Analysis of Floodplain Fish Habitat on the San Joaquin for the San Joaquin River Restoration Project (SJRRP)

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SJRRP Project Objectives

• Restore a self-sustaining Salmon fishery on the San Joaquin River
• Minimize water supply impacts to Friant water users

SJRRP Project Actions

• Increase flows from Friant Dam
• Improve channel and control structures
• Reintroduce Chinook Salmon
SJRRP Potential Changes

- Levee Setbacks in Reaches 2B and 4B1
- Significant increase or change in vegetation in Reaches 2A and 4A
- Approximately 150 miles in Project Reach
How much more floodplain is necessary?

How should the floodplain be designed?

How will vegetation affect flood capacity?
How Much More Floodplain is Necessary?

(Additional Required Habitat) = 
(Required Habitat) – (Existing Habitat)

Estimated from ESHE: Simulation of spring and fall-run juvenile Chinook Salmon

Estimated from SRH-2D: Simulation of two-dimensional depth averaged hydraulic conditions
Available Habitat
2D Hydraulic Model

Suitable Habitat Estimates
- Minimum of depth, velocity, cover
  - 2 weeks of Inundation
  - By Reach
  - For each water year type

Cover polygon
- H.S.I. based on vegetation type
- H.S.I. of 1 for edge habitat

Habitat Criteria Ranges
- Depth Rearing (0.8 – 3.9 feet)
- Velocity Rearing (0 – 2.1 fps)

1D and 2D Hydraulic Models

Connection between the two models

Required Suitable Habitat minus Available Suitable Habitat

Suitable Habitat Deficits
- For weighted average water year type
  - In each reach

Reach 2B & 4B Suitable Habitat Deficit
- $2B = \text{Sum of Reaches 1, 2, and 3}$
- $4B = \text{Sum of Reaches 4 and 5}$
- Reaches with enough habitat available not included in sum

Reach 2B & 4B Total Inundated Area
- Suitable Habitat Deficit / % of inundated area that is suitable

Habitat Required
ESHE Model

Required Suitable Habitat
- Fisheries Needs
- Cohort model
- Finds maximum number of fish in each reach on one day
- Based on territory estimate

ESHE Model

Juvenile Fish Numbers (Lower Reach 1B)

Habitat Complexity

Returning Adult Long-term Population Targets

Purpose: Provide minimum design criteria for levee setback area extent by project and habitat quality (i.e. vegetation and other floodplain surface modifications)
Available Habitat
Hydraulic Modeling: SRH-2D

- Solves the depth-averaged Navier-Stokes equations
- Produces two-dimensional \((x,y)\) mean flow field and water depth
- Bed shear stresses calculated via Manning’s Resistance equation
- Apparent (Reynolds) stresses parameterized using Boussinesq formulation and eddy viscosity
- Wetting-drying algorithm updated for each solution time step

www.usbr.gov/pmts/sediment
Lai, *J. Hydr. Eng.*, 2009
Build a model
Example Calibration (Reach 2A)

$Q = 7400 \text{ cfs}$
Example Calibration (Reach 2A)

\[ Q = 1000 \text{ cfs} \]
Reach 1B Hydraulic Simulation (1500 cfs)

Legend
- Vegetation Mapping

Velocity (ft/s)
- 8.2
- 0.0

Scale: 0, 1,000, 2,000, 4,000 Feet
Habitat Assessment

Objective:
Map simulated physical variables (e.g., depth and velocity) to a quantitative metric of habitat quality for a given species

Dependency:
Need a functional relationship between physical variable and habitat quality based on field observations
Habitat Suitability Index (HSI)

\[ HSI_T = \min(HSI_D, HSI_V, HSI_C) \]

\( HSI_T \) = total habitat suitability of the grid cell
\( HSI_D \) = depth habitat suitability of the grid cell
\( HSI_V \) = velocity habitat suitability of the grid cell
\( HSI_C \) = cover habitat suitability of the grid cell
Depth and Velocity HSI

Chinook Salmon Juvenile Fall Run from Stanislaus

Aceituno (1990)
# Cover Habitat Suitability Index

<table>
<thead>
<tr>
<th>Cover Type</th>
<th>HSI&lt;sub&gt;C&lt;/sub&gt; score for each cover type</th>
<th>Assumed HSI Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cover Type</strong></td>
<td>Raleigh 1986</td>
<td>Sutton 2006</td>
</tr>
<tr>
<td>No Cover, River Wash</td>
<td>0.01</td>
<td>N/A</td>
</tr>
<tr>
<td>Gravel Bars</td>
<td>0.25</td>
<td>0.3</td>
</tr>
<tr>
<td>Grass, Herbaceous</td>
<td>N/A</td>
<td>0.5</td>
</tr>
<tr>
<td>Willow Riparian and Willow Scrub</td>
<td>N/A</td>
<td>0.8</td>
</tr>
<tr>
<td>Wetland/Marsh</td>
<td>0.3</td>
<td>0.6</td>
</tr>
<tr>
<td>Edge Habitat</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Example HSI for Reach 2A
## Available Suitable Habitat

<table>
<thead>
<tr>
<th>Reach</th>
<th>Total Inundated (acres)</th>
<th>Available Suitable</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Fraction</td>
<td>Acres</td>
</tr>
<tr>
<td>1B</td>
<td>798</td>
<td>0.07</td>
<td>56</td>
</tr>
<tr>
<td>2A</td>
<td>743</td>
<td>0.14</td>
<td>104</td>
</tr>
<tr>
<td>3</td>
<td>770</td>
<td>0.08</td>
<td>62</td>
</tr>
<tr>
<td>4A</td>
<td>427</td>
<td>0.13</td>
<td>56</td>
</tr>
<tr>
<td>4B2</td>
<td>1041</td>
<td>0.27</td>
<td>281</td>
</tr>
<tr>
<td>5*</td>
<td>1373</td>
<td>0.27</td>
<td>371</td>
</tr>
</tbody>
</table>
Necessary Suitable Habitat in Reaches 2B and 4B1 to Overcome Current Deficit

Divided river into upstream and downstream reaches

Assumed upstream deficit could be met with Reach 2B and downstream deficit with Reach 4B1

<table>
<thead>
<tr>
<th>Reach</th>
<th>Current Deficit of Suitable Habitat (acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2B</td>
<td>416</td>
</tr>
<tr>
<td>4B1</td>
<td>73</td>
</tr>
</tbody>
</table>
How to design floodplain habitat?

23 miles in Reach 4B1 and 13 miles in Reach 2B will be vegetated and re-contoured
Analysis of Historical Photography
Example cross sections in Reach 4B1
Inundation modeling in Reach 4B1
How will vegetation affect flood capacity?

- Currently testing various strategies to estimate vegetation roughness
- Desert Research Institute (DRI) collected data in two example areas:
  - average Leaf Area Index (LAI)
  - average small & large stem diameter
  - average density per unit ground area
  - average height
Methods to be tested in SRH-2D hydraulic simulation:


Summary

• Hydraulic modeling used to support:
  – Computing area needed for floodplain habitat
  – Improving design of floodplain habitat
  – Assessing impact of vegetation on floodplain conveyance