the entire system as synchronously as possible.

Bi-weekly Chinook redd surveys were conducted in the Cedar River (Burton et al. 2006) and Bear Creek Basins to generate an alternative escapement estimate. Due to the occurrence of sympatric sockeye and coho salmon, only completed redds with an attending female Chinook were counted in the total. Redds are used to generate an escapement estimate by simply taking the total number of redds, and multiplying that number by the average number of fish per redd. In this case, the spawning ground escapement, $\boldsymbol{E}_{\mathbf{r}}$, is estimated by:

$$E_r = R * \Phi \qquad \text{(Equation 3)}$$

where R is the total number of redds and Φ represents the average number of fish per redd. In the Cedar/Sammamish watershed we assume that Φ is 2.5 with one female and 1.5 males per redd. The reason the ratio is 1.5 males per redd is to account for the fact that males often fertilize more than one redd (Briggs 1953; Chebanov and Riddell 1998; Healey and Prince 1998; Berejikian et al. 2000).

Chinook carcasses were identified and retrieved during each spawning ground survey. All Chinook carcasses were examined for the presence of external marks (tags or adipose fin-clip), then scanned for presence of a CWT in the snout. If a fish was found to have an adipose fin-clip or a CWT, we consider it to be marked and of hatchery origin. In this report, an unmarked fish does not have a fin clip or a CWT. Both POH (postorbital to hypural plate) and FL (fork length) were measured on Chinook to the nearest cm, sex was recorded, and females were examined for egg retention (termed spawning success). The body cavity was opened on female Chinook and checked for 0, 25, 50, 75, or 100 percent egg retention. Egg retention of 0-5 percent was assigned a 0, 6-25 percent to the 25 category, 26-50 percent to the 50 category, 51-75 percent to the 75 category, and 76-100 percent to the 100 category. Six scales were removed from each carcass to determine age. Scales were removed from the area several rows above the lateral line between the posterior end of the dorsal fin and the anterior insertion of the anal fin (INPFC 1963). Scales were mounted on gummed scale cards and read by WDFW staff at the Scale and Otolith Lab in Olympia. Age notation used the Gilbert-Rich system, with the total age noted normally and the freshwater age represented as a subscript (Koo 1962). For the purposes of this report, we will use the total age without the freshwater subscript since greater than 95 percent of the Chinook in the Cedar/Sammamish watershed only spend one year rearing in freshwater.

RESULTS

Weekly spawning ground surveys were initiated in September and concluded in mid-November in each survey year to correspond with the beginning and end of the spawning period. We estimated the abundance of Chinook in both the Cedar River and Bear Creek Basins using the AUC and redd counts. Abundance estimates for Issaquah Creek are a combination of counts collected by the hatchery and our survey efforts and are not based on the AUC index or redd escapement methodologies.

TIMING AND ABUNDANCE

Adult Chinook begin migrating through the Chittenden Locks into the Cedar/Sammamish watershed in June, peaking in August, and continuing until early October (Figure 3). Most of the Chinook that returned to the spawning grounds in the watershed in 2003 (71 percent), 2004 (80 percent), and 2005 (89 percent) returned to Issaquah Creek (Table 2). In some years, tribal and sport harvest of Chinook occurs between the locks and the spawning grounds, and these numbers are not included in our analysis or estimates. In addition, incidental harvest by the tribes occurs in sockeye and coho fisheries in Lake Washington and Lake Sammamish.

Chinook first arrive on the spawning grounds in Issaquah Creek in September, peak in early October, and finish spawning in early November. Of the fish that are collected at the hatchery, approximately 2,500 are spawned artificially to meet egg take goals, and the surplus (58 percent in 2003, 75 percent in 2004, and 68 percent in 2005) are passed upstream and allowed to spawn naturally in Issaquah Creek (Table 2). Hatchery counts at Issaquah Creek (Table 2) include fish that were lethally spawned at the facility and those that were released back into the creek.

Table 2. Adult Chinook AUC (area-under-the-curve) index escapement, redds, and number of carcasses sampled by basin in 2003-2005. The UW Hatchery data only include those that were lethally spawned. Carcasses collected in Issaquah Creek include those sampled at the hatchery facility and natural spawners from the mainstem and East Fork.

Basin		2003	2004	2005
Cedar River	AUC Escapement	558	587	557
	Redds	336	511	337
	Carcasses	329	401	279
Bear Creek	AUC Escapement	248	204	320
	Redds	147	121	122
	Carcasses	235	142	274
Issaquah Creek	Hatchery Counts	5,842	13,033	7,077
	Carcasses	235	188	159
UW Hatchery	Hatchery Counts	1,563	2,520	1,278
	Carcasses	Not Surveyed	150	Not Surveyed

The AUC escapement for Chinook in the East Fork of Issaquah Creek was 19 in 2003, 119 in 2004 and 86 in 2005. We did not calculate AUC escapement for the rest of the Issaquah Creek Basin or the lower 5.8 RKMs, since the hatchery records the number of fish taken for broodstock and the number of fish passed above the weir. We found three Chinook redds in the East Fork of Issaquah Creek in 2003, 25 in 2004, and 11 in 2005. In 2003-2005 approximately three fourths of the fish recovered on the spawning grounds in Issaquah Creek are marked (Table 3).

Table 3. Proportions of Chinook sampled in each basin that were unmarked or marked, for both females and males in 2003 through 2005.

2003		Total		Female		Male	
	n	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked
Bear Ck.	235	0.48	0.52	0.26	0.17	0.22	0.35
Cedar R.	329	0.72	0.28	0.31	0.10	0.41	0.18
Issaquah Ck.	235	0.27	0.73	0.12	0.18	0.15	0.55
2004		Total		Female		Male	
	n	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked
Bear Ck.	142	0.37	0.63	0.26	0.26	0.11	0.37
Cedar R.	401	0.66	0.34	0.39	0.20	0.28	0.15
Issaquah Ck.	188	0.19	0.81	0.06	0.42	0.13	0.39
2005		Total		Female		Male	
	n	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked
Bear Ck.	274	0.21	0.79	0.07	0.43	0.14	0.35
Cedar R.	279	0.68	0.32	0.26	0.18	0.42	0.14
Issaquah Ck.	159	0.23	0.77	0.09	0.41	0.14	0.36

Fish return to the UW hatchery starting in early-October and continue through the third week in November. The UW hatchery facility spawned 1,563 marked Chinook in 2003, 2,520 in 2004, and 1,278 in 2005 (Table 2). All unmarked adult Chinook that returned to their facility in each of these years were released into Portage Bay.

In the Cedar River, a few Chinook enter in August but the majority arrive on the spawning grounds in late-September through the end of October (Figure 7). The peak live counts in the Cedar River during our study period occurred on 14 October 2003 (205 Chinook), 28 September 2004 (214 Chinook), and 4 October 2005 (270 Chinook). The AUC escapement estimate for Chinook in the Cedar River mainstem below Landsburg Dam was 532 in 2003, 563 in 2004, and 511 in 2005. Weekly surveys were also conducted in four Cedar River tributaries below Landsburg Dam including: Taylor Creek, Walsh Lake Diversion, Rock Creek, and Peterson Creek. In each year there were insufficient numbers of fish in Rock or Peterson Creeks to generate an accurate AUC estimate. The AUC escapement estimate for Walsh Lake Creek, was 24 in 2003, 20 in 2004, and one in 2005. In Taylor Creek, the AUC escapement estimate was 28 in 2003, 16 in 2004, and 31 in 2005. Tributary spawning accounted for approximately ten (2003), six (2004), and six (2005) percent of the Chinook that returned to the Cedar River Basin in the past three years. The AUC escapement estimate for the entire Cedar River Basin was 610 in 2003, 623 in 2004, and 557 in 2005. In 2003-2005, approximately thirty percent of

the returning adult Chinook on the spawning grounds in the Cedar River Basin were marked (Table 3).

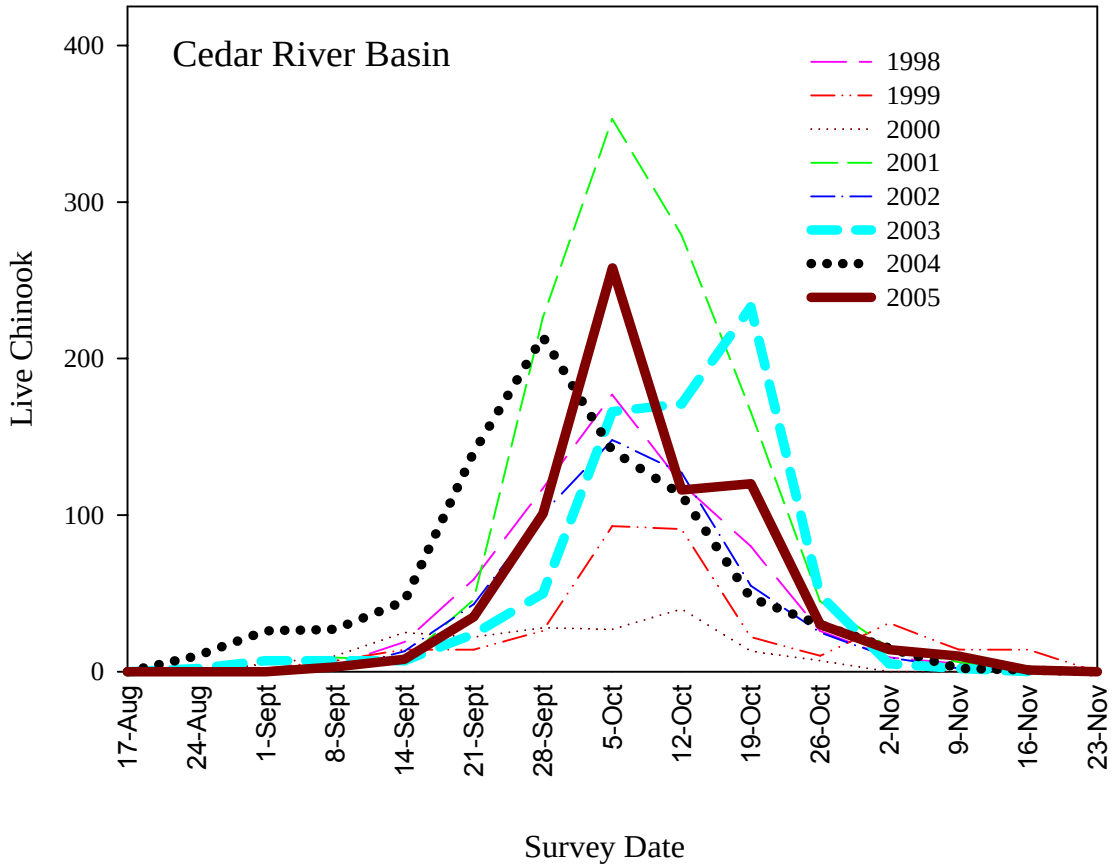

Figure 7. Live counts of Chinook in the Cedar River Basin (1998-2005).

Fish passage at Landsburg was provided in 2003, and 79 Chinook (16 females and 63 males) migrated upstream of Landsburg Dam in the first year (Table 4). In 2004, 51 Chinook (22 females and 29 males) were passed upstream of Landsburg Dam, and in 2005 there were 69 (17 females and 52 males). In 2003 and 2004, the majority of those fish were marked, 70 and 68 percent, respectively. In 2005, that trend changed and only 42 percent of the Chinook passed above Landsburg Dam were marked. We did not conduct live counts for the Cedar River above Landsburg Dam although redd surveys were conducted by staff from Seattle Public Utilities (Burton et al. 2006).

Table 4. Adult Chinook fish passage data collected at Landsburg Dam, 2003-2005 (Faulds in prep).

Year		Total		Female		Male	
	n	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked
2003	79	24	55	6	10	18	45
2004	51	17	34	7	15	10	19
2005	69	40	29	12	5	28	24

In 2003, there were a total of 336 Chinook redds in the Cedar River Basin. Of these, 303 were in the mainstem below Landsburg Dam, 15 were above the dam, and 18 were in tributaries downstream of the dam (Burton et al. 2006). The escapement estimate for 2003 Chinook in the Cedar River Basin, based on redd counts, was 840 Chinook on the spawning grounds. Redd counts in 2004 were substantially better than 2003 with a total basin count of 511 Chinook redds. Like 2003, the majority (470) of Chinook redds in the Cedar River Basin in 2004 were located in the mainstem river below Landsburg Dam (Burton et al. 2006). In 2004, 20 redds were constructed above Landsburg Dam, and 21 were in tributaries downstream of the dam. The 2004 escapement estimate for Chinook in the Cedar River Basin based upon redd counts was 1,277 Chinook. Like previous years, the majority (320) of Chinook redds in the Cedar River Basin in 2005 were located in the mainstem Cedar River below Landsburg Dam (Burton et al. 2006). Nine redds in 2005 were constructed above Landsburg Dam, and only eight redds were found in tributaries of the Cedar River below Landsburg Dam (Burton et al. 2006). In 2005, seven of the tributary redds were located in Taylor Creek and the other was found in Peterson Creek. The 2005 escapement estimate for the Cedar River Basin based on redd counts was 843 Chinook.

Chinook salmon return to the spawning grounds in Bear Creek during late-September, peak in early October, and end by the second week in November. The peak live count occurred on 2 October 2003 (106 Chinook), 14 October 2004 (75 Chinook), and 6 October 2005 (199 Chinook) (Figure 8). The AUC escapement estimate for Chinook in the Bear Creek Basin was 248 in 2003, 204 in 2004, and 320 in 2005. These counts are the sum of weekly surveys conducted in Bear Creek and two of its tributaries, Cottage Lake and Evans Creeks. Approximately 67 percent of the Chinook that returned to the Bear Creek Basin in 2003 through 2005 returned to Cottage Lake Creek. Greater than 50 percent of the returning adult Chinook in the Bear Creek Basin were marked (Table 3).

Surveyors counted 147 Chinook redds in the Bear Creek Basin during 2003. Most of the redds (120) were located in Cottage Lake Creek, 24 were located in Bear Creek, and three were in Evans Creek. The 2003 escapement estimate for Chinook in the Bear Creek Basin based upon redd counts was 368 fish. During 2004, there were 121 redds counted in the Bear Creek Basin. Like 2003, most of the 2004 Chinook redds were located in Cottage Lake Creek (96), and the remainder (25) were located in Bear Creek. No Chinook redds were observed in Evans Creek during 2004. The 2004 spawning ground escapement estimate for Chinook in the Bear Creek Basin based on redd counts was 303 fish. In 2005, we located 122 Chinook redds in the Bear Creek Basin with 82 of those found in Cottage Lake Creek and 40 found in Bear Creek. No

Chinook redds were located in Evans Creek during 2005 surveys. The 2005 spawning ground escapement estimate for Chinook in the Bear Creek Basin using redd counts was 305 Chinook.

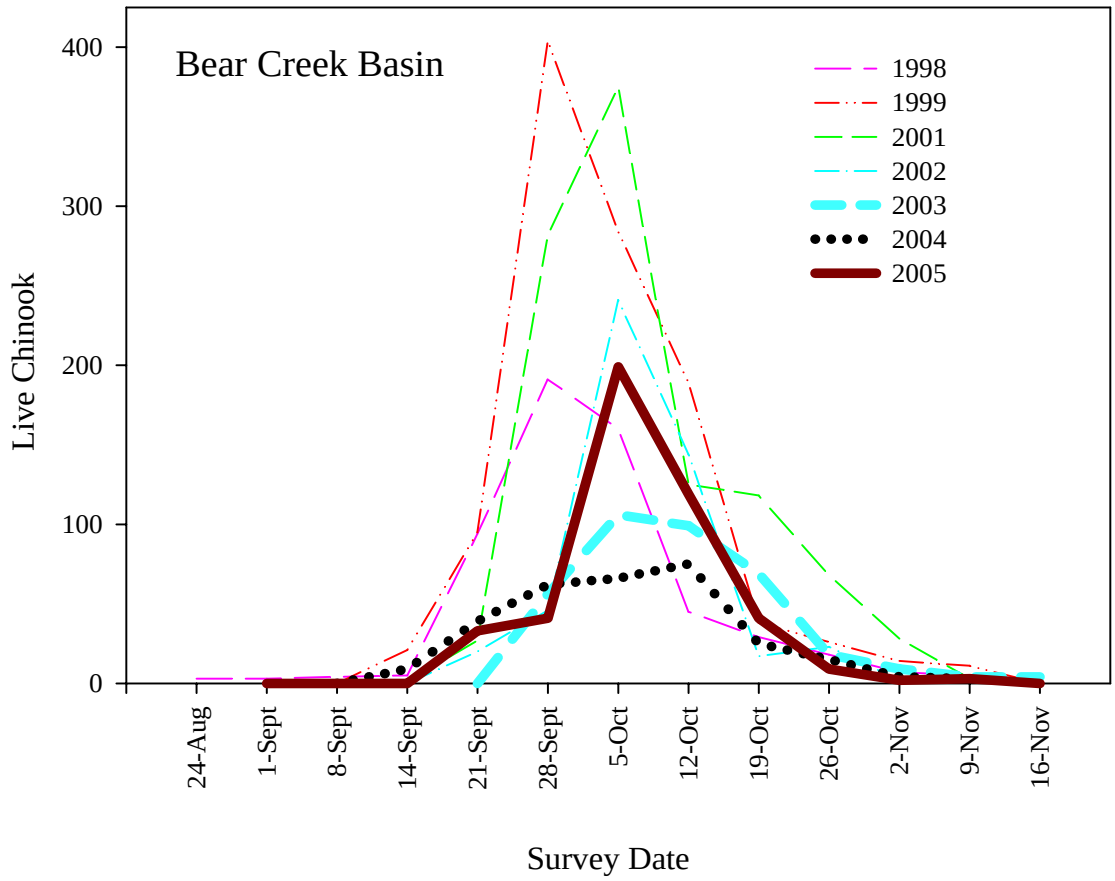

Figure 8. Live counts of Chinook in the Bear Creek Basin (1998-2005).

AGE AND ORIGIN

It is important to note that Issaquah hatchery origin fish returning to Cedar/Sammamish watershed as five-year-old adults in 2003 were not marked with an adipose fin clip prior to release. However, all of the UW hatchery origin fish returning to the basin as age-two, three, four, and five were marked with a marked adipose fin. Only 4.5 percent of the carcasses sampled in 2003 were five year olds of unknown origin, while the vast majority of both marked and unmarked fish are four year olds (Table 5).

The dominant age class for returning Chinook to the Cedar/Sammamish Watershed is four year olds although this may vary from year to year. In 2003, the dominant age class for male Chinook was different for marked and unmarked fish with the majority of marked fish being age-3 (from the 2000 broodyear), and most of the unmarked fish returning at age-4 (from the 1999 broodyear). In 2004, we again saw the strength of the 2000 broodyear in the males, with the majority of marked fish returning in 2004 at age-4. The unmarked component of Chinook in 2004 was again comprised of age-4 returning males and did not correspond to the observations from 2003. In 2005, we found a difference in the number of age-3 and age-4 marked fish, but

the age-3 component of the unmarked fish was stronger than the age-4. This suggests that the 2001 broodyear was not as strong as the previous broods.

Table 5. Sex, age, and origin of Chinook carcasses sampled in the entire watershed for each year.

			Age-2		Age-3		Age-4		Age-5	
Year	Sex	*n*	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked
2003	Males	444	1	4	70	195	101	44	29[1]	
	Females	274			10	35	112	57	60[1]	
2004	Males	243	12	10	22	31	87	73	7	1
	Females	303			7	6	133	105	47	5
2005	Males	357	3	14	98	78	61	74	10	19
	Females	319			19	53	51	121	30	45

[1]The 1998 brood were not mass marked at hatcheries, as a result we do not know the true origin of these fish.

In 2003, 2004, and 2005, the females returning to the watershed as four year olds were more common than any other age class (Table 5). This pattern applied to both marked and unmarked females, but was more evident in the marked component of the samples. This pattern is consistent with observations at the Issaquah Creek Hatchery with the vast majority (greater than 90 percent in some years) of returning females being age-4.

We tested the null hypothesis that there was not a difference in sex ratios of the carcasses we sampled on the spawning grounds in 2003 through 2005 using a nonparametric Binomial Test of Proportions. We did not find a difference between the proportions of males versus females ($n=2089$; $p=0.726$). However, we found a statistically significant difference between the proportions of females versus males that were marked over the three years of this study. Using a Pearson's Chi-Square contingency table, we found a higher proportion of males that are marked than females on the spawning grounds ($n=2089$; $p=0.10$) suggesting that the straying component among males is greater.

We tested to see if there was a difference between the FL (fork length) of marked versus unmarked fish of the same age. Fish were separated by year, age, sex, and basin. A non-parametric Kruskal-Wallis Test was used because the variable fork length was neither normally nor lognormally distributed. A confidence limit of 95 percent was applied to all of the tests ($\alpha=0.05$). We first combined Cedar River, Bear, and Issaquah Creek Basins and tested for a difference in length between marked and unmarked Chinook by age and sex. When statistical significance was observed, with the exception of three-year-old males in 2004, unmarked fish were greater in length (Table 6).

Table 6. Results of Kruskal-Wallis test for difference between FL (fork length) of marked and unmarked fish in all basins, both sexes, for age 3, 4, and 5-year-old fish. Numbers in bold denote statistical significance (P<0.05).

2003		**Females**			**Males**	
Age	P-Value	Larger Group	*n*	P-Value	Larger Group	*n*
3	0.946		45	0.685		265
4	0.000	*Unmarked*	169	0.010	*Unmarked*	145
5	0.004	*Unmarked*	60	0.897		29
2004		**Females**			**Males**	
Age	P-Value	Larger Group	*n*	P-Value	Larger Group	*n*
3	0.176		89	0.002	*Marked*	152
4	0.611		383	0.003	*Unmarked*	226
5	0.379		52	0.250		8
		Females			**Males**	
Age	P-Value	Larger Group	*n*	P-Value	Larger Group	*n*
3	0.136		72	0.738		176
4	0.322		175	0.058		137
5	0.651		76	1.0		29

We tested to see if there was an overall pattern in the relationship between origin (marked or unmarked) and fork length for each age group and only found significance in the four-year-old component with both unmarked males and females being larger than their marked counterparts (Table 7).

Table 7. Results of Kruskal-Wallis test for difference between FL (fork length) of marked and unmarked fish, pooled for all years, in all basins, both sexes, for age 3, 4, and 5year-old fish. Numbers in bold denote statistical significance (P<0.05).

	Females			**Males**		
Age	P-Value	Larger Group	*n*	P-Value	Larger Group	*n*
2	NA		0	0.484		67
3	0.105		175	0.747		593
4	**0.006**	***Unmarked***	711	**>0.001**	***Unmarked***	519
5	0.268		140	0.964		37

We then tested for a difference in length between the three basins. Although there were not clear correlations, significance was observed more frequently in males than in females (Table 8).

Table 8. Results of Kruskal-Wallis test investigating whether there is a difference between FL (fork length) of Chinook in each of the basins. Results are grouped by sex, age, and origin. Numbers in bold denote statistical significance (P<0.05).

		Unmarked			Marked		
	Age	P-Value	Larger Group	*n*	P-Value	Larger Group	*n*
Females							
2003	3	0.521		10	0.945		35
	4	**0.041**	***Issaquah***	112	0.810		57
	5	0.785		51	0.158		9
2004	3	0.157		7			1
	4	0.870		134	0.823		177
	5	0.157		47	0.546		5
2005	3	0.520		18	0.636		53
	4	0.637		51	0.495		122
	5	0.346		30	0.672		45
Males							
2003	3	**0.010**	***Bear***		0.079		195
	4	0.567			0.737		44
	5	0.856					1
2004	3			22	**0.007**	***Bear***	40
	4	**0.015**	***Cedar***	98	**0.006**	***Bear***	116
	5	0.671		7			
2005	3	**0.039**	***Cedar***	98	0.783		78
	4	**0.007**	***Issaquah***	61	0.472		74
	5	0.676		10	0.176		19

PRE-SPAWNING MORTALITY

We categorized spawn success as 0-25 percent unspawned as being “successful,” and 75-100 percent unspawned as “unsuccessful.” Although spawning “success” is subjective term, there is no doubt that the level of fitness of an individual is reduced if the number of potential offspring is reduced by retaining eggs. The 50 percent category was omitted but only accounted for less than four percent of the carcasses sampled in each year.

In 2003, a total of 300 female Chinook carcasses were sampled for PSM (pre-spawn mortality) in the Cedar River, Bear, and Issaquah Creek Basins. The Cedar River Basin had the lowest occurrence of pre-spawn mortality with 1.5 percent of the 134 carcasses sampled having greater than 75 percent egg retention both of which (n=2) were hatchery origin. Of the Cedar River females that were marked (n=31), seven had greater than 25 percent egg retention, while only two of the unmarked females had greater than 25 percent egg retention (n=74), suggesting a relationship between hatchery origin (marked fish) and PSM. The Bear Creek Basin had a slightly higher rate of PSM with 8 percent (n=8) of the 95 female carcasses sampled, and approximately one third of those fish were marked. Issaquah Creek Basin had the highest incidence of PSM with 23 percent of the 71 carcasses sampled, 75 percent of those were marked. It appears that there is a positive relationship between PSM and marked fish in each basin during 2003 with marked fish having a significantly higher rate of PSM than unmarked fish.

In 2004, 301 female Chinook carcasses were sampled for PSM in the Cedar River and Bear Creek Basins. Chinook carcasses sampled in the Issaquah Creek Basin were sampled at the hatchery so PSM could not be investigated. In the Cedar River Basin we sampled 232 carcasses and 3 percent (n=6) of those were PSM, and 67 percent of those were marked. Three of the 69 carcasses sampled in the Bear Creek Basin in 2004 were PSM, and only one was marked.

In 2005, we sampled 321 female Chinook carcasses for evidence of pre-spawning mortality. In the Cedar River Basin, we sampled 122 carcasses and only one (0.8 percent) exhibited PSM and it was marked. In the Bear Creek Basin we sampled 138 female Chinook carcasses, and 6.5 percent of those were PSM (n=9), and all of them were marked. Eighteen of 79 female carcasses (22.7 percent) sampled in the Issaquah Creek Basin in 2005 were PSM, and 17 of those were marked.

We examined all ages and tested for a difference in spawn success between marked and unmarked female Chinook for each basin for each year using a Chi square test with contingency tables at the 95 percent confidence level to test for differences in PSM between marked and unmarked fish. In 2003, three-year-old marked females were more successful in spawning, and four-year-old unmarked Chinook were more successful (Table 9).

Table 9. Relationship between PSM (pre-spawn mortality), age, and origin from Chi square test. Numbers in bold denote statistical significance (P<0.05).

	2003			**2004**			**2005**		
Age	P-Value	More successful	*n*	P-Value	More Successful	*n*	P-Value	More Successful	*n*
3	**0.031**	***Marked***	46	0.338		14	0.622		72
4	**<0.001**	***Unmarked***	175	0.166		251	0.003	***Unmarked***	175
5	*	*	*	0.578		54	0.025	***Unmarked***	76

*The 1998 brood were not mass marked at hatcheries, as a result we do not know the true origin of these fish.

In 2004, no statistically significant patterns were observed, but in 2005 both four and five-year-old unmarked females were more successful at spawning. It is interesting to note that in three

of the four cases where there was a statistically significant difference between spawning success of marked vs. unmarked female Chinook, the unmarked group was more successful (Table 9). In addition, after pooling data across all years we found an overall trend of unmarked females being more successful at spawning than their marked counterparts in both four and five-year-old age classes (Table 10).

Table 10. Relationship between PSM (pre-spawn mortality) and origin from Chi square test for all years. Numbers in bold denote statistical significance (P<0.05).

Age	P-Value	More successful	*n*
3	0.440		137
4	**<0.001**	***Unmarked***	601
5	**0.011**	***Unmarked***	140

CODED WIRE TAG RECOVERIES

In 2003-2005 we have recovered 70 CWT's from four different watersheds (Table 11). We collected 30 Chinook carcasses that contained CWT's in 2004, and 19 in 2003 (Table 8). Most (54 percent) of the fish collected originated from the UW hatchery located at Portage Bay. Twenty seven percent originated from the Suquamish Tribe's Grover's Creek Salmon Hatchery located on the Kitsap Peninsula (Figure 1). In 2005, eleven (16 percent) were recovered from Issaquah, one originated from Tulalip Bay (Bernie Gobin/Tulalip Creek Hatchery), and another from the Cowlitz River, a tributary of the Columbia River (Table 11).

Prior to 2003, Cedar/Sammamish watershed CWT Chinook recoveries on the spawning grounds included fish originating from UW hatchery, Grover's Creek Hatchery, WDFW hatcheries on both Issaquah Creek and Soos Creek, and the cooperatively operated Elliot Bay Seapens.

Table 11. 2003-2005 CWT (coded wire tag) recoveries on the spawning grounds in the Cedar/Sammamish watershed.

Year	Recovery location	Release location			
		UW	Grover's Creek	Other	Total Recovered
2003	Bear Creek Basin	2	2		4
	Cedar River Basin	11	3		14
	Issaquah Ck. Basin		1		1
2004	Bear Creek Basin	8	5		13
	Cedar River Basin	7	2		9
	Issaquah Ck. Basin	5			5
	Other streams	3			3
2005	Bear Creek Basin	2	4	4[1]	10
	Cedar River Basin		2	3[2]	5
	Issaquah Ck. Basin			6[3]	6

[1] One from the Cowlitz River and three from Issaquah Creek
[2] Two from Issaquah Creek and one from Bernie Gobin/Tulalip Creek
[3] Six from Issaquah Creek

DISCUSSION

This study documents the timing, abundance, and several population characteristics of naturally spawning Chinook salmon in the Cedar/Sammamish watershed. Data presented in this report describes the incidence of straying hatchery Chinook on the spawning grounds of naturally spawning fish from hatcheries within and outside of the Cedar/Sammamish watershed. These data provide important insight into specific attributes of Chinook salmon that spawn in the Cedar/Sammamish watershed and are useful in monitoring trends within this population in the context of salmon recovery planning (WRIA 8 2005).

Accurate spawning ground escapement estimates are critical in understanding the population dynamics and productivity of naturally spawning Chinook and aid in identifying limiting factors within the Cedar/Sammamish watershed. Bradford (1995) suggests that the freshwater phase alone accounts for over half of variability in the abundance of returning adult salmon. By combining efforts to monitor adults and smolt production we can better understand factors that undoubtedly affect freshwater habitat conditions such as scour, disturbance, or rearing capacity of habitat and have some insight about ocean conditions for a specific broodyear. Chinook escapements in the watershed over the last 21 years show evidence of decline with many of the lowest returns occurring in the last ten years (Figure 2). In the period from 2003 through 2005, we observed a more stable trend of naturally spawning Chinook in the watershed. The year-to-year variability among basins in the Cedar/Sammamish watershed has also been observed in other areas of the Puget Sound ESU (PSTRT 2003; Quinn et al. 2005). This decline is a result of many factors including: habitat alterations, hatchery practices, altered flow regimes, ocean survival, climate, and harvest (Federal Register 1999; Lichatowich 1999; McElhany et al. 2000; ISAB 2002; Tolimieri and Levin 2004). Recovery efforts are underway in the Cedar/Sammamish

Watershed through zoning regulations, critical areas ordinances, restoration actions, and habitat rehabilitation (WRIA 8 2005). Changes in harvest practices have also taken place over the past decade with substantial decreases in the exploitation rate on Chinook from the Cedar/Sammamish Watershed (PSIT and WDFW 2004). The HSRG (Hatchery Scientific Review Group) has started to look at the specific goals of salmon hatcheries in Washington State and have identified necessary steps that need to be taken to reduce the affect of hatchery fish on wild stocks (Mobrand et al. 2005).

While progress is made on habitat rehabilitation, hatchery reform, and reduced harvest on depressed stocks, only recently have we begun to understand some large-scale factors that influence productivity of salmon stocks such as ocean and climate conditions (Beamish et al. 1997; Mantua et al. 1997; Tanasichuk 1997). For instance, Tolimieri and Levin (2004) found an overall decrease in the average abundance of Chinook salmon in the Pacific Northwest since 1976 attributed to a climatic change. Locally, Winder and Schindler (2005) found a dramatic shift in the zooplankton community in Lake Washington that was a result of climate change. The shift is consistent with the findings of other scientists who have observed similar changes in other aquatic organisms (Myers et al. 1998; Finney et al. 2000). It will be important to integrate information on climate change and resulting marine and freshwater productivity with the other recovery efforts in order to succeed in salmon recovery in the Puget Sound ESU. There is little doubt the large scale climatic patterns will continue to influence the recovery of Chinook salmon across the range of the species, but it is important to continue with recovery efforts to increase the productivity of freshwater habitats in the Cedar/Sammamish watershed for salmon to withstand some of the larger forcing factors effecting their success.

Though we feel confident in our representation of Bear and Issaquah Creek sex ratios from carcass collections in 2003-2005, our carcass collection in the Cedar River may be biased toward the collection of female carcasses. The Cedar River is a much larger system than Bear Creek and bias may be associated with a larger female body size compared to males and the observation that females will often reside on a redd until senescence, while males will move away from a redd after spawning in order to find another female to spawn with (Briggs 1953; Groot and Margolis 1991; Chebanov and Riddell 1998; Zhou 2002).

We have observed differences in the strength of broodyears (e.g., the 2000 broodyear was strong while the 2001 broodyear was weaker) through our sampling efforts, and it will be important to monitor these differences over time to identify trends such as a change in the age structure, size, or spawning success of Chinook in the watershed. Declines in size and age at maturity may lead to populations of Chinook that are less well suited to their environment than their predecessors and less likely to adapt to or survive large disturbances, either natural or anthropogenic (Roni and Quinn 1995; Reisenbichler 1997; Quinn 2004). In comparing the overall lengths of Chinook in the watershed to those throughout their range, the Chinook in the Cedar/Sammamish Watershed appear to be in the high-middle range of Chinook salmon populations from Oregon to Alaska (Roni and Quinn 1995). Similarly, the dominant age class for Chinook salmon in the Cedar/Sammamish watershed is four years which is consistent with other fall Chinook throughout Puget Sound (Baranski 1979) and typical for ocean type Chinook throughout their range (Groot and Margolis 1991).

Pre-spawning mortality is an indicator of reduced fitness in females and has implications for estimates of freshwater productivity using redds as an index of abundance (Fleming and Gross 1992). In the Cedar/Sammamish watershed, we found the lowest incidence of PSM on the

spawning grounds in the Cedar River with two percent or less each year, and the highest observed PSM occurred in Issaquah Creek (approximately 23 percent) in both 2003 and 2005. We found that PSM was higher for marked fish than unmarked Chinook (Table 10), and it will be important to continue to monitor this in the future. Fleming and Gross (1993) found that hatchery female coho averaged a mere 82 percent of the breeding success of wild females in the same system supporting our observations of unmarked female Chinook having a lower incidence of PSM than marked females. Several other studies have observed a similar phenomenon, and have suggested that through domestication, hatchery females are less fit to spawn naturally than their wild counterparts (Fleming and Gross 1992, 1993; Reisenbichler 1997; Quinn 2004; Thorpe 2004; Goodman 2005; Oosterhout et al. 2005).

For nearly 70 years the Issaquah hatchery has been releasing large numbers of Chinook into the basin yet the ecological effects are poorly understood. After the implementation of mass marking beginning with the 1999 broodyear, we are now able to track the distribution of hatchery fish throughout the watershed and understand the proportion of hatchery fish on the spawning grounds. Interbreeding of hatchery fish with the wild population in the Bear Creek Basin is substantial since over half of the fish returning to the Bear Creek Basin have been marked in each year we have sampled. Large numbers of hatchery origin Chinook spawning in the wild have been demonstrated to have negative genetic impacts on extant wild populations (Reisenbichler 1997; McElhany et al. 2000; Myers et al. 2004; Utter 2005) particularly in cases such as the Cedar/Sammamish watershed where returns of hatchery Chinook are increasing while returns of naturally spawning fish have declined overall since the early 1980s (Figure 2). Our observations in the Bear and Issaquah Creek Basins in 2003 through 2005 (Table 3), suggest that these populations are being driven by hatchery fish straying from the Issaquah Creek Hatchery. These observations are consistent with the findings of genetic analyses conducted by Marshall (2000), Young and Shaklee (2000) and Warheit and Bettles (2005). In the Cedar River the introgression with Issaquah Creek hatchery stock appear to be less than the other basins in the watershed (Warheit and Bettles 2005). However, approximately 30 percent of carcasses recovered below Landsburg Dam are marked.

We found a negative correlation between the geographic distance from the Issaquah Hatchery and the proportion of the naturally spawning population that was of hatchery origin (adipose fin marked) suggesting that the straying effects are largely proximal. Additionally, tributaries of the Sammamish River may have a much higher incidence of hatchery Chinook on the spawning grounds than the Cedar River since the Sammamish River is a migratory corridor for all fish returning to tributaries of Lake Sammamish, most notably the Issaquah Creek Hatchery. It has been suggested that warm water in the epilimnion of Lake Sammamish draining into the Sammamish River may also have an affect on straying rates by enticing fish in pursuit of escaping the warm water temperatures in the Sammamish River into areas of thermal refugia offered in tributaries such as Bear and Cottage Lake Creeks (WRIA 8 2005). It is clear that we do not fully understand the spatio-temporal scales at which the hatcheries in the watershed effect conspecific natural spawning fish, but through this work and the implementation of mass marking at the hatcheries, we are beginning to understand these interactions.

Variation in straying among rivers and streams may be influenced by fishing regulations, angler access, heredity, practices of local hatchery personnel, and other factors (Hassler and Scholtz 1983; Quinn and Fresh 1984; McIssac and Quinn 1988). Quinn and Fresh (1984) found straying to be positively correlated with age at return and negatively correlated with number returning. Older fish arrived on the spawning grounds earlier in the season and stray more

during years of poor overall returns (Quinn and Fresh 1984). The variability observed in the number of returning adults to the hatcheries in the basin (Figure 2) coupled with the interannual variability in straying observed on the spawning grounds and at the Landsburg fish passage facility suggests that stray rates may be different from year to year at particular locations within the watershed. Although we have considerable straying within the basin (UW and Issaquah Creek Hatcheries) and a small number from the Grover's Creek Hatchery, we have not observed appreciable straying from adjacent watersheds such as the Snohomish or Green River despite large hatchery programs that occur there.

A similar experience was observed by Pascual and Quinn (1994), where they found homing to the Columbia Basin to be very precise despite considerable straying within the Columbia Basin. Quinn and Fresh (1994) found that Chinook salmon fidelity averaged 98.6 percent in the Cowlitz River, and that most of the strays were found in nearby spawning areas although fish were found in spawning locations in Puget Sound and the Juan de Fuca Strait, similar to our recovery of a Cowlitz River Chinook in Bear Creek in 2005. The relatively small number of strays may have a disproportionate consequence on the genetic composition of regionally adapted Chinook since many Chinook populations naturally occur in small, locally adapted spawning populations (Groot and Margolis 1991). Although the majority of fish return to their natal stream, Quinn (1993) found hatchery fish strayed more than wild fish. Stewart et al. (2004) also found that males stray more than females which supports our findings and lends further credence to the hypothesis that older fish stray more than younger fish since female Chinook are typically older than males (Groot and Margolis 1991).

Empirical evidence demonstrates a potential for deleterious interactions, both demographic and genetic, from allowing hatchery-origin salmon to spawn in the wild (Allendorf and Waples 1996; NRC 1996; Felsenstein 1997; Chebanov and Riddell 1998; PSTRT 2003; Goodman 2005; Myers et al. 2004; Utter 2005). Oosterhout et al. (2005) suggested that hatchery supplementation programs may yield short-term increases in adult coho, but that these small gains would have long-term consequences that contribute to an overall decline in the abundance of wild fish. Several other studies suggest that hatchery reared fish reduce the ability of populations of wild fish to increase in abundance which is often the intent of managers in initiating a hatchery (Fleming and Gross 1992; Carr et al. 2004; Thorpe 2004; Weber and Fausch 2005). Some of the impacts of previous hatchery practices on wild stocks may be reduced by using locally adapted stocks (Brannon et al. 2004) and through properly integrating naturally produced fish into hatchery production. We do not know if that is the case in the Cedar/Sammamish watershed, but given the proportion of hatchery origin fish on the spawning grounds it is important to measure the impact of supplementation programs in the watershed. Similar studies throughout the Pacific Northwest prompted the ISAB (Independent Scientific Advisory Board) to recommend that management agencies be vary cautious when making decisions that allow hatchery-origin adult salmon to spawn in the wild (ISAB 2002). Several authors point out that when hatchery origin Chinook are allowed to spawn with wild fish a loss of local adaptation may occur which reduces the ability of the wild population to persist (NRC 1996; Chebanov and Riddell 1998; ISAB 2002; Brannon et al. 2004; Utter 2005). Recent work by Warheit and Bettles (2005) suggest that some genetic degradation has occurred within these Chinook populations in the Cedar/Sammamish watershed as a result of hatchery introgression.

Successful management of Chinook requires integration of short-term strategies aimed at preventing further erosion of genetic resources with longer-term strategies of conservation, protection, habitat restoration, and monitoring to increase the abundance of wild stocks

(Nehlsen et al 1991; McElhany et al. 2000; Reisenbichler et al. 2003; Goodman 2005; Utter 2005). This is particularly important once a population declines to a level that warrants ESA listing. Our observations of hatchery straying on the spawning grounds supports the notion that hatcheries have unknown and unintended consequences on natural spawning populations where hatcheries do not occur particularly within the same watershed. Neither Bear Creek nor the Cedar River basins have Chinook hatcheries; although in both cases, hatchery strays from within and outside of the watershed stray to the spawning grounds in these two basins. Marshall (2000) and work by Warheit and Bettles (2005) suggest that there is already genetic exchange occurring between Chinook populations in Issaquah Creek, Bear Creek, and the Cedar River Basins supporting our observations of the occurrence of hatchery strays on the spawning grounds. This reinforces that it is critical to work on recovery efforts that reduce further genetic influences of hatchery produced Chinook on natural origin spawners and to understand how hatchery operations can be modified to benefit wild stocks in the Cedar/Sammamish Watershed. It is imperative to monitor those populations to evaluate the extent of further genetic erosion, productivity, and changes in population parameters in order to implement strategies that maintain the viability of Chinook in the Cedar/Sammamish Watershed while at the same time providing for sustainable and harvestable levels.

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