Opportunities for Enhancing Juvenile Salmon Nursery Habitat in Urbanized Ecosystems?

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WET/SAFS/UW photo by C. Simenstad
How do shoreline (nearshore) ecosystems benefit juvenile salmon?

Does shoreline development impact juvenile salmon?

Can we mitigate the effects of shoreline development on juvenile salmon?
ROLE OF ESTUARIES IN SALMON EARLY LIFE HISTORY
= “nursery function”?

• Juveniles of “ocean-type” salmon, rather than “stream-type” and typical hatchery races, e.g., are the most estuarine dependent on habitat integrity (and frequently in jeopardy?)
• Physiological transition during migration
• Significant shift in feeding and predation regimes
• Site of rapid growth
• Buffer freshwater rearing during extreme events
FOR PACIFIC SALMON, LIFE IS JUST A CONTINUUM OF BOTTLENECKS!

<table>
<thead>
<tr>
<th>Species-LH Type</th>
<th>Freshwater Residence</th>
<th>Downstream Migration</th>
<th>Estuarine Residence</th>
<th>Estuary-Ocean Transition</th>
<th>Ocean Residence</th>
<th>Possible Life History Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>PINK</td>
<td>Virtually none</td>
<td>Immediate &amp; rapid, as fry</td>
<td>Short; ~2 weeks</td>
<td>Rapid</td>
<td>Fixed; 2 years</td>
<td>1</td>
</tr>
<tr>
<td>CHUM</td>
<td>Virtually none</td>
<td>Immediate, as fry</td>
<td>Short-moderate, 2-3 weeks</td>
<td>Rapid</td>
<td>Variable; 1-5 years</td>
<td>10</td>
</tr>
<tr>
<td>SOCKEYE-lake type</td>
<td>Extensive, 1-3 years in lakes</td>
<td>Relatively rapid, as smolts; 1-2 weeks</td>
<td>Short; few days</td>
<td>Highly variable</td>
<td>Variable; 1-3 years</td>
<td>9</td>
</tr>
<tr>
<td>-ocean type</td>
<td>Short</td>
<td>Rapid, as fry</td>
<td>Often extensive; 1 week-5 months</td>
<td>Unknown</td>
<td>Fixed; 1 years</td>
<td>1</td>
</tr>
<tr>
<td>COHO-stream type</td>
<td>Extensive; 1-4 years</td>
<td>Relatively rapid, as smolts; 1-2 weeks</td>
<td>Short; few days</td>
<td>Highly variable</td>
<td>Variable; 1-5 years</td>
<td>11</td>
</tr>
<tr>
<td>-ocean type</td>
<td>Virtually none</td>
<td>Rapid, as fry</td>
<td>Long? May involve protracted overwintering, and return upstream to rear?</td>
<td>Unknown?</td>
<td>Fixed; 1 year</td>
<td>1</td>
</tr>
<tr>
<td>CHINOOK-stream type</td>
<td>Variable; 1-2 years</td>
<td>Variable; few days to months</td>
<td>Short; few days</td>
<td>Highly variable</td>
<td>Variable; &lt;1 to 6 years</td>
<td>&gt;13</td>
</tr>
<tr>
<td>-ocean type</td>
<td>Variable; few days to months</td>
<td>Variable; rapid as fry, longer as fingerlings</td>
<td>Highly variable; days to 6 months</td>
<td>Highly variable; often prolonged</td>
<td>Variable; &lt;1 to 6 years</td>
<td>36</td>
</tr>
</tbody>
</table>

(Simenstad and Fresh, unpubl.)
LIFE HISTORY TYPES OF JUVENILE CHINOOK SALMON FRESHWATER AND ESTUARINE REARING IN SIXES RIVER (Reimers 1973)

ESTIMATED ABUNDANCE OF JUVENILE FALL CHINOOK IN TRIBUTARIES (catch per seine haul), MAIN RIVER (catch per seine haul), AND ESTUARY (population estimates) IN SIXES RIVER 1969 (Reimers 1973)

Date

Relative Abundance (% of Total)

0 5 10 15 20 25 30 35 40 45 50

9-Mar 29-Mar 18-Apr 8-May 28-May 7-Jun 27-Jul 16-Aug 5-Sep 25-Sep 15-Oct

- Tributaries (Edison and Dry Creeks)
- Main River (6 km)
- Lower Estuary (Stations 1-12)
• “The underlying premise of most studies that examine nursery-role concepts is that some nearshore, juvenile habitats contribute disproportionately to the production of individuals that recruit to adult populations.” (Beck et al. 2001)

• Support greater contributions to adult recruitment from any combination of four factors:
  – density
  – growth
  – survival of juveniles
  – movement to adult habitats

• Advantage/disadvantage of Beck et al. (2001) perspective:
  – focus on mechanism of contribution to recruitment
  – focus only on production
KNOWLEDGE NEEDS TO UNDERSTAND SCALE(S) AFFECTING HABITAT REQUIREMENTS

• resolution relevant to organism’s interactions with landscape....what defines “habitat”?

• factors affecting spatial pattern:
  – life history/autecology (reproduction, dispersal)
  – disturbance
  – biological interactions (herbivory)
  – physiology (stressors, disease)

• scales of processes controlling spatial organization of landscape patterns

• MUST consider not only direct, but also indirect, habitat support
Definition: downstream from the upstream limits of tidal influence of any river or stream entering Puget Sound, to the western limit of the Strait of Juan de Fuca, including those adjacent uplands that directly affect nearshore processes, and encompassing intertidal and subtidal areas, extending to the depth limits of the photic zone.
THE ESTUARINE-NEARSHORE CONTINUUM OF PHYSICS, CHEMISTRY AND ECOLOGY = MOSAIC
JUVENILE SALMON “ECOSCAPES”

Optimum conditions:

- Shallow water 0.3-1.5 m depth (sloughs, tidal channels, flats)
- Vegetated edge (marsh, eelgrass)
- Abundant epibenthic (sometimes neustonic) prey
- LWD?

ANADROMOUS PUNCTUATED MIGRATION

euhaline-euryhaline  brackish-oligohaline  tidal-freshwater
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**JUVENILE SALMON “ECOSCAPES”**

**ANADROMOUS PUNCTUATED MIGRATION**

**OVERWINTERING**
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JUVENILE SALMON “ECOSCAPES”

ANADROMOUS PUNCTUATED MIGRATION

TIDAL / EVENT

OVERWINTERING

euhaline-euryhaline  brackish-oligohaline  tidal-freshwater
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JUVENILE SALMON “ECOSCAPES”

- ANADROMOUS PUNCTUATED MIGRATION
- TIDAL / EVENT
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**Salmon Water Types:**

- euhaline-euryhaline
- brackish-oligohaline
- tidal-freshwater
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ECOSCAPE IMPLICATIONS

- Sequencing of fish pathways through ecoscape with ontogenetic development and environmental change
- Importance of mosaic structure and ecoscape connectivity as migratory corridors among habitats
- Inherent problems:
  - conceptual: dynamic, rather than traditional static view of habitat
  - tools: haven’t had readily available technology to assess salmon ecoscape at appropriate resolutions
  - management, and particularly restoration, continues to be piecemeal, both within and across ecosystems…….needs to become integrated!
- How can the composition and organization of estuarine ecoscapes benefit juvenile salmon…..whether natural or build?
ARE THERE “RULES” FOR JUVENILE SALMON USE OF ESTUARINE-NEARSHORE SHORELINES?

• Size dependent
  ✓ the bigger the fish, the less “dependent” they are on shallow water
  ✓ however, doesn’t mean that they do not utilize shallow water
• Shallow water is relative to tide!
• Species-life history/physiology dependent
  ✓ salinity
  ✓ turbidity
• Varying ‘selectivity’ for prey produced or concentrated in nearshore ecosystems
• Behavioral changes associated with certain nearshore features
  • disturbance (sudden movement, noise, light flashes, etc.)
  • shading (depending on adaptation)
THE ESTUARINE-NEARSHORE CONTINUUM OF PHYSICS, CHEMISTRY AND ECOLOGY = MOSAIC
SCALES OF SHORELINE FUNCTION

- Internal
  - Within marine riparian ecosystem

- Ecosystem
  - Exchanges between ecosystems

- Ecotone-Landscape
  - Across land-margin
  - Landscape element

- Cultural
  - Traditional use

- Recreational/aesthetic
  - Anthropogenic value
SCALES OF SHORELINE FUNCTION -- Internal

- **Primary production**
  - sources of OM to direct herbivory and detritus pool
  - habitat for resident non-fisheries species
- **Secondary production**
  - consumers and prey
- **Decomposition, detritus production**
  - OM entrainment
  - environments conducive to physical, chemical and biological decomposition
- **Nutrient cycling**
  - plant uptake
CONCEPTUAL DIAGRAM OF DETRITUS-BASED FOOD WEB OF ESTUARINE AND NEARSHORE ECOSYSTEMS OF PUGET SOUND AND WASHINGTON COASTAL ESTUARIES

(modified from Dorsey et al. 1978)
SCALES OF SHORELINE FUNCTION--

Ecosystem

- Sediment and water flux to nearshore
- Food web contributions
  - export of organic matter and nutrients
  - potential prey organisms (e.g., insects, amphipods)
- Modulation of ecosystem processes
  - temperature (shading)
  - humidity
  - shoreline geomorphology
- Surface and groundwater modification
  - mechanical filtration
  - soil/plant uptake and transformation
  - contaminant removal
SEDIMENT FLUX TO SHORELINE

- chronic, high frequency, low intensity
- episodic, low frequency, high intensity
WATER FLUX TO SHORELINE

- non-estuarine delta features
- meso-scale low salinity plumes
- OM and prey export
- nutrient mediation
NATURAL AND ALTERED SHORELINE GEOMORPHOLOGY

- Loss of littoral sediment
- Wave reflection/scour
- Hydrological impacts
- Loss of riparian vegetation
- Passive erosion
- Cumulative impact

courtesy Hugh Shipman, WDOE
PREY OF JUVENILE SALMON IN ESTUARIES AND NEARSHORE MARINE HABITATS

- epibenthic crustaceans
- aquatic insect larvae and pupae
- neustonic/drift adult insects
- plankton and other free-swimming invertebrates
ORGANIC MATTER AND INSECT PRODUCTION
SCALES OF SHORELINE FUNCTION—Ecotone/Landscape

- Migratory corridors and transitional habitats
  - upland and marine consumers
- Mediate flux of material and energy
  - erosion from winds and waves
  - mass wastage
- Disturbance
  - maintain ecosystem diversity and complexity
- Sustain longshore sediment transport that maintains diverse, distant shoreforms
SHORELINES AS MIGRATORY CORRIDORS AND ECOTONES

- anadromous fishes
- small mammals
- avifauna
Eelgrass (*Zostera marina*) as fundamental nearshore segment in habitat continuum (“ecoscape”) of juvenile chum salmon in Hood Canal:

- migratory corridor
- refuge from predation
- foraging habitat
LIKELY FACTORS CONTRIBUTING TO THE “VALUE” OF EELGRASS LANDSCAPE STRUCTURE TO JUVENILE SALMON

<table>
<thead>
<tr>
<th>Migration Corridor</th>
<th>Refuge from Predation</th>
<th>Foraging Success</th>
</tr>
</thead>
<tbody>
<tr>
<td>extent</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>connectivity</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>core</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
MASS WASTAGE, VEGETATED SHORELINES AND DISTURBANCE

courtesy Hugh Shipman, WDOE
LANDSCAPE GEOMORPHIC PROCESSES
SAND SPITS, BARRIER BEACHES AND LAGOONS

courtesy Hugh Shipman, WDOE
SCALES OF SHORELINE—Cultural

- **Habitation**
  - permanent occupation
  - seasonal sites

- **Resource harvest**
  - shoreline resources
  - subsistence and cultural materials, e.g., ethobotanical harvest for baskets, and other products
NORTHWEST NATIVE AMERICANS AND THE SHORELINE

Van Olinda, O. S., ca 1902-1905; Skagit potlatch house with people gathered outside, Whidbey Island. Canoes pulled up onto beach in front of house, and canoes and other boats moored in water.; UW Libraries Special Collection, NA832.

ca 1900; Lushootseed man, woman, older woman and five children (and the dogs) pose in front of tents, 1895-1905. Drying in front of them are clams & fish; UW Libraries Special Collection, NA849.
SCALES OF SHORELINE—Recreational/Aesthetic

- Buffer landward development
- Contiguous nature
- Perception of integrity
JUVENILE SALMON IN PUGET SOUND: Ghosts of Habitat Past?

- extensive loss of estuarine rearing habitat
- reduced connectivity
- forced transport to marine environments

Is the marine nearshore acceptable replacement for estuarine habitat of ocean-type juvenile salmon?
Sand and gravel beach with longshore bar and trough. Sediment from nearby bluffs has built a dry berm and backshore area above MHHW.

Sandy beach with upland dunes of windblown sand. Coastline is marked by zone of permanent beach vegetation, low shrubs, and beach grasses.

Profile of sediment-starved beach. Sediment supplied by erosion of low bluffs has not kept up with its removal by waves, and no dry backshore area has developed.

Beaches adjacent to bulkheads are commonly eroded below MHHW because these structures reduce the sediment supply from the uplands. A man-made structure defines the coastline.
BEACH LOWERING

courtesy Hugh Shipman, WDOE
JUVENILE SALMON IN PUGET SOUND: Ghosts of Habitat Past?
RESTORATION PROJECTS IN THE DUWAMISH RIVER ESTUARY
TAKE-HOME MESSAGE

• consider nearshore landscape….from watershed to nearshore marine
• anything will contribute…..the challenge will be how to cumulatively make a difference
• be strategic…..where are the gaps (literally and figuratively)?
• provide a “habitat ecoscape” with integrity and sustainability
• not only incorporate human dimensions (can’t avoid it in urban setting) but take advantage of it!
Let’s not lose the concept of what salmon need in the way of habitat!