A streamlined approach for modeling salmonid habitat in the Central Valley

Mark Tompkins, Emanuel Rodriguez, Maddee Rubenson, Skyler Lewis

CWEMF, September 25, 2024

Why is Habitat Modeling Important to CVPIA?

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Near-term Restoration Strategy

for the

Central Valley Project Improvement Act

Fish Resource Area

FY2021–FY2025

Final Version

Priority Restoration Actions

The actions that comprise the SIT-recommended restoration strategy for Chinook salmon are in Table ES-1, which includes brief descriptions of each action.

Table ES-1. SIT-recommended Restoration Actions for Chinook Salmon

These are the recommended restoration actions for Chinook salmon and the runs that would primarily benefit from the action. Numbering does not indicate priority level or sequencing.

Restoration Action	Runs primarily benefiting
Action 1: Juvenile habitat restoration in mainstem Sacramento River above the American River confluence. One project in the Sacramento River between the Feather and American Rivers with a BACI design and tier 3 monitoring.	All
Action 2: Reconnect ephemeral non-natal tributaries to the mainstem Sacramento River during a single project with a BACI design and tier 3 monitoring.	Winter
Action 3: Juvenile habitat restoration in Battle Creek in winter-run juvenile rearing locations.	Winter
Action 4: Juvenile habitat restoration in American River.	Fall
Action 5: Juvenile habitat restoration in the Stanislaus River downstream through the San Joaquin River at Vernalis.	Fall
Action 6: Juvenile habitat restoration in Clear Creek.	Spring, Fall
Action 7: Improve survival in Butte Creek in downstream areas.	Spring, Fall
Action 8: Juvenile habitat restoration in the lower Feather River below the confluence of the Yuba River.	Fall, Spring
Action 9: Maintain existing spawning habitats in Upper Sacramento, American, and Stanislaus Rivers; Clear and Butte Creeks.	All

Why is Habitat Modeling Important to CVPIA?

PRESS RELEASE

Notice of Funding Opportunity for Central Valley Project Improvement Act fisheries habitat and facilities improvement now available

Jan 11, 2024

Media Contacts
Joanna Gilkeson

SACRAMENTO, Calif. - The Bureau of Reclamation and the U.S. Fish and Wildlife Service today announced the Notice of Funding Opportunity for projects that enhance Chinook salmon and steelhead trout production and associated habitats in the Central Valley, consistent with the Central Valley Project Improvement Act.

Reclamation and the Service are awarding up to $40 million (subject to appropriations) in fiscal year 2024 through multiple grants or cooperative agreements to projects prioritized by the CVPIA Near-Term Restoration Strategy. This funding opportunity implements the spawning and rearing habitat restoration activities

Why is Habitat Modeling Important to the CVPIA DSM?

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RESTORATION ECOLOGY
The Journal of the Society for Ecological Restoration

SER SOCIETY FOR ECOLOGICAL RESTORATION

RESEARCH ARTICLE

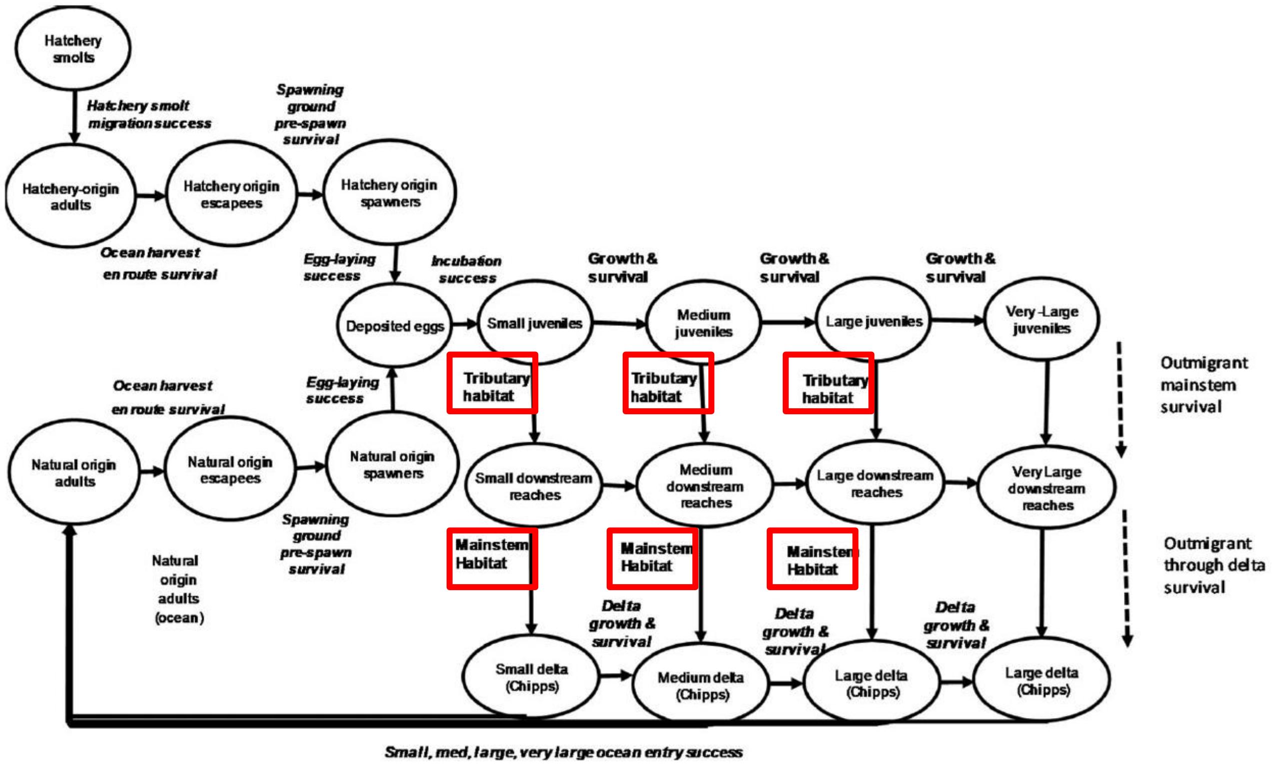
Decision analysis for greater insights into the development and evaluation of Chinook salmon restoration strategies in California's Central Valley

James T. Peterson[1,2], Adam Duarte[3]

Considerable resources have been invested in ecological restoration projects across the globe to restore ecosystem integrity. Restoration strategies are often diverse and have been met with mixed success. In this article, we describe the Chinook salmon (*Oncorhynchus tshawytscha*) decision-support models developed by the Central Valley Project Improvement Act Science Integration Team as part of a larger structured decision-making effort aimed at maximizing natural adult production of Chinook salmon in California's Central Valley, the United States. We then describe the decision-analytic tools the stakeholder group used to solve the models and explore model results, including stochastic dynamic programming, forward simulation, proportional scoring, relative loss, expected value of perfect information, response profile analyses, and indifference curves. Using these tools, the stakeholder group was able to develop and evaluate restoration strategies for multiple Chinook salmon runs simultaneously, a first for the restoration program. We found that actions targeted at one run were detrimental to others, which was unexpected. Furthermore, information uncovered during this process was used to direct efforts towards targeted research/monitoring to reduce critical uncertainties in salmon demographic rates and make better restoration decisions moving forward. The decision sciences have established a wide range of analytical tools and approaches to simplify complex problems into key components, and we believe the concepts described in this article are of great interest and can be applied by many restoration practitioners that undoubtedly face similar difficulties when implementing restoration strategies for complex systems.

Key words: decision-support model, habitat restoration, *Oncorhynchus tshawytscha*, stochastic dynamic programming, structured decision-making, value of perfect information

Why is Habitat Modeling Important to the CVPIA DSM?



Why is Habitat Modeling Important to the CVPIA DSM?

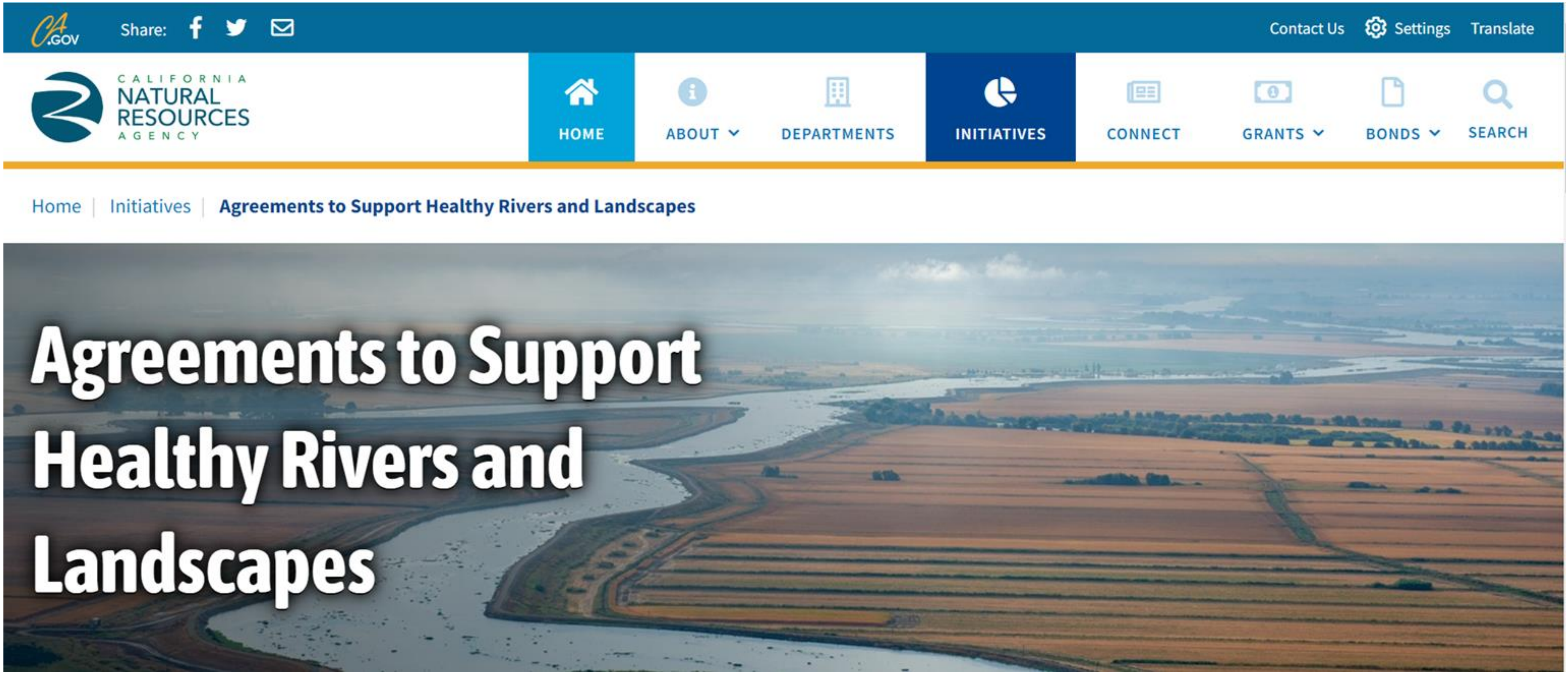
Sensitivity Analysis

The sensitivity analysis indicated that the most influential DSM inputs included the current estimates of existing habitat, median discharge, and temperature across all runs and initial abundance and total amount of water diverted for winter-run (Table 2). Sen-

YOU CAN'T MANAGE WHAT YOU DON'T MEASURE!

Why is Habitat Modeling Important to California?

Why is CVPIA Habitat Modeling Important to California?



Why is CVPIA Habitat Modeling Important to California?

SAN FRANCISCO ESTUARY MAGAZINE

Reorienting to Salmon Recovery

By Alastair Bland

Evolution of CVPIA Habitat Modeling Data

Initial (~2014) CVPIA Habitat Modeling “Data”

Coarse Resolution Planning Tools for Prioritizing Central Valley Project Improvement Act Fisheries Activities

James T. Peterson
USGS Oregon Cooperative Fish and Wildlife Research Unit
Oregon State University Corvallis, Oregon

Kevin McDonnell and Michael C. Colvin
Department of Fisheries and Wildlife
Oregon State University Corvallis, Oregon

Draft Progress Report
July 28, 2014

Initial (~2014) CVPIA Habitat Modeling "Data"

WAY

Table 2.4. Mean and standard deviation (in parenthesis) of Chinook Salmon adult holding habitat (pools/km) and spawning, fry and parr in-channel rearing, and juvenile floodplain habitat availability (100m^2/km) by watershed. Values in bold and underlined were based on empirical data and all others were based on expert opinion. See text for a description of each habitat type and source of data.

Watershed	Holding	Spawning	Fry	Parr	Floodplain
American River	1.3 (0.16)	**2156 (1078.0)**	2289 (1064.5)	3092 (1332.8)	14944 (6442.6)
Antelope Creek	11.3 (1.67)	460 (120.2)	1008 (304.5)	829 (262)	404 (149)
Battle Creek	6.2 (2.79)	776 (178.6)	3081 (736.5)	5657 (1137.1)	20 (40)
Bear Creek	4.6 (1.10)	152 (37.5)	764 (216.1)	671 (194.8)	437 (207.8)
Bear River	1.3 (1.96)	395 (149.1)	239 (90.8)	351 (131.9)	323 (124.5)
Big Chico Creek	2.3 (0.56)	101 (26.4)	15 (3.8)	246 (61.5)	20 (40)
Butte Creek	7.1 (4.94)	**265 (132.4)**	1488 (744)	1211 (726.4)	1768 (3536.3)
Calaveras River	0.5 (0.07)	11 (6.6)	1885 (461.1)	2085 (525.1)	2274 (968.6)
Clear Creek	20.6 (4.39)	**1303 (651.6)**	**2928 (585.5)**	**2055 (821.9)**	1768 (3536.3)
Cosumnes River	0.5 (0.10)	161 (62.5)	1591 (542.9)	2430 (651.2)	91763 (7021.2)
Cottonwood Creek	9.9 (3.91)	278 (129.9)	1338 (563.5)	1362 (460.9)	367 (80.2)
Cow Creek	4.6 (1.01)	182 (79.6)	**1838 (344.9)**	**1047 (421.5)**	650 (318.8)
Deer Creek	4.1 (1.23)	402 (73.7)	268 (50.6)	479 (156.5)	380 (94.2)
Elder Creek	4.3 (2.55)	116 (51.3)	270 (53.2)	473 (148.3)	391 (165.5)
Feather River	1.1 (0.13)	1543 (188)	1726 (615.3)	1593 (517.6)	671 (840.4)
Merced River	7.1 (4.94)	92 (69.3)	628 (464.8)	658 (488.3)	705 (535.5)
Mill Creek	14 (4.02)	624 (265.6)	1549 (301.9)	1384 (274)	399 (144.9)
Mokelumne River	0.2 (0.03)	2786 (809)	3039 (464)	4658 (628.3)	4758 (687)
Paynes Creek	9.7 (4.48)	152 (37.5)	848 (285.8)	715 (250.4)	384 (126.6)
San Joaquin River	0.1 (0.08)	5 (5)	1896 (732.5)	2217 (424.8)	1667 (1347.3)
Stanislaus River	4.6 (0.69)	6156 (2062.6)	**835 (286.2)**	**709 (242.3)**	2815 (1366)
Stony Creek	1.5 (1.47)	24 (25.5)	150 (300.0)	10 (10)	10 (10)
Thomes Creek	4.2 (1.20)	122 (46.6)	263 (48.5)	470 (143.6)	381 (151)
Tuolumne River	0.8 (0.35)	**335 (124)**	**532 (200.0)**	**1141 (575.3)**	836 (623.3)
Upper-mid Sacramento River	0.8 (0.53)	**3272 (1091.6)**	**2492 (747.7)**	**953 (6803.2)**	1660 (2068.7)
Lower-mid Sacramento River	2.9 (0.61)	**3316 (574.1)**	**2062 (839.4)**	**2161 (866.4)**	3593 (2157.1)
Yuba River	3.6 (2.48)	**3396 (1697.9)**	**1211 (363.2)**	**433 (343)**	755 (248.7)

OFF

Current CVPIA Habitat Modeling Data

DSMhabitat 2.0 | Reference | Articles | News

Modeled Habitat Areas

This package is for estimating spawning and rearing (instream and floodplain) habitat within the Sacramento and San Joaquin river systems for use with the CVPIA salmon life cycle model.

Installation

```
# install.packages("remotes")
remotes::install_github("CVPIA-OSC/DSMhabitat")
```

Usage

This package provides habitat related datasets to the `fallRunDSM`, `springRunDSM`, `winterRunDSM`, and `latefallRunDSM` packages.

```
# datasets within the package
data(package = 'DSMhabitat')
```

About the Models

This data package includes flow to suitable habitat area relationships for salmonid (Fall Run, Spring Run, Winter Run, Late Fall Run, and steelhead - pending) spawning, instream rearing, and floodplain rearing habitat.

Where available, results from Instream Flow Incremental Methodology (IFIM) studies were used to generate instream spawning and rearing flow to suitable area relationships. For watersheds without IFIM (or comparable) studies, suitable instream areas were scaled from nearby, geomorphically similar watersheds.

Similarly, where available, results from floodplain hydraulic modeling studies were used to generate floodplain flow to suitable area relationships. Where no modeling studies were available, suitable floodplain area were scaled from nearby, geomorphically similar watersheds. Specific methods and supporting documents for instream and floodplain habitat inputs in every watershed are provided on the reference tab.

Links

Browse source code

Report a bug

Fish and Wildlife Service's CVPIA website

Bureau of Reclamation's CVPIA website

License

Full license

CC0

Citation

Citing DSMhabitat

Developers

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Author, maintainer

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Author

Mark Tompkins
Author

Sadie Gill
Author

Current CVPIA Habitat Modeling Data

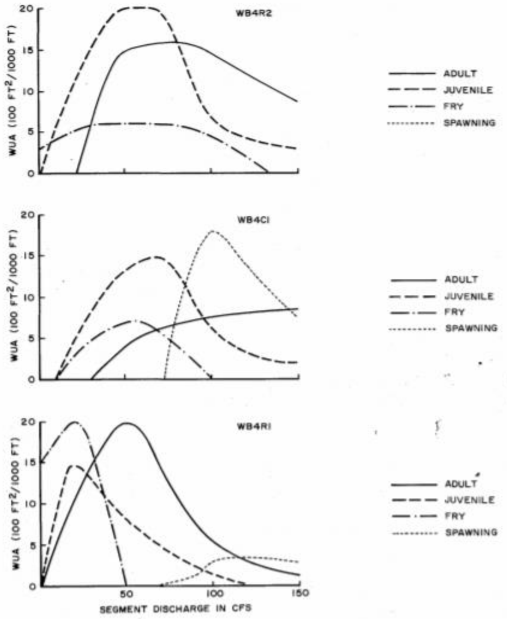


Figure 14. Weighted usable area for brown trout vs. discharge for three study reaches in segment IV of example.

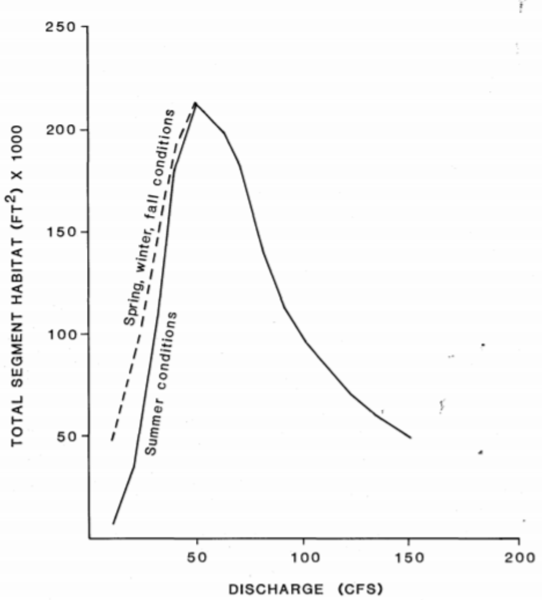


Figure 15. Total adult brown trout habitat in segment IV as a function of discharge under summer (solid line) and nonsummer conditions (dashed line).

Current CVPIA Habitat Modeling Data

Future CVPIA Habitat Modeling Approach

BUREAU OF RECLAMATION

U.S. FISH & WILDLIFE SERVICE

Near-term Restoration Strategy

for the
Central Valley Project Improvement Act
Fish Resource Area
FY2021–FY2025

Final Version

Table ES-2. Chinook Salmon Information Priorities.

Chinook salmon information priorities and the expected time needed to produce the information. Numbering does not indicate priority level or sequencing.

Chinook Salmon Information Needs	Duration
Info Need 1: Juvenile Chinook salmon survival: tributaries, mainstem, delta, ocean, and the effect of habitat on survival.	>5 years
Info Need 2: Juvenile Chinook salmon growth: tributaries, mainstem, delta, and the effect of habitat on growth.	2–3 years
Info Need 3: Juvenile Chinook salmon movement: site fidelity and effect of habitat type, the effect of temperature and flows on movement.	2–3 years
Info Need 4: Juvenile Chinook salmon territory size: site fidelity and effect of habitat type and other conditions.	2–3 years
Info Need 5: Southport Levee setback assess fish use, growth, and survival.	2–3 years
Info Need 6: Update habitat modeling and estimates for: Sacramento River upstream of American River, American River, Stanislaus River, San Joaquin River downstream of Stanislaus River to Vernalis, Clear Creek, Battle Creek, Feather River, Yuba River.	2–3 years
Info Need 7: Habitat change through time.	3–5 years
Info Need 8: Juvenile Chinook salmon production emphasis on tributaries with existing long-term data that are calibrated: American River, Red Bluff Diversion Dam, Stanislaus River, Mokelumne River, Clear Creek, Feather River.	>5 years
Info Need 9: Adult escapement and prespawn mortality.	>5 years

Future CVPIA Habitat Modeling Approach

CVPIA Science Integration Team

Search Ctrl + K

Home

About

Current SIT Activities

SIT Subgroups

SIT DSM Proposals

Resources

Documents

Interactive Web Apps

DSM R Packages

Proposal Status

Active Proposals

These are the active proposals for changes to the DSMs.

Proposal Title	Summary	Status
Habitat Inputs Proposal	Update habitat inputs with Habitat Suitability Index (HSI) derived estimates instead of Weighted Usable Area (WUA) approach.	Prototyping accepted March 2021, changes incorporated as data become available

Was this helpful?

Export as PDF

Future CVPIA Habitat Modeling Approach - Deer Creek

Home | Project Description | **Hydraulic Modeling** | Habitat Suitability | Hydrology

Hydraulic Modeling

A two-dimensional hydraulic model was developed for lower Deer Creek using LiDAR and aerial photography from 2017 and bathymetric (i.e. below water) surveys in 2017 and 2018. The model outputs include water depths and velocities. Model results can be viewed by clicking on the boxes on the map to the right. Inundation depths are provided for the 50-year flow (21,000 cfs) under existing conditions and the proposed project (Alt 1a).

Future CVPIA Habitat Modeling Approach - Deer Creek

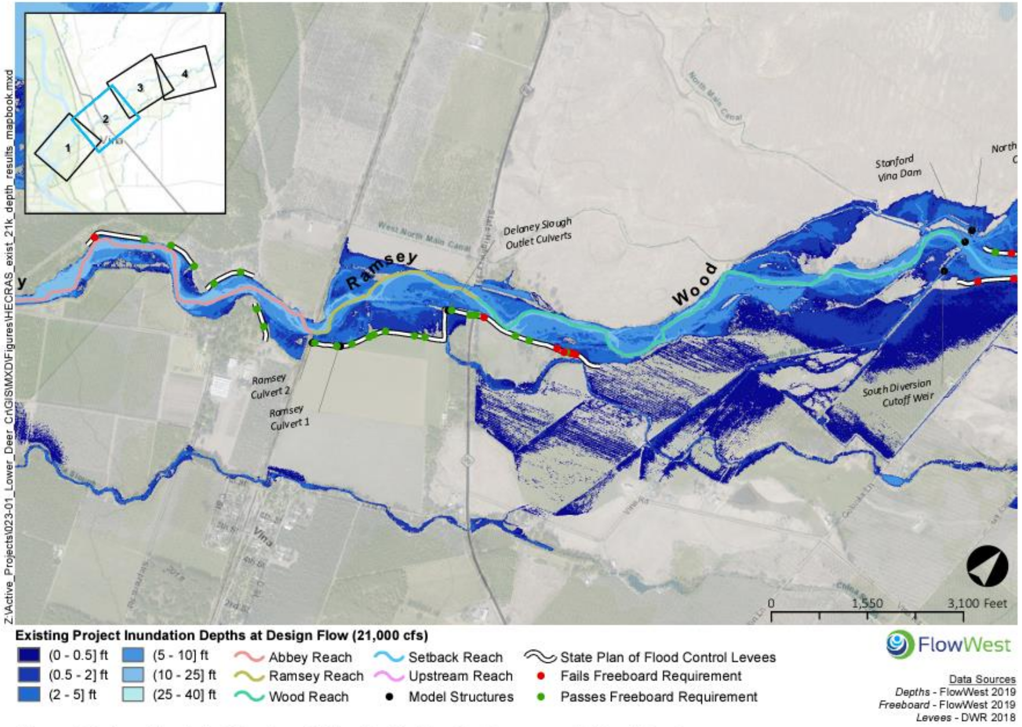


Figure A-2. Deer Creek Existing Inundation Depth Map for Ramsey and Wood Reach

Future CVPIA Habitat Modeling Approach - Deer Creek

Home | Project Description | Hydraulic Modeling | **Habitat Suitability** | Hydrology

Habitat Suitability

Habitat suitability criteria from USFWS (Gard 2019) was combined with outputs from the hydraulic model described elsewhere in this web application to compare suitable fish habitat at a range of flows under existing conditions and alternative setback options. Species include Fall, Late-Fall, and Spring Run Chinook Salmon, Steelhead, and Hardhead. For each species, adult spawning, juvenile rearing, and fry rearing suitable habitat was evaluated.

Habitat Type

○ floodplain ◉ instream

Species

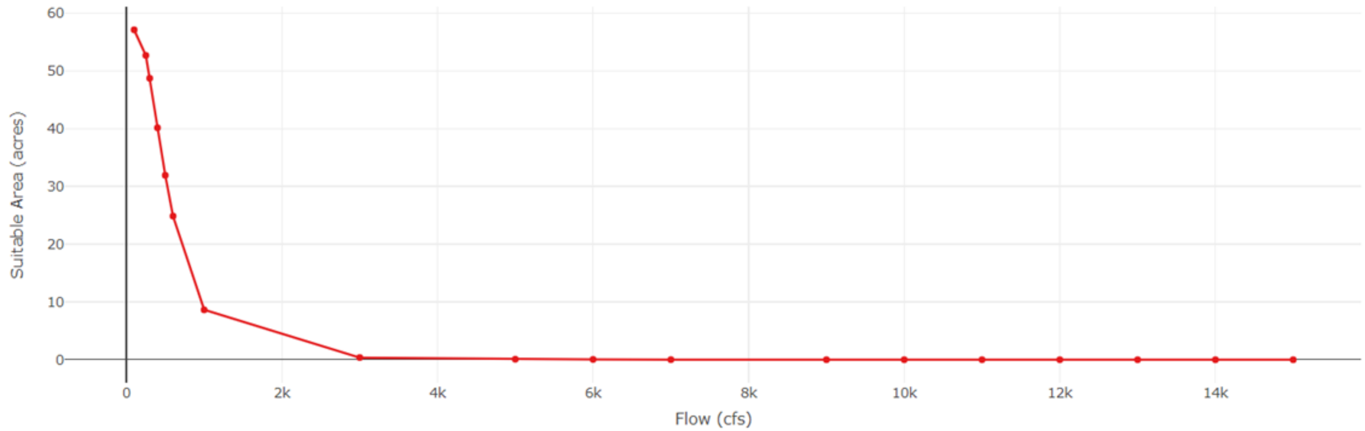
Fall run Chinook

Life Stage

Juvenile

Scenario

Existing



Flow (cfs)	Existing
100	57
250	53
300	49
400	40
500	32

Future CVPIA Habitat Modeling Approach - Deer Creek

Habitat Suitability

Habitat suitability criteria from USFWS (Gard 2019) was combined with outputs from the hydraulic model described elsewhere in this web application to compare suitable fish habitat at a range of flows under existing conditions and alternative setback options. Species include Fall, Late-Fall, and Spring Run Chinook Salmon, Steelhead, and Hardhead. For each species, adult spawning, juvenile rearing, and fry rearing suitable habitat was evaluated.

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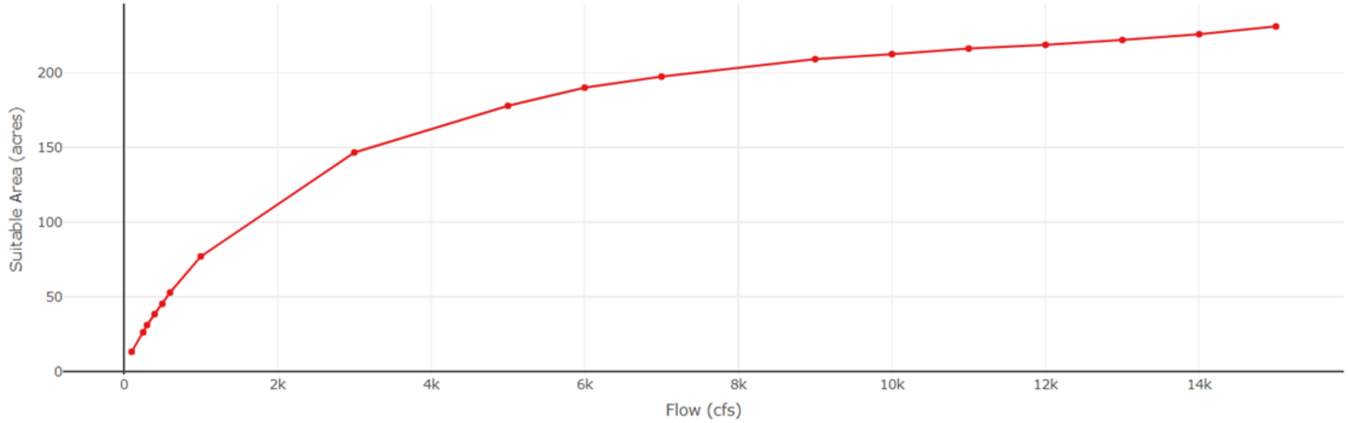


Flow (cfs)	Existing
100	13
250	26
300	31
400	38
500	45

Future CVPIA Habitat Modeling Approach - Pros / Cons

High resolution

Standard tools

High cost

Limited coverage (spatial and temporal)

Typically 5-10 years (if ever) between updates for a given watershed!

HabiStat -

Team Members:

Rene Henery, California science director (Trout Unlimited)

Natalie Stauffer-Olsen, staff scientist (Trout Unlimited)

Mia Van Docto, hydrologist (Trout Unlimited)

Maddee Rubenson, data scientist & project manager (FlowWest)

Mark Tompkins, co-founder & geomorphologist (FlowWest)

Skyler Lewis, data scientist & geomorphologist (FlowWest)

Project funded by the State Water Contractors

Habistat - Filling in the Habitat Modeling Gaps

FlowWest

SWC STATE WATER CONTRACTORS FOUNDED 1982

TROUT UNLIMITED

Background: Within the Central Valley of California, there is limited consistent, interoperable, and easily updated habitat data

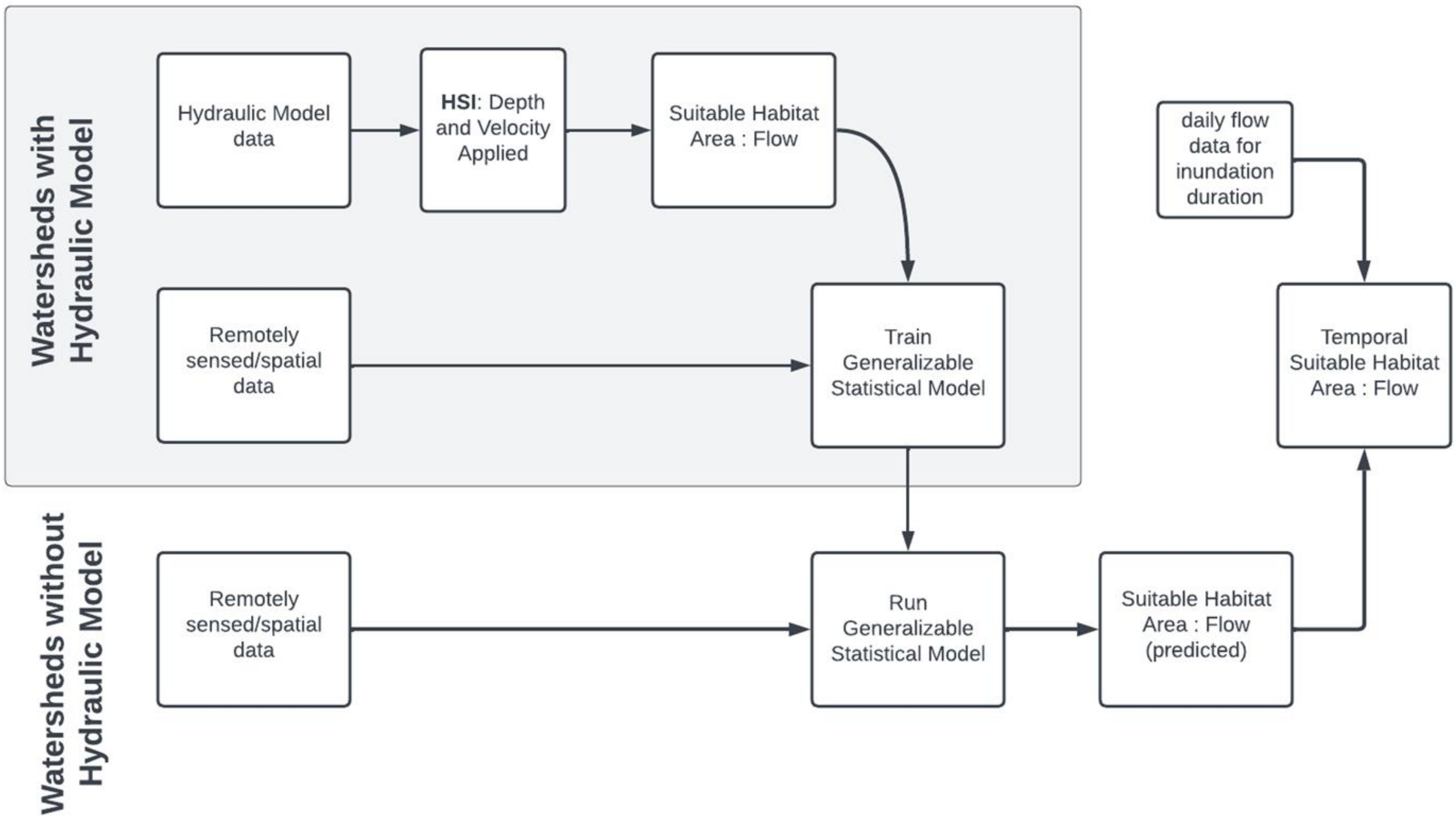
Objectives:

1) Predict suitable habitat area-to-flow relationships for salmonid spawning and rearing for all runs* using existing hydraulic models and reach-level geophysical characteristics

2) Develop a data pipeline that allows for updating predictions as new models are developed

*Currently focusing on Fall Run Chinook spawning and rearing

Methods

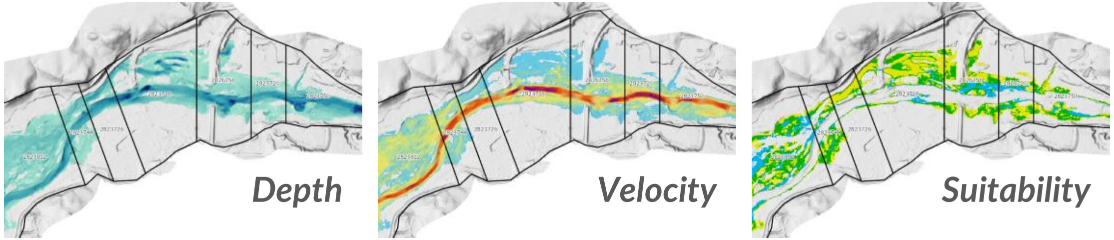

Watersheds with Hydraulic Model
Hydraulic Model data
HSI: Depth and Velocity Applied
Suitable Habitat Area : Flow
Remotely sensed/spatial data
Train Generalizable Statistical Model
daily flow data for inundation duration
Temporal Suitable Habitat Area : Flow
Watersheds without Hydraulic Model
Remotely sensed/spatial data
Run Generalizable Statistical Model
Suitable Habitat Area : Flow (predicted)

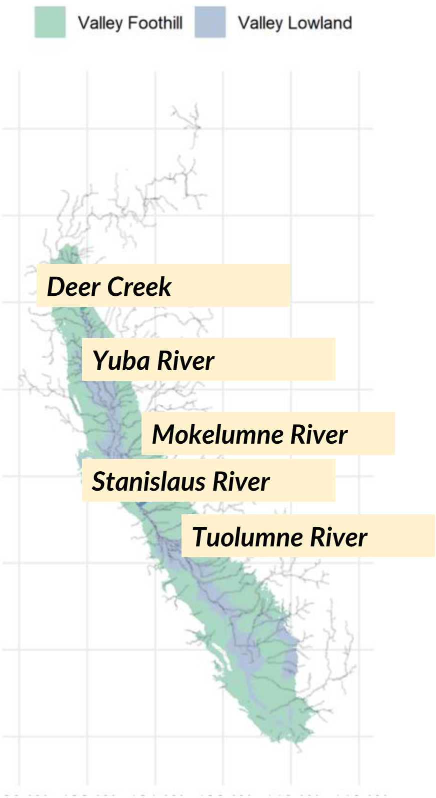
Training Data: Hydraulic Model Streams

Habitat suitability calculated using depth and velocity results from the following hydraulic models at a series of flows:

- **Deer Creek** (Delaney Slough to Sacramento River)
- **Tuolumne River** (Basso-La Grange reach)
- **Stanislaus River** (Knights' Ferry to San Joaquin River)
- **Yuba River** (Englebright Dam to Feather River)
- **Mokelumne River** (Camanche Dam to Woodbridge)

At each flow, fall run chinook habitat suitability indices are applied and totalled within each NHD reach and its adjacent floodplain:



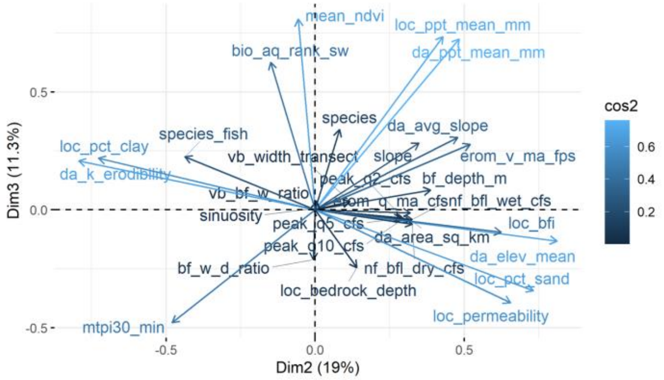


Training Data: Predictor Variables

All predictor variables are at the NHD ComID reach scale and expressed as interaction terms with flow.

- **Channel characteristics** — slope, sinuosity, bankfull depth, width:depth ratio
- **Reach characteristics** — baseflow index, % clay, % sand, permeability, depth to bedrock, local precipitation, local NDVI
- **Drainage basin characteristics** — area, mean elevation, mean annual precipitation, mean slope, mean erodibility (K factor)
- **Channel confinement** — valley bottom width, valley:channel width ratio, levee confinement, topographic position index (TPI)
- **Flow statistics** — dry season baseflow, wet season baseflow, mean annual flow, mean annual velocity, 2-year flow, 5-year flow, 10-year flow
- **Classifications** — UC Davis hydrologic class (e.g snowmelt, mixed rainfall-snowmelt, etc.);HQT gradient class: valley lowland vs valley foothill vs bedrock (above valley foothill)

Principal Components Analysis

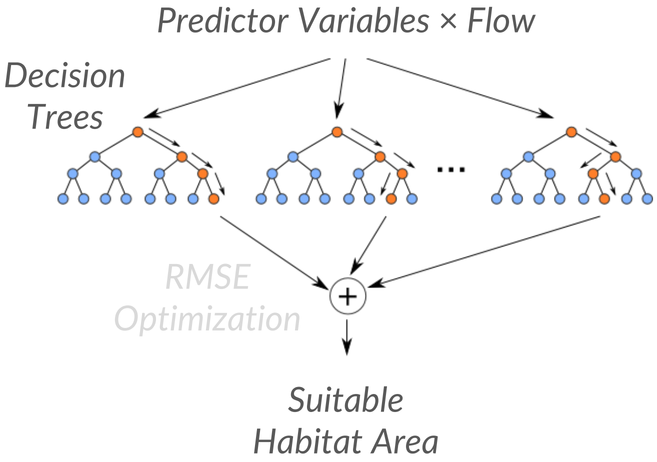


$$SuitableHabitatArea_{i,q} = \alpha + \beta Flow_q + \gamma_1 Slope_i + \delta_1 Flow_q Slope_i + \gamma_2 DrainageArea_i + \delta_2 Flow_q DrainageArea_i + \ldots$$

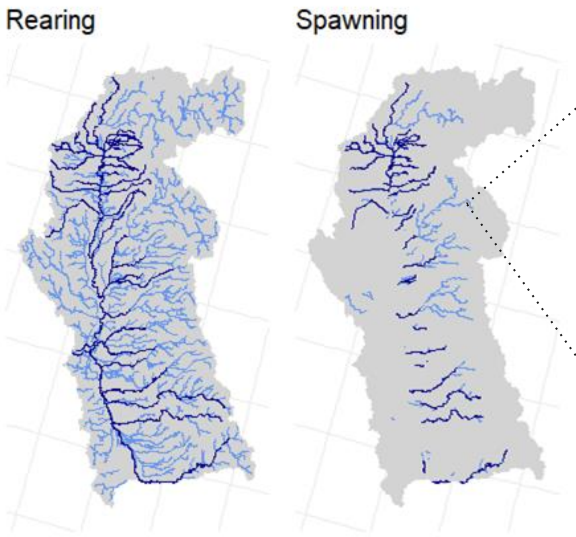
Random Forest Regression Model

- Ensemble learning method that fits and combines multiple random decision trees
- Accounts for complex interactions and non-linear effects
- Split reaches 80% training/validation (tune model parameters using 10-fold cross-validation) and 20% testing

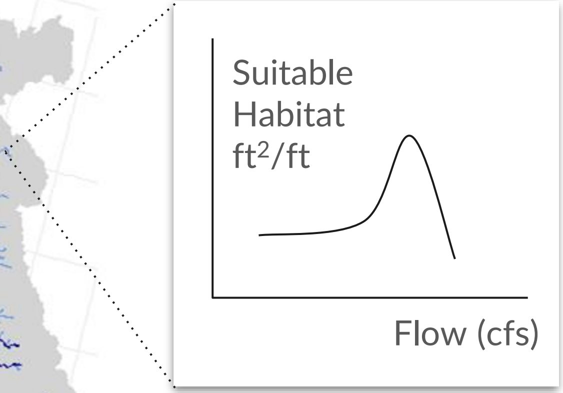
Random Forest model:



Geographic scope:

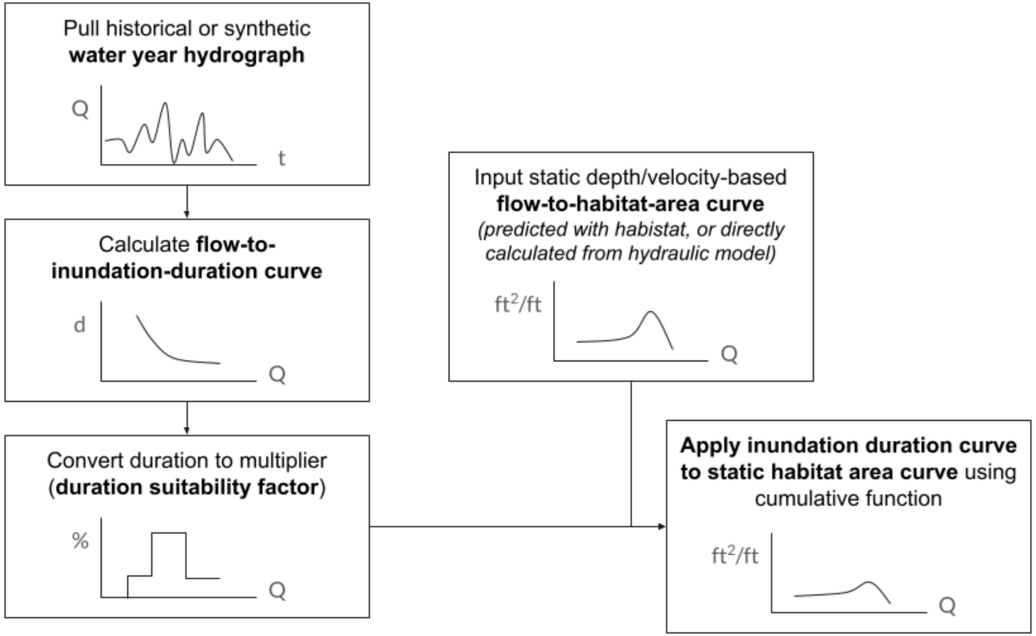


Output for each reach:

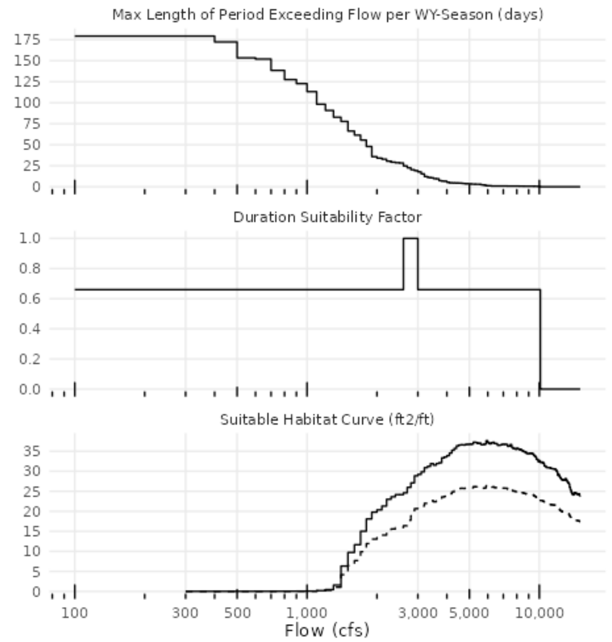


Inundation Duration Criteria

Process:



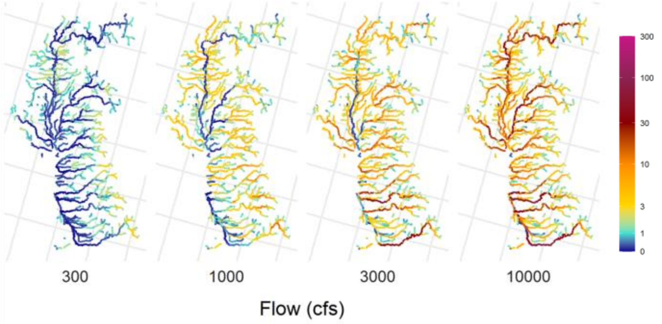
Example:



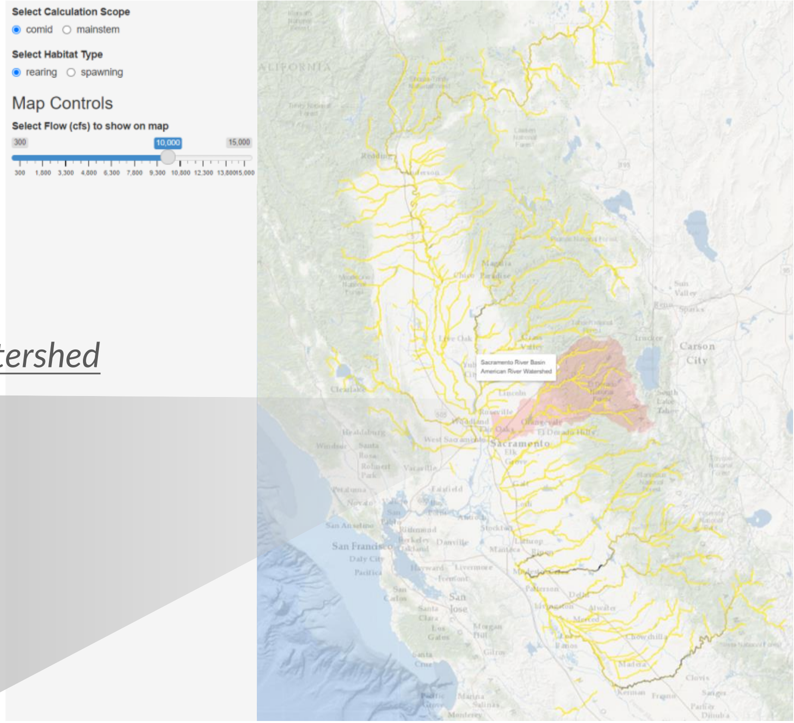
Preliminary Results

Output Flow-to-Habitat Area Predictions

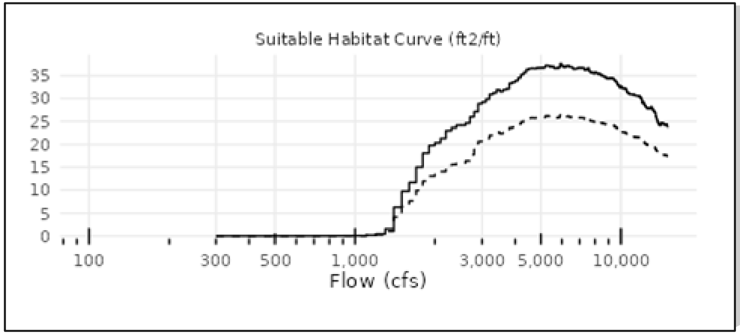
Habitat Area Predictions at Each Flow



Interactive Web App for Data Access (under development)



Flow:Habitat Curves for Each Reach, Stream, and Watershed



What's Next?

Now:

- Call for hydraulic models as training data (currently have Stanislaus River, Deer Creek, and Yuba River, Tuolumne River, Mokelumne River)
- Continued model validation (compare against mapped habitat extents; work with local salmonid habitat experts to sanity-check predictions)

Next 3-6 months: Input and process feedback

Early 2025: Sharing of results and data through an R package and documentation

For more information

Github: https://github.com/FlowWest/swc-habitat-suitability

Contact Information

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- Skyler Lewis slewis@flowwest.com

Questions?

Why is Habitat Modeling Important to CVPIA?

Section 3406(b)(1) of the CVPIA directs the Secretary of the Interior to "...implement a program which ***makes all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991.***" The CVPIA defines natural production as "fish produced to adulthood without direct human intervention in the spawning, rearing, or migration processes."

Topics

Why is habitat important to CVPIA?

Why is habitat important to the CVPIA DSM?

Why is CVPIA habitat modeling important to California?

Initial (~2015) CVPIA habitat modeling “data”

Current CVPIA habitat modeling data

Future CVPIA habitat modeling data

Full census example (Deer or Tuolumne) where feasible

Habistat approach to fill in the blanks in space and time

Questions?