CHAPTER 3: THE SCIENCE FOUNDATION

Chapter 3: The Science Foundation

What do we know and need to know about salmon and their habitat needs?

The science foundation for the WRIA 8 Conservation Plan rests upon our knowledge of Chinook salmon and habitat conditions within the Lake Washington/Cedar/Sammamish watershed. This section of the plan provides a description of the scientific information used to develop the WRIA 8 conservation strategy, including analytical tools, existing information about salmon populations, and habitat conditions within the system.

Scientific Analysis Approach

The WRIA 8 Technical Committee (W8TC) developed three tools to use in determining basin conservation strategies for Chinook habitat protection and restoration. Those tools included a Viable Salmonid Population (VSP) framework, a Watershed Evaluation, and an Ecosystem Diagnosis and Treatment (EDT) model adapted for WRIA 8. A description of each tool follows, as well as a discussion of how it was developed and applied to form the conservation strategies. The results of applying these tools, as well as the strategies developed for salmon conservation, are identified in Chapter 4, Chinook Conservation Strategy for WRIA 8.

Viable Salmonid Population Framework

NOAA Fisheries developed the VSP concept as guidance for regional conservation efforts to restore the viability of salmon populations. A viable salmonid population is defined as "an independent population of any Pacific salmonid (genus *Oncorhynchus*) that has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic changes over a 100-year time frame (McElhany et al. 2000)." Four population attributes are used to evaluate population viability:

- Abundance: How many fish are there at various life stages?
- Productivity/Population growth rate: Is the population replacing itself or growing?
- Spatial Structure: How are fish geographically distributed?
- Diversity: How many life history strategies (variation in how habitat is used in space and time) are present and how diverse is the population genetically?

Please see Appendix C-1 and McElhany et al. (2000) for additional information on the VSP concept, VSP attributes and their evaluation.

Objective, Development and Application

The VSP framework was developed to document hypotheses relevant to current population status and prescribe logical objectives to minimize the risk of extinction faced by WRIA 8 Chinook populations. The framework was developed through:

1. Defining the VSP attributes based on McElhany et al. (2000);
2. Documenting assumptions and guiding hypotheses for each VSP attribute (diversity, spatial structure, productivity, and abundance);
3. Evaluating how changes in population or habitat conditions affect risk for each VSP attribute, based upon assumptions, hypotheses and current population conditions;

4. Prescribing qualitative VSP objectives; and
5. Forming conclusions about the overall priority among populations within WRIA 8.

The framework was used, in conjunction with the Watershed Evaluation and EDT Modeling results, to interpret, prioritize, and sequence habitat restoration and protection potentials for WRIA 8 (see Appendix C). The evaluation of relative risk is a fundamental aspect of ESA response, and the VSP framework (and Watershed Evaluation) helped the W8TC interpret the EDT model results appropriately.

Watershed Evaluation

Watershed conditions, such as types of land use and vegetation cover, have a large effect on aquatic habitat conditions and the processes that create and maintain that habitat. For example, upland watershed conditions have a large influence on runoff amounts and quality through storage and filtering of rainfall and recharge of groundwater sources, which in turn, affects water temperatures and flows in aquatic ecosystems (Ziemer and Lisle 1998). As such, watershed conditions are an important component of any conservation plan addressing aquatic habitats and species. Neither the VSP framework nor the EDT Modeling account for watershed conditions and therefore, the watershed evaluation filled a hole in the analytical approach.

Objective, Development and Application

The Watershed Evaluation was developed to account for watershed conditions and how those conditions 1) influence existing instream habitat and 2) facilitate or limit the effectiveness of habitat protection and restoration actions that could be implemented. Development of the watershed evaluation included:

1. Evaluating watershed conditions for each sub-basin through the use of indicators. Indicators included both impact factors that degrade aquatic habitat and mitigative factors that contribute to aquatic habitat integrity (Table 3-1).
2. Ranking sub-basins into high impact, moderate impact, and low impact categories, based upon the watershed conditions.
3. Categorizing fish use of sub-basins using Chinook salmon demographic information (Table 3-2). This information was also used in the VSP Framework to assess relative Chinook spatial distribution in WRIA 8. Sub-areas were organized as:
    - Core areas: High Chinook abundance and frequent use (used in all years).
    - Satellite areas: Moderate Chinook abundance and moderately frequent use (used in most years).
    - Migratory areas: Areas used only for migration and rearing, not spawning.
    - Episodic areas: Low Chinook abundance and infrequent use (used in few years).
4. Developing priority tiering for sub-basins based upon watershed conditions and fish use. Developing broad strategies to address watershed conditions for each tier.

Table 3-1: Factors used to evaluate and rank watershed conditions.	
Impact Factors	**Mitigative Factors**
Total impervious area (%)	Forest cover (%)
Road crossings per kilometer (#/km)	Riparian forest cover (%)
Storm Volume	Wetlands (%)
Gradient >4% (% length)	Gradient <2% (% length)

The priority tiering was applied to WRIA 8 to identify the sub-basins that should be addressed first to minimize risk to Chinook populations. Watershed conditions were used to develop sub-basin specific land use recommendations, in light of EDT modeling results for instream habitat conditions. The Watershed Evaluation Report can be found in Appendix C.

EDT Modeling

The EDT model was developed to help diagnosis the condition of salmon populations based upon the instream habitat conditions they encounter and our understanding of how salmon respond to those habitat conditions (Lestelle et al. 1996; Mobrand 1999). The model is habitat-based and predicts how Chinook populations respond to changes in habitat resulting from such events as human modifications, climate change or natural landscape-scale events, to the extent that these changes can be described in terms of physical habitat changes in streams.

<u>Objective, Development and Application</u>

The objective of using EDT in WRIA 8 was to assess existing habitat conditions in order to develop prioritized habitat actions for Chinook salmon recovery ("diagnosis"). The second objective of the model was to test the relative benefits of suites of prioritized actions ("treatment") to allow the WRIA to pick the most effective suite of habitat protection and restoration actions, although this use of the model has not yet been utilized. The "diagnosis" portion of EDT was also conducted for coho salmon, although results have been interpreted only for Chinook at this time.

The "diagnosis" portion of the model included:

1. Establishing reaches for all Chinook- and coho-bearing aquatic areas with WRIA 8;
2. Compiling and entering environmental data (e.g., sediment, riparian vegetation, channel morphology) into the model describing current and 'template' (historic) habitat for each reach. Template conditions in the model are assumed to be 1850s pre-European settlement habitat with the current hydrologic routing (i.e., Cedar flows into Lake Washington rather than the Black River, and the outlet of the system is through the Ship Canal and Ballard Locks rather than the Duwamish River).
3. Narrowing the set of environmental data to those "ecological attributes" that most directly influence Chinook and coho populations, based upon "rules" for how Chinook and coho interact with the environment.
4. Applying "rules" to the ecological attributes to determine biological performance for Chinook and coho "survival attributes" (e.g., habitat diversity, key habitat quality, flow, and channel

stability). For WRIA 8, rules had to be developed for Lake Washington, Lake Sammamish, the Sammamish River, the Ship Canal, and the marine nearshore. Because of uncertainties regarding how WRIA 8 Chinook use the nearshore and estuary, as well as the documented use of the WRIA 8 estuary and nearshore by Chinook from other WRIAs, the Technical Committee did not rely on the relative geographic priorities produced by habitat modeling efforts. Using the comparison of historic versus current habitat conditions in the Tidal Habitat Model, the Technical Committee developed recommendations that focus on reversing the effects of anthropogenic modifications to the system and protecting remaining areas of functioning habitat.

5. Evaluating the influence of survival factors on population performance (i.e., habitat capacity, productivity, and life history diversity) through model application.

More detail about the EDT concept and model can be found at the Mobrand Biometrics, Inc. website (www.mobrand.com). A summary of the WRIA 8 Ecosystem Diagnosis and Treatment (EDT) Habitat Model is included in Appendix C-3.

The modeling results included identifying regional priority areas where habitat protection and restoration would most influence the Chinook populations and the habitat problems that affect individual reaches within the region. Those results were interpreted by the W8TC and integrated with results from the VSP Framework and Watershed Evaluation to develop a conservation strategy for each WRIA 8 Chinook population.

WRIA 8 Salmon Populations

The Puget Sound Technical Review Team (PSTRT, 2001) has identified two independent populations of Chinook in WRIA 8: the Cedar River and Sammamish River Chinook. The Sammamish River population includes North Lake Washington and Issaquah sub-populations. The population identifications are based on geography, migration rates, genetic characteristics, life history patterns, phenotypic attributes, population dynamics, and environmental and habitat conditions, all of which serve as indicators of reproductive isolation.

In their determination of population structure, the PSTRT notes that it is unclear whether the tributaries draining into the north end of Lake Washington historically supported an independent Chinook population. However, the PSTRT has also identified two factors indicating that this area has the potential to support independent Chinook populations. First, the PSTRT states that the Sammamish River drainage (including Issaquah Creek and the North Lake Washington Tributaries) is larger than the smallest watershed containing an independent population in their analysis of Puget Sound Chinook populations. Second, a recent analysis of spawner capacity developed for the PSTRT by NOAA Fisheries (NOAA Fisheries 2003) indicates that the Bear/Cottage system, the lower portion of North Creek, and Issaquah Creek have a high probability of supporting Chinook spawning, while Swamp Creek, Little Bear Creek, Carey and Holder Creeks, and the upper portion of North Creek have a moderate probability of supporting Chinook spawning.

While two populations are identified in WRIA 8 by the PSTRT, recent genetic information available at the time the Conservation Strategy was developed indicated that there may be enough difference between the North Lake Washington Chinook and fish returning to the Issaquah Creek Hatchery to consider them separate from one another (Marshall 2000), which may be especially true from a fisheries management perspective. In addition there are other differences such as run timing (e.g., the North Lake Washington Chinook run starts earlier than Issaquah Hatchery returns, peaks at approximately the same time, and tails off over a longer period) that may reflect genetic differences between North Lake Washington and Issaquah Chinook that should be maintained.

After much discussion, the WRIA 8 Technical Committee decided to take a precautionary approach and plan for three populations: the Cedar River population, the North Lake Washington population, and the Issaquah population. The Technical Committee recognizes that the Issaquah and North Lake Washington populations are closely linked, with the Issaquah Hatchery population influencing the North Lake Washington population. The W8TC based their decision to plan for three populations on the desire to adopt a conservative approach to WRIA 8 Chinook populations in light of uncertainties about population structure, and the potential that unique genetic characteristics necessary for the long-term viability of the Issaquah and North Lake Washington populations, if lost, may not be recovered. This conservative approach is consistent with the Steering Committee's objective that the Plan preserves options and opportunities for recovery. By identifying three populations, the WRIA placed priority on protecting all Chinook within the watershed, as well as any local adaptations that these fish possess. This approach supports the continued survival of offspring of naturally spawning Issaquah Hatchery Chinook strays which would be protected under the Endangered Species Act. In addition, the three population approach errs on the side of caution to maintain future opportunities for conservation in the Issaquah sub-area. Finally, this approach confers ancillary benefits on other species such as coho, and supports the widest level of stakeholder participation, all of which are consistent with the Steering Committee's stated goals and objectives. Throughout this document, three populations will be discussed, consistent with the direction that WRIA 8 chose to take with Chinook recovery. <u>The reader should note that the use of the term 'population' as it relates to Chinook throughout this document reflects the WRIA 8 Technical Committee's precautionary approach, and that the term is therefore NOT synonymous with the PSTRT's use of the term</u>.

The discussions surrounding WRIA 8 population structure are continuing as new information materializes. In 2003, returning adult hatchery Chinook were adipose-clipped for the first time. Stray rates in that year indicated that there were more hatchery-origin fish on the spawning grounds than expected (22% of spawners in the Cedar River mainstem, 54% of spawners in Bear/Cottage Creeks, and 48% of all spawners in the WRIA). While straying is a natural phenomenon, the large releases of hatchery fish (e.g. 2 million Chinook fry are released annually from the Issaquah hatchery) combined with small populations of naturally-spawning Chinook in WRIA 8 (average adult returns to the Cedar River, for example, was only 325 fish between 1998 and 2002) mean that the relatively high contribution rates of hatchery-origin fish could pose a risk to the genetic diversity of the Cedar and North Lake Washington populations.

The WRIA 8 Technical Committee has initiated a genetic study with Washington Department of Fish and Wildlife (WDFW) to analyze juvenile samples taken from the three assumed populations in WRIA 8, samples from hatcheries known to contribute to adult returns (e.g., University of Washington, Issaquah, Grover's Creek)[1], as well as archived scale and tissue

[1] Hatchery-origin salmon are differentiated from natural-origin salmon by a clipped adipose fin. While the practice of 'ad-clipping' helps to identify hatchery origin of returning adults, it does not identify the specific hatchery of origin. In order to confirm the hatchery of origin, a hatchery-specific Coded-Wire Tag (CWT) is implanted in a portion of juveniles released from the hatchery. The Issaquah hatchery recently began a CWT program for a portion of hatchery releases, but these tagged fish have not yet returned as adults. In the absence of this confirmation, the assumption that the majority of ad-clipped hatchery fish observed on the Cedar River and North Lake Washington spawning grounds are coming from the Issaquah hatchery is based on the following lines of evidence:

samples from adult spawners. It is expected that this study will help address a number of uncertainties surrounding current genetic differences that exist among wild and hatchery Chinook stocks in WRIA 8. However, it is likely that there will be continued questions regarding the interactions of hatchery and wild Chinook. The WRIA 8 Technical Committee and participating scientists plan to review the genetic study and provide the information to the PSTRT for consideration in identifying independent populations within WRIA 8. The Technical Committee will then adapt the Conservation Strategy in light of this new information. Potential revisions to the Conservation Strategy are summarized in Chapter 4 and in Appendix C-5.

Cedar River/South Lake Washington Population

Adults from all WRIA 8 populations return to the watershed primarily between June and September. The Cedar River/South Lake Washington population (Cedar) spawns in the Cedar River and in some of its tributaries (Taylor, Peterson, and lower Rock creeks and the Walsh Lake Diversion Ditch) between September and November. Juveniles, after emerging from the gravel, migrate into the south end of Lake Washington either as fry or fingerlings between February and June. While in the lake, the juveniles rear and migrate north along the shoreline in shallow habitats with gentle gradient and small substrates (Tabor and Piaskowski 2002). They also utilize small creek mouths (Tabor et al. 2003). Once they become larger (May or June), most of the juveniles move offshore and prepare to exit WRIA 8 through the Ship Canal and Hiram M. Chittenden Locks (Locks). Chinook smolts typically enter saltwater between May and July (DeVries 2001; DeVries 2002). They then spend time rearing in the marine nearshore environment of WRIA 8 and other areas of Puget Sound before migrating to the larger ocean.

Based upon the abundance of adults using various areas and the frequency of that use, the following categorizations were made for the sub-basins with the Cedar River (Table 3-2):

- Core areas: Lower and Middle Cedar River (below Landsburg Dam)
- Satellite areas: Upper Cedar River (above Landsburg Dam), Taylor / Downs Creek and Walsh Lake Diversion Ditch.
- Migratory areas: Lake Washington, Ship Canal, Lake Union, Locks and Marine Nearshore.

- Geographic proximity and number of fish released. The only other Chinook hatchery within WRIA 8 is the University of Washington's Portage Bay facility, which releases less than 10% of the fish released by Issaquah (180,000 vs. 2,000,000 annually).
- It is unlikely that the majority of ad-clipped fish observed in the Cedar came from hatcheries other than Issaquah. Although CWTs from Grovers Creek and the UW have been recovered in the Cedar River (during 2003 13 CWTs were recovered out of 329 carcasses), these hatcheries produce far fewer fish and CWT a significantly greater portion of releases (60-100% depending on the year). Although 100% of UW releases were tagged in 1996-7, no UW tags were found on the Cedar River spawning grounds when these fish returned as adults. Similarly, 100% of Grovers Creek fish released in 1995 were tagged, and no Grover's Creek fish were observed on the Cedar spawning grounds when these tagged fish returned as adults.
- The Soos Creek Hatchery began ad-clipping Chinook prior to the Issaquah Hatchery. In years when 4 and 5 yr-old ad-clipped fish were returning to the Soos Creek hatchery, no ad-clipped fish were observed in the Cedar River. Also, the Soos Creek hatchery CWTs 10-15% of releases and no Soos Creek tags have been found in WRIA 8 to date.
- Significant numbers of ad-clipped Chinook were first observed on the Cedar River in the first year (2003) that clipped adults began returning to the Issaquah hatchery in significant numbers (as 3-yr olds).
- The timing of ad-clipped fish in the Cedar River coincides with the peak returns to the Issaquah Hatchery, and is different from peak returns to the UW, Soos, and several other regional hatcheries.

- Episodic areas: Lower Rock Creek, Peterson, Walsh Lake Diversion Ditch, Madsen and Molasses creeks.

Diversity. Diversity is the least understood of the VSP attributes throughout the watershed. Adults are generally believed to be wild, native fish (Table 3-2), although juvenile hatchery Chinook salmon were introduced to the system between 1944 (Ajwani 1957) and 1965 (WDFW hatchery planting records). In addition, hatchery adults were found in the Cedar River during the 2003 spawning season (about 25% of adult returns; Burton et al. 2004), the first year that ad-clipped Issaquah hatchery fish returned to the watershed in significant numbers. Spawning generally occurs between August and November (Priest and Berge 2002; Burton et al. 2003). Juveniles emerge from the gravel between January and April and exhibit two rearing strategies, both consistent with an ocean-type life history (i.e., spending less than one year in freshwater). In most years, the majority of juveniles enter Lake Washington within days of emergence (fry migrants; Seiler et al. 2003). A smaller portion of juveniles rear in the river, then enter the lake as larger fingerling migrants later in the spring and early summer. The small proportion of fingerling migrants in the population is believed to be caused, in part, by habitat loss in the Cedar River.

Insert Table 3-2: WRIA 8 Chinook Salmon Population Analysis Matrix
11 X 17 file

Abundance. The number of adult Chinook returning to spawn in the Cedar River has declined in recent years, with the five lowest escapements occurring in the last eight years (Figure 3-1). However, 2001 and 2002 illustrated increases in the number of redds over 1999 and 2000 (Table 3-3). Between 1964 and 1999, the adult returns to the Cedar River averaged approximately 750 fish. However, the National Marine Fisheries Service Biological Review Team (NMFS BRT) estimated the 5-year geometric mean abundance between 1998 and 2002 of 327 fish returning to spawn in the Cedar River (NMFS BRT 2003). Abundance trends illustrate that the Cedar River population is in steep decline. Reduced abundance is primarily driven by habitat degradation and the loss of life history diversity, among other factors that fish face upon entering Puget Sound (e.g., ocean conditions, harvest).

Spatial Structure. Adult Chinook habitat use in the Cedar River system is concentrated in the mainstem river below Landsburg Dam (river miles [RM] 14-18), with small use of larger tributaries. The area above Landsburg Dam was made accessible to Chinook in the fall of 2003, increasing the spawning area available in the Cedar River system. There is no known use of tributaries to Lake Washington for spawning. Juveniles exhibit some spatial variation, with fry migrants using shallow shoreline and small creek mouth habitats in Lake Washington and fingerling migrants using edge habitat in the Cedar River itself.

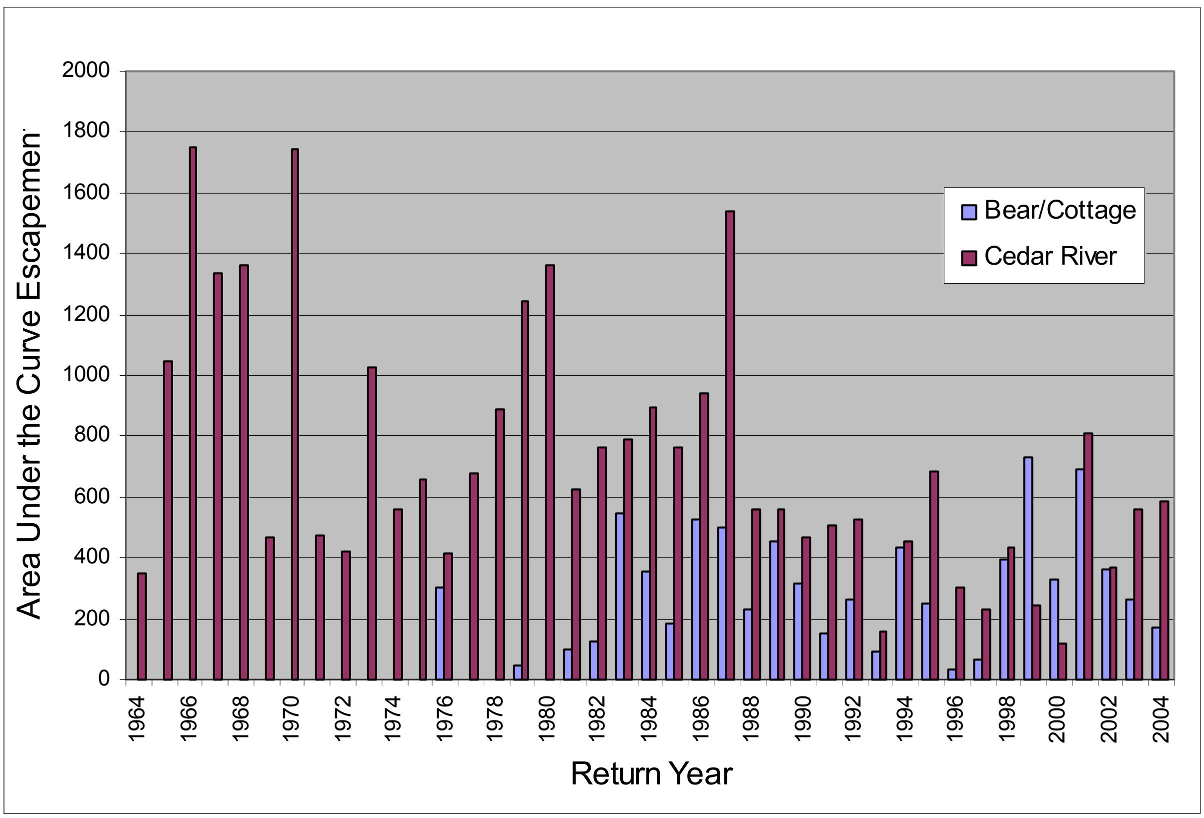

Figure 3-1: Historic escapement index estimate for Lake Washington Chinook based on fish counts and Area Under the Curve methodology, 1964-2004 (Burton et al. 2004)

Table 3-3: Number of redds recorded in the Cedar River and tributaries in 1999-2002.				
Survey Year	**Initiation of Surveys**	**Completion of Surveys**	**Total Cedar Redds**	**Trib. Redds**
1999	Aug. 18th	Nov. 19th	180	NS
2000	Aug. 17th	Nov. 30th	53	0
2001	Aug. 15th	Nov. 15th	390	8
2002	Aug. 7th	Nov. 15th	269	12

Productivity. The WRIA has not calculated a population growth rate for the Cedar River population, although Table 3-2 includes information on the estimated numbers of fry and smolts produced per adult female. The NMFS BRT estimated population growth rates for the Cedar River population for the 5 most recent years (1997-2001). The growth rate for the Cedar population ranges between 0.933 and 0.966 depending on the number of years of data and influence of hatchery fish on the spawning grounds (see Appendix C-1 for more discussion of these growth rates; NMFS BRT 2003). A population growth rate of 1 indicates that the population is replacing itself. A growth rate above 1 is a population that is increasing in size and a rate below one indicates a population in decline. Calculations by the NMFS BRT, as well as the steep decline in adult returns between 1964 and today, suggest that the population does not currently replace itself in most years. Reduced productivity appears to be strongly linked to habitat loss.

North Lake Washington Population

The North Lake Washington population (NLW) spawns in the tributaries to northern Lake Washington and the Sammamish River between September and November. This includes Bear, Little Bear, North, Swamp and Kelsey creeks. Similar to migration behavior seen in the Cedar River, juveniles migrate into the Sammamish River or Lake Washington either as fry or fingerlings between February and June. Juveniles rear as they migrate towards Lake Washington and typically enter the lake at a larger size than their fry migrant counterparts from the Cedar River. While a small portion of the NLW juveniles use nearshore areas in Lake Washington, most fish are believed to move into offshore areas quickly. NLW Chinook smolts pass through the Ship Canal and Locks to reach Puget Sound during May, June and July (DeVries 2001; DeVries 2002). As with other Chinook smolts from WRIA 8, they rear in marine nearshore areas of Puget Sound before heading to the ocean.

The following categorizations were made for the sub-basins with the NLW population (Table 3-2):

- Core areas: Bear and Cottage creeks.
- Satellite areas: Evans, Swamp, Little Bear, North, and Kelsey creeks.
- Migratory areas: Sammamish River, Lake Washington, Ship Canal, Lake Union, Locks and Marine Nearshore.
- Episodic areas: McAleer, Juanita, Thornton, May, and Coal creeks.

Diversity. The NLW population is believed to be composed of wild, native fish (Table 4-2), however, a substantial number of hatchery fish have been found on the spawning grounds (about 54%) during 2003. These hatchery fish are presumed to be from Issaquah Creek due to a very similar migration pathway and the fact that ad-clipped Chinook have not been observed in significant numbers on the spawning grounds until ad-clipped Chinook began returning to the Issaquah hatchery. For more discussion about the presumption that hatchery Chinook are from the Issaquah hatchery, please see the footnote on page 6 of this Chapter. Spawning generally occurs between September and November (Mavros et al. 2000). Juveniles emerge from the gravel between January and April and exhibit two rearing strategies, a fry migrant and smolt migrant. The proportion of fish exhibiting the smolt migrant life history type appears to be related to river flow and this type dominates in low flow years (Seiler et al .2003). It is hypothesized by the WRIA 8 Technical Committee that this population historically had relatively even genetic diversity due to the similarity between the tributary sub-basins connected to the Sammamish River. Typically salmon are best adapted to their natal streams due to selective pressures of the habitat of that system (e.g., flow regimes, habitat types, underlying geology). When conditions are similar between sub-basins, there are few differences in the selective pressures to drive genetic diversification or cause increased survival of fish with different genetic traits than those of the larger population. Because Bear, Little Bear, North, and Swamp creeks historically had similar conditions, such as flow regimes and habitat types, it is unlikely that salmon returning to Bear Creek evolved to be significantly genetically distinct from those returning to Little Bear, Swamp, or North Creeks.

Abundance. As with the Cedar River population, the NLW population has declined in number in recent years. Between 1985 and 1999 the adult returns to Bear Creek, the core spawning area, averaged approximately 400 fish (Table 3-2). The NMFS BRT estimated the 5-year geometric mean abundance (1998-2002) of 331 fish returning to spawn (NMFS BRT 2003). Returns to other NLW creeks ranged between one to 25 fish, except for Kelsey Creek that has averaged 138 adult returns in 1999 and 2000. Spawning surveys on many of the creeks in this population have been spotty, providing less accurate abundance information than is available for the Cedar River. Overall, the abundance of this population is considered extremely low for long term viability.

Spatial Structure. The spatial structure of the NLW population is severely restricted, mostly as a result of habitat degradation. Adult Chinook spawning occurs primarily in Bear Creek (90%), with small numbers using other tributaries of the Sammamish River and Lake Washington. The Technical Committee hypothesizes that spawning was historically more evenly distributed across the larger creeks, such as Bear, Swamp, North, and Little Bear. The PSTRT (2001) notes that there is a lack of information regarding historic Chinook use of the Sammamish River tributaries, making this hypothesis difficult to confirm. Based on the spawner capacity analysis recently developed for the PSTRT by NOAA Fisheries (NOAA Fisheries 2003), the Bear/Cottage system and the lower portion of North Creek had a high probability of supporting Chinook spawning, while Swamp Creek, Little Bear Creek, and the upper portion of North Creek had a moderate probability of supporting spawning. Juveniles exhibit some spatial variation in the time that they inhabit the Sammamish River and Lake Washington (fry and smolt migrants).

Productivity. The WRIA has not calculate a population growth rate for the North Lake Washington population, although Table 3-2 includes information on the estimated numbers of fry and smolts produced per adult female in Bear Creek. The NMFS BRT estimated population growth rates for the North Lake Washington population for the 5 most recent years (1997-2001). This growth rate estimate ranges between 0.995 and 1.077, depending on the number of years of data and influence of hatchery fish on the spawning grounds (see Appendix C-1 for more discussion of these growth rates; NMFS BRT 2003). A population growth rate of 1 indicates that the population is replacing itself. A growth rate above 1 is a population that is increasing in size and a rate below one indicates a population in decline. The population is in better shape than the Cedar River population, however, productivity needs to increase to increase abundance and allow the population to spread to vacant habitats.

Issaquah Population

The Issaquah population spawns in tributaries to Lake Sammamish, including the Issaquah Creek system and Lewis and Laughing Jacobs creeks. This population also contains the Issaquah hatchery and population propagation occurs through both natural and artificial spawning between September and November. Migration behavior and timing of naturally-spawned juveniles have not been investigated in great detail, however, limited information indicates that they migrate into Lake Sammamish as either fry or fingerlings, similar to behavior seen in the NLW and Cedar populations (Seiler et al. 2003). Juveniles rear as they migrate towards Lake Washington and typically enter that lake at a large size, moving quickly into offshore areas. While in Lake Sammamish, juvenile chinook likely use shallow areas with gentle slopes, similar to fish in Lake Washington. As with other WRIA 8 smolts, those from the Issaquah population pass through the Ship Canal and Locks to reach Puget Sound during May, June and July, and then rear in Puget Sound before reaching the ocean.

The following categorizations were made for the sub-basins with the Issaquah population (Table 3-2):

- Core areas: Issaquah Creek including tributaries Upper, Middle, Lower, East Fork, North Fork, and Fifteenmile Creek).
- Satellite areas: None.
- Migratory areas: Lake Sammamish, Sammamish River, Lake Washington, Ship Canal, Lake Union, Locks and Marine Nearshore.
- Episodic areas: McDonald, Lewis and Laughing Jacobs creeks.

Diversity. The Issaquah population is composed of both naturally-spawned and hatchery fish (Table 3-2). It is unknown if Issaquah Creek or other tributaries supported an independent population of Chinook salmon prior to the hatchery.

Abundance. The Issaquah hatchery population is the only WRIA 8 population seen as healthy, with an average of about 3,000 adults returning annually between 1986 and 1999 (Table 3-2).

Spatial Structure. The spatial structure of the Issaquah population is limited to mostly the Issaquah Creek system. Current spatial structure is affected by habitat degradation and leaves the naturally-spawning proportion of the population open to catastrophic events.

Productivity. Because this population is hatchery dominated and not identified by the PSTRT, there are no estimates of the number of returning adults for each spawner. It is hypothesized that productivity (or success) of hatchery fish is not as high as that of naturally-spawning fish (based on existing research from other areas and salmonid species), although this has not been examined in WRIA 8. The relative success of hatchery versus naturally-spawning Chinook is being evaluated as part of the joint Chinook spawner surveys being performed by WDFW, the City of Seattle, and King County on the Cedar River, Bear/Cottage Creeks, and several other tributaries. Regardless, habitat in the Issaquah system and throughout WRIA 8 has been significantly impacted in the spawning, rearing, and migration areas.

Relationship between the WRIA 8 Populations

As discussed earlier, the WRIA 8 plan is based upon three Chinook populations, while the PSTRT identifies two populations. Our understanding of the relationships between populations within WRIA 8 are complicated by the amount of hatchery straying witnessed in 2003 (and presumed to have occurred in previous years before hatchery fish were ad-clipped) and limited by our current information about genetic differentiation within the watershed. A genetic study of WRIA 8 populations, currently underway, will help address a number of uncertainties surrounding current genetic differences that exist among wild and hatchery Chinook stocks in WRIA 8. However, additional studies will be necessary to evaluate the interactions of hatchery and wild Chinook.

In addition to uncertainties over two versus three WRIA 8 Chinook populations, there are some creeks that have questionable population affiliation (i.e., Lake Washington tributaries such as May Creek and Kelsey Creek). As more information becomes available, population affiliations for different sub-basins in the watershed may be modified accordingly.

Regardless of the population designations and the interactions between fish using different areas of the watershed, habitat needs are ubiquitous.

Relationship to Puget Sound Chinook ESU

The Puget Sound ESU contains 22 populations (PSTRT 2001). The PSTRT is concerned with a viable ESU and developing a strategy to achieve this relies upon all remaining 22 populations. In developing this strategy, the PSTRT will consider geography of the populations, differences in catastrophic risks, life history diversity and risks to individual population VSP attributes. The final strategy is not likely to rely upon all Puget Sound populations being at low risk of extinction, and the PSTRT could conceivably pursue an ESU recovery plan that maintains the WRIA 8 populations at high risk of extinction. Regardless of the acceptable level of risk to each population, the PSTRT has stated that none of the remaining 22 populations in Puget Sound can be allowed to go extinct if recovery is to occur.

However, the WRIA 8 Chinook populations are unique from other populations in the Puget Sound ESU, as these populations are the only ones that use a lake for rearing and migration. Even if WRIA 8's populations are managed at high risk of extinction as part of ESU recovery, the unique habitat use of these populations can be important for preserving unusual life history traits in the ESU. Additionally, WRIA 8 is the most highly urbanized watershed in the ESU and represents an opportunity to illustrate that urbanization and healthy salmon populations do not have to be mutually exclusive.

Habitat Conditions in WRIA 8

This section describes the historical and current habitat conditions, along with the factors that limit aquatic habitat, and therefore, salmon populations. This information is summarized from Kerwin (2001). Please refer to that report for more detail.

Historical Habitat Conditions and Major Watershed Alterations

Prior to settlement by European descendants, WRIA 8's aquatic areas were a network of lakes, streams, sloughs, marshes, islands, beaver ponds and estuaries. The watershed consisted of forested land, with meandering rivers and creeks. The Sammamish River valley was a complex of marsh and slough habitat. However, in the 1800's major alterations began in the Lake Washington/Cedar/Sammamish basin and continued into the 1900's. These alterations include:

- Logging of old growth forest changed land characteristics (e.g., soils, infiltration and evapotranspiration). Logging activities also disrupted instream habitat processes from log transport (e.g., splash dams), altered upland water storage and runoff, and reduced woody debris inputs.
- Construction of the Ship Canal and Locks created a new connection between Lake Washington and Puget Sound. The connection changed the outlet of Lake Washington from the Black River, at the south end of the lake, to the Ship Canal. This project caused Lake Washington's water surface elevation to drop about 10 feet (3 m), which in turn exposed about 2 mi^2 (5.4 km^2) of previously inundated shallow water area. Reduced water levels led to a 12.8% decrease in the lake shoreline, drained many of the lake's wetlands, and changed the tributary mouths that entered the lake (Chrzastowich 1983). Lowering the level of Lake Washington also dropped the elevation of Lake Sammamish and dried the marshes along the Sammamish River. With these alterations, the Black River went dry and the Lake Washington/ Sammamish system was separated from its historical drainage course to the Green/Duwamish River. About the same time, the Cedar River was re-routed into Lake Washington. Salmon were faced with a highly altered migration route to reach their natal habitat, as well as an abrupt, artificial estuary through which to migrate as they moved in and out of the WRIA 8 system.
- Urbanization and flood control activities further changed aquatic areas in WRIA 8. Water withdrawals to serve urban and agricultural areas removed both surface and groundwater from the Cedar and Sammamish rivers, and some of the tributaries. Vegetation was cleared to make way for development, affecting the infiltration and overland flow of water and degrading riparian areas. Riparian areas were further affected by flood control activities along many of the rivers and creeks, which disconnected the stream channel from its surrounding areas through the construction of levees, dikes and revetments. These structures modified sediment and wood recruitment, along with stream-floodplain interactions. Dredging was conducted in some areas to further reduce flooding, which effectively straightened and simplified the stream channels. Along lake and marine shorelines, development for residential, commercial, and industrial uses moved to protect property through installing bank armoring. Installation of armoring affected sediment recruitment from bank erosion and bluff sloughing.

Collectively, these alterations have disrupted many of the ecological processes that create and maintain aquatic habitat.

Current Habitat Conditions

Current habitat conditions in most areas of WRIA 8 are degraded. These habitat conditions are today a large result of our land use practices. Below is a brief description of habitat conditions for major sub-basins in WRIA 8. More details about existing habitat conditions can be found in Kerwin (2001).

Lake Washington

Lake Washington, the largest lake in Washington State west of the Cascades, has a surface area of 34.6 mi^2 (89.6 km^2), with a length of 18.6 mi (30 km) (north-south) and an average width of 1.5 mi (2.4 km). The mean and maximum lake depths are 108 ft and 220 ft (33 and 67 m), respectively. Lake Washington receives inflow from the Cedar and Sammamish rivers, as well as numerous creeks such as Kelsey, Thornton, Juanita, McAleer, Lyon and May. The lake drains through the Ship Canal to Puget Sound. The lake has over 80 miles of lake shoreline and almost all of the area surrounding the lake is developed for residential and commercial uses and, as such, the majority of the lake shoreline (>82%) is armored (Fresh and Lucchetti 2000; Weitkamp et al. 2000). The shoreline also contains numerous overwater structures (>2,700; Kerwin 2001). Lake Washington is used by all three populations in WRIA 8 as a migratory and rearing area.

Shoreline habitat conditions are important for juvenile Chinook using Lake Washington, particularly those from the Cedar River population. Degraded shoreline conditions resulted originally from lowering the lake water surface levels when the Locks were constructed. Further adverse impacts are a result of urbanization and the majority of the lake shoreline is now used for urban residential uses. Landscaped yards and bank armoring (bulkheads and riprap) have reduced the amount of riparian vegetation and woody debris contributed to the lake. Armoring has also modified substrates in shallow areas due to prevention of bank erosion and altering sediment dynamics at the water-land interface. Overwater structures have increased shading and segmented the lake shoreline and nearshore areas, affecting aquatic organisms such as benthic invertebrates, a prey item of juvenile Chinook (Warner and Fresh 1998; Kahler et al. 2000; Koehler 2002). Docks and piers also affect the migration movements of juvenile Chinook. These alterations have reduced the amount and quality of shallow water habitat, an important habitat for rearing juveniles (Tabor and Piaskowsi 2002; Tabor et al. 2003).

Lake Sammamish

Lake Sammamish covers about 7.6 mi^2 (19.8 km^2), with a length of 8 mi (13 km) (north-south) long and a width of 1.2 mi (2 km), and drains an area of 260.5 mi^2 (250 km^2). The mean depth of the lake is 58 ft (17.7 m) and a maximum of 105 ft (32 m). Issaquah Creek is the major tributary to Lake Sammamish, with other inflow from creeks such as Tibbets, Lewis and Laughing Jacobs. The Sammamish River drains the lake at the north end and a flow control weir in Marymoor Park controls the lake discharge. The majority of the lake shoreline is privately owned, mostly for residential uses. There are a few major parks along the lake shoreline, including Marymoor Park at the north end, Idylwood Park on the northwest side, and Sammamish State Park at the south end, which includes the mouth of Issaquah Creek. As with Lake Washington, much of the shoreline of the lake is armored and many docks and piers have been constructed to support recreation. Lake Sammamish is used as a migration corridor by the Issaquah Creek population.

There is similarity in habitat conditions and habitat use by Chinook between Lake Washington and Lake Sammamish. The shoreline habitat conditions of Lake Sammamish are important for juvenile Chinook (Tabor and Piaskowsi 2002; Tabor et al. 2003) from the Issaquah population. Shoreline armoring affects the quality and quantity of riparian vegetation and woody debris. Overwater structures affect both prey resources and migration behavior of Chinook salmon. These alterations have reduced the amount and quality of shallow water habitat.

The Cedar River

The Cedar River, originating in the Cascade Mountains, is the largest tributary to Lake Washington. The river is about 46 mi (74 km) in length and can be separated into the upper Cedar River, above Landsburg Dam, and the lower Cedar River. The upper Cedar River is about 25 mi (40 km) long and can be separated into sections between Landsburg Dam and Cedar Falls (accessible to anadromous fish) and between Chester Morse Reservoir and the headwaters (inaccessible to anadromous fish). The watershed drains an area of 125 mi^2 (324 km^2) and is almost completely owned by the City of Seattle. The watershed is operated to provide a clean source of drinking water for Seattle and surrounding areas. As such, it is mostly forested with coniferous trees in mutli-seral stages, from old growth to recently harvested areas (logging has been discontinued in the watershed in 1993). The upper Cedar River (between Landsburg Dam and Cedar Falls) became accessible to salmon in the fall of 2003 when a fish ladder was completed at Landsburg Dam. For the entire 2003 season, a total of 79 Chinook were passed above Landsburg Dam and spawning surveys confirmed the presence of 15 Chinook redds.

With passage at the ladder, there is about 14 mi (23 km) of additional habitat now available to Chinook, characterized primarily by a narrow valley with step-pool and plane-bed channel forms. There are several tributaries that enter the river, with upper Rock Creek being the largest. The mainstem channel does not contain much woody debris, due to past practices of removing wood to protect the dam at Landsburg. However the habitat is otherwise of high quality due to the cessation of logging and lack of development. This area is used by Chinook salmon for spawning and limited rearing as they move downstream. The area of the Cedar River above Chester Morse Reservoir is the only area in WRIA 8 known to contain bull trout and bull trout use the lake for general residence and tributary areas (i.e., Cedar and Rex rivers) for spawning and rearing.

Operation of the City of Seattle's water supply facilities on the Cedar River captures 43% of the upper Cedar River watershed runoff and significantly influences stream flows and aquatic habitat throughout the river below Masonry Dam (RM 35.6). A number of activities have been implemented in an effort to avoid flow-related impacts in the river including a comprehensive Instream Flow Incremental Methodology Study (IFIM; Cascade Environmental Services, Inc. 1991), adoption of an instream flow management regime (based on the IFIM study and additional biological and hydrologic investigations), and activities implemented as part of the Cedar River Habitat Conservation Plan instream flow management program (see City of Seattle 2000 [Sections 4.4, 4.5.2 and 4.6], 2002, 2003 and 2004 for more information). Instream flow management of the Cedar River aims to provide beneficial instream habitat conditions and avoid harm to fish species through a guaranteed flow regime, minimum and supplemental flow commitments, limits on stream rate reductions, and instream flow monitoring and research to inform real-time stream flow management activities. The program also includes evaluating the effectiveness of the instream flow program at avoiding impacts to fish species in the Cedar River.

The lower Cedar River, downstream of Landsburg Dam, runs for approximately 21 mi (34 km) before entering the southern end of Lake Washington. The lower river drains an area of 66 mi^2 (171 km^2) that contains a mixture of land uses. Most of the lower watershed is rural with forest cover; however urbanization has occurred in the vicinity of Renton and Maple Valley. The lower valley of the river is broad, with a wide floodplain in many areas and many tributaries including Lower Rock Creek, Peterson Creek, Taylor/Downs Creek and the Walsh Lake Diversion Ditch. A good portion of the lower river banks are armored with revetments and levees to provide flood control. That, combined with flow regulation from the dam at Landsburg, has reduced connectivity between the river and adjacent floodplain areas (Perkins 1994).

Bank armoring and residential land uses in riparian areas have reduced the sediment and wood supply, disturbed riparian vegetation, and reduced the areas available to accommodate flow during flood events. As such, the instream habitat is rather simple, with primarily glide and riffle habitat and few pools or off-channel areas. Chinook use the lower river for migration, spawning and rearing, although spawning is adversely affected by scour-causing flows (exacerbated by the lack of a floodplain). Rearing opportunities are limited by the lack of habitat complexity (e.g., pools and edge habitat).

<u>Sammamish River</u>

The Sammamish River, 13.8 mi (22.2 km) in length, connects the northern ends of lakes Sammamish and Washington. Including the watershed of Lake Sammamish (97 mi^2 or 251 km^2), the Sammamish River watershed covers about 240 mi^2 (622 km^2). The Sammamish River can generally be divided into two sections based on topography. The upstream section, running from the outlet at Lake Sammamish to River Mile (RM) 4.5 (7.2 km), runs through a broad valley that is more than one mile wide in places. This area contains the mouths of Bear and Little Bear creeks. Land uses in this upper section of the river include open space and recreation, urban residential and commercial uses associated with the cities of Redmond and Woodinville, and agriculture. The lower section of the river, from RM 4.5 to the confluence with Lake Washington, has a narrower valley that includes the mouths of Swamp and North creeks. Similar to the upper section, land uses include urban development in the cities of Bothell and Kenmore and open space. The Sammamish River is used mainly as a migratory corridor, with some rearing, by the Issaquah and NLW populations.

The Sammamish River has undergone some of the most dramatic alterations in the WRIA 8 system. Prior to settlement, the river was highly sinuous with many swamp, marsh, and forested wetland areas that were influenced by backwater effects from Lake Washington up past the confluence with Little Bear Creek. When the lake level was lowered, floodplain farming became possible on a large scale as much of the wetland areas were drained. Subsequently, much of the river was straightened during drainage projects and the projects to reduce flooding through dredging and bank armoring further eliminated connections between the river and its floodplain. As a result, river channel was reduced to approximately half its historic length, and wetland areas were reduced from approximately 3,000 acres (12 km^2) to 150 acres (0.6 km^2) (King County, 2002). These actions have altered sediment transport and the Sammamish River now contains a large amount of fine sediments. Adjacent land uses and bank armoring have degraded riparian conditions, affecting sediment and wood contributions from riparian areas. The channel and instream habitat has been highly simplified, with less than 1% pool habitat (R2 Resource Consultants 1999). The river also exhibits extremely high temperatures during the summer and early fall.

<u>Ship Canal and Lake Union</u>

The Ship Canal, approximately 14 km in length, was constructed in 1916 to provide navigable passage between Lake Washington, Lake Union and Puget Sound. The waterway is a narrow, armored channel in the Montlake and Fremont cuts and widens in Portage Bay, Lake Union, and Salmon Bay. Lake Union itself covers about 0.96 mi^2 (2.5 km^2) and has an average depth of 33 ft (10 m). Land use along the Ship Canal and in Lake Union is dominated by residential neighborhoods in the upland areas and water-dependent businesses bordering the shoreline. These water-dependent businesses include marinas, commercial shipyards and dry-docks, along with some houseboat communities. Development of the Ship Canal waterway has lead to extensive armoring of the shoreline, loss of natural shoreline vegetation, and increased overwater structures (Weitkamp et al. 2000; Toft et al. 2003). All three of WRIA 8 populations use this area for migrating from the Locks to Lake Washington.

The Ship Canal and Lake Union lack quality shallow water habitat and shoreline complexity. In addition, water temperatures in the Ship Canal have been increasing steadily over the last 30 years, with an increase in the number of days that temperatures are greater than 68^{o}F (20^{o}C) (Weitkamp et al. 2000). The area also is characterized by degraded water and sediment quality from upland urban runoff and adjacent commercial and industrial sites. The contribution of contaminants and increased nutrients is further complicated by the presence of salt water in the Ship Canal and Lake Union due to operation of the Locks. The salt water prevents mixing and creates anaerobic conditions in the summer. However, there is also some indication that the cooler salt water upstream of the Locks may help with regulating water temperatures and fish transition between salt and freshwater.

Hiram M. Chittenden Locks

The U.S. Army Corps of Engineers constructed the Locks in 1916, in conjunction with the Ship Canal. The Locks are located at the western end of the Ship Canal, at the downstream end of Salmon Bay. The water upstream of the Locks is mostly freshwater, although some saltwater does intrude into the area from Lock operations. The area downstream of the Locks is primarily saltwater, although a small freshwater lens occurs immediately adjacent to the downstream side of the structure. A narrow tidally influenced channel (inner Shilshole Bay) connects the Locks area with outer Shilshole Bay in Puget Sound.

The Locks includes two lock chambers (a large and a small lock), a dam, six spillways, a saltwater drain and a fish ladder (Figure 3-2). The lock chambers are connected hydrologically to the upstream and downstream water bodies through underground filing culverts. These culverts deliver freshwater from the upstream side of the Locks to the chambers to raise the water level and drain water in the chambers to the downstream side of the Locks to lower the water level. Water movement through the filling culverts happens rapidly and flows occur with great velocity. Immediately upstream of the Locks is a saltwater drain, which is located in a low point of Salmon Bay. The drain carries saltwater, which is heavier than freshwater and settles on the bottom of Salmon Bay, to the downstream side of the Locks. The spillways of the dam spill excess water. During smolt outmigration, they are fitted with smolt flumes to pass juveniles over the dam. Land uses downstream of the Locks are primarily residential and the shoreline of the waterway is primarily armored and lacks riparian vegetation (Toft et al. 2003). The Locks and the area immediately adjacent are used by migrating salmon, both adults and smolts. The adults primarily pass through either the lock chambers or the fish ladders. Juveniles primarily move through either the smolt flumes, lock chambers or the filling culverts. Upstream and downstream areas adjacent to the Locks are used for physiological transition between salt water and fresh water.

There are several problems that the Locks pose for aquatic habitat and for salmon directly. The Locks can cause direct injury to salmon smolts as they exit the system through entrainment in the filling culverts for the lock chambers. Additions to the Locks, such as smolt flumes and strobe lights, have been designed to entrain less fish into the culverts. Habitat-related issues include the lack of estuary habitat to transition between fresh and salt water. The amount of estuary area around the Locks is very small and there is an abrupt transition in salinity and temperature conditions. The estuary habitat is further restricted due to bank armoring and loss

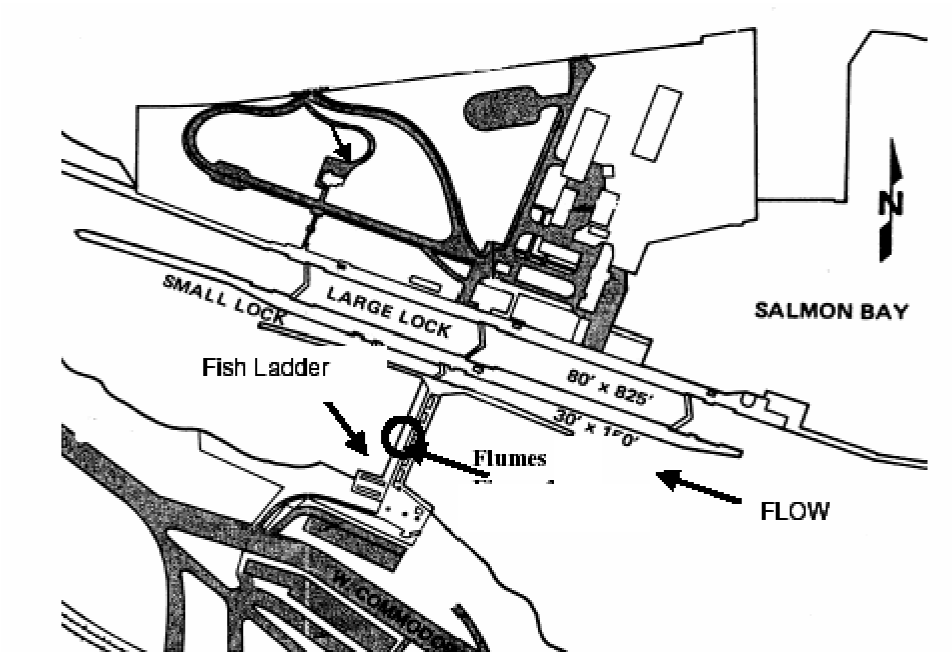

Figure 3-2: Illustration of the Ballard Locks (Kerwin 2001).

of riparian vegetation that has lead to a loss in shallow water habitat in the downstream area of the Locks.

<u>Marine Nearshore</u>

WRIA 8's marine nearshore stretches between West Point in the City of Seattle, northward to Elliott Point in the City of Mukilteo. The marine nearshore area is generally defined as the area between the upland-aquatic interface to the lower limit of the photic zone in the aquatic environment (roughly minus 30 m or 98 ft MLLW). The nearshore environment extends landward to include coastal landforms such as coastal bluffs, the backshore, sand spits, and coastal wetlands, as well as marine riparian zones on or adjacent to any of these areas. In addition, the nearshore environment includes subestuaries such as the tidally influenced portions of stream mouths.

The nearshore environment contains a variety of habitat types, such as eelgrass meadows, kelp forests, mud and sand flats, and tidal marshes. Similar to the interactions of streams with their floodplains, marine systems undergo physical, biological, and chemical processes to create and maintain habitat. These processes relate to tidal action, wave and wind energy, sediment recruitment and transport, and upland hydrology, among others (see KCDNR 2001). As with many other areas in WRIA 8, urbanization has occurred along much of the shoreline. Residential development occurs along the majority of WRIA 8's marine shoreline, with commercial and industrial uses occurring in some locations. These developments have armored banks and removed riparian vegetation. Much of the WRIA 8 shoreline is armored to protect the railroad tracks that run along the shoreline north of Shilshole Bay. Salmon use marine nearshore areas for rearing and migration, with juveniles using shallow shoreline habitats.

Marine shoreline habitat has been degraded through urbanization. Shallow gravel habitat has been lost due to disruption of natural beach forming processes, resulting from bank armoring that restricts the recruitment of sediment from adjacent areas. In addition, bank armoring concentrates wave energy at the face of the structure, increasing erosion of beach sediments. Docks, piers and jetties also alter sediment transport dynamics. The shoreline has also lost complexity from filling of tidal marshes and backshore areas, bank armoring and removal of riparian vegetation. Aquatic and terrestrial vegetation has also been lost due to development of shorelines and runoff from urbanized areas. While riparian vegetation has been directly removed as shorelines are developed, aquatic vegetation is affected by freshwater storm drains that concentrate runoff and impact marine aquatic plants that are adapted to increased salinity levels, such as eelgrass. Runoff can also increase turbidity, reducing the ability of light to penetrate the water and making deeper areas uninhabitable for photosynthetic plants.

<u>WRIA 8 Creeks</u>

The habitat conditions of creeks that drain to the Cedar and Sammamish rivers, lakes Washington and Sammamish and the marine nearshore area are numerous and include Piper's, Boeing, Bear, Little Bear, Thornton, Peterson, Kelsey and Rock creeks, among others. These creeks drain the surrounding watersheds, transporting water from upland areas to larger receiving water bodies. The creek watersheds contain a variety of land uses from undeveloped to rural residential and agriculture, to roads and rights-of-way, to commercial and industrial activities. Some, like Cottage Creek, are fairly undeveloped, while others like Thornton Creek are extremely urbanized. These creeks, depending on size and habitat conditions, can be used by adult Chinook for spawning. Juveniles may also spend limited time in the creeks to rear before migrating to downstream areas of the WRIA 8 system. For creeks that enter Lake Washington, Lake Sammamish, and the marine nearshore, the creek mouth habitat may be used by juveniles as they migrate along lake and marine shorelines (Tabor et al. 2003; Beamer et al. 2003).

Creek habitat can be affected by many land use practices. Impervious surfaces in the watershed alter the frequency, volume and quality of storm runoff reaching the creek. In the worst cases, these high flows are exacerbated by bank armoring and encroachment into the floodplain, which have reduced the channel capacity. Isolating the floodplain also cuts off the sediment supplies and disrupts the processes of sediment recruitment and transport. Often riparian vegetation is removed or degraded by either flow conditions or direct removal for residential landscaping. Lastly, culverts, weirs, and other instream structures cause barriers for the movement of fish and sediments. Creek habitat conditions vary in quality depending on their position in the urbanizing landscape. Kerwin (2001) provides more detail on individual creeks and Chapter 4, Chinook Conservation Strategy for WRIA 8, provides information about sub-basin conditions for creeks that contain spawning populations of Chinook salmon.

Habitat Limiting Factors

While WRIA 8 contains different sorts of habitats, the habitat limiting factors can be summarized into general categories for the lakes, rivers, and creeks, although the magnitude of impact varies by type of water body and specific watershed area. While these factors are listed separately, it is important to realize that the limiting factors interact with one another to exacerbate the habitat problems seen in WRIA 8's aquatic systems. The habitat limiting factors in WRIA 8 include:

Altered Hydrology

Urbanization within WRIA 8 has drastically altered upland, stream, and lake hydrology in most areas. Urbanization in upland areas (e.g., vegetation clearing, soil compaction, road and building construction) increases the amount of impervious surface within watersheds which, in turn, influences the infiltration of precipitation and increases the amount and rate at which surface water runoff reaches aquatic areas (Dunne and Leopold 1978; Poff et al. 1997). In river and creek habitats, the increase in flow can cause significant modifications to instream habitat and channels often respond to these flow regime changes through an overall enlargement, specifically channel incision and widening (Dunne and Leopold 1978). The increase in flow can have far reaching implications by displacing natural structure (e.g., coarse sediment and wood), increasing rates of erosion and decreasing overall bank stability. The effects of higher stream flows are further exacerbated by poor riparian conditions and disconnection of the stream channel from the floodplain, through bank armoring, channel incision and encroachment.

Alternatively, stream hydrology can be altered by regulation of instream flows and water withdrawals (either surface water or groundwater), that typically reduce water levels. This can reduce the flows available to form habitat and connect with off-channel areas. Flow withdrawals, particularly in drier months, can reduce base flow levels and reduce available habitat areas for fish.

Historic changes from lowering the level of lakes Washington and Sammamish, as well as regulating lake levels to vary only by 2 feet, reduces shoreline habitat complexity by limiting seasonal wetland formation and other habitat-forming interactions at the water-land interface. The amount of water available in Lake Washington also affects operations of the Locks and dictates how water is used at the smolt flumes and for boat lockages, affecting the outmigration route, and hence survival, of juveniles.

Loss of Floodplain Connectivity

Streams and rivers are dynamic systems that constantly interact with their surrounding floodplain (Naiman and DeCamps 1990; May 1996; Morley 2000). Bank armoring, dredging, channel incision and urban encroachment effectively channelize the stream and severely limit interactions between the stream channel and the adjacent floodplain. This reduces the recruitment of coarse sediments and wood from floodplain areas, and limits materials available for habitat forming processes. Additionally, urban systems have lost riparian areas as a result of bank armoring, development of drainage infrastructure, and increased buildable area in the watershed (May 1996). Without the floodplain, streams and rivers lose habitat complexity, most notably off-channel and margin refuge habitats that provide resting areas for migrating fish and slow velocity areas during high-energy discharge events. The interactions of water bodies with their adjacent land is similarly important for the lakes and marine nearshore of WRIA 8, which allows sediment and wood recruitment (discussed further under channel/shoreline complexity below).

Lack of Riparian Vegetation

Land development and encroachment into areas adjacent to streams has reduced the extent, composition, and integrity of riparian vegetation along all water bodies of WRIA 8. Mature, native plant communities, dominated by deciduous and coniferous trees, have been replaced by pavement, commercial/ industrial activities, landscaped residential yards and invasive-dominated shrub communities (e.g., Japanese knotweed and Himalayan blackberries). In addition, riparian zones have been isolated from aquatic environments by bank armoring. As a result, riparian function has been altered. The riparian zone along stream banks, as well as lake and marine shorelines, has little woody debris to contribute to the habitat of the adjacent aquatic area. Other riparian inputs, such as leaf litter and terrestrial insects, are reduced as well (Gregory et al. 1991; Morley et al. 2003; Sobocinski 2003). In creeks and rivers, degraded riparian vegetation combined with increased high flow events reduces bank stability and increases bank erosion (May 1996). These riparian alterations, combined with other factors, have reduced aquatic habitat complexity and the availability of prey resources for salmonids.

Disrupted Sediment Processes

Sediment recruitment, storage, and transport can be severely altered by altered hydrology, bank armoring, and reduced floodplain interactions. Depending on the flow dynamics, land uses, and underlying geology of the area, aquatic areas can suffer from either a lack of coarse sediments (e.g., gravel) or an abundance of fine sediments. Decreased gravel classes have been observed in urban streams as a result of altered sediment supplies and velocities (Finkenbine et al. 2000). Disconnecting stream, lake or marine nearshore areas from their adjacent floodplain/land interface has reduced sediment recruitment. Currents or flow velocities are responsible for distributing these substrates in the aquatic environment and without additional input, the system is left sediment deficient. In streams, increased stream gradients and flow velocities have further reduced retention of in-stream sediments (Pizzuto et al. 2000). These conditions reduce the ability of aquatic habitats to create and maintain habitats. In freshwater areas, this reduces the amount of spawning substrates that are available for salmonids and the habitat complexity of the stream or lake area to benefit rearing juveniles. In salt water areas, there is a loss of shallow gravel substrate areas for juvenile refuge and feeding.

While coarse sediment recruitment is a problem with floodplain isolation, increased fine sediment is often a problem as well, especially in urbanized streams (Wydzga 1997). Fine sediment can be supplied through either upland construction or erosion of the shoreline. Channel bank erosion, in particular, is a major source of fine sediment, which is exacerbated by increasing high flows (Paul and Meyer 2001). While habitat problems associated with find sediments are mostly limited to creeks and rivers, the introduction of fine sediment has implications for the food web. Most benthic invertebrates cannot forage effectively in areas dominated by fine sediments (Collier 1995). Sedimentation can also cause egg mortality by filling intragravel spaces in redds, which reduces water flow or traps developed fry in the substrate. Suspended sediments also affect salmonid behavior (Newcombe and Jensen 1996).

Loss of Channel and Shoreline Complexity

The combination of altered hydrology, loss of floodplain connection, degraded riparian communities, and altered sediment processes severely limits habitat forming processes and therefore, habitat complexity. This occurs in both lotic (streams and rivers) and lentic systems (lakes and the marine nearshore). In streams and rivers, the channel and banks are simplified, resulting in few pools and an abundance of glides and riffles, lack of instream structure, lack of coarse substrates, overhanging vegetation and woody debris, and little variation of edge habitat at the channel-floodplain interface. In lakes and the marine nearshore, there is an absence of high-quality, shallow water habitat with small substrates, in-water wood, overhanging vegetation, and variable edges at the land-water interface. Juveniles have poor rearing habitat that does not provide areas for foraging and refuge from predators (or in streams, high flows). Adult salmonids do not have areas to hold or rest while migrating, nor do they have large areas of suitable spawning habitat.

Barriers

Road crossings and other development activities have placed many creek channels in pipes and culverts (Finkenbine et al. 2000). Weirs and dams have also been installed in stream channels to reduce channel gradient and decrease stream velocity (May 1996). These structures were typically not designed to pass sediment or wood, and as a result, these materials are trapped in upstream areas, limiting their ability to contribute to downstream habitat formation. In addition, instream structures are often impassable to fish by creating outfall or velocity barriers (WDFW 1999), thereby restricting the amount of instream habitat available to fish. Fish ladders and downstream flumes, such as at the Locks and Landsburg Dam (Cedar River), are passable to adults and juveniles but may have detrimental impacts through delayed migration or other sub-lethal effects (although none have been documented).

Other Factors that Affect Chinook Salmon in WRIA 8

In addition to habitat limiting factors, other conditions affect WRIA 8 salmon populations as well. These conditions and activities interact with salmon populations in complex ways that are not discussed in detail here. Rather, these factors are presented in a simplistic fashion to provide a general overview of the negative effects that can occur on Chinook populations.

Degraded Water and Sediment Quality

Human-induced changes to water quality (e.g., industrial effluent, sewer overflows, urban runoff) can alter water temperatures, turbidity, oxygen content and nutrient and contaminant concentrations (Karr 1995; Paul and Meyer 2001). Water and sediment quality are degraded in the Ship Canal, Lake Union, and the Sammamish River, primarily in relation to water temperatures, although sediment quality is of concern in the Ship Canal and Lake Union as well. In general, these changes can affect the kinds, amounts, and activity of all aquatic organisms in streams (Welch et al. 1998). For salmonids in particular, poor water quality can harm them directly or indirectly through oxygen depletions, lethal temperature levels, acute and chronic toxicity, or prey reductions (Karr 1995; Bjornn and Reiser 1991).

Introduced Fish and Plant Species

These invasive species alter community and food web dynamics by increasing competition and/or predation for native species and affecting habitat types. Introduced fish can directly compete with native fish for prey or space or they can affect predation levels. Lake Washington, Lake Union, Lake Sammamish and the Puget Sound nearshore contain a variety of introduced aquatic species that may directly or indirectly affect juvenile salmon. For example, bass and perch are introduced fish that prey on juvenile salmonids. Shoreline alterations assist these non-native species through reducing juvenile refuge habitat and increasing bass and perch habitat (Kahler et al. 2000). Invasive aquatic plants can also increase habitat for predators (Bryan and Scarnecchia 1992). Invasive terrestrial plant species affect terrestrial litter and insect inputs, which can alter food web dynamics.

Ocean Conditions

Ocean conditions, in terms of temperatures and upwelling patterns, vary substantially from year to year. These conditions affect the growth and survival of salmon in the ocean and therefore, adult returns to WRIA 8. While these conditions are beyond the control of WRIA 8, they will influence yearly variations in Chinook returns and complicate understanding the progress toward recovery.

Harvest

Commercial and sport fishing reduces the number of adult Chinook, as well as other salmon, that return to spawn in their natal rivers. Harvest of fish can damage populations in three ways, 1) through reducing adult returns to levels below that needed to sustain their population, 2) through selective harvest that focuses on certain portions of the population, affecting the population demographics (e.g., run timing, fish size), 3) as by-catch during fishing for other marine species. In WRIA 8, WDFW and the Muckleshoot Indian Tribe co-manage harvest of fish from the WRIA 8 system to maintain adequate adult returns. There has not been any directed terminal harvest on WRIA 8 Chinook in over a decade. Any harvest of Chinook is a result of by-catch or incidental harvest. Through the North of Falcon process, harvest rates are regulated in international and coastal waters as well as Puget Sound and the marine waters of Washington state by Washington state treaty tribes and WDFW. However, as fish move further from Washington state, there are an increasing myriad of national and international agencies that regulate fishing rates, types and areas.

Hatcheries

Many of the Chinook hatcheries operating in the Pacific Northwest served as mitigation for blocking access to habitat. The largest issue surrounding Chinook hatcheries (as well as for other salmon species) is the potential for hatchery fish to become well-adapted to hatchery conditions (and poorly-adapted for spawning in the natural environment) and then interbreeding with wild spawning fish. This situation can lead to an overall decrease in the adaptations in the population for spawning and rearing in natural conditions, therefore reducing the reproductive success of the population and their ability to replace themselves. Hatchery practices for collecting, spawning and rearing fish can either control for these impacts or exacerbate them. Knowledge about this issue, as well as other less severe impacts of hatcheries, is increasing although much is still to be learned. Recent hatchery reviews and recommendations of the Hatchery Scientific Review Group (HSRG, 2004) are intended to modify hatchery practices and reduce or avoid detrimental impacts to naturally spawning populations. WDFW is currently reviewing HSRG recommendations and making decisions about implementation. However, there remains a large question about whether salmon recovery and hatchery programs can both operate simultaneously and successfully at the same time.

In WRIA 8, there is also concern regarding operation of a sockeye hatchery on the Cedar River and the potential Chinook impacts that could occur. Cedar River Chinook populations could be affected by 1) competition on the spawning grounds between adults with increased numbers of sockeye and 2) competition in Lake Washington between juveniles. Concerns over sockeye and Chinook interactions in Cedar River spawning areas include energetic costs to female Chinook associated with defending a redd site from more numerous sockeye produced from the hatchery, increased difficulty with finding a suitable redd site, and egg mortality due to redd superimposition of Chinook redds by sockeye. Studies conducted between 1999 and 2002 have found that disturbance of Chinook redds by sockeye has varied from 0.6% to 88%, varying with both Chinook and sockeye numbers on the spawning grounds, however it is not known how that disturbance affects egg-to-fry survival (Burton et al. 2003). This disturbance effect, as well as effects related to energetic costs for Chinook defending redds and ability of Chinook to find suitable spawning sites under increasing sockeye densities are currently being evaluated under a Supplemental Environmental Impact Statement for the Cedar River Sockeye Hatchery.

Increasing the numbers of sockeye fry entering Lake Washington could have implications for a number of species inhabiting the lake, including Chinook. Specific concerns about the effects of increasing sockeye numbers on Chinook in the lake include the depletion of prey resources and food web interactions resulting in increased predator numbers. While Chinook and sockeye tend to inhabit different areas of Lake Washington, their prey resources overlap when Daphnia become abundant in the lake. Analyses of prey resources in Lake Washington have indicated that the capacity of the lake is adequate to support increased numbers of sockeye fry, however, there is uncertainty about the effects on prey resources when the hatchery is at full production (Seattle 2003; TetraTech/KCM, Inc. 2003). Increased sockeye numbers could also affect predation in Lake Washington in two ways. Populations of predatory fish, such as northern pike minnow, may increasingly feed on sockeye as sockeye numbers increase. This may result in growth in the predator population, and in turn, increased predation pressures on Chinook. The other scenario is that sockeye buffer predation pressure on Chinook salmon, reducing Chinook predation. Conditions in Lake Washington for Chinook as a result of sockeye hatchery operation are also under further evaluation.

Uncertainties about Salmon-Habitat Relationships

While there has been much research into the relationships between ecological processes, the habitat created, and habitat use by salmonids, knowledge is still incomplete. Kerwin (2001) lists outstanding data gaps for all of WRIA 8's water bodies. While salmon recovery planning moves forward in spite of these uncertainties, the adaptive management foundation to WRIA 8's salmon conservation plan will allow habitat protection and restoration actions to be refined, based upon new information.

Other Uncertainties

The main uncertainty in WRIA 8 is the population structure of the Chinook in the watershed. As discussed earlier in this chapter, WRIA 8 has considered the PSTRT's designation of two independent populations (Cedar and Sammamish) and decided to take the more conservative, precautionary approach of identifying three populations (Cedar, North Lake Washington, and Issaquah) for planning purposes until additional genetic information is available in February of 2005. The discussions surrounding WRIA 8 population structure and the most appropriate habitat priorities will continue as new information materializes. Additional years of information on stray rates as well additional genetic information will be helpful in understanding the situation. However, a number of other questions may also need to be addressed at some point within this watershed, for example:

- How much of a contribution do hatchery strays make to the gene pool in the Cedar and NLW tributaries?
- How does straying affect the local adaptation of the Cedar and NLW groups (e.g., reproductive success)?
- How does hatchery straying affect population dynamics/persistence given low returns?

As knowledge about the WRIA 8 population structure progresses, WRIA 8's salmon conservation plan must be adaptively managed to reflect any new information. Currently, this plan accounts for potential changes in habitat priorities under different population scenarios (1 versus 2 versus 3 populations). This discussion is included in Chapter 4.

Conclusions/Implications for the Chinook Recovery Plan

Development of the WRIA 8 watershed for human uses has dramatically altered aquatic habitat conditions and the processes that form them. Those habitat conditions, combined with the effects of water and sediment quality, invasive species, harvest, hatcheries, and ocean conditions, have impacted WRIA 8 Chinook populations. The WRIA 8 conservation strategies address the habitat component of this suite of challenges facing WRIA 8 Chinook populations. These strategies are discussed in Chapter 4, Chinook Conservation Strategy for WRIA 8.

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Table 3-2. 2003 WRIA 8 Chinook salmon population analysis matrix

		Diversity				Abundance				Distribution					Productivity					
						PROFESSIONAL SURVEYS		OBSERVATIONS (since 1996, except Kelsey							production/ female		Mean survival ratios			
Chinook salmon population affiliation	Chinook salmon subareas	Population affiliation origin[1]	Production type[1]	Status[1]	Known minimum life history trajectories[2]	Mean adult abundance	Years of record	Mean adults observed	Incidence of chinook per years of observation	Basin Area (mi2)	BFW, min (from EDT)	Length of stream used, miles	Number of tributaries used/ length used, miles	Low gradient un-confined reaches (%)/ miles	Fry	Smolts	Fry/ egg deposited	Smolts/ egg deposited	Total %	WRIA 8 Population Designation Core/ Satellite/ Episodic[4]
Cedar	Cedar	Native	Wild	Depressed	2	746	64-66, 68-99	n/a	n/a	65	70-100 f	24.9	4/ 3.0	22/ 83[3]	489	136	12.2	3.4	14.4	Cedar Core
	Upper Cedar	Mixed	Comp.	Unk		79	2003			128	70-100 f	unk	unk	18/ 54						Cedar Sat
	Taylor	Native	Wild	Depressed	2	12	98-2003			7.5		1.2	0	54/ 5.5						Cedar Sat
	Peterson	Native	Wild	Depressed	2	1	98-2003			6.4	8 ft	0.2	0	75/ 3.4						Cedar Epi
	Rock	Native	Wild	Depressed	2	3	1960-2003			14.8	17-35 ft	1.3	0	76/ 4.1						Cedar Epi
	Walsh	Native	Wild	Depressed	2	1	98-2003			6.6	8 ft	0.3	0	35/ 5.6						Cedar Epi
N. Lk. Wash.	Bear[5]	Native	Wild	Unk	2	404	85-99	n/a	n/a	50	10-27 ft	17.1	2/ 7.2	61/ 44	21	72	0.5	1.8	2.3	NLW Core
	Little Bear	Native	Wild	Unk	1	11	71-89, 94, 96	1	1 out of 5	15	12-18 ft	7.6	1/ 0.8	56/ 12						NLW Sat
	North[6]	Native	Wild	Unk	1	25	74, 76, 81, 84, 86-88,01	8	3 out of 5	29	10-24 ft	10.8	1/ 0.5	71/ 22						NLW Sat
	Swamp[7]	Native	Wild	Unk	1	6	75-77, 80-81, 84-88, 90	0	0 out of 5	25	10-24 ft	12.2	1/ 2.0	65/ 14						NLW Sat
	Thornton	Native	Wild	Unk	1	3	99-00	1	2 out of 5	11.6	12-15 ft	1.7	1/ 0.2	33/ 4						NLW Epi
	McAleer	Native	Wild	Unk	1	n/a	n/a	11	2 out of 5	3.6	10 ft	2.6	0	61/ 4						NLW Epi
Issaquah	Issaquah[10]	Non-native	Comp.	Healthy	2	2,796	86-99	n/a	n/a	60	8-30 ft	26	5/ 13.4	23/ 34						Iss Core
	Lewis	Non-native	Comp.	Healthy	1	n/a	n/a	9	4 out of 5	1.9		0.6	0	5/ 0.2						Iss Epi
	Laughing Jacobs	Non-native	Comp.	Healthy	1	n/a	n/a	n/a	n/a	16		0.5	1/ 0.5	68/ 0.5						Iss Epi
Unaffiliated based on SASSI and TRT	Kelsey[8]	Native	Wild	Unk	1	138	99-00	70	11 out of 11	17	5-19 ft	13	3/ 5.9	76/ 17						NLW Sat[9]
	Coal	Native	Wild	Unk	1	n/a	n/a	0	1 out of 5	9	7-9 ft	2.1	0	14/ 2						NLW Epi
	May	Native	Wild	Unk	1	2	82, 98-99	2	2 out of 4	14	9-15 ft	3.2	0	49/ 14						NLW Epi
	Juanita	Native	Wild	Unk	1	1	88	0	0 out of 3	6.6	2 ft	2.2	0	60/ 5						NLW Epi
	Pipers	Unk	Unk	Unk	1	n/a	n/a	n/a	n/a	2.9		0.4	0	12/ 1 est.						Unaffiliated Epi

1 from SASSI
2 Minimum life history trajectories currently represents the number of observed juvenile life history strategies
3 Includes Upper Cedar River Watershed
4 Core/Satellite/Episodic:

Core subareas: Chinook salmon are present on an annual basis in the subarea and the subarea represents the center of (highest) abundance for each population affiliation (for spawning, rearing, and migration areas). It is recognized that geographic size of the subarea and the amount or location of suitable spawning and/or rearing habitat often distributed within the subarea (e.g., among tributaries within spawning areas or along shoreline areas) are critical for long term maintenance of the core breeding group, or deme. Because of persistent levels of abundance, the variation in abundance and distribution of these demes have been best accounted for within the watershed, though data gaps exist.

Satellite subareas: Chinook salmon are present most years (more than half the years of a typical 4-5 year life cycle) and are less abundant than in core areas, though population uncertainty exists that is reflective of the level of effort made to determine abundance and distribution. Records are more incomplete, effort is inconsistent among potential satellite areas and methods of enumeration vary. However, it is recognized that geographic size of the subarea and the amount of suitable spawning and rearing habitat often distributed among tributaries within the spawning subarea are critical for long term maintenance of the satellite and core breeding groups

Episodic use subareas: Chinook salmon are present infrequently, and may not be present or observed during the typical 4-5 year life cycle, indicating that when fish are observed, they are strays from another production area and not necessarily the progeny of natural production from the area in question. Epizodic use areas typically are smaller in geographic size, offer limited spawning and rearing opportunities (relative to core and satellite areas), due not only to limited habitat availability, but also due to habitat degradation that likely has a greater negative influence over the limited area, and the likelihood that natural production will be successful and hence contribute to the maintenance of the local breeding group and the core population as a whole.

5 Bear Creek inlcudes Lower Bear, Upper Bear, Cottage Lake and Evans subareas.
6 North Creek includes Upper North and Lower North Creek subareas.
7 Swamp Creek inlcudes Upper Swamp and Lower Swamp Creek subareas.
8 Kelsey Creek includes Upper Kelsey and Lower Kelsey Creeks as well as Mercer Slough.
9 Proximity to Cedar River suggests Kelsey Creek could be a satellite of the Cedar. Geomorphology suggests Kelsey Creek chinook are closer to North Lake Washington population. Technical committee assigns to NLW tribs.
10 Issaquah Subbasin includes North Fork, East Fork, Lower Issaquah, Middle Issaquah, Upper Issaquah, Fifteenmile, and McDonald subareas.