APPENDIX B
Duwamish Blueprint
November 6, 2014

Scientific Information on Salmonid Use and Habitat in the Duwamish Estuary

Key resources for people seeking to understand the extent and nature of the transition zone can be found in:

WRIA 9 Chinook Salmon Research Framework (NRC and Technical Committee)

Salmonid Utilization of Restored Off-Channel Habitats in the Duwamish Estuary, 2003 (NRC and R2 Consultants; Greg Ruggerone and Eric Jeanes) (PDF in WRIA 9 file)

Historical Aquatic Habitats in the Green and Duwamish River Valleys and the Elliott Bay Nearshore (Collins and Sheikh, 2005)
http://your.kingcounty.gov/dnrp/library/2005/kcr2038.pdf

Juvenile Chinook Migration, Growth and Habitat Use in the Lower Green River, Duwamish River and Nearshore Elliot Bay 2001-2003 (Tom Nelson; not ready as final; draft
http://www.nws.usace.army.mil/PublicMenu/Doc_list.cfm?sitename=ERS&pagename=MONITORING)

2005 Juvenile Chinook Duwamish River Studies
http://your.kingcounty.gov/dnrp/library/2006/kcr1953.pdf:

a. Habitat Utilization, Migration Timing, Growth, and Diet of Juvenile Chinook Salmon in the Duwamish River and Estuary (Ruggerone, Nelson, Hall, Jeanes)
b. Fish Assemblages and Patterns of Chinook Salmon Abundance, Diet, and Growth at Restored Sites in the Duwamish River (Cordell, Toft, Cooksey, Gray)

Technical Information from Duwamish River Salmon Studies

The resources above were used to update the boundaries of the Duwamish transition zone, as defined in this blueprint.

Modified Figure 13 (Figure 1, below) from the 2005 Duwamish Studies report (Ruggerone et al. 2006) shows that natural origin Chinook fry sampled in 2005 were found throughout the Duwamish from River Mile 1.0 to River Mile 8.5, with the highest abundance in the lower Duwamish just below the turning basin and at Codiga. The red circles denote the areas of the highest catch per unit of effort (CPUE) of juvenile Chinook during 2003 sampling (King County, 2003 unpublished data), when more fish were found at sites just above the turning basin up to the current location of North Wind's Weir (River Mile 6.5) and at the lower estuary sites.

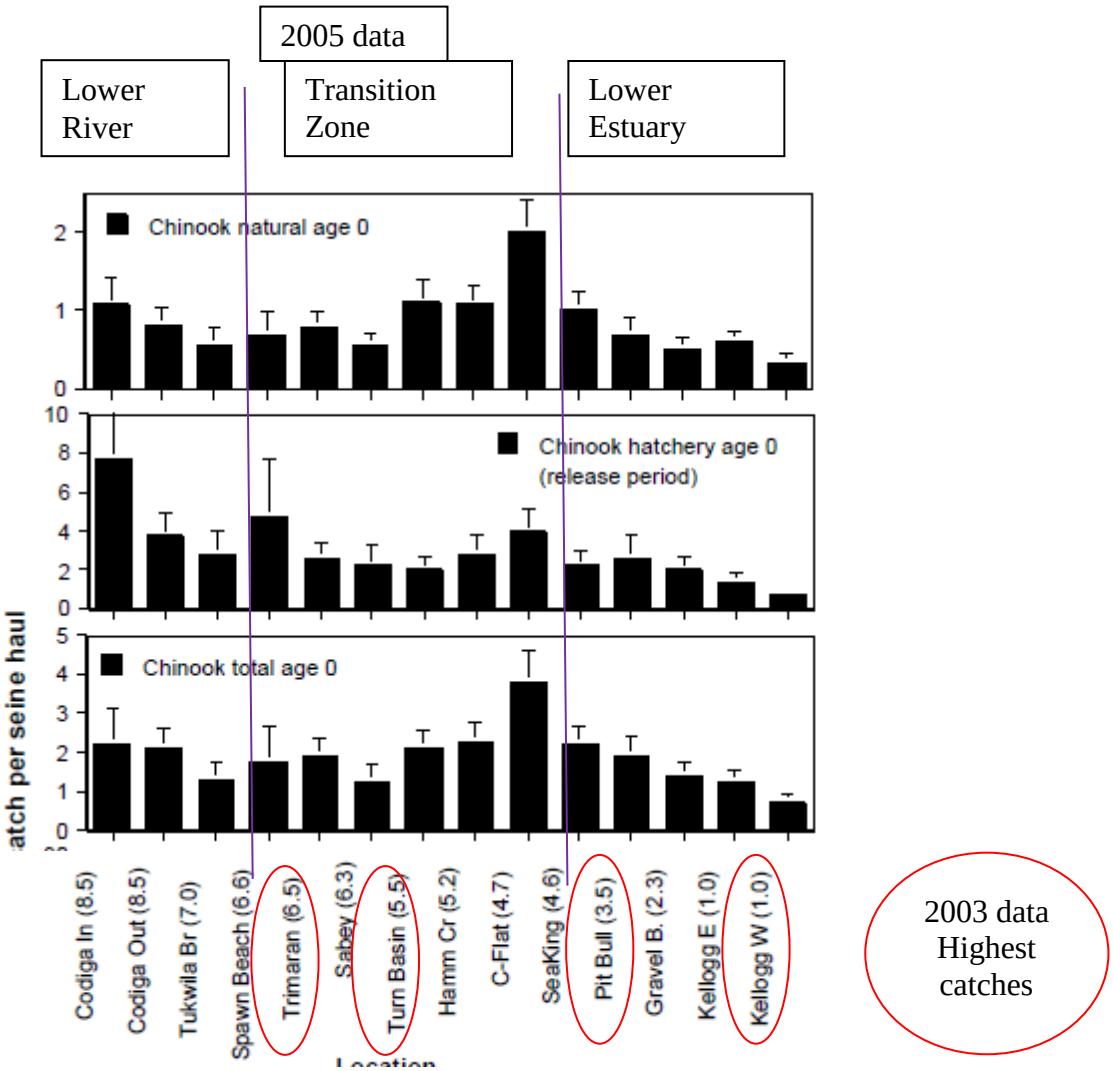


Figure 1. Modified Figure 13 from Ruggerone et al. 2006.

Juvenile Chinook were found in different densities in different areas of the Duwamish at different times (Figure 2) and at different salinity levels (Figure 3) of the outmigration period (Ruggerone et al. 2006), which is generally from February through July. This suggests that young fry use the middle and downstream areas of the Duwamish during the February-March portion of the outmigration, and larger juveniles, migrating from late March through July, are spending time in the middle and upstream areas of the Duwamish (also see data summarized in Table 1). Unfortunately, in both years (2003 and 2005) when extensive juvenile Chinook sampling was done in the Duwamish, the outmigration of juvenile Chinook consisted of a higher percentage of fry outmigrants than most years (Table 1). It is unclear how the skewed outmigration might have affected the results used to define the transition zone. More sampling is needed in years when outmigration of parr and fry are relatively equal in order to verify the current data apply during a typical outmigration period. Furthermore, more sampling above RM 8.5, below RM 1.0, and at sites with varying elevations would help determine the factors most important to juveniles. Further research is also needed to explore if inlet/outlet size is responsible for some of the

variability seen in juvenile use of created off-channel habitats. While there is need for more research, the existing data suggest that juvenile habitat in all areas of the Duwamish between RM 1.0 and 8.5 needs to be restored in order to maximize life history diversity of Chinook.

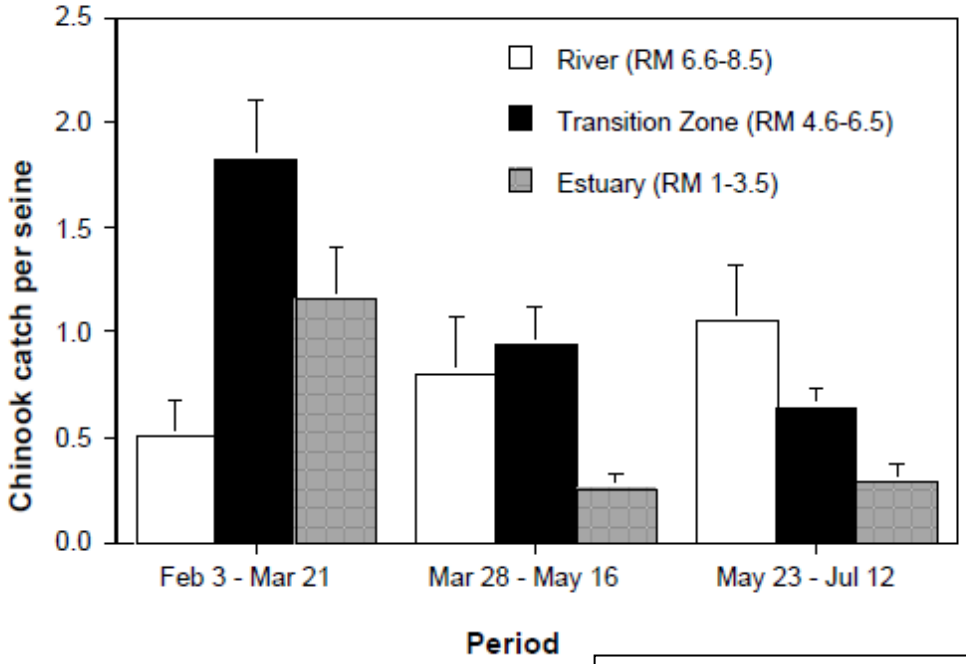
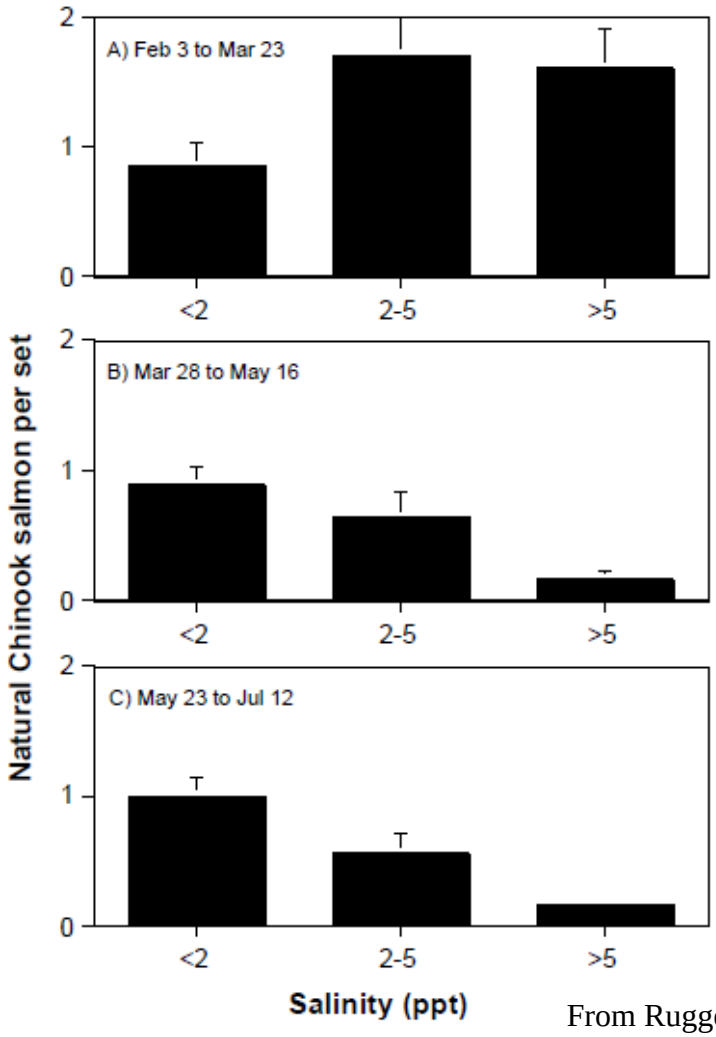


Fig. 14. Geometric mean catch of subyearling natural Chinook salmon (+ 1 SE) during each sampling period and each zone of the lower Duwamish River and estuary during 2005.

Figure 2. Juvenile Chinook capture locations and timing in 2005 (Ruggerone et al. 2006).

Table 1. 2005 juvenile fish data, summarized by location in the Duwamish and compared to Green River outmigrant numbers (Topping and Zimmerman 2013). 2003 and 2005 had unusually high percentages of fry-sized migrants, compared to the average over 13 years, so results might be different in an average year.

Geographic location	?	Lower Estuary	?	Transition Zone	?	Lower River	Upper Duwamish
River Mile	0-1	1-3.5	3.5-4.7	4.7-6.5	6.5-6.8	6.8-8.5	8.5-11
	Not sampled		Not sampled		Not sampled		Not sampled
Timing and Catch per unit effort		Moderate Catches early (Feb thru March), lower catches later		Highest catches early and middle (Feb thru mid May		Highest catches late (May thru July)	
Dominant life history type		Fry		Fry, Parr		Parr	
Average	Average % of fry migrants between 2000-2012 was 57% (compared to parr migrants)						



From Ruggerone et al 2006

Fig. 16. Geometric mean + 1 SE of natural subyearling Chinook fry in relation to salinity (2.5 ft depth) during each period of migration.

Figure 3. Duwamish salinity measurements and associated numbers of Chinook fry in those locations at different times during the Chinook outmigration period from February to July in 2005 (Ruggerone et al. 2006).

Salmon Habitat Plan: Summary Scientific Information on the Duwamish

For ease of reference, information summarized in Chapter 4 of the Salmon Habitat Plan is re-printed here. This information covers:

i. Historical conditions
ii. Current conditions
iii. Change in habitat conditions
iv. Fish utilization

For additional information, please see the WRIA 9 Strategic Assessment Report – Scientific Foundation for Salmonid Habitat Conservation, specifically sections:

1.4.4
2.3.1.4
3.2.4
4.6.1
5.5.1
6.3

Historical Conditions

The historical Duwamish River estuary was small relative to other estuaries in Puget Sound due to its unique topography (Collins and Sheikh 2004).* The narrow floodplain in the upper part of the Duwamish River valley likely funneled the floodwater from the watershed and resulted in overbank flooding and the creation of "swampy marshes" (freshwater wetlands). Similar to conditions in the Lower Green River Subwatershed, these floodwaters likely carried with them juvenile salmonids that used these wetlands as rearing habitat. At the lower end of the river where it becomes tidally influenced, there were several types of tidal marshes that contained different plant communities. Collins and Sheikh (2004) classified them as riverine-tidal marshes and they totaled approximately 166 hectares [410 acres] in the mid-1860s. There were approximately 175 hectares [432 acres] of estuarine wetlands in the mid-1860s, primarily downstream of present day Kellogg Island. Blind tidal estuarine channels (i.e. "dead-end" channel connected at only one end) provided the most channel edge on the Duwamish with the mainstem providing the next largest amount of channel edge habitat (Collins and Sheikh 2004). Information from other estuaries in the Northwest (Simenstad et al. 1982, Levings et al. 1986, Healey 1991) suggests that it was likely an important rearing habitat for multiple life histories of Chinook salmon. Numerous small channels in the estuary were bordered by key dense marsh vegetation that contributed to the production of salmon prey.

Current Conditions

Channel characteristics in the Duwamish River vary by reach and were monitored as part of surveys performed in 2003 and 2004 (TerraLogic and Landau 2004, Anchor Environmental 2004a). Habitat attributes included riparian vegetation, invasive species, overwater structures, bank armoring, large woody debris, and pilings. In general, observed habitat conditions reflect extensive alterations to the upper (RM 5.7 to 11) and lower (RM 0 to 5.7) Duwamish River. The average width of the channel was 50 meters in the upper river. There are three large pools with a spacing of one pool per 59 channel widths. Over 90% of the lower Duwamish is armored (60% with riprap; 24% with steel or concrete bulkheads). About 48% of the shoreline has no vegetation; 30% is Himalayan blackberry; nearly 10% is landscaped; 6% is other invasive shrubs; and 3% is immature deciduous vegetation. Approximately 87% of the shoreline has greater than 75% impervious surface in the area adjacent to the river. There are 56 piling groups, 49 pieces

* References in this Appendix are not reprinted here. See the WRIA 9 Strategic Assessment Report – Scientific Foundation for Salmonid Habitat Conservation at: http://your.kingcounty.gov/dnrp/library/2005/KCR1901.pdf

of large woody debris, including two large accumulations, and 14 occurrences of Japanese knotweed [2014 update: over 133 knotweed occurrences along the Duwamish in the City of Tukwila alone]. Kellogg Island and the Turning Basin are two of the areas that have little or no armoring and are higher in habitat quality. A number of investigations within the Duwamish River have documented sediment contamination with polychlorinated biphenyl (PCBs), polycyclic aromatic hydrocarbons (PAHs), phthalates, inorganics, and organotins. In 1997, the natural resource trustees for the Duwamish River initiated an investigation to evaluate the extent and severity of PCBs in the sediments of the waterway. The major findings indicated that almost 71 of the 350 acres sampled, or just under 20% of the waterway, were estimated to have PCB levels that exceed the state standards.

Change in Habitat Conditions

The valley bottom of the Duwamish differs in the lower valley versus the upper valley (see river miles noted above). Historically, the upper valley resembled the lower Green River with natural levees depositing along the riverbanks, whereas the lower valley riverbanks are lower in elevation than the rest of the valley bottom. Today, armoring and levees have mostly altered the natural riverbanks. Historically, this area was prone to flooding and these floodwaters supported about 200 hectares [494 acres] of freshwater wetlands that have been decreased to about 7 hectares [17 acres]. In addition, historically there were riverine-tidal forested and scrub-shrub wetlands but these are completely gone (Blomberg et al. 1988; U.S. Fish and Wildlife Service 1990).

Estuarine habitats were extensive historically but are currently found only in small patches. Historical estimates of estuarine mudflats were 900 hectares [2,224 acres] and estuarine wetlands were 174 hectares [430 acres]. Filling of wetland and marsh habitats began in 1895. Today there are only about 1% of mudflats and 11% of tidal marshes remaining. The filling of the mudflats and the straightening and widening of the former channel completely altered the estuarine habitat.

A healthy estuary provides transition zone habitats that aid juvenile salmon in osmoregulation (adapting to saltwater), growth, and survival. The transition zone is characterized by a mixing of fresh and saltwater. This mixing creates brackish water that supports a unique ecology. A much greater expanse of this transition zone habitat was historically available closer to and within Elliott Bay prior to regular dredging, reduced freshwater flow from river diversions, and extensive filling of historical intertidal areas in the Duwamish River and Elliott Bay. The freshwater-salt water mixing zone has been vastly reduced in size and moved upstream to its current location. The Strategic Assessment defines the current location of the transition zone between river miles 7.0 and 5.5. Additional data generated in 2005 suggest the location during the outmigration of juvenile salmonids may be between river miles 6.5 and 4.7 or 4.8 (Figure 4-1).[*] The final results of this study will be used to help determine the location of projects intended to rehabilitate/substitute transition zone habitat. Dredging for maintenance of navigation now leaves only a thin margin of tide flats along the shoreline with an artificially

[*] The transition zone boundaries were further defined in 2014 as described in the body of the Duwamish Blueprint.

deepened central channel from about river mile 5.0 to Elliott Bay. The one exception to these narrow slices of intertidal habitat is at Kellogg Island (river miles 1.1-1.4).

Fish Utilization

Several year classes of Chinook (fry, yearlings, and possibly two-year-old fish) were found in the Duwamish Estuary between January and September in 2002 and 2003 (Nelson et al. 2004, Goetz et al. 2003, Ruggerone and Jeanes 2004). Two peaks in abundance occurred in the estuary: the first, composed of fry, was observed from late February to early March, and the second for fingerlings occurred between mid-May and mid-June. Subyearlings were consistently captured at river mile 5.5 and 6.5, which has been postulated to be a critical estuarine transition zone where the river and salt wedge initially mix. This transition zone is also where the river widens, velocities decrease, and estuarine mudflats begin to appear. The boundaries of the existing transition zone are being refined at the time of publication [in 2005]. Chinook salmon utilize estuaries to acclimate to marine water and to grow in a relatively food-rich environment where predators are often less abundant. In general, smaller salmon (e.g., fry) are likely to rear in estuaries for longer periods, before moving into marine nearshore areas.

Natural origin fry (marked at lower Soos Creek in winter 2003) were found in the transition zone within one to 31 days (53% of the fry were found within 1-4 days) after release (Nelson et al. 2004) and may rear in this area to fingerling size before migrating out to Elliott Bay during the outmigration peak in June. This scenario, if confirmed, would amount to an estuarine residence of up to five months, much longer than commonly believed. From observing peak catch data in 2002 and 2003, most natural fingerlings arrived in the estuary in May to acclimate and feed for several weeks, before departing to marine waters. Nelson et al. (2004) reported that Chinook growth rates in the Duwamish estuary in 2003 were initially steady, but increased to rates between 0.44 and 0.54 mm/day from April through June, except for three weeks from mid May to early June, when hatchery Chinook occupied the area. During this time of hatchery fish residence, growth rates dropped 75% to 0.13 mm/day, indicating the existence of a juvenile density-dependent depression in growth. In addition to reduced growth rates, natural origin Chinook fingerlings may have been physically displaced as well. This phenomenon was apparent in the transition zone (Nelson et. al 2004), and in restored off channel estuarine habitats (Ruggerone and Jeanes 2004). These results suggest that there is a shortage of available food and habitat capacity as a result of competition between hatchery and natural Chinook in the estuary, especially in the transition zone. Ruggerone and Jeanes (2004) demonstrated that restoration of large amounts of off channel habitat is necessary to have a measurable effect. This finding is based on an estimate that only 0.16% of the three million hatchery Chinook, and 0.16 to 0.33% of the natural subyearling Chinook population used the five off channel restoration sites these authors sampled in the Duwamish estuary in 2003.

Since 2000, nine sub-adult (mean size 290 mm) and one adult (585 mm) bull trout have been captured in the Duwamish River. The large adult was captured in May 2003 near Kellogg Island (river mile 1.0); the sub-adults were captured in the transition zone (river mile 5.5) in August and September 2000 and September 2001 (Goetz and Jeanes 2004).

Additional Planning and Technical Resources Related to the Duwamish (in chronological order):

- Distribution and Food habits of Juvenile Salmonids in the Duwamish Estuary. J. Meyer, T. Pearce, and S. Patlan, 1981. U.S. Fish and Wildlife Service.
- East, West, and Duwamish Waterways Navigation Improvement Study, U.S. Army Corps of Engineers, June 1982
- Changes in Duwamish River Estuary Habitat over the Past 125 Years. George Blomberg, Charles Simenstad, and P Hickey. 1988. In proceedings , First Annual meeting on Puget Sound Research.
- Potential Intertidal Habitat Restoration Sites in the Duwamish River Estuary. Curtis Tanner 1991. Prepared for the Port of Seattle and U.S. EPA.
- Concept Document – Elliott Bay Duwamish Restoration Program. EBDRP 1994. Panel Publication 7. http://www.darrp.noaa.gov/northwest/elliott/pdf/ebpnl07a.pdf
- Lower Duwamish Habitat Restoration Plan for Puget Sound's Duwamish Estuary and Elliott Bay, September 1996, – authorship unclear – perhaps Duwamish Coalition?
- Salmonid Utilization of Restored Off-Channel Habitats in the Duwamish Estuary, Greg Ruggerone and Eric Jeanes, 2003
- Lower Duwamish Inventory Report, TerraLogic, 2004
- Lower Green River Baseline Habitat Survey, Anchor Environmental, 2004 (some overlap of study area with "Lower Duwamish Inventory Report")
- WRIA 9 Chinook Salmon Research Framework, WRIA 9 Technical Committee
- Juvenile Chinook Migration, Growth and Habitat Use in the Lower Green River, Duwamish River and Nearshore Elliot Bay 2001-2003, Tom Nelson (not ready as final; draft is available at: http://www.nws.usace.army.mil/PublicMenu/Doc_list.cfm?sitename=ERS&pagename=MONITORING)
- Lower Duwamish Waterway Sediment Transport Report. QEA 2008.
- Restoration and Enhancement Plan, City of Seattle Master Shoreline Program. City of Seattle 2012.