Landscape Planning Framework for Restoration and Protection of Juvenile Salmon Habitat using the Columbia River Estuary Ecosystem Classification

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Spatial Planning for Conservation

Contemporary conservation planning draws on seven sets of ideas (below) intended to safeguard the persistence of biodiversity in a conservation area network. Planning for persistence requires, at the very least, incorporation of rules of spatial configuration that take these ideas into account.

1. Biogeographical theory
2. Metapopulation dynamics
3. Successional pathways
4. Spatial autoecological requirements
5. Source-sink population structures
6. Effects of habitat modification
7. Species as evolutionary units

Decision Support Tools for Spatial Planning Restoration/Conservation

Viable Salmon Populations (VSP)

VSP principles are the foundation of ESA planning of Pacific salmon recovery (McElhany et al. 2000), encapsulating the importance of evolutionary processes:

1. Abundance (A)
2. Growth rate/productivity (P)
3. Spatial structure (SS)
4. Diversity (D)

Although seldom considered, the spatial structure of estuarine rearing habitats used by different juvenile salmon Evolutionarily Significant Units (ESU) and life histories during seaward migration should be an equally important conservation focus.

Problem Statement

Many restoration initiatives do not necessarily need to be spatially specific; however, when addressing critical habitat of endangered migratory species, our approaches need to be more strategic than merely *ad hoc*, random acts of opportunistic restoration.

Particularly for anadromous salmon, with their diverse life histories that contribute to population resilience.

Columbia River salmon even more challenging, with 13 endangered ESU (5 Chinook ESU of particular issue for habitat restoration in estuary).

Good general evidence for benefit of estuarine restoration to salmon, but need to be more attentive to different estuarine rearing habitat requirements over space and time by different genetic stocks.
Objectives and Approach of Landscape Planning Framework

- Supported by Columbia River “action agencies” BPA and USACE in ESA salmon recovery in the Basin
- Develop scientific guidance to support proactive identification of estuarine habitat restoration and protection needs of different genetic and life histories of Columbia River Chinook salmon
- Advance a spatially-explicit understanding of juvenile Chinook salmon habitat requirements based on variation in dynamic ecosystem processes along estuary continuum
- Use Columbia River Estuary Ecosystem Classification ("Classification") as background for Juvenile Salmon Estuarine Habitat Landscape Planning Framework (Landscape Planning Framework; LPF)
Columbia River Estuary Ecosystem Classification

- Hierarchical space/time structure
- Initial concept document (USGS OFR 2011-1228)
- Geodatabase completed July 2013
- Summary report and “users guide” (USGS PP) anticipated December 2013-January 2014

1—Ecosystem Province
2—Ecoregion
3—Hydrogeomorphic Reach
4—Ecosystem Complex
5—Geomorphic Catena
6—Primary Cover Class

Subcatena = “ecosystems”

Fish Habitat Catena
Development of fish habitat catena (FHC)

- Based on combinations of *Classification* classes that distinguish variability in juvenile salmon estuarine habitat
- Juvenile, ocean-type Chinook salmon habitat requirements
  - Direct FHC
  - Indirect FHC
  - Supporting drainage
- Guiding principles for restoration and conservation
Juvenile Salmon Habitat Factors

- **Habitat Selection**
  - Direct opportunity (access)
    - depth
    - temperature
    - velocity
    - salinity
    - turbidity
  - Indirect attractants/deterrents
    - prey availability
    - perceived predation threat

- **Habitat Capacity**
  - Direct support
  - Indirect factors
    - water quality (e.g., dissolved oxygen)
    - competitors
    - predators
    - food web processes

- **Factors**
  - fish size
  - seasonality
  - genetic stock

- **Fish Habitat Catena (FHC)**
  - categorize (based on *Classification* catena and subcatena classes)
  - characterize “habitat quality”
  - map distribution
  - Identify variability in use by unique genetic stocks
LANDSCAPE PLANNING FRAMEWORK

Process and Scales of Analyses

1. Identify Juvenile Salmon Habitat Requirements + Constraints
   - Literature Validation

2. Identify FHC-Scale Attributes

3. Identify Landscape-Scale FHC Attributes

4. Identify Genetic Stock Attributes

5. Identify Metrics

6. Identify Metrics

7. Identify Metrics

8. Map/Rank at FHC + Landscape Scale
   - Current
   - Potential? (informed by historical FHC)

9. 1st Order Principles or Concepts
   - Literature Validation

10. Conservation and Restoration Planning Guiding Principles

11. Seasonal/Water Flow Variability

12. Analysis of Restoration & Protection Alternatives
Fish Habitat Catena

Fish Habitat Catena (FHC) integrate three+ levels of the Classification that capture multiple scales and categories of ecosystem structure and processes:

(1) eight *hydrogeomorphic reaches* embody formative geologic and tectonic processes that created the existing estuarine landscape and capture the influence of the resulting physiography on interactions between fluvial and tidal hydrology and geomorphology across 230 km of the estuary;

(2) 21 *ecosystem complexes* comprise broad landforms created predominantly by geologic processes during the Holocene; and,

(3) 36 *geomorphic catenae* (and 40 *subcatenae*) that represent distinct geomorphic landforms, structures, and ecosystems most likely to change over short time periods.
Level 3 — Hydrogeomorphic Reach

Division or adjustment to the up- or downstream boundaries of the EPA Level IV Ecoregions based on spatial data indicating marked transitions in large-scale hydrogeomorphic and tidal-fluvial forcing, including:

(a) maximum (historic) salinity intrusion;
(b) transitions in maximum flood (pre-regulation) tide level;
(c) the upstream extent of current reversal; and
(d) convergences with major tributaries and slough systems.
Merging **Classification Geomorphic Catena and Subcatena** to FHC
Level 3-Hydrogeomorphic Reach
Level 4-Ecosystem Complex
Level 5-Geomorphologic Catena
Level 5+ Subcatena
Level 4-Ecosystem Complex
Level 5-Geomorphologic Catena
LANDSCAPE PLANNING FRAMEWORK

Level 5+ Subcatena
Subcatena + Direct FHC
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Direct FHC (Available, Altered)
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Direct + Indirect FHC

Level 2: Indirect Fish Habitat
Fish Habitat Status
- Altered
- Open
Examples of Fish Habitat Catena in the Columbia River Estuary
Variability in Fish Habitat Catena in the Columbia River Estuary

Examples of Fish Habitat Catenae:
1. Tributary sub-estuary, Reach B
2. Mainstem island, Reach C
3. Tributary delta, Reach G
Why Does Genetic Stock Matter?

genetic stock groups resolved with Genetic Analysis of Pacific Salmon (GAPS) microsatellite loci

Source: D. Teel; NOAA-NWFSC
Why Does Genetic Stock Matter?

CHINOOK STOCKS
- Rogue River (Fall)
- Spring Creek Group (Fall) *
- Upriver Bright (Fall)
- West Cascade (Fall) *
- West Cascade (Spring) *
- Willamette (Spring) *

UPPER COLUMBIA STOCKS
- Deschutes River (Summer-Fall)
- Mid-Columbia River (Spring)
- Snake River (Fall) *
- Snake River (Spring-Summer) *
- Upper Columbia River (Spring) *
- Upper Columbia River (Summer-Fall) *

* ESA Listed stock

PRODUCTION
- Natural
- Hatchery
- Hatchery and Natural

Source: D. Teel; NOAA-NWFSC
Why Does Genetic Stock Matter?

- 11 genetically distinct stocks of Chinook reared in shallow water habitats.
- Stock compositions varied seasonally and by life history type in all reaches.
- Stock diversity was greatest in reaches F and G (and lowest in C and D).
- Life-history variability (defined by size and time) was greater for naturally produced fish than for hatchery fish.

Source: D. Teel; NOAA-NWFSC
Quantifying Fish Habitat Catena at Multiple Scales

- Apply landscape metrics as quantitative measures of spatial structure or arrangement of FHC at all appropriate scales: landscape-, reach-, ecosystem complex- or local-scale

- Select metrics to characterize habitat “quality”
  - Select metrics for FHC according to guiding principles
  - Analyze fish habitat metrics (using FRAGSTATS)

- Landscape Distribution and Arrangement
  - Analyze FHC metrics at landscape scale
  - What constitutes the available fish habitat ‘continuum’?
  - What constitutes potentially restorable muted/isolated FHC?
  - How can restoration and preservation be complementary?

- Reach-, Ecosystem Complex- and Local Scale
  - Prioritization, design, monitoring
Spatial Planning FHC Baseline

- **Direct:** channel margin (intermittently exposed) and lake/pond; B & F
- **Muted and isolated:** floodplain channel and lake/pond; A-B & F or C, F-G
- **Direct confluences:** tidal channel; A-C
- **Muted confluences:** few above reaches A-B
- much fewer potential beaver FHC above reaches A-C
Number of direct FHC could be expanded by restoration of muted and isolated FHC in reaches A and D-E.

Total area of direct FHC available would benefit most from restoration actions in reaches C and G.
Complexes with FHC overlaid (yellow)

% FHC per ecosystem complex, classified in quartiles

Muted/isolated FHC where fish habitat access could be restored by barrier removal

Green = muted/isolated FHC that could yield high % of FHC if restored when merged with protection

Habitat to protect/enhance
Analysis of Wolf Bay using Fish Habitat Catena:
- Located in Reach B
- Not affected by muted/isolated FHC
- Mostly a protection project with some enhancement thrown in
- Occurs within a complex with a relatively high concentration of FHC (27%)

<table>
<thead>
<tr>
<th>Wolf Bay METRICS</th>
<th>Site</th>
<th>Reach B</th>
<th>Increase/Value</th>
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<tbody>
<tr>
<td>Total FHC Area</td>
<td>144399.80</td>
<td>56920324.38</td>
<td>0.25%</td>
</tr>
<tr>
<td>% FHC Area</td>
<td>23.92%</td>
<td>15.48%</td>
<td></td>
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<tr>
<td>Total Edge</td>
<td>10725.90</td>
<td>1398622.80</td>
<td>0.77%</td>
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<tr>
<td>Edge Density</td>
<td>742.79</td>
<td>245.72</td>
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<tr>
<td># Patches</td>
<td>126</td>
<td>19467</td>
<td>0.65%</td>
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<tr>
<td>Patch Density</td>
<td>8.73</td>
<td>3.42</td>
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<tr>
<td># Nodes</td>
<td>11</td>
<td>190</td>
<td>5.79%</td>
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<tr>
<td>Node Density</td>
<td>0.18</td>
<td>0.01</td>
<td></td>
</tr>
</tbody>
</table>

Site has high % FHC occurrence compared to Reach B total
Site has high edge density compared to Reach B total
Site has high patch density compared to Reach B total
Site has high node density compared to Reach B total

Reach B Total area: 367593567.78  
Wolf Bay site area: 603644.11
(All areas in sq meters and distances in meters)

% Area by FHC Class

- 0% - 2% FHC
- 2% - 6% FHC
- 6% - 17% FHC
- 17% - 53% FHC
- 53% - 100% FHC
- Wolf Bay Fish Habitat Catena
- Modified

Direct FHC classes

- Upper flooded
- Intermittently flooded
- Permanently flooded
- Tidal channel
- Tertiary channel
- Undifferentiated
- Filled areas
- Wolf Bay Site
- Nodes

Enhance site by improving connection under RR trestle
Where From Here?

Landscape Planning Framework is still a work in progress!

- Incorporate other datasets as available:
  - temperature? predators? DO? prey availability/value
- Historic change:
  - What FHC landscape did Columbia River salmon evolve with? How much has the baseline shifted?
- Inundation modeling:
  - How does change in flooding regime change FHC? What ESU juvenile salmon benefit/not?
  - What flow regulation options? CRT?
  - What does climate change foretell?
- Dissemination of geodatabase and publication
Summary

- Landscape Planning Framework provides a potentially viable tool for more strategic planning restoration and conservation of estuarine habitat for Pacific salmon.
- Directly applicable to Columbia River estuary; extendable methodology?
- Not a ranking, but provides spatial data for salmon life history modeling and for prioritization in other ‘models’ to make critical decisions about not only what restoration and preservation actions might involve, but also where and how they should optimally be deployed.
- When addressing recovery planning of anadromous species such as Pacific salmon, we should be obligated to place proactive spatial planning ahead of convenience.
Thank You!.......questions?

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