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Assessment of Habitat Availability, Capacity, and Limitations for Chinook Salmon and Steelhead in the Willamette River and its Major Tributaries

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Research Question and Goals

Research Question:

How do dam operations influence habitat availability, carrying capacity, and density-dependent processes for adult spawning and juvenile rearing (Chinook salmon and steelhead) in the Willamette River basin downstream of Project dams?

Goals:

- Review and summarize existing methods for estimating habitat availability under different flow and temperature scenarios.

- Review existing habitat availability and carrying capacity studies in the Willamette River basin.
    - Identify critical knowledge gaps

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Overview

- Link habitat availability, capacity, and density dependence
- Review habitat modeling methods
- Assess in-basin habitat studies and data
- Introduce pilot study to validate habitat modeling

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Linking Habitat, Capacity, and Density Dependence

Habitat Quantity and Quality

↓

Carrying Capacity

↓

Density Dependent
Population Dynamics

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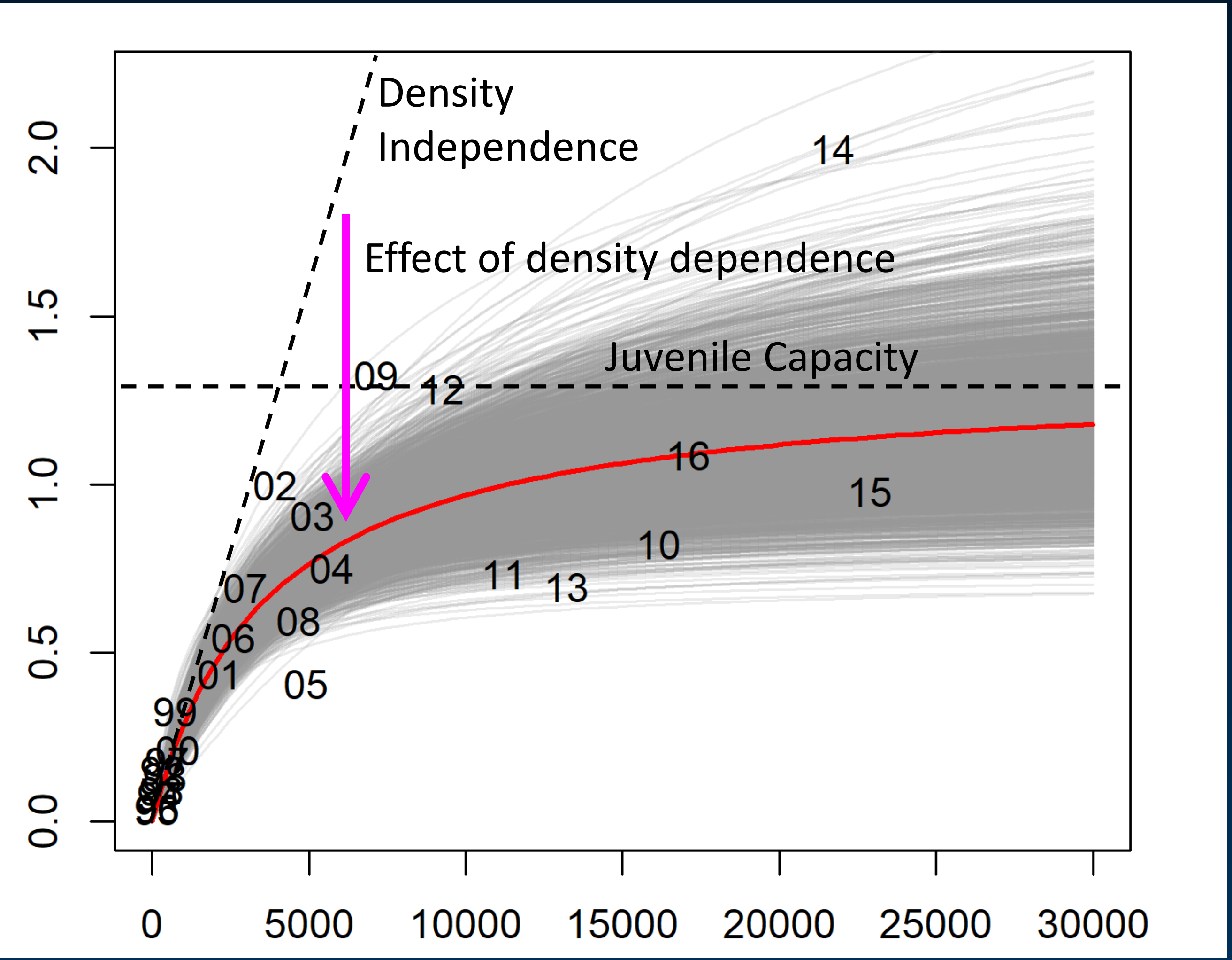
Linking Habitat, Capacity, and Density Dependence

Juvenile outmigrants (millions)



Female spawners

Snake R. Fall Chinook Salmon at Lower Granite Dam

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Linking Habitat, Capacity, and Density Dependence

Capacity = Suitable Habitat Area X Maximum Fish Density

Varies over time and space

Varies by species and lifestage

Function of physical attributes:
- Depth
- Velocity
- Substrate
- Cover

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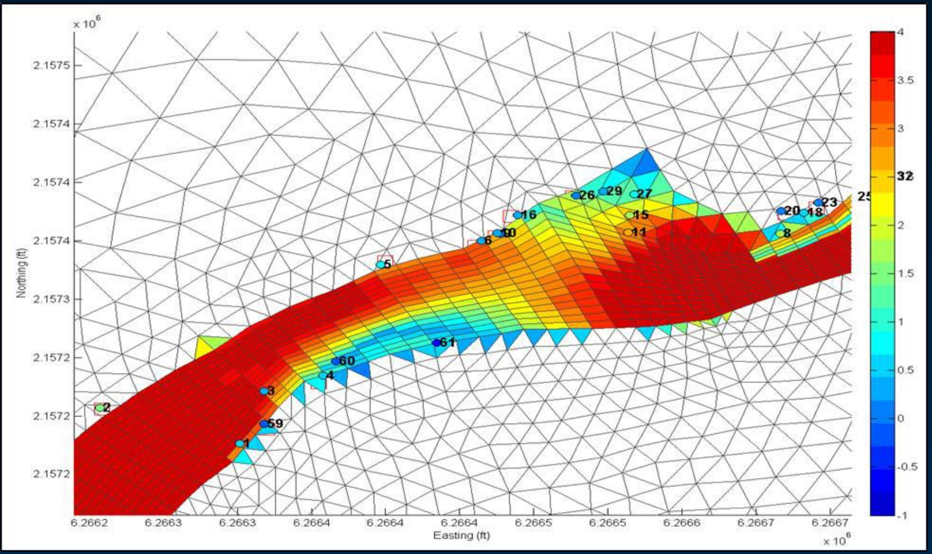
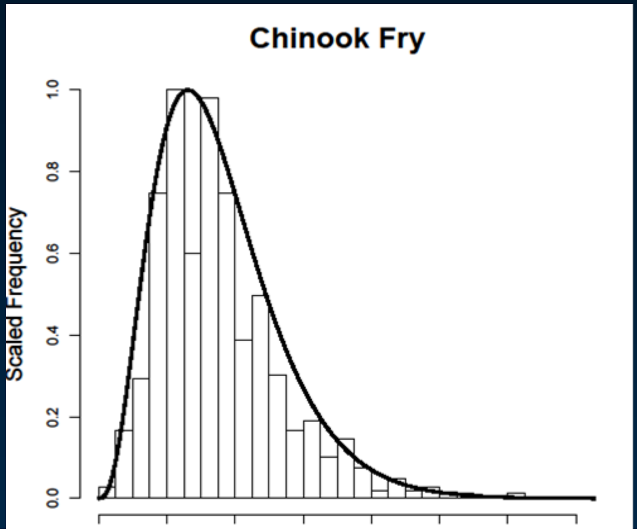
Typical Habitat Modeling Workflow

2D Hydraulic Models



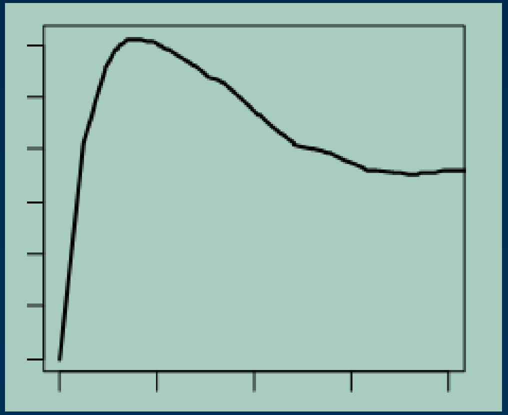
Habitat Models



Depth, Velocity, Cover, Substrate

Summarize over Spatial Units

Habitat area or Carrying capacity



River discharge

Habitat Methods Review

Data

Habitat Suitability Indices

Resource Selection Functions

Occupancy Models

Abundance Models

Data

Bioenergetic Approaches

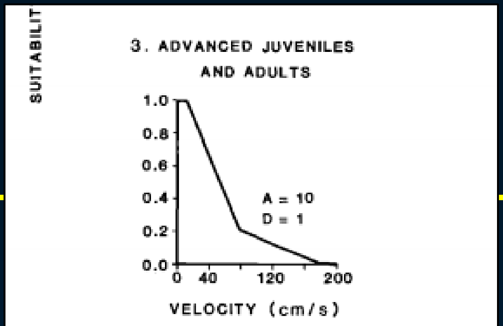
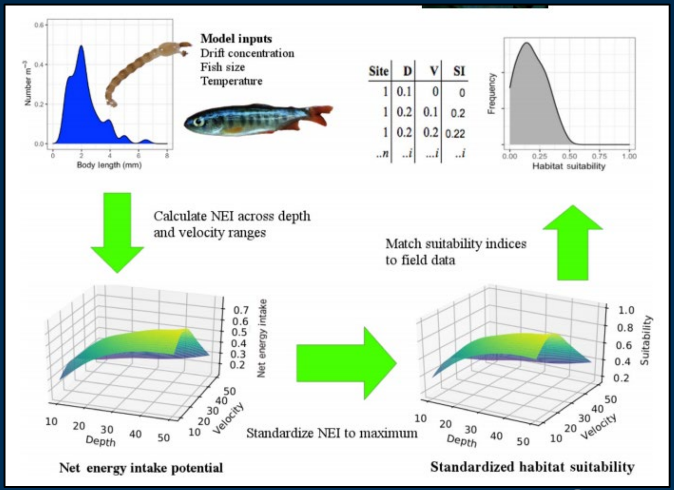


FIGURE 1.—Suitability index curves for water velocity (cm/s) for paddlefish spawning and egg incubation (1), advanced larvae and early juveniles (2), and advanced juveniles and adults (3); A is the number of panelists who agreed on the curve; D is the number who disagreed.

Crance, 1987

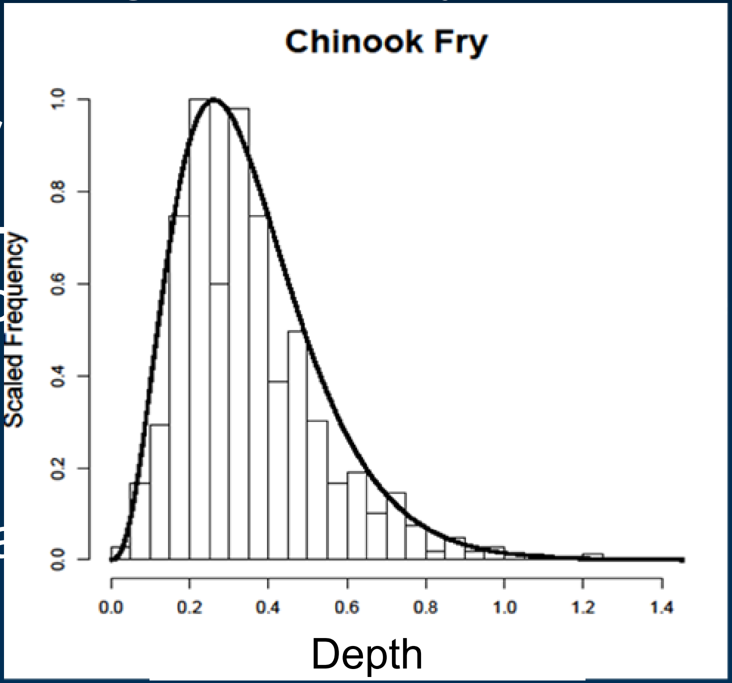


Naman et al., 2019

Habitat Suitability Indices

- Habitat function
  - Univariate habitat suitability index (HSI)
    - (0, 1) scale
  - Function for combining univariate HSI
    - Variables weighted equally

- Data requir
  - Presence-
    - microhab observed
  - Expert Op
  - Literature
    - Out-of-ba



Som et al. (2015)

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Resource Selection Functions

- Habitat function
  - Probability of observing fish versus not observed
  - Logistic regression techniques
    - Variable weights determined by model fit to data
    - Can evaluate interactions among variables
    - Model selection to determine best model structure

- Data requirements
  - Presence and non-presence data
  - Microhabitat variables where fish are observed and not observed

Occupancy Modeling

- Habitat function
  - Probability of true presence and absence
  - Accounts for false absences
    - Not observed but present
  - Logistic regression techniques
  - Can assess factors affecting detection

- Data requirements
  - Presence and non-presence data
  - Repeated samples
    - To estimate detection probability

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Bioenergetic Approaches

- Food acquisition is a dimension of habitat
- Habitat function
  - Net rate of energy intake (NREI)
  - Energetic costs versus benefits
  - Integrates both biotic and abiotic factors
- Data requirements
  - Drift concentration
  - Fish size
  - Water temperature

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Increasing Strength of Inference

Habitat Suitability Indices

Resource Selection Function

Occupancy Models

Abundance Models

Bioenergetic Approaches

Data → Data

Inference to population

Weak → Strong

Importance of Within-Basin Models

Millidine et al. (2016):

avoid transferring models between locations …
especially in the absence of model validation;

Beecher et al. (2010):

when the models have not been validated by empirical data, irretrievable commitments of natural resources (e.g., issuance of perpetual water rights) should be avoided.

Shirvell (1989):

The 'best' prediction … resulted from using … , river-specific habitat suitability criteria

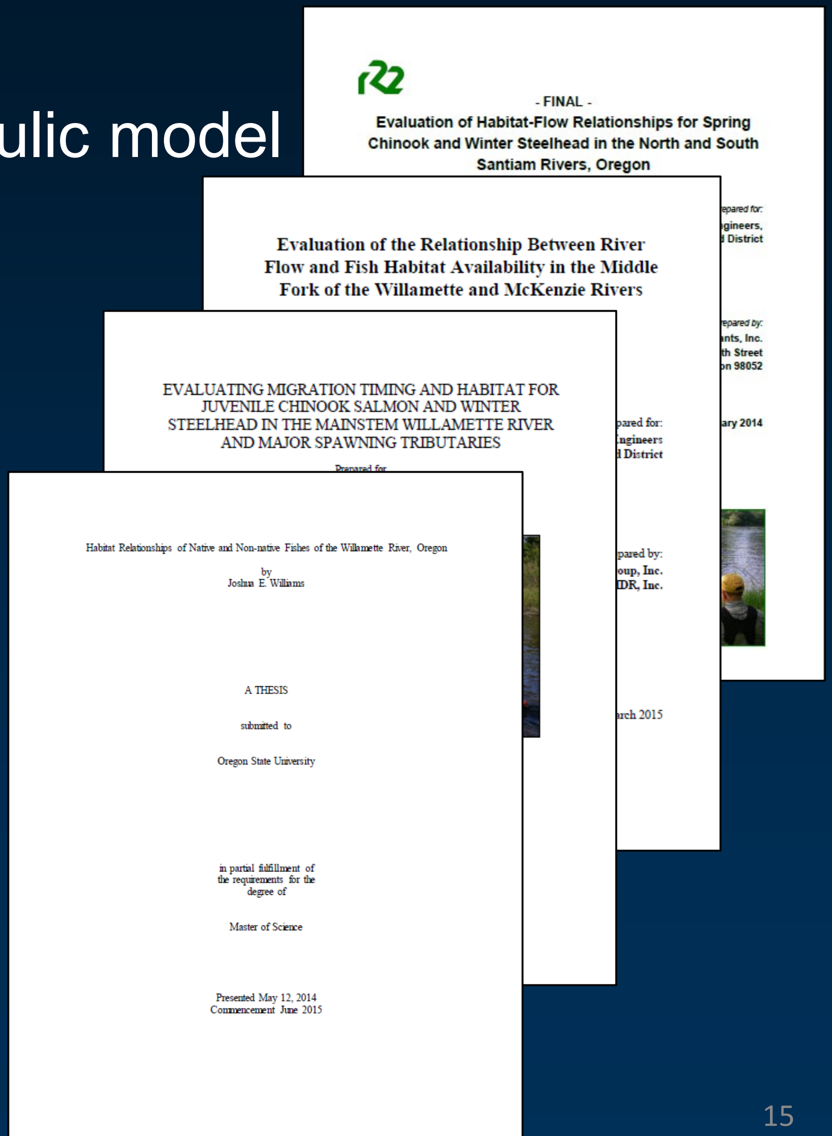
Can existing data inform habitat modeling?

Context:

Habitat timeseries with 2D hydraulic model

Emphasis on:

- R2 (2005, 2009, 2014)
- RDG (2015)
- Bond et al. (2017)
- Whitman (2017)
- Williams (2014)
- Stayton Hydro (2010)
- SLICES
- Willamette Fish Database


- FINAL -
Evaluation of Habitat-Flow Relationships for Spring Chinook and Winter Steelhead in the North and South Santiam Rivers, Oregon

Evaluation of the Relationship Between River Flow and Fish Habitat Availability in the Middle Fork of the Willamette and McKenzie Rivers

EVALUATING MIGRATION TIMING AND HABITAT FOR JUVENILE CHINOOK SALMON AND WINTER STEELHEAD IN THE MAINSTEM WILLAMETTE RIVER AND MAJOR SPAWNING TRIBUTARIES

Habitat Relationships of Native and Non-native Fishes of the Willamette River, Oregon

by
Joshua E. Williams

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented May 12, 2014
Commencement June 2015

Can existing data inform habitat modeling?

- Valuable data, but of limited utility
- Many used PHABSIM (HSI-based)
  - Course measurement of existing physical habitat
  - Rely on out-of-basin habitat suitability indices
- Incompatible spatial scales
  - Fish data collected at meso-habitat level
  - Habitats not sampled representatively
- Studies were designed for different purposes
  - Not to inform 2D hydraulic habitat models

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Critical Data Gaps

- Lack of Willamette-specific habitat use data
  - At a scale required to inform 2D habitat modeling
- Needed to support and validate existing modeling
  - SWIFT
- Pilot Field Study in 2020

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USGS Pilot Study in 2020

Habitat Suitability Indices

Resource Selection Function

Occupancy Models

Accounts for imperfect detection

Abundance Models

Bioenergetic Approaches

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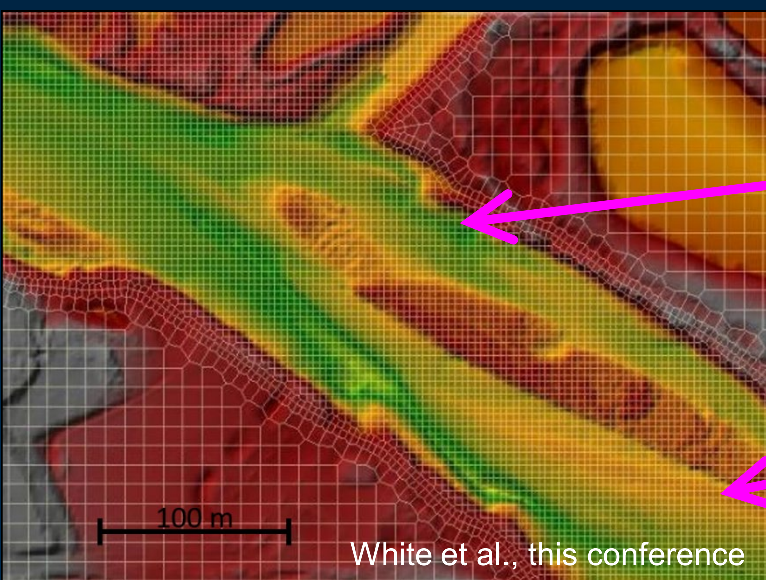
NRC Research Press

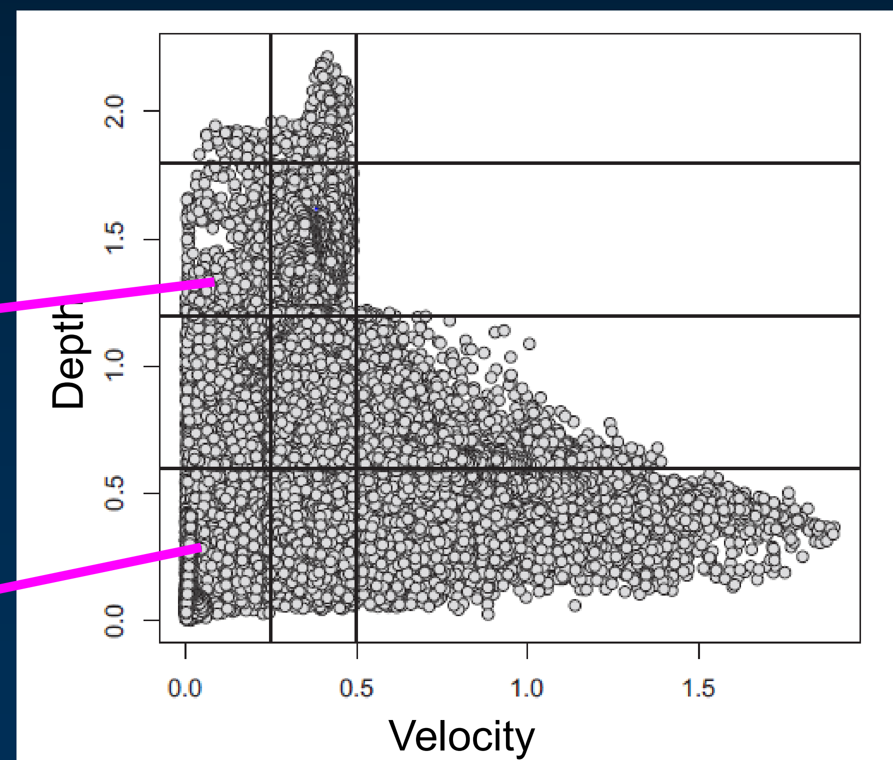
ARTICLE

N-mix for fish: estimating riverine salmonid habitat selection via N-mixture models

Nicholas A. Som, Russell W. Perry, Edward C. Jones, Kyle De Juilio, Paul Petros, William D. Pinnix, and Derek L. Rupert

Using 2D hydraulic model for sample site selection:





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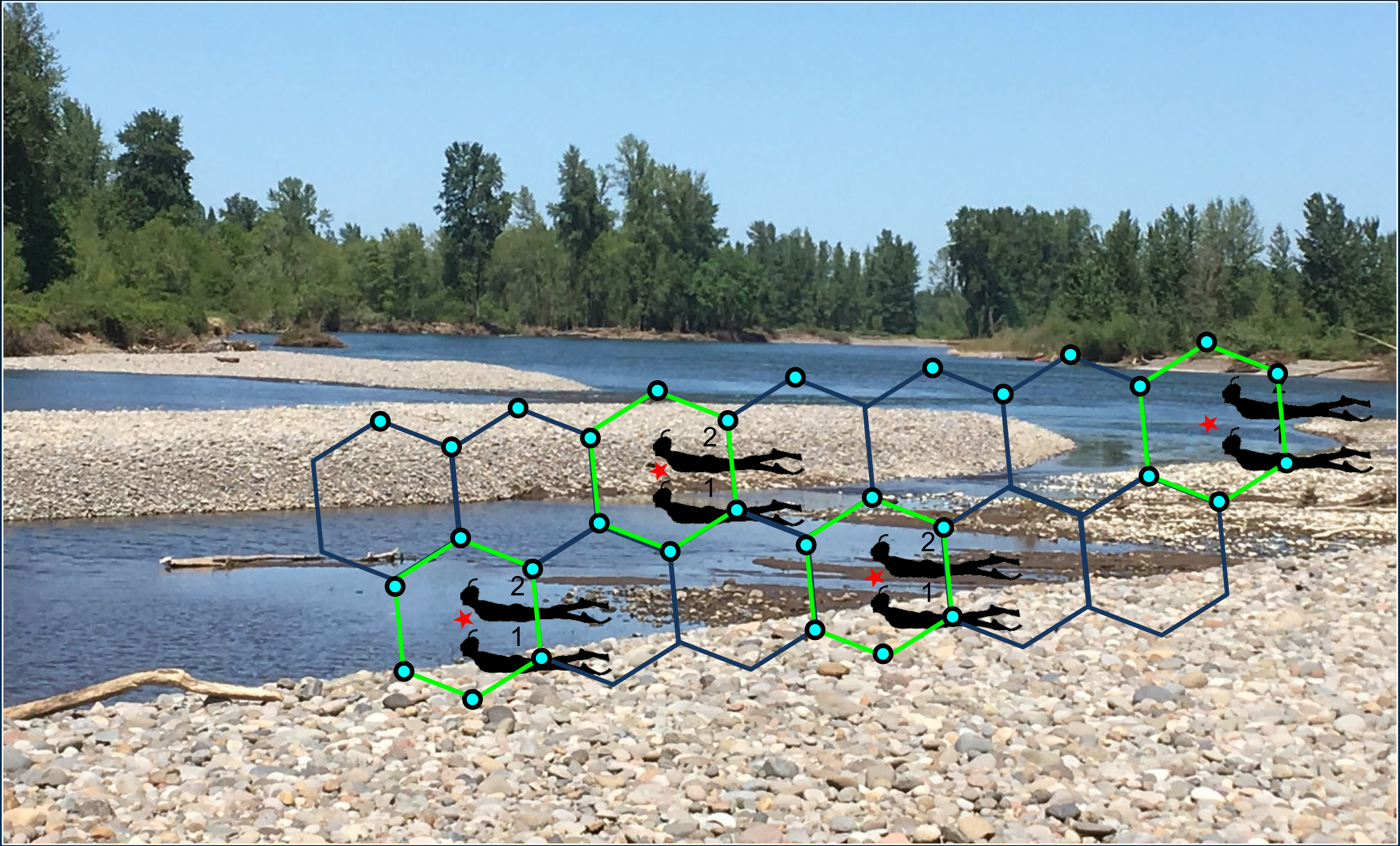
Double Observer Snorkel Survey



Summary

- Many improved methods of habitat modeling
- Most require data collection and analysis
  - Strengthens inference to population of interest
- Lack of Willamette-specific data
  - To inform 2D habitat modeling
- 2020 Pilot Study
  - Fish data to validate existing habitat models

Questions?

Habitat definitions

Defining Habitat

Species	Size Class	Criteria	Narrow	Median	Broad
Chinook salmon	Pre-smolt (>60mm)	Depth (ft)	0.15-2.25	0.15-3.5	0.15-Inf
		Velocity (ft/s)	0-1.25	0-1.63	0-3
		Bed Slope	<0.4	<0.55	Any
Chinook salmon	Fry (<60mm)	Depth (ft)	0.15-2.0	0.15-3.5	0.15-5
		Velocity (ft/s)	0-0.5	0-1.25	0-1.5
		Bed Slope	<0.4	<0.55	Any
Steelhead	Pre-smolt (>60mm)	Depth (ft)	0.15-1	0.15-1	0.15-Inf
		Velocity (ft/s)	0-1.75	0-3.25	0-3.5
		Bed Slope	NA	NA	NA
Steelhead	Fry (<60mm)	Depth (ft)	0.25-1.25	0.25-2	0.25-5
		Velocity (ft/s)	0-0.5	0-1.25	0-2
		Bed Slope	NA	NA	NA

Values from literature review by Jim, Tyrell, and Jessica, reviewed by SWIFT members

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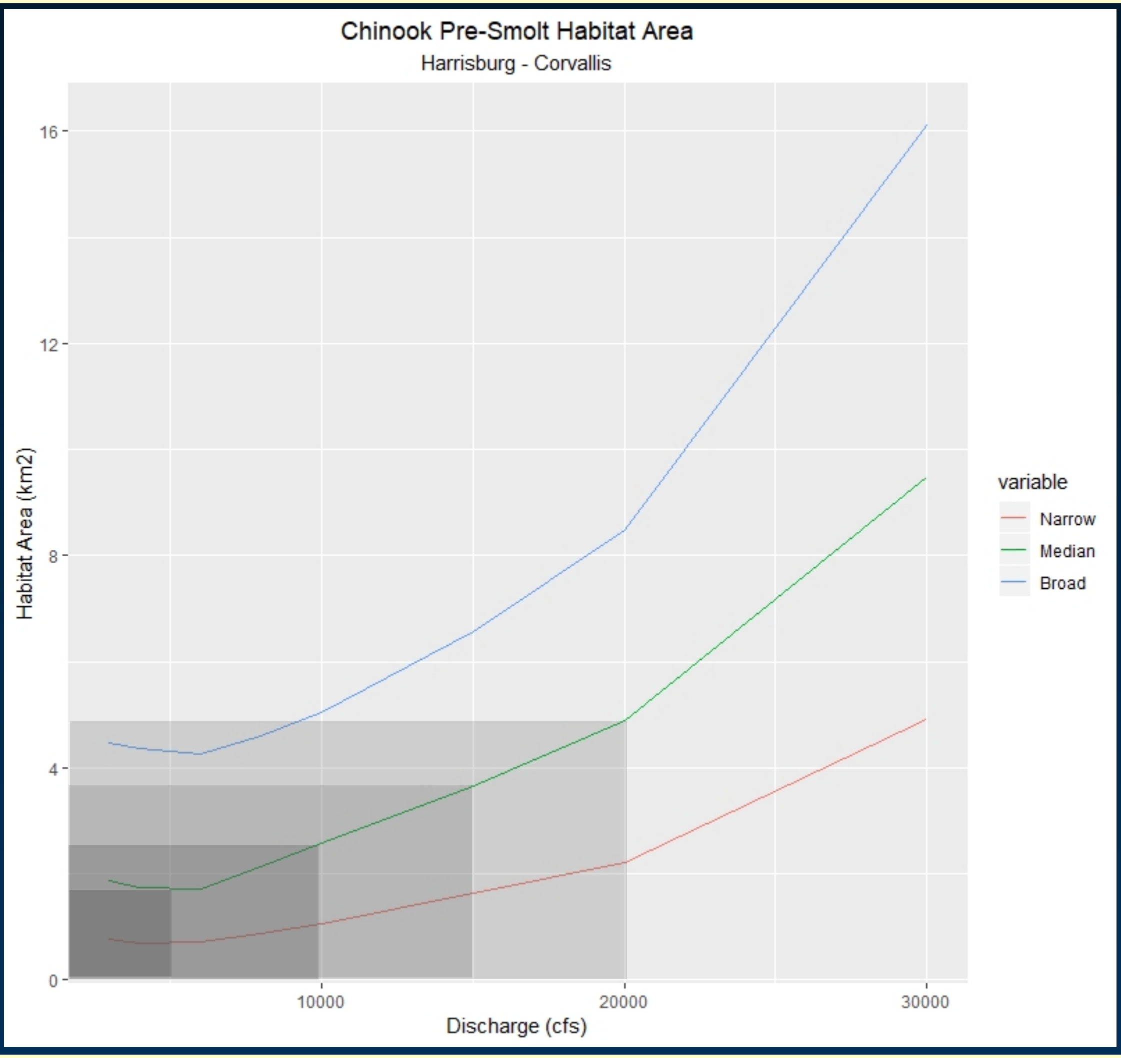
Preliminary Results – subject to revision

Habitat area versus discharge



Validation objectives

Model validation

Determine how model predicts conditions relative to discharge and temperature regime in 2020

Base sampling periods relative to juvenile life history and range of model behavior

Assess model performance across different hydrogeomorphic reaches

Habitat validation

Obtain fish abundance estimates relative to modeled habitat cells to verify or refine habitat definitions

Drift sample collection

Utilize presence of field staff to collect aquatic invertebrate drift samples for future analysis regarding NREI and carrying capacity

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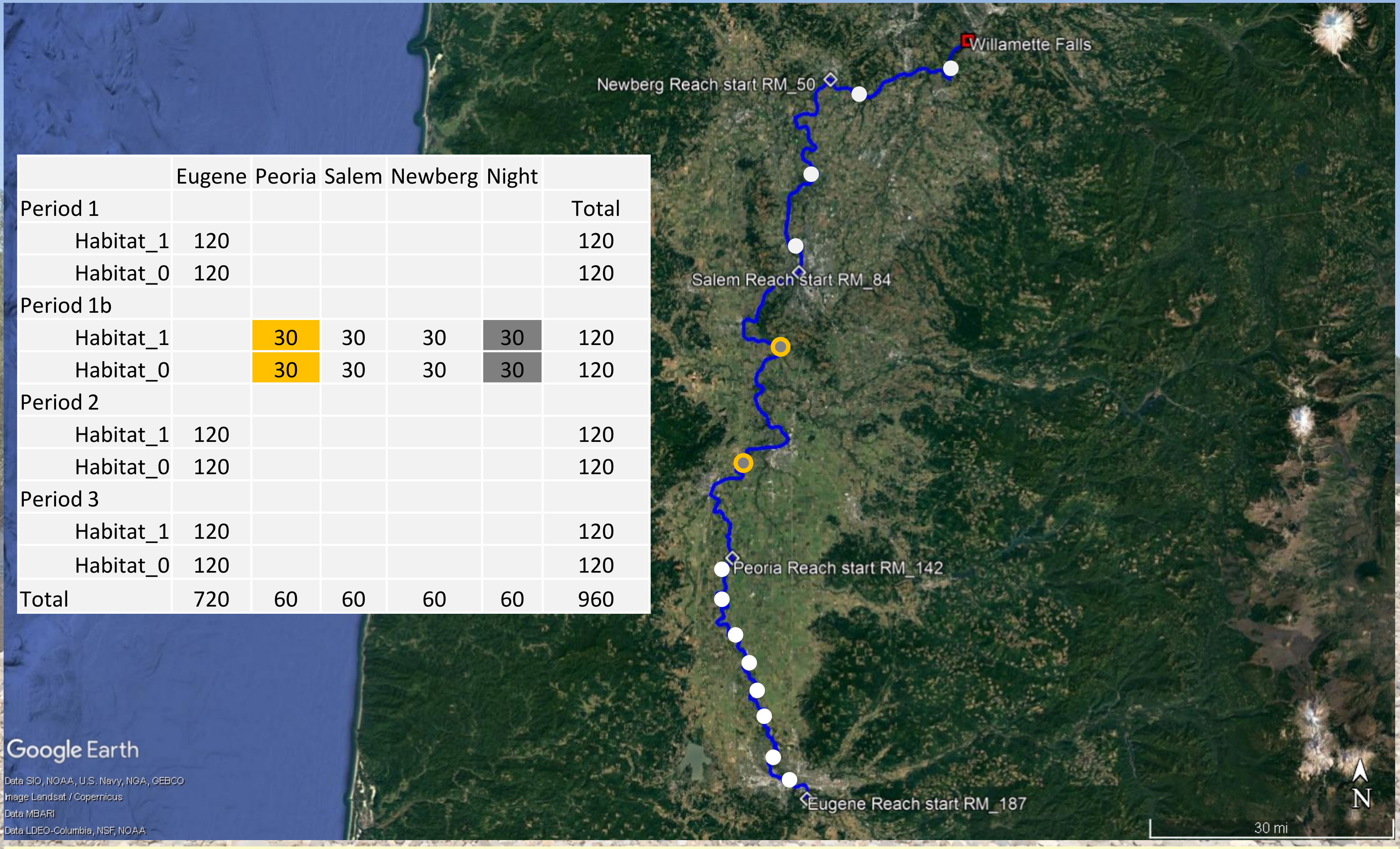
Mainstem reaches; segment; cells

	Eugene	Peoria	Salem	Newberg	Night	
Period 1						Total
Habitat_1	120					120
Habitat_0	120					120
Period 1b						
Habitat_1		30	30	30	30	120
Habitat_0		30	30	30	30	120
Period 2						
Habitat_1	120					120
Habitat_0	120					120
Period 3						
Habitat_1	120					120
Habitat_0	120					120
Total	720	60	60	60	60	960



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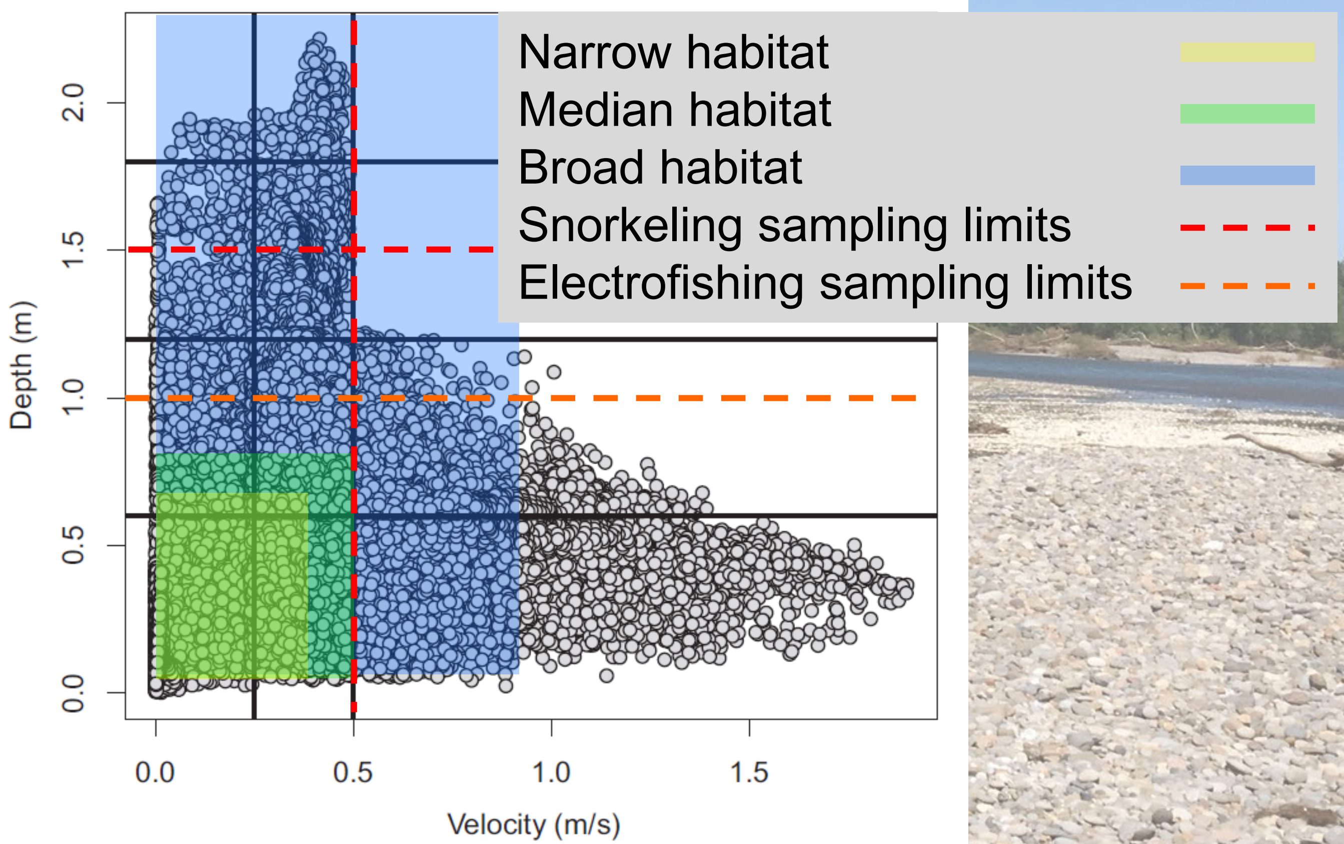
Sampling strategy example

Fig. 1. Bivariate plot of spatially indexed depth and velocity values predicted by a two-dimensional hydrodynamics model at one site and discharge. Vertical and horizontal lines form bins from which spatially stratified individual sample locations were selected.



Plot example from Som et al 2017; N-mix for fish: estimating riverine salmonid habitat selection via N-mixture models; CJFAS

Proposed model validation …

Validate Mainstem Willamette models of ORWSC

Spatially balanced random sample of locations
- Stratified by rkm, habitat area uniformity, and reach (Headwaters, Peoria, Salem, Newberg)
- Designated as habitat and non-habitat by model prediction using SWIFT habitat criteria

Flow variation
- Relevant to hydraulic variation (<5, 5-10, 10-15, 15-20 kcfs)

Temperature variation
- Relevant to seasonal variation (5-10, 10-15, 15-20 °C)

Life stage utilizing mainstem habitat
- Fry and juvenile rearing
- Two size classes (<60 mm fry; >60 mm juvenile (presmolt))

Seasonality
- Three sampling periods: mid April to late September

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Proposed model validation …

Diel variation

Day/night (±1 hr after and before civil twilight)

Physical parameters

Depth, temperature, velocity, sampled area, lateral temperature assessment, dominate substrate classification (D40 gravelometer), vegetation type classification

Fish assessment

Salmonid presence/absence, enumeration

Other species encountered

Multiple observer

Analysis estimates

Detection probability, probability of presence, occupancy, relative abundance

“This is how we do it …”

At each site (day 1):

- Deploy temperature lateral cross-section array (~24 hrs)
- Drift samples (taken prior to upstream disturbance)

For each cell (day 1):

- Deploy cell boundary polygon, record centroid GPS location, depth, velocity, and temperature

For each cell (day 2):

- Snorkel survey each cell

At each site (day 2):

- Retrieve temperature lateral cross-section array

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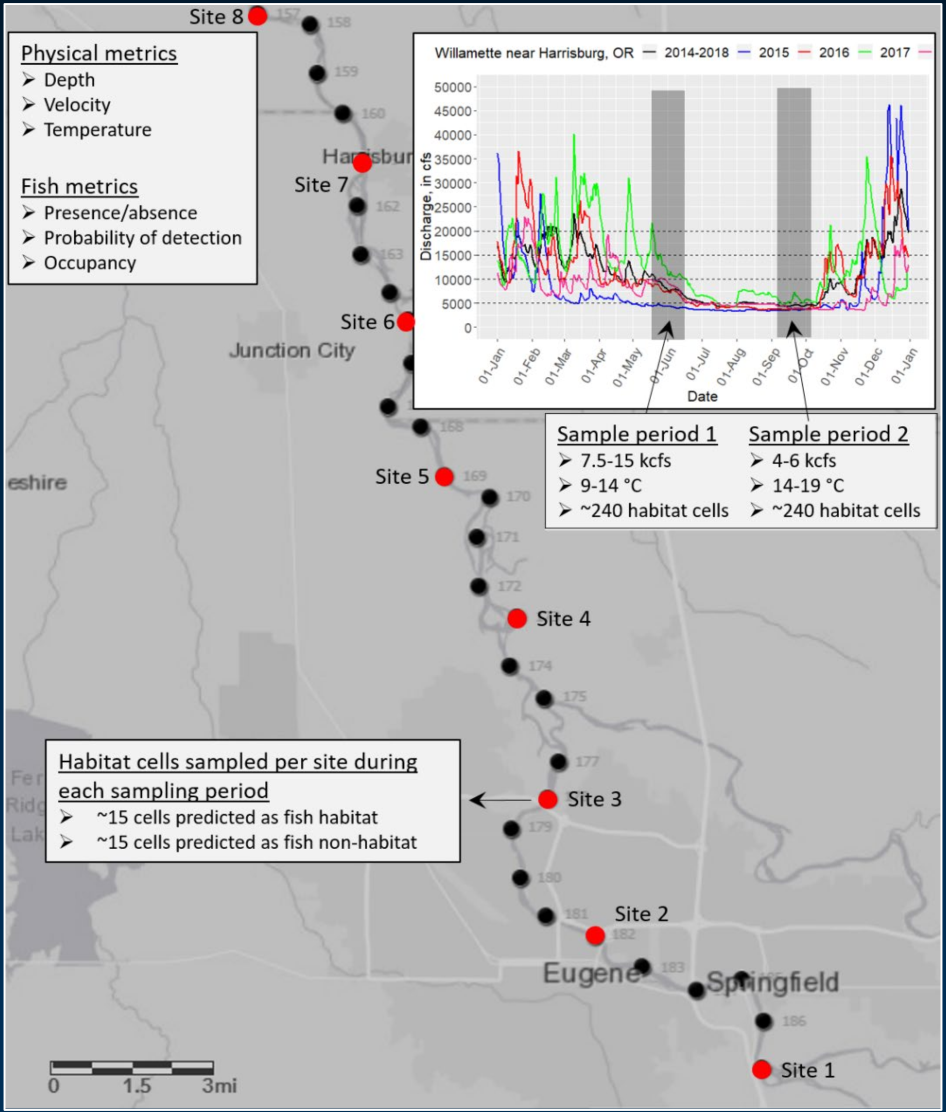
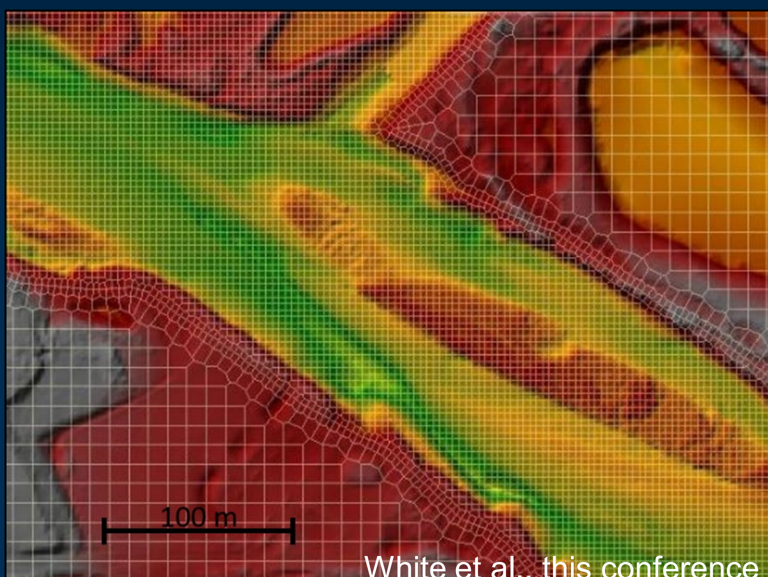
Field Data t



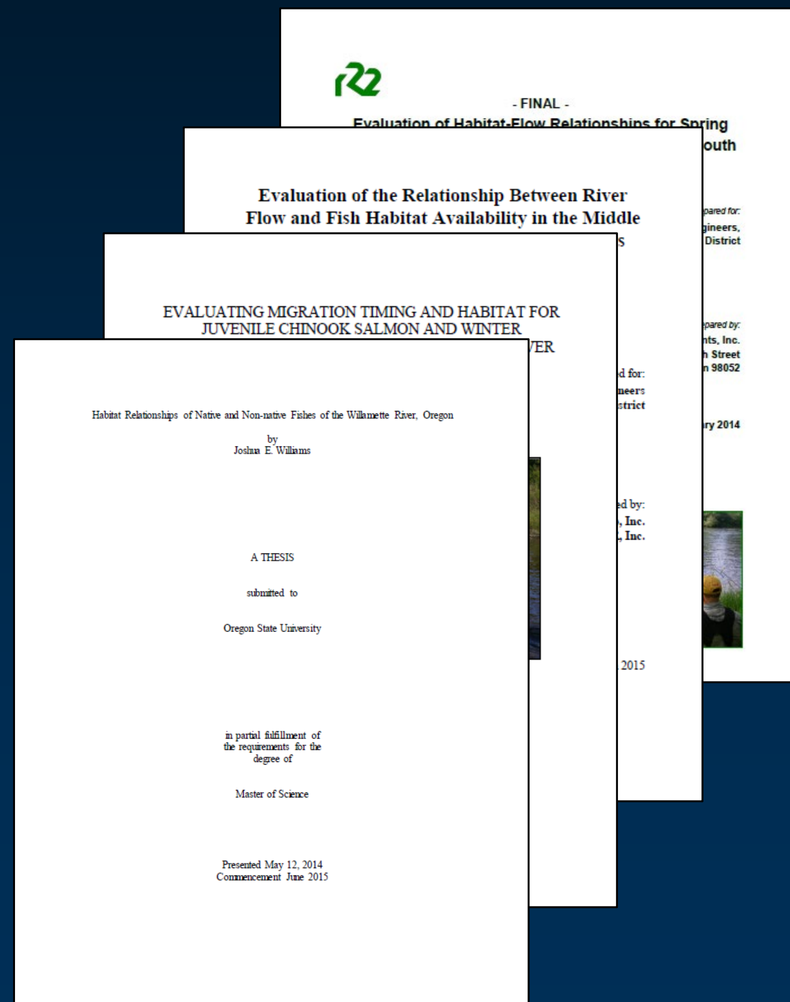
Site 8
Site 7
Site 6
Site 5
Site 4
Site 3
Site 2
Site 1
Harrisburg
Junction City
Eugene
Springfield
0 1.5 3mi
Physical metrics
Depth
Velocity
Temperature
Fish metrics
Presence/absence
Probability of detection
Occupancy
Willamette near Harrisburg, OR — 2014-2018 — 2015 — 2016 — 2017
Discharge, in cfs
Date
Sample period 1
7.5-15 kcfs
9-14 °C
~240 habitat cells
Sample period 2
4-6 kcfs
14-19 °C
~240 habitat cells
Habitat cells sampled per site during each sampling period
~15 cells predicted as fish habitat
~15 cells predicted as fish non-habitat

Existing Studies

- Numerous studies available
  - 1934-2017
  - Spatial limitations
  - Primarily PHABSIM
  - Solid foundation
  - Emerging methods promising



White et al., this conference



SWIFT Approach

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