Abundance

H-Action	Habitat	Harvest	Hatchery
Effect	Population abundance (and capacity to support adult and juvenile life stages) has been in decline over the long-term, affected by reductions in habitat capacity from the historical barrier at Landsburg (now accessible), reductions in floodplain and channel area from revetments and levees constructed mostly during the 1960s, flow management, and other habitat impairment affecting capacity. An estimated 56% loss in active channel area occurred between 1865 and 1989 (Perkins 1994). In tributaries below Landsburg, urbanization and other land- and water- use has resulted in reduced baseflow and increased peak flows, leading to reduced spawning and rearing capacity. Recent habitat restoration projects have improved conditions in some tributaries and some reaches of the mainstem Cedar River, although effects on abundance are not known. Other habitat alteration (such as the Chittenden Locks) affects adult/juvenile abundance directly. Potentially high direct and cascading effects on fish passage and migration in the locks and Ship Canal exist and these are worsened by increased temperatures and decreased dissolved oxygen levels in the locks and Ship Canal. Smolt flumes at the locks have improved juvenile passage survival in recent years. A temporary adult exclusion screen was installed on the saltwater drain in 2008. Lower river and estuarine rearing capacity is reduced compared to historical habitat by the disconnection of the Cedar and alteration of the Black and Duwamish rivers. The vast majority of lake shorelines and the nearshore in WRIA 8 and Puget Sound has been developed and degraded, and pocket estuaries have been greatly altered near WRIA 8, likely affecting abundance. In summary: EDT modeling suggests habitat degradation has reduced abundance by 95% compared to historical equilibrium abundance.	Harvest impacts on spawner abundance are currently less than in the past: total exploitation of South Sound Fall Chinook was reduced from 83% (avg. '82-'99) to 60% (avg. '00-'05). Lake Washington terminal harvest was further reduced to protect Cedar Chinook and total exploitation has been ~ 50% since the early 1990s. No directed terminal harvest occurs on Cedar Chinook, but total incidental harvest in WRIA 8 coho and sockeye fisheries has ranged from about 500 to 1600 Chinook between 2004-2008 (Stolnack 2009), which on average represents an impact on potential basin escapement of about 4%. Over 85% of incidental catch is hatchery fish. FRAM modeling shows total exploitation rate of approximately 50% from all harvest in 2007 and recent years, though exploitation rate was apparently lower in 1995-1999. In summary: annual harvest from all areas reduces run size (abundance) by roughly 50%, though most of this reduction occurs in the US and Canadian Pacific and Puget Sound fisheries, not in terminal fisheries	Hatchery programs have increased total adult returns and spawner abundance. As a result, the actual (run) size of the naturally-produced spawning population was masked prior to marking of hatchery Chinook in 2003, thereby giving the impression that the natural habitat was producing more fish – i.e., Cedar River NOR abundance was probably lower than observed prior to mass marking. Currently (2003-2008), pHOS[1] ranges from ≈10-34% of the return. Hatchery contribution of spawners was likely higher in the past as a result of outplants in the Cedar River from Issaquah and Green River hatcheries from 1945-1965. The juvenile contribution from hatchery origin spawners may buffer the population from effects of predation, assuming total juvenile abundance (esp. after hatchery release) doesn't trigger competition. However, competition is thought to be minimal since Issaquah releases are not made in the Cedar and occur at or near fingerling smolt stage. Issaquah Chinook outmigrate to saltwater fairly quickly (days to 2 weeks), food is not believed to be limiting in the Lake, and most hatchery Chinook do not spatially overlap with Cedar Chinook. Introgression from hatchery x NOR adult Chinook may reduce the fitness and therefore abundance of adult unmarked Chinook on the spawning grounds in the Cedar River. The effect of hatchery Chinook on fitness of Cedar River Chinook is expected to be less than that reported for some other hatchery programs, e.g., steelhead, since Issaquah Chinook spend less time in the hatchery environment and are local stock/ genetically similar.
Certainty of effect	High	High	High
Questions/ Risks/ Issues	Will the increase in mainstem habitat capacity at current plan levels be sufficient to recover Chinook abundance? To what degree will any increases in mainstem habitat capacity be offset by reductions in mainstem or tributary rearing or spawning capacity due to increasing urbanization?	Are unharvested hatchery returns too abundant? Are selective fishery opportunities missing? What is the mortality rate on NOR fish	Is hatchery contribution to the spawning grounds needed to support the population? Why is pHOS lower in years of greater hatchery fish abundance? Does interannual variation in freshwater temperatures during adult migration affect pHOS in the Cedar River?

[1] pHOS: Proportion of hatchery-origin spawners on the spawning grounds.

	How much does the migratory corridor effect juvenile and adult abundance? Does estuarine capacity and nearshore rearing success limit abundance of W8 Chinook? What magnitude of shoreline restoration along Lake Washington is needed to recover abundance of juvenile and adult Chinook?	associated with selective harvest in specific areas? Are there any unintended effects on abundance from selective fisheries?	

Productivity

Cedar Action	Habitat	Harvest	Hatchery
Effect	Productivity is reduced by habitat degradation including impairment of natural riparian and geomorphic processes affecting habitat quality and quantity. Elevated rates of pre-spawning mortality and reduced egg viability due to fish passage problems and thermal conditions in the Locks and Ship Canal likely influence the productivity of Chinook in the Cedar River. Egg to fry survival is believed to be limited by elevated rates of redd scour exacerbated by floodplain development and flood control infrastructure, and extended flood duration as a consequence of water management. Fry to smolt survival is likely limited by predator abundance in river, lake, and Ship Canal, and influenced by habitat alterations (e.g. inadequate large woody debris and vegetation cover, urban lights). Fry to smolt survival is also believed to be limited by a lack of complex low velocity instream habitats and modification of the Lake Washington shoreline. Alteration of natural hydrology (ground water withdrawals, surface water storage and diversion, magnitude and duration of flows, wetland losses) and impairment of natural floodplain/riparian functions limits egg to smolt survival compared with historic conditions. Changes in lake shoreline habitat quality from natural conditions affect juvenile survival in Lake Washington (e.g., piers, docks, bulkheads, changes in cover and substrate). Approximately 24 introduced non-native fish species occur in lakes Washington and the Sammamish and interactions with some nonnative fish (e.g. smallmouth bass) can reduce survival of juvenile Chinook. Abrupt transition zone between fresh/saltwater and warm/cold water for juveniles and adults at the Ballard Locks may reduce productivity. NMFS BRT[2] estimated the short-term population growth rate for the Cedar River (1990-2002) ranged from 0.89-1.07. This estimate counts spawners only, not total run size and doesn't distinguish between natural and hatchery origin fish. However, actual productivity would have been lower due to inability to distinguish hatchery origin spawners. More recent productivity estimates will be generated based on known relative hatchery composition, age data, total spawning abundance and harvest. Intrinsic population productivity may have been reduced through changes in migratory pathways (changed from Duwamish to Lake Washington), but historic intrinsic productivity is uncertain.	Harvest-induced changes in size (smaller adults) can affect scour/redd depth and intrinsic productivity (lower fecundity). Note however that 80 percent or more of all harvest is hook and line and is not size selective. In '80s and '90s, large mesh gear may have been selective for removal of larger Chinook. Current mesh sizes in terminal areas for coho and sockeye do not select for larger Chinook. Spawner abundance and productivity are reflected in a spawner/recruit relationship (e.g. Beverton Holt), where the growth rate of the population is higher at lower levels of abundance due to density dependent factors. Therefore, harvest tends to increase productivity (recruits per spawner) in general. However, when spawner abundance is critically low, then harvest impairs productivity through Allee and other effects. Introduction of warm water species for recreational harvest creates new predation effects. Predation reduces	Hatchery adults with higher prespawning egg retention results in lower productivity per fish on spawning grounds. Differential egg retention potentially may result from non-genetic causes, e.g., Issaquah hatchery strays may accumulate more thermal stress or depleted energy stores before entering Cedar River to spawn. UW Hatchery fish are different from Issaquah and Cedar (Warheit and Bettles 2005) and relative risk to productivity (and diversity) may be higher from introgression with UW hatchery strays (also CWT strays from other basins). However, very small numbers of UW Chinook stray to the Cedar River. There are no studies testing for or indicating depressed productivity/fitness caused by breeding between local or closely related natural-origin and hatchery-origin Chinook that are released as fry or fingerlings. Outplants in Cedar were primarily of Green River origin, the Cedar being a former tributary. The current hatchery strays spawning in the Cedar are from Issaquah, Grovers, and UW hatcheries, which are also originally Green River fish. If fitness loss exists, likely it is low; any fitness losses must also be considered in light of potential for high local adaptation or higher extinction risk

[2] NMFS BRT: National Marine Fisheries Service Biological Review Team

	Water quality problems exist and toxic or sub-lethal effects from heavy metals, organics and other pollutants (PAHs) may reduce productivity directly (or indirectly affecting homing or other behaviors), but these effects are not well documented in Chinook. More clearly pressing current and future water quality issues are temperature and dissolved oxygen (DO) in migratory areas (Locks, Ship Canal, Lake Washington)	population productivity and abundance Harvest of hatchery fish may improve fitness and productivity of NOR[3] Chinook in the Cedar River.	in the absence of hatchery fish. Risk of elevated predation rates on Chinook during nights of hatchery sockeye fry releases. Alternatively, hatchery sockeye fry releases reduce predation rates on Chinook due to buffering effect.
Certainty of effect	Good agreement. Low productivity is assumed , but strong year-classes recently suggest there is variability to the upside.	High certainty of low current effect on productivity, and uncertain historical effects on size (and therefore productivity).	Low certainty
Questions/ Risks?	What is current natural spawner productivity? Is the recent trend in higher productivity due entirely to ocean effects, or is it traceable to freshwater life stages? Does increased stream rearing habitat translate to improved productivity? What is the influence of nearshore and estuarine transition on survival/productivity? Can we determine the performance of fry vs. smolt migrants? How much impact does migratory corridor play in overall productivity? What are the long term effects on productivity of extensive knotweed and other invasive plant infestations in riparian areas? How much potential productivity is lost if the natural distribution and loading of wood in the Cedar River are constrained by recreation, infrastructure, or safety concerns ?		Does hatchery introgression reduce population productivity via higher pre-spawning mortality or lower survival and fitness? Hypothesize low effect, but not based on data or studies.

Spatial Structure

Cedar Action	Habitat	Harvest	Hatchery
Effect	Spatial distribution is life history dependent (fry vs. smolts rearing structure). Early rearing in locations with tributary junctions are likely important, but less so for spawning. Historically, it is likely that Chinook were distributed predominately along the mainstem Cedar, with use above and below Landsburg proportional to suitable habitat area, and use of tributaries playing a relatively minor role in terms of overall spatial structure but tributaries playing a stronger role in structuring spatial distribution within the mainstem due to tributary confluence effects. Nevertheless, stormwater, channel modifications, passage issues, low summer-fall flows, and culverts limit distribution and use of tributaries to lower river by Chinook juveniles and adults compared to historic conditions. EDT modeling suggests the proportional composition (under template conditions) above Landsburg was 27% of all spawners. Since passage was restored, composition	Harvest has potential to affect historical run timing from disproportionate harvest of part of the run (e.g., early returning fish). This would likely be a Puget Sound-wide phenomenon and a historical artifact if it existed. Past directed Chinook harvests in the mid ‘80s to early ‘90s occurred during the month of August in the Ship Canal and in Shilshole Bay and is assumed to have harvested a mixture of fish from the middle of the run and all portions of the basin. The	In its early years, the sockeye hatchery broodstock collection weir appeared to delay and affect distribution of spawning Chinook, but protocols since have reduced delay. A new weir was installed in 2008 at a new location. Chinook passage and spawning distribution will continue to closely monitored and these data evaluated for potential weir effects. Since Landsburg Dam was laddered, a higher proportion of marked hatchery fish has accessed the upper river than the proportion remaining in the lower river mainstem. This higher stray contribution also occurs in some of the north bank tributaries below the dam. Some speculate that hatchery Chinook straying into these areas may be homing to the scent of the Issaquah watershed, some of

[3] NOR =Natural origin recruits

	has ranged from 2.6-11.3% (through 2008; excluding lower 1-5.5RM). The spatial distribution of the population is largely longitudinal along the length of the mainstem Cedar River, but focused upstream from RM 5.5. This may represent an upstream shift in spatial distribution relative to historical structure if the lower river miles and confluence with the Black River were more important habitat areas spatially than today. Distribution in Lake Washington for Cedar River fry migrants and smolts is strongly skewed to the south end and shoreline early in spring (with affinity for shoreline and small tributary deltas/mouths), then offshore in early summer. It is assumed that the spatial structure of juveniles and adults in Puget Sound and the Pacific Ocean overlaps with other populations.	arrival timing of Cedar River NOR Chinook to the locks is unknown, and any spatial structure within the Cedar River population is also unknown. Based on available tagging study data, the arrival timing at the Locks of Cedar Chinook is not different from any other Lake Washington Chinook except for UW Hatchery Chinook, therefore it does not appear that past directed harvest had a disproportionate impact on Cedar Chinook.	which 'leaks' into the northeastern Cedar watershed. The overall hatchery stray contribution to the Cedar River declined to 10% in 2007 and 2008, coincident with an increase in overall escapement. Hatchery strays are expanding spatial structure more so than progeny of naturally-spawned fish in Cedar tributaries.
Certainty of effect	High certainty of information and agreement.	High certainty of low effect.	High certainty of information and agreement.
Questions/ Risks?	Is there spatial structure within Cedar River Chinook?		Questions/ uncertainty about sockeye hatchery broodstock collection weir effects on Chinook? This will continue to be closely monitored.

Diversity

Cedar Action	Habitat	Harvest	Hatchery
Effect	It is hypothesized that the in-stream juvenile rearing life history trajectory has been reduced by habitat loss in combination with the duration of high flows in response to flood control. The observed outmigration is skewed to fry migrants except during periods of low winter flows. Rerouting of the Lake Washington outflow eliminated estuarine-rearing for fry and fingerlings which now rear in the lake. There is a possible convergence of rearing requirements for both Cedar and Sammamish populations. It is unknown to what degree fry migrants contribute to adult returns after pre-smolt residency in the Lake, but they are presumed to do so. Their survival is based on lake conditions, forage, and predation. Lack of habitat complexity including wood structure and low velocity margin habitats is believed to reduce rearing life history diversity. The potential loss of a historical spring Chinook life history is unknown. The presence and contribution of a yearling smolt life history is also unknown, although a small number of PIT-tagged Chinook smolts have been detected as migrants at locks one year after tagging. There are historic reports of tribal catches of spring Chinook in May in the Black River, which may have been native to the upper Cedar River. Recently, yearlings have been observed in the Cedar River above and below Landsburg. Water quality effects on returning adults at locks varies over return timing, which may influence run timing and therefore diversity. Loss of floodplain connectivity, land	Incidental by-catch of early or late timed Chinook occurs during sockeye and coho harvest in some years. This incidental catch may lead to a small reduction in the number of early or late timed Chinook, but it is thought that this only results in tens of Cedar River Chinook. The bycatch during coho fisheries is weighted toward UW hatchery fish. [Evidence for this statement from coded wire tag data not readily available, but most net coho fisheries occur in the ship canal in September -- when over 80 percent of basin Chinook have passed the locks, and a high proportion of the Chinook still running in the ship canal are UW hatchery fish bred to return later than Cedar River and Issaquah fish – in order to coincide with the fall semester.] In '80s and '90s, large mesh gear may have been selective for removal of larger Chinook. Current mesh sizes in terminal	The effects of past hatchery releases and current strays on genetic/ life history diversity in the Cedar River are unknown. Chinook populations today are those extant after the 1917 rerouting of Lake Washington from a tributary of the White/Duwamish into a separate lake system with an outlet through the Chittenden Locks, with subsequent supplementation using Green River stock. Whether any historical genetic influence survived the rerouting is unknown.

	cover changes, and groundwater withdrawals are limiting cool water refuge and resources for early timing of spawning and habitat types for rearing diversity. Early spawning fish are likely less numerous given higher temperatures and low flows and winter scour. Late spawning fish may be less numerous given reduced spring outmigration flows relative to earlier spawning fish. These combined effects probably lead to compression of spawning timing. Late arriving fish spawn lower in river, with implications for diversity and persistence of spatial structure.	areas for coho and sockeye do not select for larger Chinook.	
Certainty of effect	High	High certainty of low effect except for historical effects.	
Questions/ Risks?	Do improvements in habitat including access above Landsburg result in an increase in diversity?		What level of hatchery influence exists from UW hatchery strays to the Cedar? To better understand risk to natural spawning populations, UW fish should all be fin-clipped and coded wire tagged. What are the relative risks between possible fitness declines due to hatchery introgression and population extinction if hatchery fish were not available?

References

Perkins, S.J. 1994. The Shrinking Cedar River; Channel Changes Following Flow Regime Regulation and Bank Armoring. Page 649-658 in Proc. Effects of Human-Induced Changes on Hydrologic Systems. American Water Resources Association 1994 Annual Summer Symposium. http://www.geopacific.com/perkins/cedtext1.htm

Stolnack, S.A. 2009. Summary of incidental Chinook take in WRIA 8, as reported in WDFW annual post-season harvest reports, 2003-2009. Lake Washington/ Cedar Sammamish Watershed (WRIA 8). Internal memo. \\Wlrnt4\wria8_science\Tech Committee\harvest.

Warheit, K.I. and C.M. Bettles. Genetic Characterization of Chinook Salmon (Onchorhynchus tshawytscha) populations within Watershed Resource Inventory Area 8 (WRIA 8), Washington State. Genetics Laboratory, Washington Department of Fish and Wildlife, Olympia, WA.