Appendix E
Fish Habitat Utilization Literature Review

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Toft et al. (2007) *City Shoreline Fish Distribution*

Study objective: study the abundance and behavior of juvenile salmon and other fishes among various marine shoreline habitat types near the city of Seattle.

Focused on 5 types of shorelines
- cobble beach
- sand beach
- riprap extending into the upper intertidal zone
- deep riprap extending into the subtidal
- edge of overwater structures

Also examined stomach contents of juvenile salmon.

Fish sampling methods included enclosure nets and snorkel surveys.

Riprap often results in greater beach slopes and steep embankments which effectively reduces the intertidal zone. These characteristics in turn, result in habitat loss for juvenile flatfishes.

At high intertidal habitats, more crab were encountered at cobble beaches compared to sand beaches and riprap. Demersal fishes (cottids) were found in greater numbers at riprap. Differences in species density between habitat type were more apparent for demersal fishes than for pelagic species.

Densities of salmon were significantly different among habitat types. The highest densities occurred at the edge of overwater structures and in deep riprap.

Deep riprap creates some structured habitat which seems to attract surfperches and gunnels. Threespine stickleback, tubesnout, and bay pipefish were also more prevalent at deep riprap than at cobble, sand, and high elevation riprap.

Beamer et al. (2006) – *Habitat and fish use of pocket estuaries in the Whidbey basin and north Skagit county bays, 2004 and 2005*

Pocket estuaries are characterized as having more dilute marine water relative to the surrounding estuary. They form behind coastal accretion landforms at embayments or small creek mouths.

Objective: large scale research to follow up with previous pocket estuary work in Skagit Bay. This research focused on Whidbey Basin and north Skagit County Bays

Hypothesis: juvenile Chinook salmon prefer pocket estuary habitat to adjacent nearshore habitat between the month of February to May.

See Table 1 on pg 4 for their nearshore zones and substrate categories.

Habitat assessment methods/details:

- Digitally mapped sites according to the "habitat" classifications outlined in table 1
- Next, the pocket estuaries were re-mapped using the oldest available data from historical orthophotos and maps.
- Historical photos were scanned and georeferenced to 1998 DNR orthophotos
- Images were fine tuned with current geologic soils and topographic maps, current LIDAR, and US Coast and Geodetic Survey maps from the 1800s.
- Data sources were compared as overlapping GIS layers

Results

- In 2004, wild juvenile Chinook densities were 52% higher in pocket estuaries compared to nearshore areas, but the difference was not statistically significant.
- In 2005, wild juvenile Chinook densities were 5 times higher in pocket estuaries than at nearshore sites. These differences were statistically significant.
- Landscape connectivity plays a role in the density of Chinook within a pocket estuary. The closer the pocket estuary to the natal stream or river, the more likely the pocket estuary will have higher densities of fish. This pattern is a very general one, but the trends are pretty apparent.
- Chum and pink salmon did not follow the same trend as Chinook in that both were caught within and outside of the pocket estuaries, however these species did not occur in greater numbers within the pocket estuaries.

Beamer et al. (2003) ***The importance of non-natal pocket estuaries in Skagit Bay***

This was the original "pocket estuary – salmon" paper. Nothing applicable here that was not covered in the later paper described above.

Fresh et al. (2006) – ***Juvenile Salmon use of Sinclair Inlet, Washington in 2001 and 2002***

Objectives:

- assess spatial and temporal use of nearshore areas by juvenile salmon and other species (beach seine)
- assess offshore use by the same fishes (tow net)
- investigate cohort residence time in Sinclair Inlet
- diets analysis

Habitat characteristics were qualitatively assessed by examining:

- area of capture (defined by the three east-west regions in the inlet)
- north or south shoreline
- type of substrate
- amount of upland and submerged vegetation
- shoreline modifications
- slope

Results:

- Sinclair Inlet is used by three distinct groups of Chinook salmon
    1. hatchery origin Chinook released into Gorst Creek. Most of these fish disperse and leave the Inlet rapidly
    2. hatchery fish from areas outside of Sinclair Inlet. Present from July – Sept.

3. Wild juvenile Chinook. Could be from Gorst Creek or other natal streams outside of the Inlet.

- Compared with other regions in the Puget Sound, forage fish were relatively scarce in nearshore surface waters. They were more abundance in tow net samples.
- The study could not detect any patterns in size, diet, and distribution of Chinook salmon that could be attributed to human alterations of the ecosystem. *There was no effect of shoreline on size or CPUE for Chinook salmon.*
    - This could be explained by several factors:
        1. fish may not respond to habitat at the site scale. Rather, patterns such as abundance, size, and diet are likely more apparent at larger spatial scales.
        2. the qualitative approach to measuring habitat attributes may not have been adequate to detect changes
        3. there could have been other unmeasured factors influencing fish patterns (physical constraints such as oceanic conditions or nearby freshwater inputs).

Beamer et al. (2005) – *Delta and Nearshore Restoration for the Recover of Wild Skagit River Chinook Salmon: Linking Estuary Restoration to Wild Chinook Salmon Populations*

Habitat can be measured and defined at multiple scales of space and time.

"Patch or site scale habitat attributes in a tidal marsh include area of the marsh, volume of the marsh, vegetation type and density, salinity and temperature patterns, and channel depth at the mouth of blind tidal channels."

The authors caution that relying solely on site or patch scale habitat attributes to understand and manage salmon can result in "ineffectual" restoration.

Landscape scale attributes include the size, shape, and location of habitat on a large scale. "…the function of any unit of habitat depends upon the context of the habitat within surrounding landscape."

The text is not very specific with habitat metrics and fish use. The general themes includes loss of historic estuarine features such as river deltas, marshes, and tidal channels. The importance of Pocket Estuaries and their role in the estuarine landscape mosaic. Connectivity between habitats and the idea of "opportunity" for migratory pathways.

Connectivity is described on a landscape scale as well as at a site scale.

Fresh (2006) – *Juvenile Pacific Salmon in Puget Sound*

Small juvenile chinook salmon prefer low gradient estuarine habitats characterized as having shallow water, fine-grained substrates (silts and mud), low salinity, and low wave energy.

Habitat function is related to conditions at multiple scales – the site and landscape scale features.

"..our ability to link nearshore habitat characteristics to function that support juvenile Chinook salmon is strongest in natal deltas and weakest along nearshorelines."

Diets of juvenile chum suggest these fish associate with habitats having fine-grained substrates and eelgrass.

Habitat opportunity refers to habitat attributes that affect the ability of juvenile salmon to access habitat (e.g. tidal elevation, hydrodynamic processes, and temperature).

"Habitat capacity refers to attributes that affect the ability of habitat to support fish once they have accessed it…(e.g. predator population sizes, prey production and prey availability)."

See table 1 pg 7 for a list of nearshore habitat attributes important to juvenile salmon. This table lists very general attributes such as water quality, physical, and biological characteristics.

At this point our understanding of juvenile salmon and linkages between habitat attributes in marine environments is weak in littoral habitats. We know a considerable amount with regard to juvenile Chinook and tidal delta habitats though. Our knowledge of the link between salmon and pocket estuaries is also increasing. Pocket estuaries closest to natal deltas are important to the migrant fry strategy of Chinook salmon.

Stillaguamish Tribe (2005) – ***Analysis of Sillaguamish Estuary use by Juvenile Chinook – A Pilot Study***

Study aimed at looking at the distribution of Chinook salmon in the Port Susan estuary. Objectives included

- test seining methods
- select site
- capture Chinook salmon during spring migration

Beach seined on a monthly basis within a range of habitat types:

- blind tidal
- delta distributary
- rocky headland
- open sand and gravel beaches
- pocket estuaries

Results:

- highest densities of Chinook in the blind tidal channel near the mouth of the Stillaguamish (>1000 chinook/Ha)
- Distributary sites of the Stillaguamish also had high densities (>40-200 chinook/Ha)

Kagley et al (2007) – ***Juvenile salmon and nearshore fish use in shoreline and lagoon habitat associated with Elger Bay, 2005- 2007***

Substrate types were classified according to the Skagit System Cooperative (2003):

- Gravel
- Mixed Coarse
- Mixed Fines
- Mud

Henderson et al. (2007) - *Juvenile salmon and nearshore fish use in shallow intertidal habitat associated with Race Lagoon, 2006 and 2007*

Higher fish density within the lagoon habitat than along the adjacent shallow nearshore.

Beamer (2007) – *Juvenile salmon and nearshore fish use in shoreline and lagoon habitat associated with Ala Spit, 2007*

Examined 2 habitat types: lagoon and adjacent nearshore.

Depth:

- Lagoon was slightly deeper

Six substrate types:

- Fines with gravel
- Gravel
- Mixed coarse
- Mixed fines
- Mud
- Sand

Wave energy and hydrological conditions drive substrate conditions and the differences at each of the habitats examined.

Four vegetation types encountered:

- eelgrass
- eelgrass and algae
- green algae
- salt marsh

Results:

- the lagoon habitat generally had more fish
- fish in the lagoon were "evenly represented" by 3-5 species
- in the adjacent nearshore salmon were the most dominant species (primarily chum).
- There were some patters consistent with substrate type and fish associations. See table 8
- Chinook were most associated when seine was set within salt marsh vegetation and fine grained substrates.
- The results of this study are merely patterns as the level of sampling "was not adequate to statistically detect differences in fish density between habitat types…"
- Concluding remarks: Ala Lagoon is an important habitat feature for juvenile Chinook due to its close proximity to the mouth of the North Fork of the Skagit River.
- The Battelle Hyrdrodynamic model indicate Ala Spit and Lagoon are strategeically located for use by Skagit River juvenile salmon through landscape connectivity.

Kagley et al. (2007) – *Juvenile salmon and nearshore fish use in shallow intertidal habitat associated with Harrington Lagoon, 2006*

Used a small beach seine to sample Harrington Lagoon and adjacent shallow intertidal nearshore habitat.

Examined substrate type at each haul location using 4 types defined by the Skagit Systems Co-op (2003)

1. gravel
2. Mixed Coarse
3. Mixed Fines
4. Mud

Vegetation (2 types)

- saltmarsh
- unvegetated

Fish assemblages were more abundant in the lagoon habitats than the adjacent nearshore areas.

Beamer et al. (2006) – *Juvenile salmon and nearshore fish use in shallow intertidal habitat associated with Harrington Lagoon, 2005*

Fish abundance was higher in the Lagoon compared to adjacent nearshore beaches sampled for the following species: sculpins, shiner perch, threespine stickleback, arrow goby. Flatfish and snake pricklabacks were only caught in the lagoon and did not occur in the nearshore catches.

Species diversity was greatest in the Lagoon compared to nearshore areas during the sampling period: Feb-June.

Beamer et al. (2004) – *The importance of Skagit delta habitat on the growth of wild ocean-type Chinook in Skagit Bay: implications for delta restoration*

Looked at otolith microstructure to identify the life history types/patterns of juvenile Chinook salmon.

Found that the proportion of Chinook outmigrants that bypass tidal delta habitats and head directly for deeper Bay locations increases when outmigrant populations from the Skagit reach 2.5million. This suggests density dependence in the estuarine habitats.

Results:

- "The longer wild sub-yearling Chinook spend in the delta, the better they grow in the bay." This concept also applies to bay habitats; "…the longer wild subyearling Chinook spend in the by, the better their growth rate in the bay."
- Fish size at bay enterence positively influenced growth rate in the bay.
- The later in the season fish entered bay habitat, the better they grew in this habitat.
- Fish with longer delta residence enter the bay later in the year.
- "..delta restoration is needed for wild Skagit Chinook recovery."

- Pocket estuaries may alleviate the density dependence occurring in tidal delta habitats by providing rearing opportunities for the "exported" fish. However, these habitats are in limited supply and the restoration potential in these areas will not address the key issue of density dependence in the estuary.

Beamer et al. (2007) – *Juvenile salmon and nearshore fish use in shoreline and lagoon habitat associated with Turners Bay, 2003-2006*

Turners Bay is described as a pocket estuary due to its tidal channel lagoon features/structures.

Sampled three habitat types:
1. lagoon
2. shallow intertidal
3. deeper intertidal-subtidal fringe

Fish assemblage for each of the habitat types changed little among years, so one year of monthly sampling may be fine for characterization.

The "…analyses strongly support the inference that sites of the same habitat type will contain the same fish assemblage."

Results:
- lagoon habitat within the pocket estuary had the highest overall fish density over the year compared to the other habitat types.
- All three habitat types were utilized throughout the year by nearshore fishes.
- Lagoon habitat typically had higher densities of smelt than adjacent nearshore habitat.
- Low tide platform and subtidal fringe habitats supports rearing conditions for forage fish; surf smelt, herring, and sandlance.

Dorn and Best (2005) – *Integration of joint city of Bainbridge Island/Suquamish tribal beach seining results into shoreline management and salmon recovery efforts in Kitsap County, Washington*

Objectives
- Identify distribution, abundance, origin, and timing of wild and hatchery Chinook salmon.
- Compare the condition factors of hatchery to wild Chinook
- Identify forage fish use of nearshore

Beach seine sites were chosen to represent different habitat conditions (altered, natural, and vegetation) within different geomorphic settings.

Results are not linked to habitat features – ***follow up to determine if there is a more completed document available for review.***

Duffy et al. (2005) – *Early marine life history of juvenile Pacific salmon in two regions of Puget Sound*

Peak catches in nearshore areas were related to peak discharge from rivers. These patterns were particularly apparent for coho in the southern sites and pink in the northern sites.

Residence time of Chinook salmon extended to 18 weeks. This value was derived from the timing of release in the river. The average time in a single area ranged 1-3 weeks.

The study noted regional patterns in residence time of hatchery Chinook in the nearshore. Fish released from the northern region use more habitats for longer periods compared with hatchery fish originating from the southern basin.

When the hatchery fish catches overlapped with wild Chinook, hatchery fish were larger. This presents opportunity for competition amongst the two size classes.

Ultimately differences between the northern and southern regions sampled are attributed to differences in hatchery release strategy, and environmental constraints such as salinity and temperature.

Nothing specific on habitat associations……..

Murphy et al. (2000) – A comparison of fish assemblages in eelgrass and adjacent subtidal habitats near Craig, Alaska

Methods – round haul 37m beach seine.

Compared fish at three vegetated habitats

1. eelgrass
2. kelp
3. filamentous algae

Results

- species richness was greatest at eelgrass and kelp sites compared with sites characterized with filamentous algae.
- Shannon-Weaver diversity index did not differ among the three habitat types.
- Juvenile rockfish were equally abundant in eelgrass and kelp
- Salmon catches were highly variable due to patchy distributions.
- Depending on the month, the difference between salmon (chum and pink) catches in eelgrass and non-eelgrass habitats was not statistically significant.
- "eelgrass habitat supported high levels of species diversity and fish abundance…"
- "rockfish were closely associated with submerged vegetation, both eelgrass and kelp."
- "Juvenile salmon were not significantly associated with eelgrass."

Tabor and Piaskowski (2002) – *Nearshore habitat use by juvenile Chinook salmon in lentic systems of the lake Washington basin, annual report, 2001*

Nighttime snorkel surveys

2000 Results

- Juvenile Chinook salmon were associated with low gradient shorelines with small substrates; sand and gravel.
- They were concentrated in very shallow water - ~0.4m deep.
- The fish appeared to avoid overwater structures

Chinook salmon originate from the Cedar River which drains into the southern end of Lake Washington.

Methods

- conducted random transect surveys
    - snorkel/fish observations
    - habitat features were recorded
- transects were delineated using aerial photos and a random number generating process selected the specific transect to be investigated/measured.
- Habitat features
    - Depth
    - Substrate
        - Dominant
        - Subdominant
    - Distance to cover
    - Type of cover
    - Distance to shore (measured from where the fish was observed underwater)

Results:

- Along the south shore Chinook salmon preferred sand and gravel substrates.
- Some Chinook were associated with cobble and boulder substrates
- Chinook rarely were observed under overwater structures.