WRIA 8 Chinook Salmon

Conceptual Model

April 27, 2017
Life cycle of WRIA 8 Chinook salmon

Key premises:
1. Each life stage occupies specific geographies and residence periods.
2. Key stressors (priorities) vary by geography and life stage.
3. Rationale for actions and monitoring must account for (1) and (2).
ADULT MIGRATION

TIMING: JUNE THROUGH SEPTEMBER

GEOGRAPHY (MAIN MIGRATION PATHWAYS FOR CORE AND SATELLITE DEMES):

SALMON BAY → CHITTENDEN LOCKS → LAKE UNION/SHIP CANAL → LAKE WASHINGTON →

→(SOUTH) LOWER CEDAR RIVER → MIDDLE CEDAR → UPPER CEDAR (predominantly mainstem spawning, though some tributaries and side channels used as well) (TIER 1; top priority)

• (Taylor Creek – Cedar tributary)

→(KELSEY CREEK – classified as part of Sammamish population) (TIER 2)

→(NORTH) SAMMAMISH RIVER →

• NORTH LAKE WASHINGTON TRIBUTARIES (NORTH, LITTLE BEAR – TIER 2, in UGA)

• SAMMAMISH RIVER → LOWER BEAR CREEK → UPPER BEAR/COTTAGE LAKE CREEK (TIER 1)

• SAMMAMISH RIVER → LAKE SAMMAMISH → LOWER ISSAQUAH CREEK (PLUS E.F) → UPPER ISSAQUAH CREEK (TIER 1)
ADULT MIGRATION

POTENTIAL STRESSES:
THERMAL/DO BARRIERS; PHYSICAL BARRIERS; HARVEST; WATER QUALITY; STREAMFLOW (TOO HIGH OR TOO LOW); PREDATION; DISEASE

NOTES:
1. Delays and stress due to THERMAL/Dissolved Oxygen issues at the Locks/Ship Canal appear to be the most severe limiting factor for this life history stage. Issue is also potentially significant in Sammamish River.
2. BARRIERS: Locks present a barrier to upstream migration, both physically and as a consequence of the abrupt salinity/temperature transition. Landsburg passage facility assumed to have minimal effect on passage timing in Upper Cedar. Milfoil may impede Kelsey Creek in late summer. Sockeye broodstock collection facility on Cedar River can delay passage and alter spawning patterns (facility managed to minimize delays).
3. HARVEST in terminal or freshwater areas (including bycatch) currently minimal. Managed under NOAA-approved Puget Sound Harvest Management Plan (Tribes and WDFW manage).
4. Effects of WATER QUALITY (e.g., toxics in Ship Canal/Lake Union) on adults’ spawning success in WRIA 8 Chinook not researched; however, pre-spawn mortality generally low where assessed.
5. STREAMFLOWS are managed on Cedar River to support fall migration and spawning needs. Elsewhere, low flows early in the migration period could impede migration (see streamflow references for flow restoration priorities).
6. PREDATION on migrating adults occurs at Locks, but has not been observed to be consistently significant at Locks or elsewhere in watershed.
7. DISEASE does not currently appear to be an issue in WRIA 8 Chinook. Other stresses (e.g., temperature) could increase disease susceptibility and contribute to pre-spawn mortality.
Adult Migration – effects of temperature

While temperature/dissolved oxygen issues may block or significantly delay migration or diminish spawning success, Chinook salmon do appear to be resilient against temperature extremes:

- Fall Chinook range extends as far south as the California San Joaquin River.
- Despite low flows and high temperatures in summer/fall 2015, the Chinook run was better than forecast.
- Fall Chinook tend to congregate in areas of cooler water until environmental cues trigger upstream migration. They may do this a number of times during migration, depending on distance to be traveled (e.g., Strange 2012).
- Sammamish River Chinook pre-spawn mortality (psm) study, conducted in summer of 2015 (hottest summer to date), estimated a psm rate in the Sammamish River of 0.33-0.37% of total Sammamish population escapement.

It is likely (though unproven) that higher temperatures in the Sammamish River in 2014 and 2015 contributed to the higher than normal number of hatchery-origin Chinook strays to the Cedar River in those years.

Sockeye salmon appear to be much more susceptible to problems related to high temperatures during adult migration.
SPAWNNG

TIMING: SEPTEMBER THROUGH NOVEMBER

GEOGRAPHY: MAJOR CORE AND SATELLITE SPAWNING AREAS

• CEDAR RIVER (Tier 1) (includes Taylor Creek)
• BEAR/COTTAGE LAKE CREEK (Tier 1)
• ISSAQUAH CREEK (BELOW AND ABOVE HATCHERY) (Tier 1) (includes East Fork)
• LITTLE BEAR CREEK (Tier 2)
• NORTH CREEK (Tier 2)
• KELSEY CREEK (Tier 2) (includes larger tributaries)
# Key Spawning Areas in WRIA 8

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<td>53</td>
<td>390</td>
<td>269</td>
<td>319</td>
<td>490</td>
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<td>262</td>
<td>322</td>
<td>420</td>
<td>724</td>
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NS = not sampled  
X = no longer accessible to Chinook
SPAWNING

POTENTIAL STRESSES:
SPAWNING HABITAT LIMITATIONS (QUANTITY AND QUALITY, COVER); HATCHERY STRAYS-INTERACTIONS; STREAMFLOW; TEMPERATURE; WATER QUALITY

NOTES:
1. HABITAT: Monitoring and analysis on Cedar River and Bear Creek indicate those areas are **not** spawning habitat limited at current abundance levels. Spawning habitat quality/quantity limitations on other creeks unknown but it is likely high in areas inside UGA.
2. HATCHERY-origin spawners’ effects on overall genetic fitness uncertain though literature suggests declines in fitness after one generation. However, egg-to-migrant survival rates are high where monitored (Cedar R. and Bear Cr.) so any decline in fitness, if present, would likely present itself at a later life stage. *Genetics studies by WDFW (Joe Anderson) indicate diminished spawning success of hatchery males in on Upper Cedar recolonization but no diminished success by hatchery females.
3. STREAMFLOW on the Cedar River is regulated to support Chinook spawning through an HCP. Elsewhere, high or low flow events on other streams may affect spawning success through limiting habitat availability.
4. High TEMPERATURE during spawning period could affect Chinook spawning success, especially in areas outside the Cedar River (currently, Cedar R. temperatures during spawning period are suitably low). May become more problematic with climate change.
5. WATER QUALITY impairments during spawning period could affect Chinook spawning success, though as noted above, high egg-to-migrant survival rates suggest the issue is not currently severe for Cedar R. and Bear Cr. demes.
6. Disturbance or harassment by humans or their pets, or human infrastructure (e.g. light from traffic) could affect spawning success especially in urban areas.

4/27/2017

Home
INCUBATION AND EMERGENCE

TIMING: SEPTEMBER THROUGH MARCH

GEOGRAPHY: MAJOR CORE AND SATELLITE SPAWNING AREAS

- CEDAR RIVER (UPPER AND MIDDLE) (Tier 1) (includes Taylor Creek)
- BEAR/COTTAGE LAKE CREEK (Tier 1)
- ISSAQUAH CREEK (BELOW AND ABOVE HATCHERY) (Tier 1) (includes East Fork)
- LITTLE BEAR CREEK (Tier 2)
- NORTH CREEK (Tier 2)
- KELSEY CREEK (Tier 2) (includes larger tributaries)
INCUBATION AND EMERGENCE

POTENTIAL STRESSES:
HABITAT LIMITATIONS (SEDIMENT QUALITY); STREAMFLOW; TEMPERATURE; WATER QUALITY

NOTES:
1. HABITAT: Monitoring and analysis on Cedar River and Bear Creek indicate those areas are not limited at this life history stage at current abundance levels. Habitat quality/quantity limitations on other creeks unknown but likely, except perhaps upper Issaquah Creek, where habitat quality is high and human impacts low.
2. STREAMFLOW on the Cedar River is regulated to support Chinook incubation through HCP. Flows above about 2,200 cfs on Cedar often result in redd scour. Elsewhere, high or low flow events may affect success through scouring or dewatering redds.
3. TEMPERATURE during incubation influences time of emergence – warmer temperatures speed embryo development and result in earlier emergence dates. Changes in overall timing of emergence could affect survival if fry emerge before prey or during high winter flows.
4. WATER QUALITY impairments during incubation period could affect Chinook survival, though as noted above, high egg-to-migrant survival rates suggest the issue is not currently severe for Cedar R. and Bear Cr. demes. Cedar River water quality is generally good during incubation window except perhaps in lowest section, where Chinook redds are rare. Elsewhere, urban runoff during storm events likely subjects embryos to varying concentrations of toxic compounds (mostly in Tier 2 areas). *Local benthic macroinvertebrate monitoring (Bellevue) links different taxa to different stresses (toxics, sediment, temperature, flows).
STREAM REARING

TIMING: JANUARY THROUGH JULY (very small fraction remains in system 1 yr)

GEOGRAPHY: MAJOR CORE AND SATELLITE REARING AREAS

- CEDAR RIVER (UPPER AND MIDDLE) (Tier 1)
- BEAR/COTTAGE LAKE CREEK (Tier 1)
- ISSAQUAH CREEK (BELOW AND ABOVE HATCHERY) (Tier 1)
- LITTLE BEAR CREEK (Tier 2)
- NORTH CREEK (Tier 2)
- KELSEY CREEK (Tier 2)
STREAM REARING

POTENTIAL STRESSES:
STREAMFLOW; HABITAT LIMITATIONS (QUANTITY AND QUALITY OF INSTREAM HABITAT, COVER, FLOOD REFUGIA, LWD); PREDATION; PREY RESOURCES; WATER QUALITY

NOTES:
1. Evidence from annual juvenile outmigrant trapping indicates that this life stage is limited in the Cedar River and Bear/Cottage Lake Creek, presumably by insufficient instream rearing and refuge habitat. (Lack of LWD thought to be significant contributor.)
2. For other areas (North, Issaquah, Little Bear and Kelsey creeks), it is unclear what limits this life history stage. Urbanized areas are likely severely limited due to the effects of urbanization: low water quality, high temperatures, excess fine sediments, and low habitat quality (including lack of LWD).
3. STREAMFLOW issues vary from year to year; peak storm flows may wash fry downstream if insufficient floodplain refuge HABITAT exists; base flows are usually adequate during the period that Chinook rear in the stream (Unusually low base flows in spring 2015 could become more common under climate change scenarios).
4. HABITAT for instream rearing may be limiting due to habitat simplification and loss of flood plains, side channels and backwaters. NOTE: includes lack of LWD as major issue.
5. PREDATION on juvenile Chinook rearing by cutthroat trout and other predators may be a factor.
6. PREY abundance and its potential limitation during stream rearing stage is unknown; prey abundance may be considered low in areas with low B-IBI scores, though Chironomids (key prey species in lake rearing stage) are often abundant even in areas with low B-IBI scores.
7. WATER QUALITY may affect Chinook survival, especially in areas where storm runoff is a problem.

4/27/2017
INSTREAM REARING AND REFUGE HABITAT CHARACTERISTICS

Low-velocity, shallow water
Instream wood of various sizes (hydraulic complexity, cover, etc.)
Floodplain connected to river; hydraulic complexity at higher flows
Plentiful riparian vegetation – large and small (cover, hydraulic roughness, insect food source)
Dynamic mosaic of habitat types – ages, species assemblages in constant flux
DOWNSTREAM MIGRATION

**TIMING:** JANUARY THROUGH JULY

**GEOGRAPHY:** MAJOR CORE AND SATELLITE REARING AREAS

- CEDAR RIVER (Tier 1)
- BEAR/COTTAGE LAKE CREEK (Tier 1)
- ISSAQUAH CREEK (Tier 1)
- LITTLE BEAR CREEK (Tier 2)
- NORTH CREEK (Tier 2)
- KELSEY CREEK (Tier 2)

Fry migrants: January through ~April

Parr migrants: ~May through July

4/27/2017
DOWNSTREAM MIGRATION

POTENTIAL STRESSES:
STREAMFLOW; HABITAT LIMITATIONS (QUANTITY AND QUALITY OF COVER,); PREDATION; WATER QUALITY

NOTES:
1. STREAMFLOW issues vary from year to year; storm flows may wash fry downstream or low flows could limit habitat and force early migration.
2. HABITAT: Salmon are traveling downstream as quickly as possible during migration; not lingering along edge habitat [check this statement].
3. PREDATION on migrating juvenile Chinook by cutthroat trout and other predators may present localized bottlenecks. (Likely key pressure at this life stage.)
4. WATER QUALITY may affect Chinook survival through delayed effects, especially in areas where storm runoff is a problem.
LAKE REARING

**TIMING:** JANUARY THROUGH JULY (year-round for small numbers residualized juveniles)

**GEOGRAPHY:** LAKE WASHINGTON AND LAKE UNION  (Lake Sammamish?)
LAKE REARING

POTENTIAL STRESSES:
PREDATION; HABITAT LIMITATIONS (QUANTITY AND QUALITY OF REFUGE HABITAT, COVER); PREY RESOURCES; TEMPERATURE; WATER QUALITY

NOTES:
1. PREDATION on juvenile Chinook during early season (January-April) assumed to be focused on southern shorelines of Lakes Sammamish and Washington. Early season water temperatures likely hinder significant predation by warm-water fish (bass). Predation by cooler-water fish (esp. cutthroat trout) in early season could affect a large proportion of Chinook population. Estimates vary (see 2016 work by Beauchamp lab).
2. PREDATION later in season (May-August) likely concentrated in Ship Canal and Lake Union, with bass more significant as water temperatures increase (Tabor et al. 2004; Tabor et al. 2007; Lantz unpublished 2016). (See also work by Beauchamp and Celadonia)
3. Shoreline HABITAT, including stream mouths, much more important at southern ends of lakes when Chinook are smaller (January-April) and are oriented to shorelines. As they grow (~May-August) orientation moves offshore to deeper waters.
4. PREDATION exacerbated by artificial night-time lighting; gravity of issue not yet quantified but likely severe.
5. PREY RESOURCES do not appear to be limiting (Koehler 2006). Prey shifts from benthos (Chironomids) when Chinook are shoreline-oriented to Daphnia spp. in water column as Chinook move offshore. Timing of spring phytoplankton bloom and link to Daphnia population dynamics should be monitored. Artificial night-time lighting may provide some benefits due to longer feeding opportunities – to be weighed against increased predation threat.
6. WATER QUALITY may have sublethal effects on Chinook survival, especially a) in near stormwater outfalls in southern ends of lakes, and b) in Lake Union.
LAKE REARING

Lake Washington is a unique feature in the ecology of Chinook salmon, and functions as the ‘estuary’ for WRIA 8 Chinook salmon.

Rearing in Lake Washington begins in the southern end near the outlet of the Cedar River (~Jan-Mar) and shifts northward toward Union Bay and the Ship Canal in later months, as juveniles move toward eventual outmigration (~May through July).

Status of Issaquah Creek naturally-produced Chinook and their use of Lake Sammamish is not well studied.
LAKE MIGRATION

TIMING: APRIL THROUGH JULY [CHECK]

GEOGRAPHY: LAKES SAMMAMISH, WASHINGTON AND UNION
LAKE MIGRATION

POTENTIAL STRESSES:
PREDATION; HABITAT LIMITATIONS (QUANTITY AND QUALITY OF REFUGE HABITAT, COVER); PREY RESOURCES; TEMPERATURE; WATER QUALITY

NOTES:
1. PREDATION later in season (May-August) during outmigration likely concentrated in Ship Canal and Lake Union, with bass more significant as water temperatures increase.
2. Shoreline HABITAT during active migration not as important as smolts are not shoreline oriented. [CHECK]
3. PREY RESOURCES do not appear to be limiting (Koehler 2006). Prey shifts to Daphnia spp. in water column as Chinook move offshore. Timing of spring phytoplankton bloom and link to Daphnia population dynamics should be monitored.
4. TEMPERATURE an issue for juvenile Chinook migration as waters warm in late spring and early summer. Some strong evidence (Celadonia report) of changes to migration pathways when temperatures increase in late spring/summer.
5. WATER QUALITY may have sublethal effects on Chinook survival, especially a) in near stormwater outfalls in southern ends of lakes, and b) in Lake Union.
6. Need to process information from 15+ years of PIT tagging studies to assess overall survival between tagging locations and receivers at Locks.
Lake Migration – Water Quality

Recent analyses showed no evidence of contamination of juvenile Chinook salmon leaving the Lake Washington system (Meador 2013 – see supplemental material). However, other research indicates that urban areas in general may contribute to loading of toxics (and reduced survival) in juvenile salmon (O’Neill et al. 2015).

Juvenile Chinook that transit the locks and Shilshole Bay were low compared to fish from other Puget Sound estuaries. Houck (personal communication – to J. Meador) reported no appreciable changes in whole body PCB concentrations in juvenile Chinook from the hatchery, freshwater systems, or estuary below the lock system separating marine from fresh water. An extensive study of the feeding and migration habits of juvenile salmon through this system found that the residence time in the estuary for this life stage may be relatively short lasting approximately 2 weeks or less (Simenstad et al. 2003). These authors observed an important freshwater prey taxa for Chinook (cladocerans) in high abundance in inner Shilshole bay due to flushing through the locks, which may contain low levels of contaminants. Another study reported that the mean travel time for juvenile Chinook between Portage Bay (UW hatchery location) and Shilshole Bay was only 53 hours (SPU 2008), which would limit their exposure to potential contaminants in the urban area between the hatchery and estuary. – Meador 2013 (supplemental material).
MIGRATION TO PUGET SOUND

TIMING: APRIL THROUGH AUGUST (Peak outmigration = late May to late June – Footen 2001, DeVries 2008)

GEOGRAPHY: SHIP CANAL, LAKE UNION, CHITTENDEN LOCKS; SALMON BAY
MIGRATION TO PUGET SOUND

POTENTIAL STRESSES:
PREDATION; TEMPERATURE; MIGRATION BARRIERS; WATER QUALITY

NOTES:
1. WRIA 8 Chinook are thought to migrate to Puget Sound at relatively large sizes (>100mm) and research suggest they are more likely to tolerate the abrupt temperature and salinity transition to saline water (Taylor Assoc., 2010). This has not been proven conclusively.
2. PREDATION later in season (May-August) likely more significant as water TEMPERATURES increase.
3. Chittenden Locks pose a MIGRATION BARRIER hazard as exit pathways may physically harm Chinook, delay their volitional passage, or direct them through suboptimal conditions and lead to indirect or delayed mortality.
4. Larger smolts are more resilient to abrupt osmoregulatory transition though indirect and/or delayed mortality cannot be ruled out (discussed in Taylor Assoc., 2010).
5. WATER QUALITY in Salmon Bay downstream of Locks may have sublethal effects on Chinook survival (O’Neill et al. 2015).
NEARSHORE FORAGING

**TIMING:** APRIL THROUGH AUGUST (see Beauchamp links and presentations)

**GEOGRAPHY:** PUGET SOUND NEARSHORE (decreasing effects with increasing distance from Locks/Salmon Bay)
NEARSHORE FORAGING

POTENTIAL STRESSES:
PREDATION; PREY RESOURCES; WATER QUALITY

NOTES:
1. Not considered highest priority for WRIA 8 Chinook recovery if WRIA 8 Chinook migrate to Puget Sound at relatively large sizes (>100mm), as research suggest larger juveniles are less likely to rely on nearshore (Taylor Assoc., 2010). However, this assumption has not been conclusively verified.
2. Field data from research on juvenile Chinook use of small non-natal streams indicates that the majority of Chinook are very small, 30-60 mm (Todd Zackey pers. comm.), which suggests (if WRIA 8 Chinook are as large as assumed) that WRIA 8 Chinook are not likely to benefit from these areas.
3. Toxic contaminants in nearshore (and offshore) areas may have a larger impact on early marine survival than previously assumed (O’Neill et al. 2015)
4. Chinook use of Puget Sound nearshore in general needs more study.
MATURATION (MARINE WATERS)

- More information is needed to document movement patterns and timing.
- Potential sources of information include the Salish Sea Marine Survival Project.