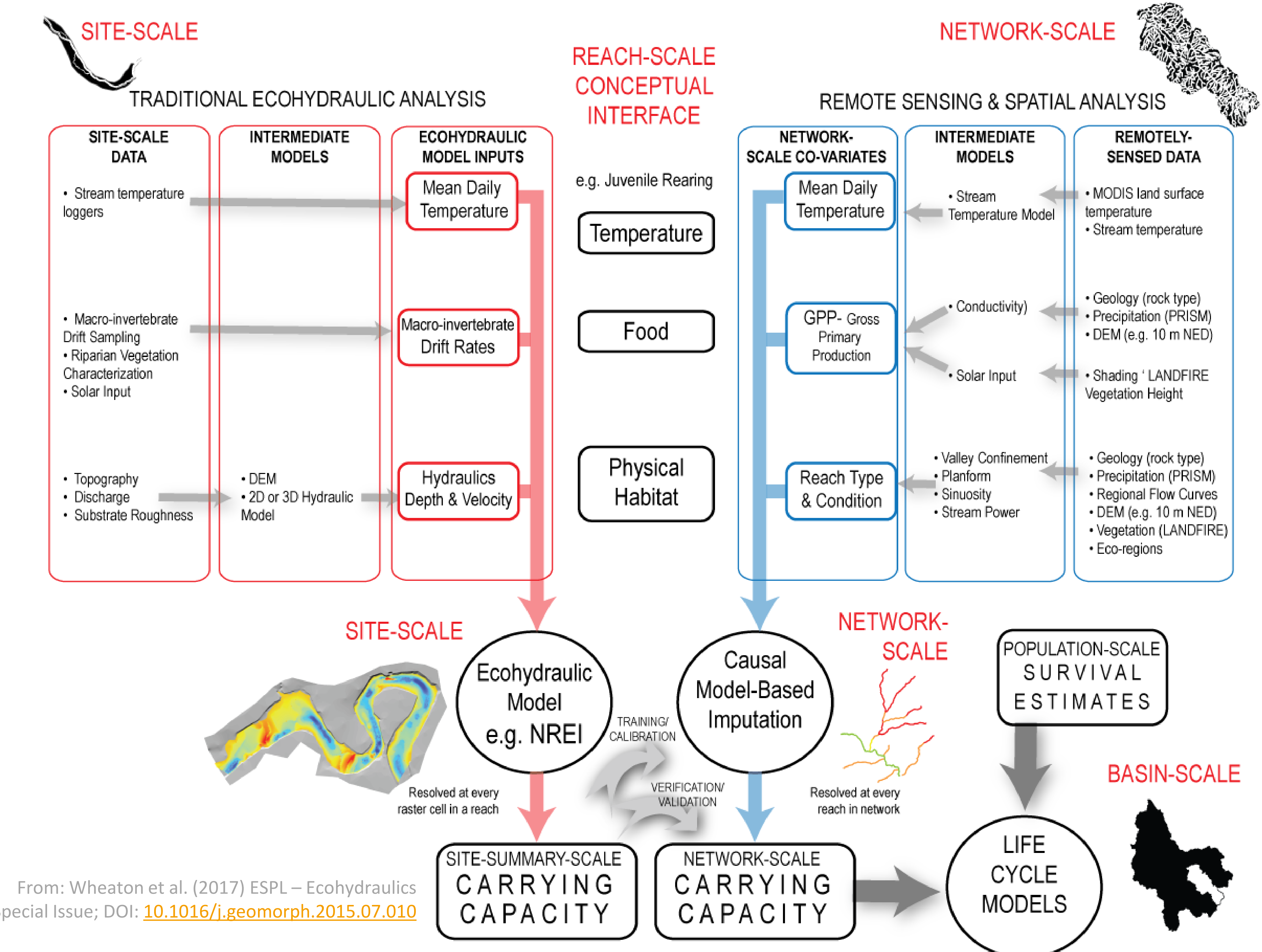
WATS 6900 – Ecohydraulics
WEEK 15: Upscaling to the Network

UtahState University
DEPARTMENT OF WATERSHED SCIENCES

JOE WHEATON

NICK BOUWES



From: Wheaton et al. (2017) ESPL – Ecohydraulics Special Issue; DOI: 10.1016/j.geomorph.2015.07.010

Network Models Of Steelhead Distribution Using The River Styles Framework, Middle Fork John Day, OR

Using rapid assessment surveys to understanding fish distributions and their habitat

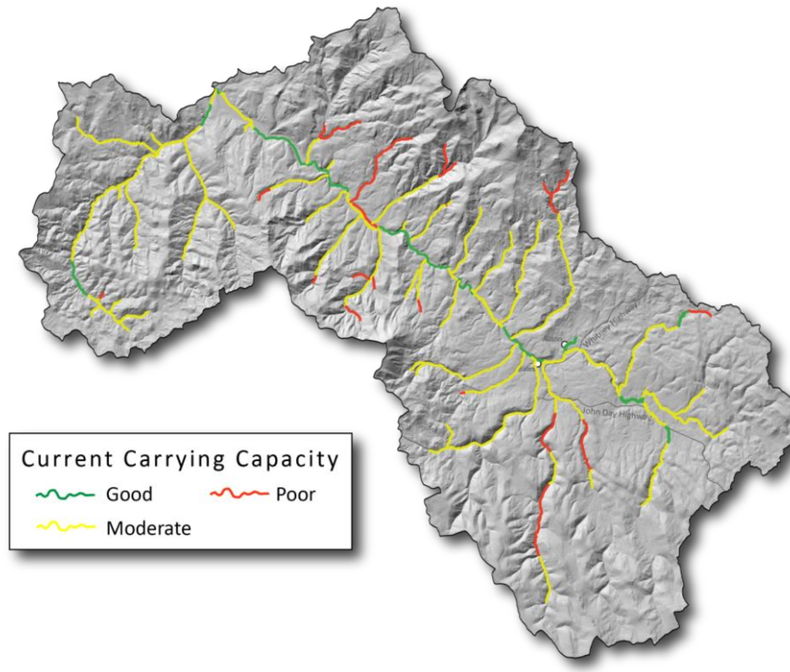
M.S. Defense Presentation

Monica Blanchard

May 1, 2015

Riverscapes Context

- Spatially explicit- **where** are:
  - Impairments/limiting factors
  - Conservation areas
  - Highest restoration potential



Spatial Scale (m)	Channel Unit 10^1	Reach 10^1 - 10^3	Segment 10^3 - 10^5	Basin $>10^5$
Current Understanding				
Understanding Needed			???	

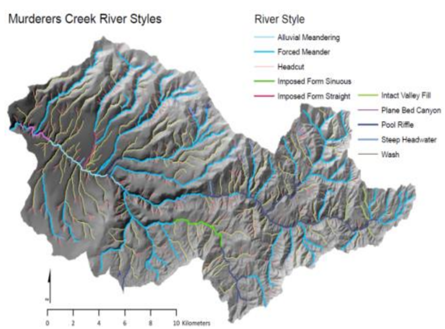
Fausch et al. (2002)

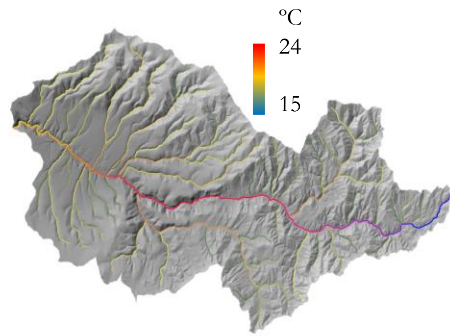
Research Questions

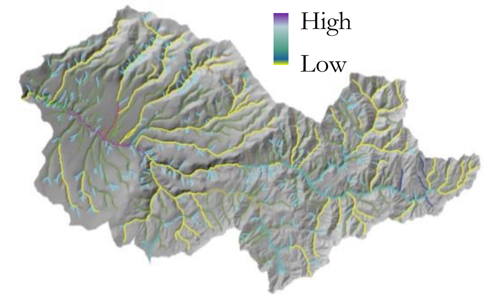
- What is the spatial variability in juvenile steelhead and features of their habitat?

- Can continuous network models be used to describe the distribution of juvenile steelhead and their habitat?

Network Juvenile Steelhead Abundance





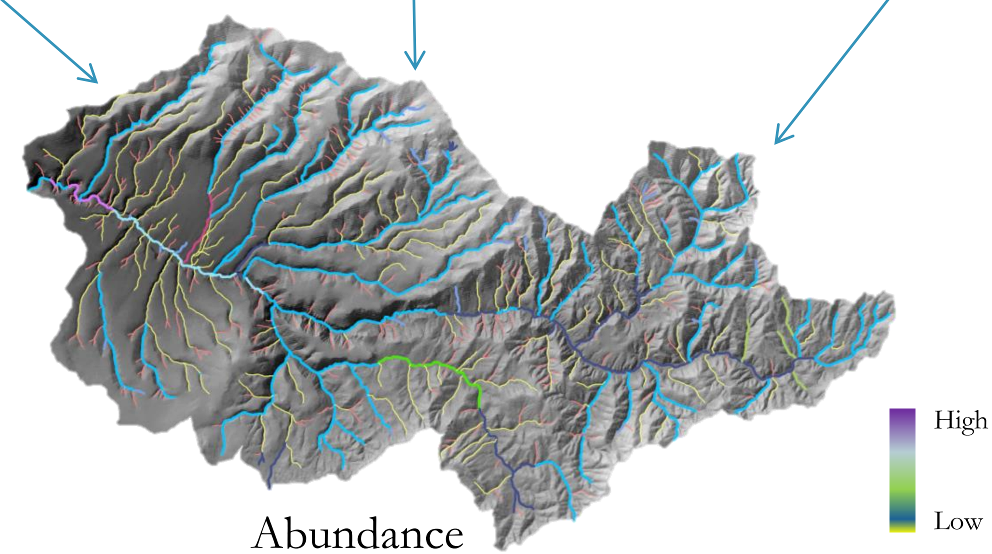


Physical Habitat

RiverStyles
O'Brien et al

Temperature
Modis LST
McNyset et al

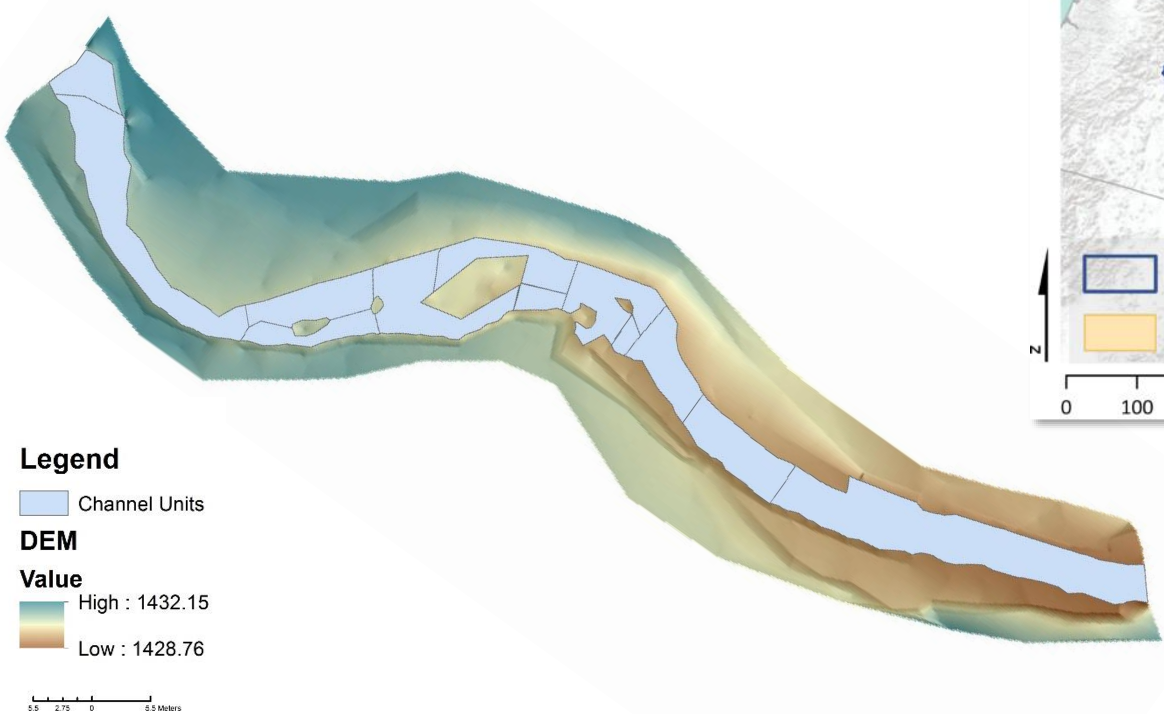
Stream Productivity
GPP
Saunders et al

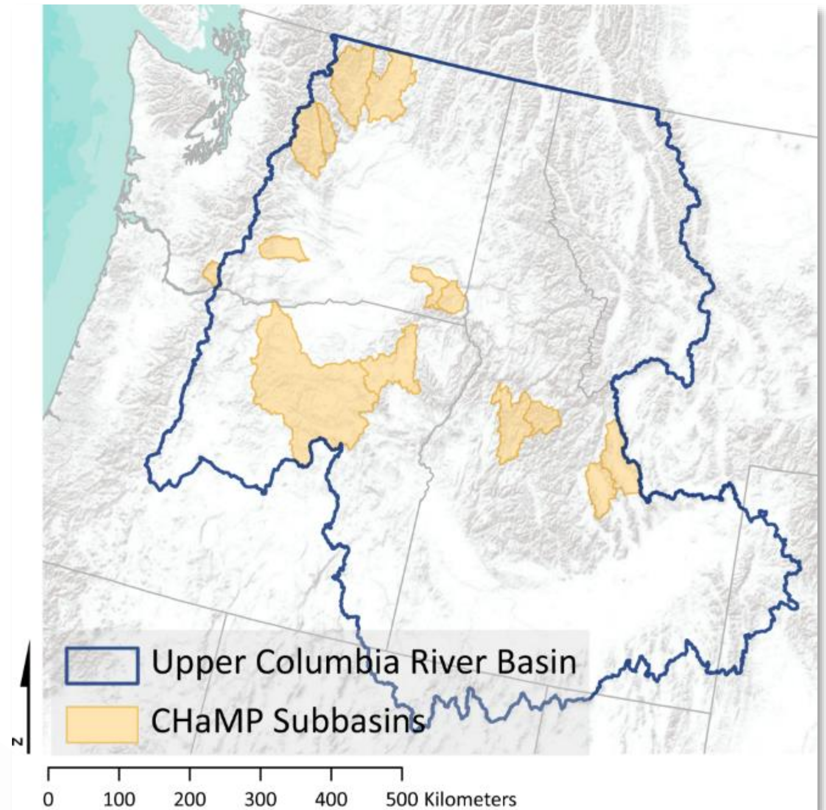


Abundance

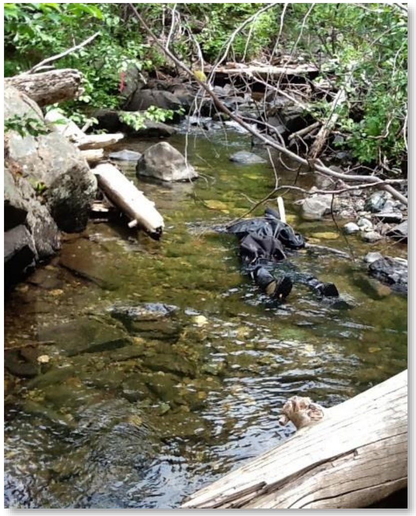
Columbia Habitat Monitoring Program (CHaMP)

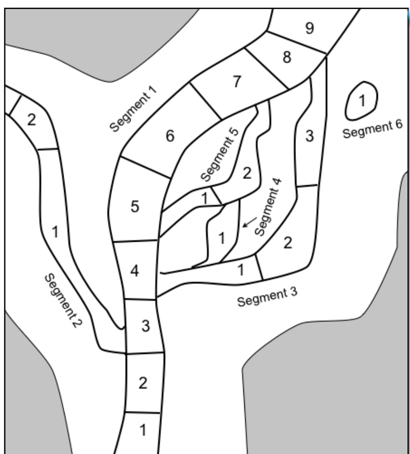
- Topographic Surveys
- Reach Level
- Geomorphic Unit





Rapid Assessment Surveys





Geomorphic Unit:

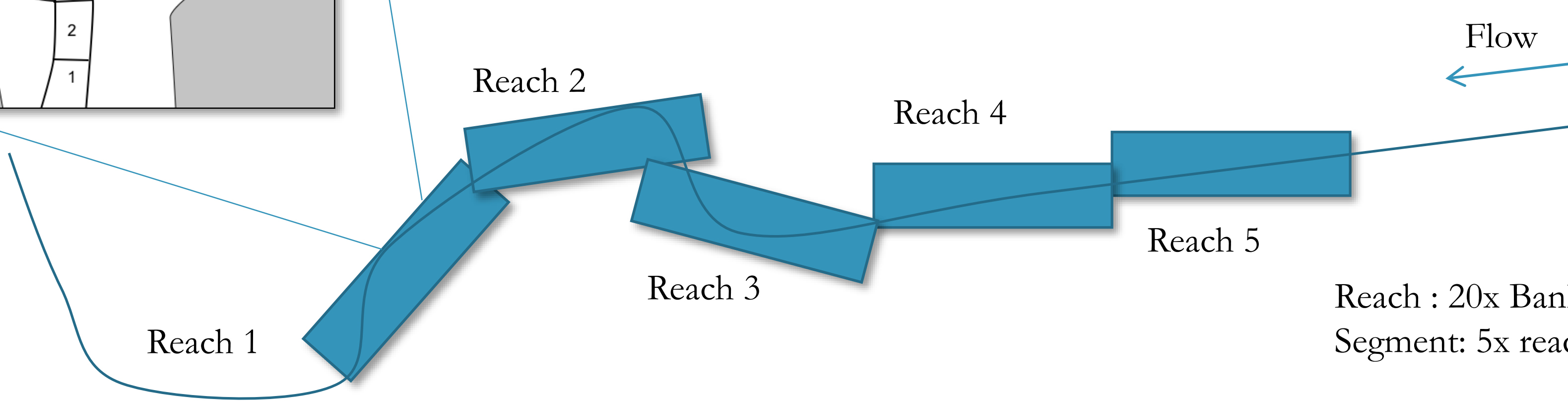
- Unit type
- Unit dimensions
- Geomorphic arrangement
- Fish cover
- Large woody debris
- Undercut banks
- Substrate size
- Roughness
- Structural elements

Reach Level:

- Conductivity
- Riparian structure
- Number of segments

Fish Data:

- Surveyed all units
- Identify species
- Count and estimate size class of salmonids
- Count non-salmonids
- Calibrated with mark-recapture

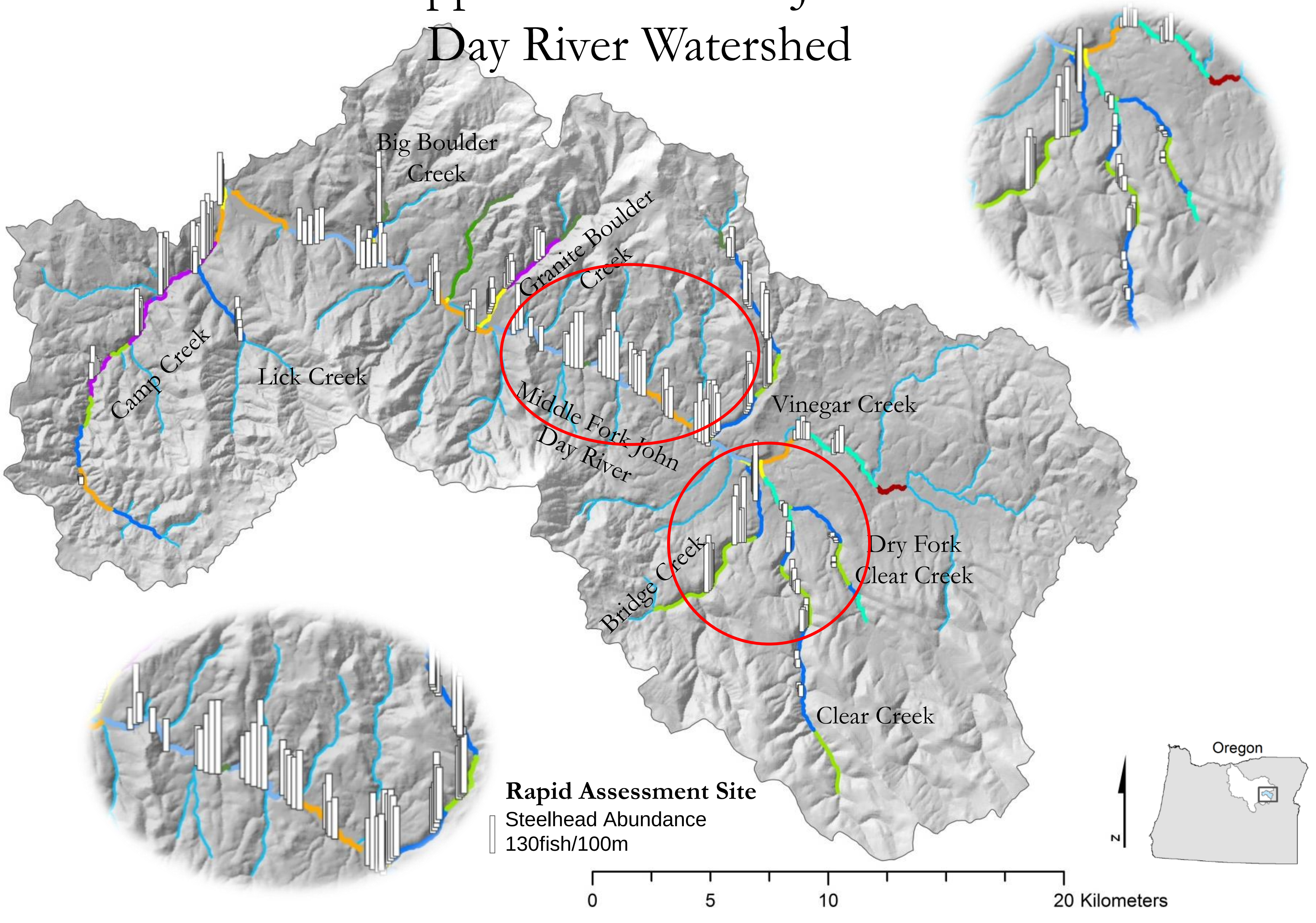


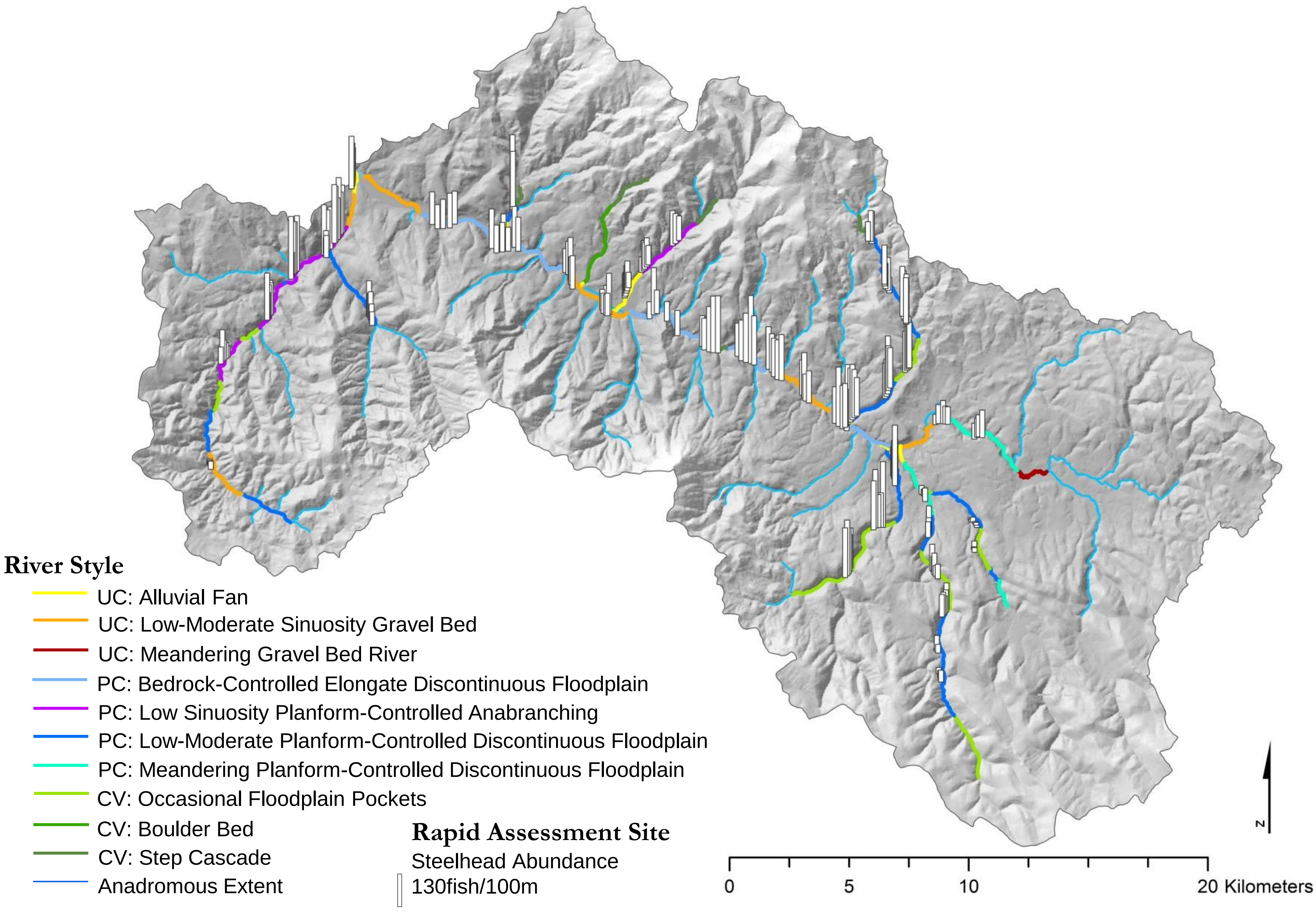
Reach : 20x Bankfull Width
Segment: 5x reach

River Style - Abbreviation	Valley Confinement	Number of Sites	Distance Surveyed (km)	Total Stream Distance * (km)
AF	Unconfined	15	2.2	17.5
LMS GB	Unconfined	19	3.7	23.9
CV OFP	Confined	30	4.1	29.2
CV SC	Confined	6	0.8	6.9
BC EDF	Partly Confined	30	7.2	23.8
LM PC DF	Partly Confined	52	6.5	41.4
LS PCA	Partly Confined	33	4.2	15.9
M PC DF	Partly Confined	12	1.8	11.7
Total		**197**	**30.5**	**170.3**

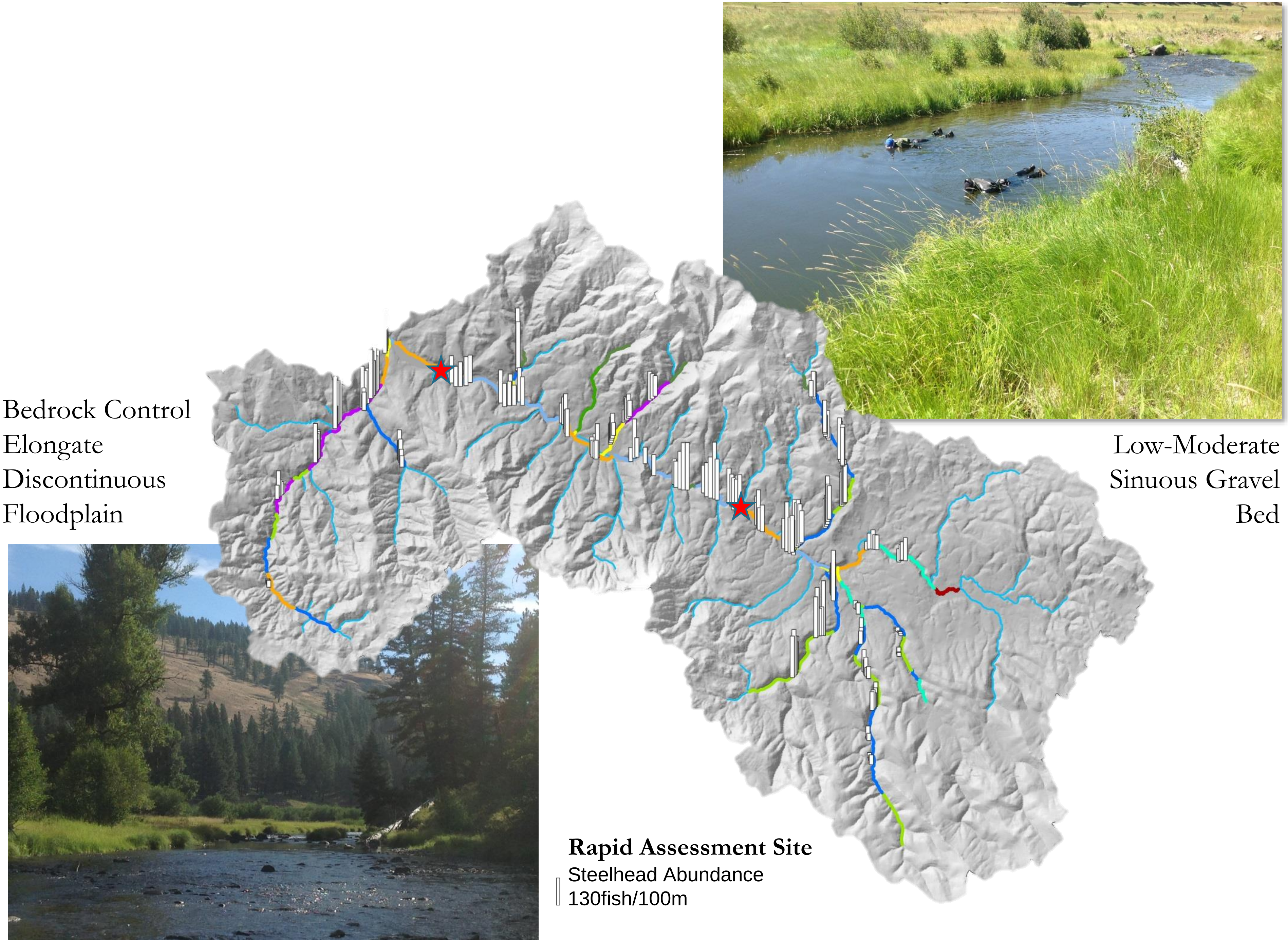
* Total stream distance includes streams accessible to steelhead and which were perennial.

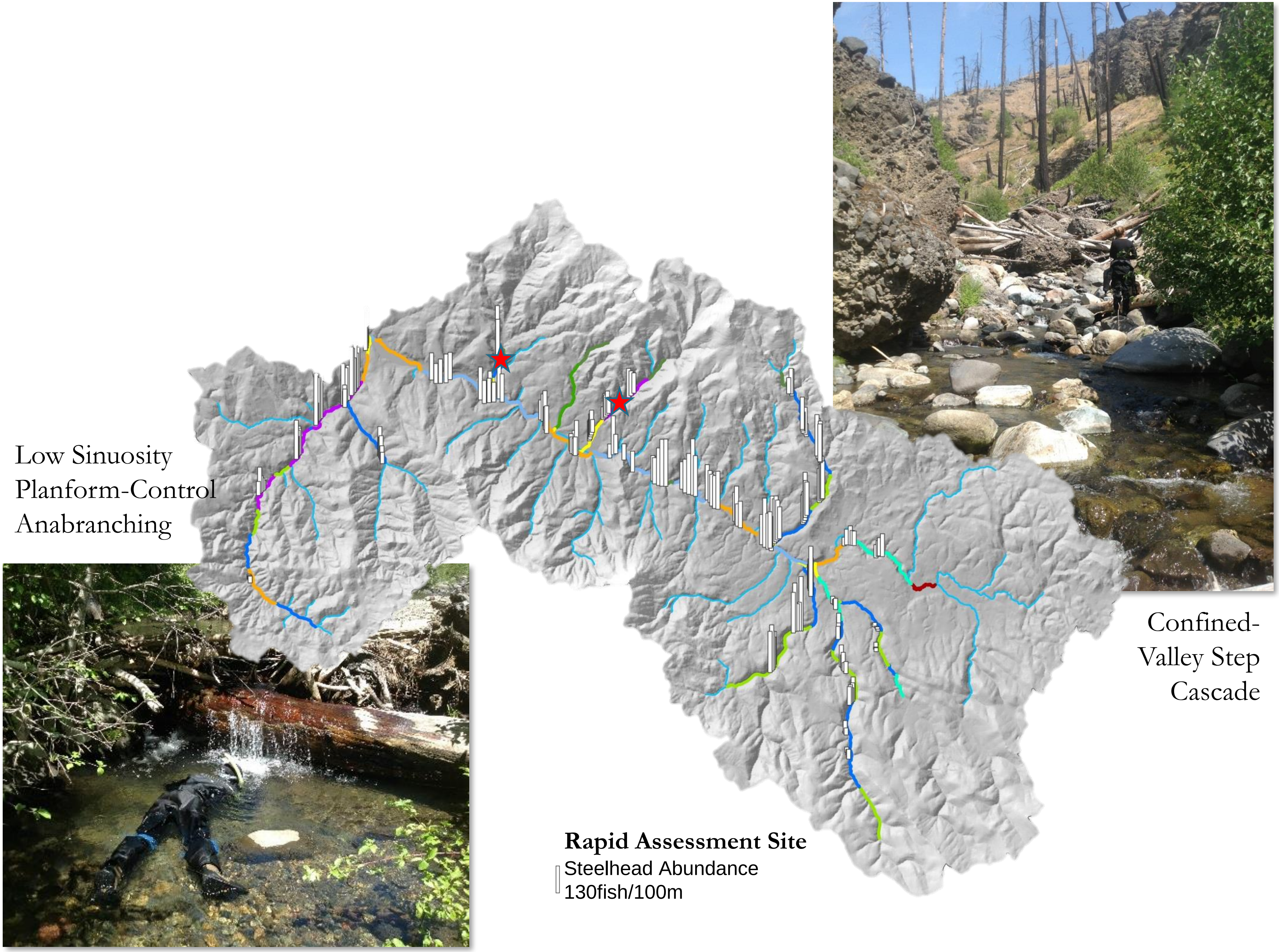
Upper Middle Fork John Day River Watershed

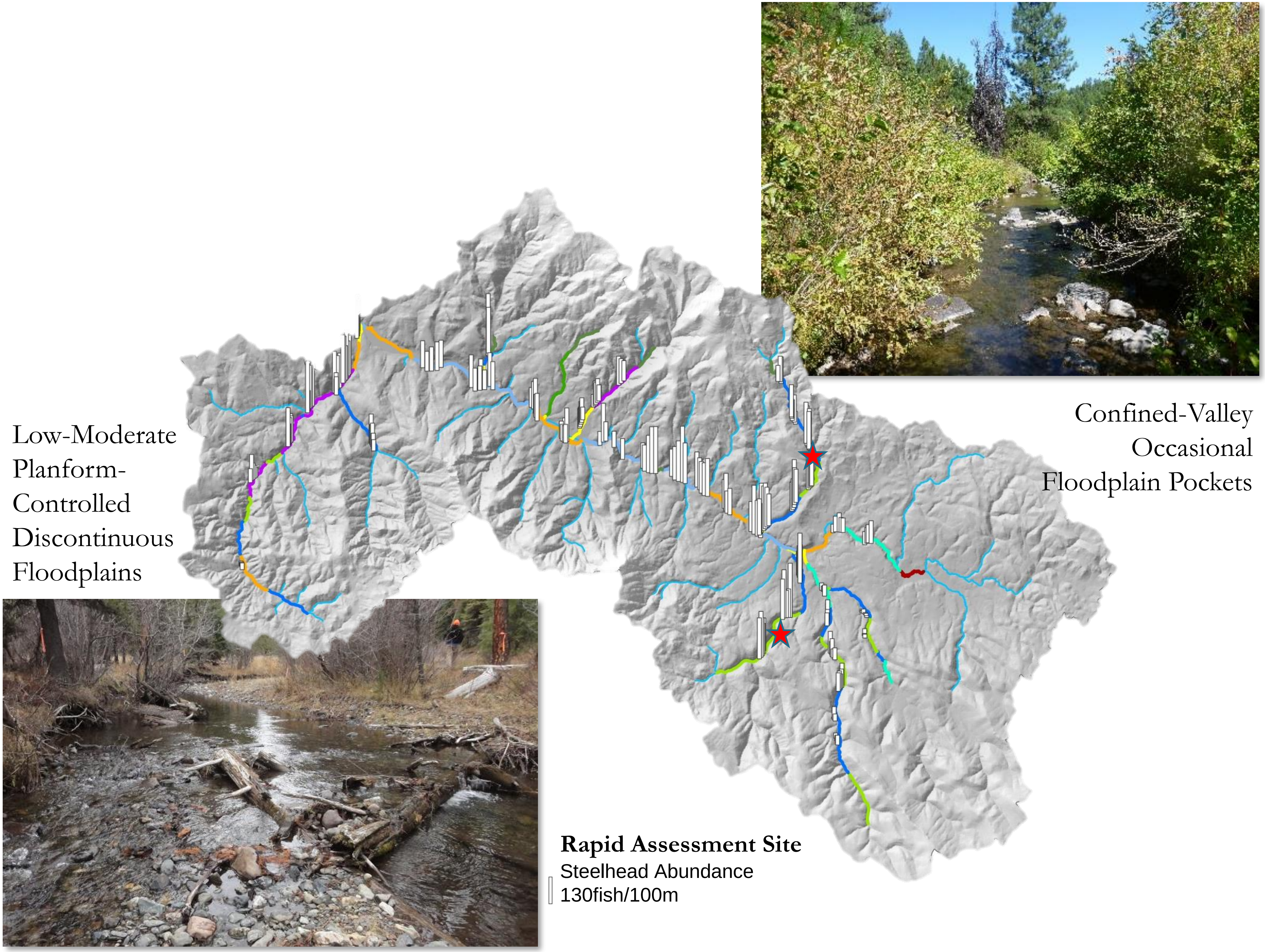




River Style
UC: Alluvial Fan
UC: Low-Moderate Sinuosity Gravel Bed
UC: Meandering Gravel Bed River
PC: Bedrock-Controlled Elongate Discontinuous Floodplain
PC: Low Sinuosity Planform-Controlled Anabranching
PC: Low-Moderate Planform-Controlled Discontinuous Floodplain
PC: Meandering Planform-Controlled Discontinuous Floodplain
CV: Occasional Floodplain Pockets
CV: Boulder Bed
CV: Step Cascade
Anadromous Extent
Rapid Assessment Site
Steelhead Abundance
130fish/100m
0
5
10
20 Kilometers
N


Bedrock Control
Elongate
Discontinuous
Floodplain
Low-Moderate
Sinuous Gravel
Bed
Rapid Assessment Site
Steelhead Abundance
130fish/100m


Low Sinuosity
Planform-Control
Anabranching
Confined-
Valley Step
Cascade
Rapid Assessment Site
Steelhead Abundance
130fish/100m



Low-Moderate Planform-Controlled Discontinuous Floodplains
Confined-Valley Occasional Floodplain Pockets
Rapid Assessment Site
Steelhead Abundance
130fish/100m

River Styles Classification and Validation

Defining River Style Attributes

Variable	Type	Units	Description
Controls			
Erodibility	Factor	1,7,8	Degrees of erodibility, scale 1-8, 1 highly erodible and 8 least erodible [a]
Channel Slope	Integer	Cm/cm	Slope extracted every 200m from NHDplus stream layer [b]
Reach Characteristics			
Valley Setting	Factor	Confined Partly-Confined Unconfined	Degree to which the river is confined against the valley margin as defined in River Styles [c]
Bankfull Width	Integer	m	Average bankfull width over reach length
Sinuosity	Factor	Straight (1.0-1.05), Low Sinuosity (1.06-1.30), Sinuous (>1.31)	Classification of stream sinuosity over a survey reach based on aerial imagery and measurements in ArcGIS [d]
Pools/100m	Integer	Count	Number of pools per 100 m of stream
Average Roughness	Integer	cm	Average roughness of reach substrate. Measured three times within each non-pool unit and average for a unit value Units average together for a reach value
LWD/100m	Integer	Count	Number of qualifying pieces of large woody debris per 100m of stream [e]

[a] ISEMP (2013), [b] Beechie and Imaki (2013), [c] Brierley and Fryirs (2005), [d] Schumm (1985), [e] CHaMP (2013)

Random Forest Classification Results: percent correctly classified (PCC)

River Style	AF	LM SGB	CV OFP	CV SC	BV EDF	LM PC DF	LS PC A	M PC DF	PCC
AF	**15**	0	0	0	0	0	0	0	**100**
LM SGB	0	**18**	0	0	0	1	0	0	**94.7**
CV OFP	0	0	**30**	0	0	0	0	0	**100**
CV SC	0	0	5	**1**	0	0	0	0	**16.7**
BC EDF	0	0	0	0	**30**	0	0	0	**100**
LM PC DF	0	0	0	0	0	**48**	4	0	**92.3**
LS PC A	0	0	0	0	0	6	**27**	0	**81.8**
M PC DF	0	0	0	0	0	6	1	**5**	**41.7**
Overall PCC									88.3

Random Forest Classification Results: percent correctly classified (PCC)

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CV OFP	0	0	**30**	0	0	0	0	0	**100**
CV SC	0	0	5	**1**	0	0	0	0	**16.7**
BC EDF	0	0	0	0	**30**	0	0	0	**100**
LM PC DF	0	0	0	0	0	**48**	4	0	**92.3**
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CV SC	0	0	5	**1**	0	0	0	0	**16.7**
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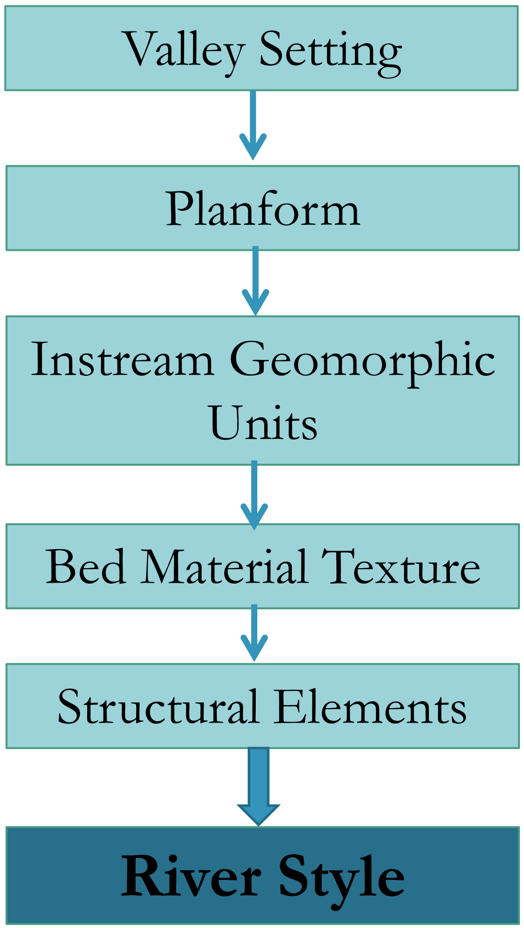
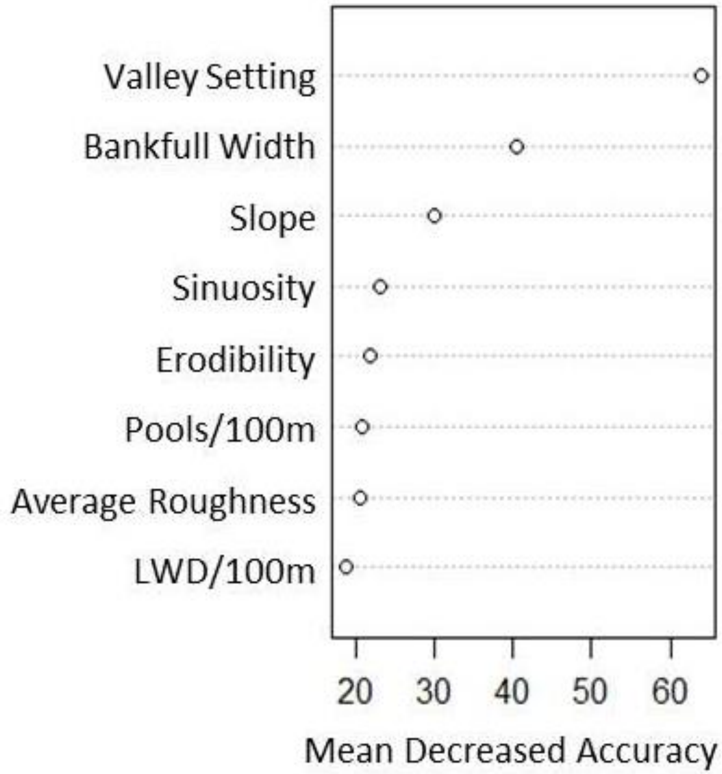
CV OFP	0	0	**30**	0	0	0	0	0	**100**
CV SC	0	0	5	**1**	0	0	0	0	**16.7**
BC EDF	0	0	0	0	**30**	0	0	0	**100**
LM PC DF	0	0	0	0	0	**48**	4	0	**92.3**
LS PC A	0	0	0	0	0	6	**27**	0	**81.8**
M PC DF	0	0	0	0	0	6	1	**5**	**41.7**
Overall PCC									**88.3**

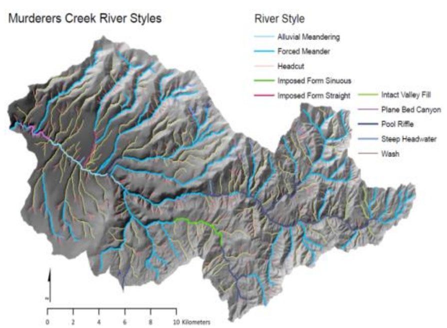
Variable Importance Plot: River Styles Classification





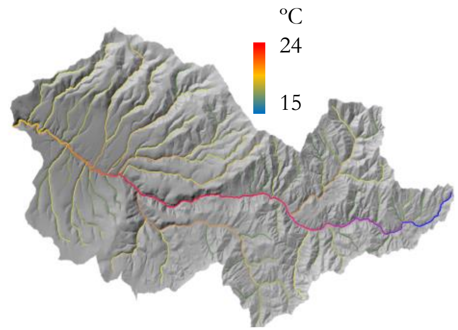
Steelhead Abundance Models

Network Juvenile Steelhead Abundance

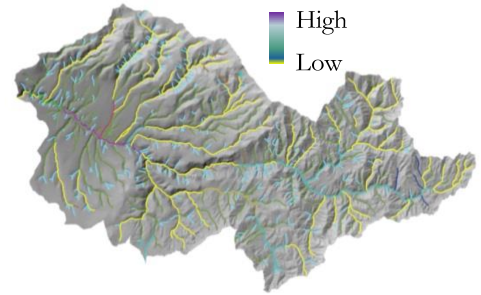


Physical Habitat

River Styles



Temperature



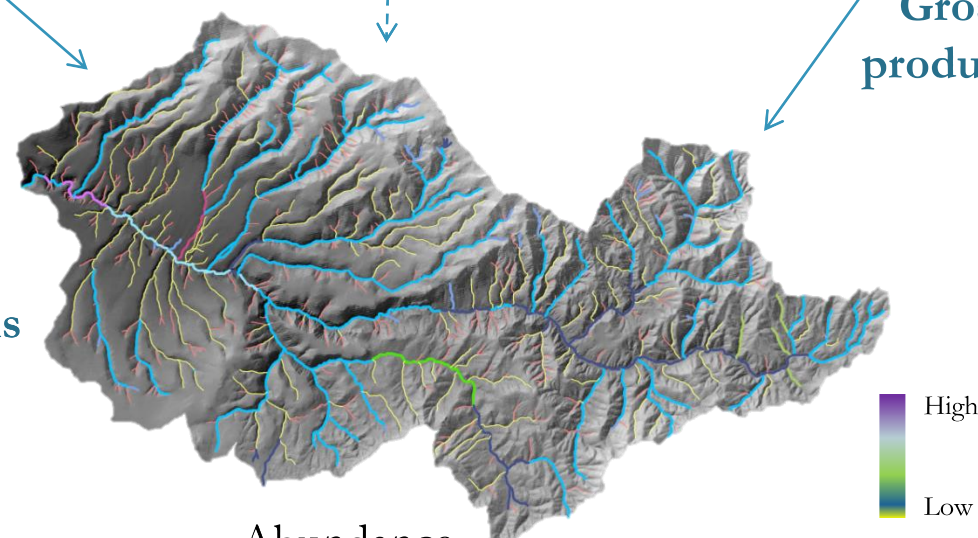
Stream Productivity

Conductivity

Solar Input

Gross primary production (GPP)

Steelhead Distributions



Abundance

Three Model Comparison

Habitat Model:

All **physical habitat metrics** that define different River Styles, along with the sample **date**

Habitat-Production Model:

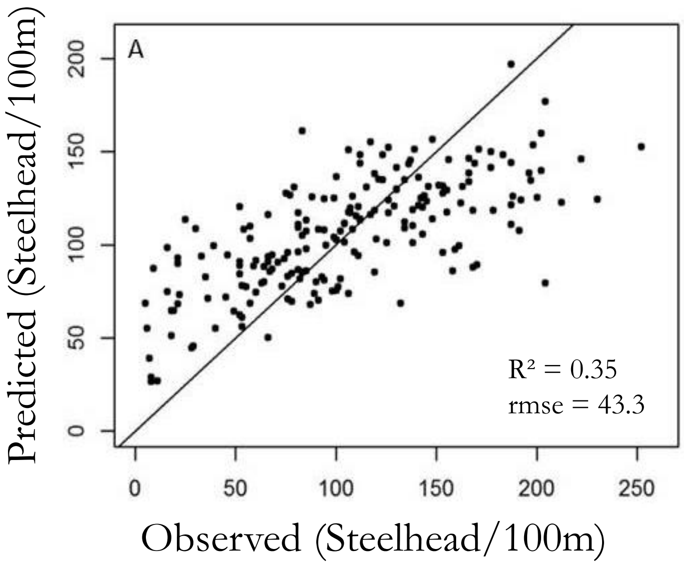
All **physical habitat metrics** that define different River Styles, along with the sample **date** and Gross Primary Product (**GPP, g 0_2/L/D**)

River Styles-Productivity Model:

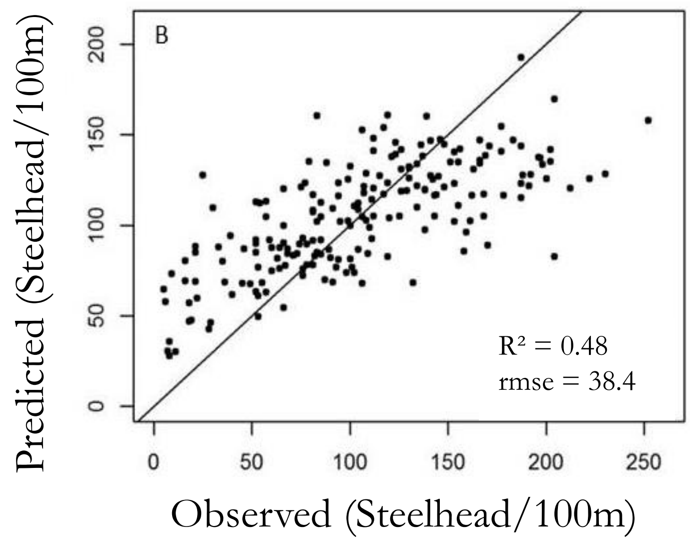
River Styles, along with the sample **date** and **GPP**

Steelhead Abundance

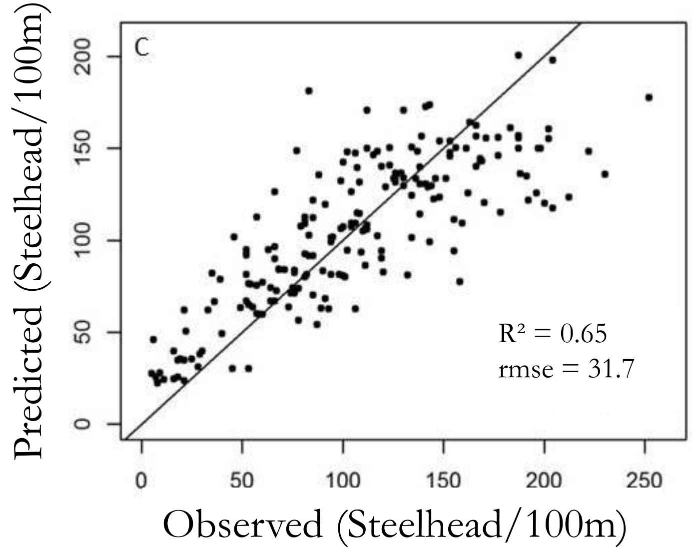
Habitat Model



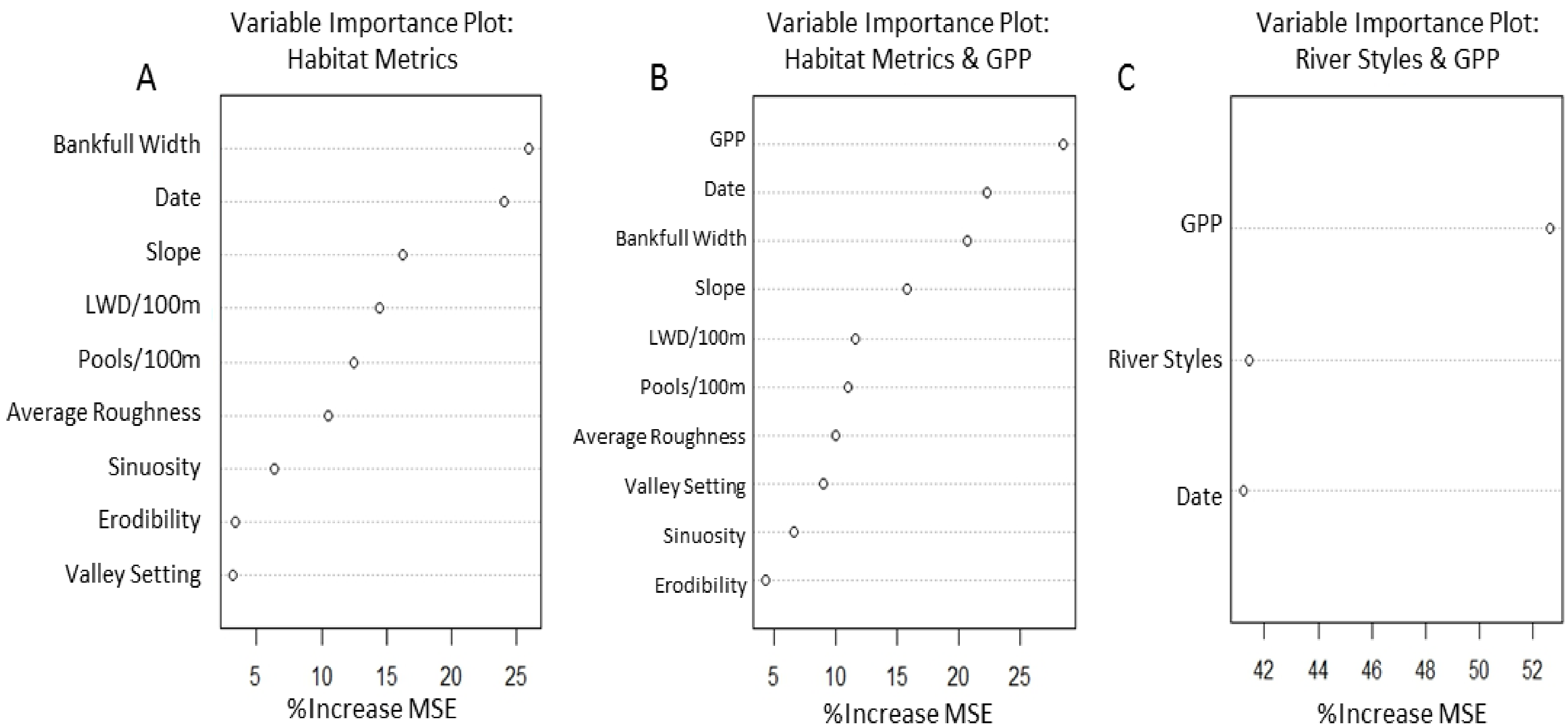
Habitat- Production Model



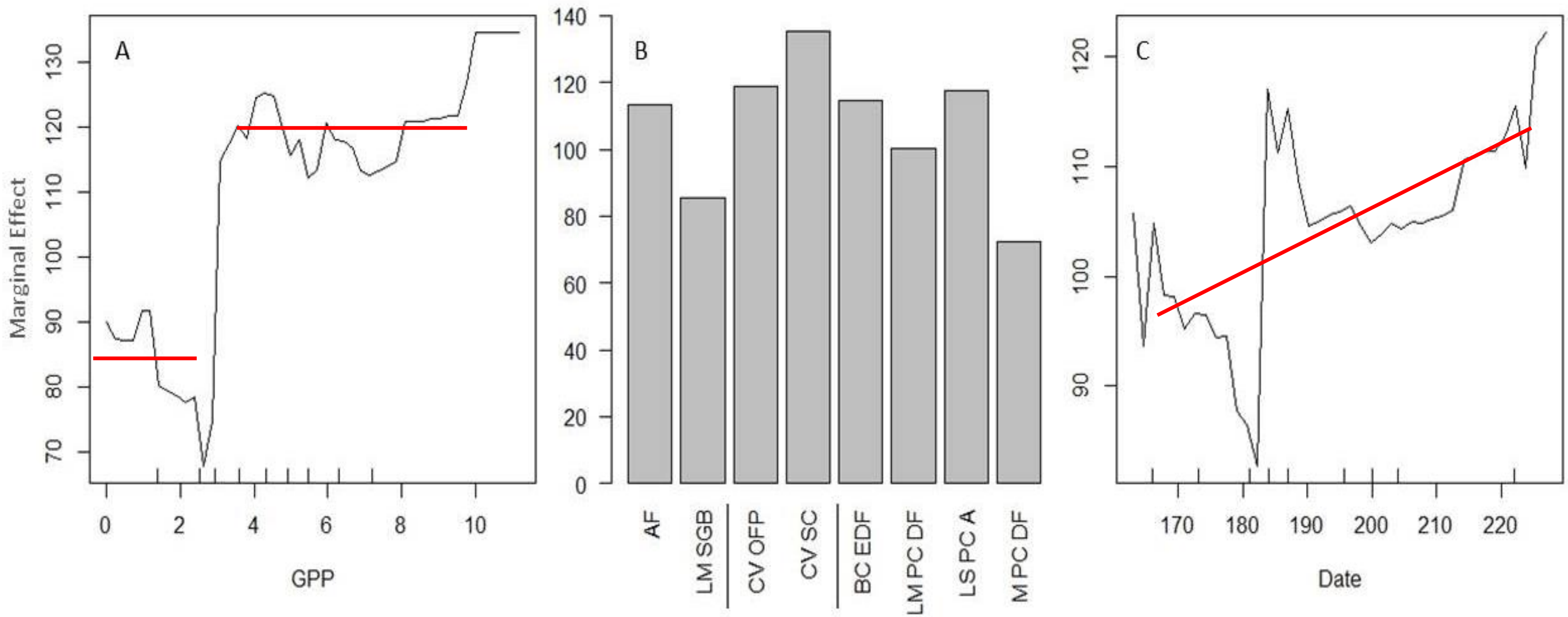
River Styles - Production Model



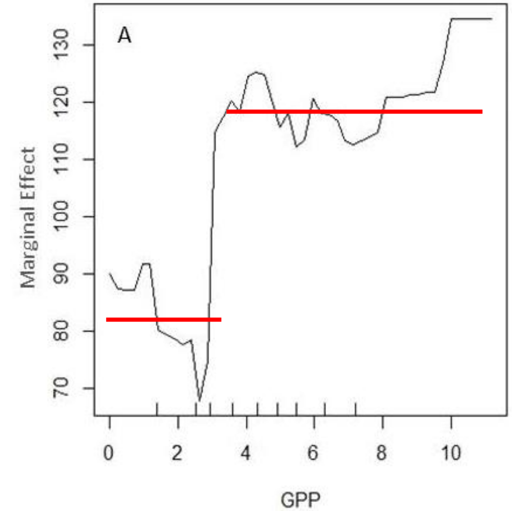
Variable Importance



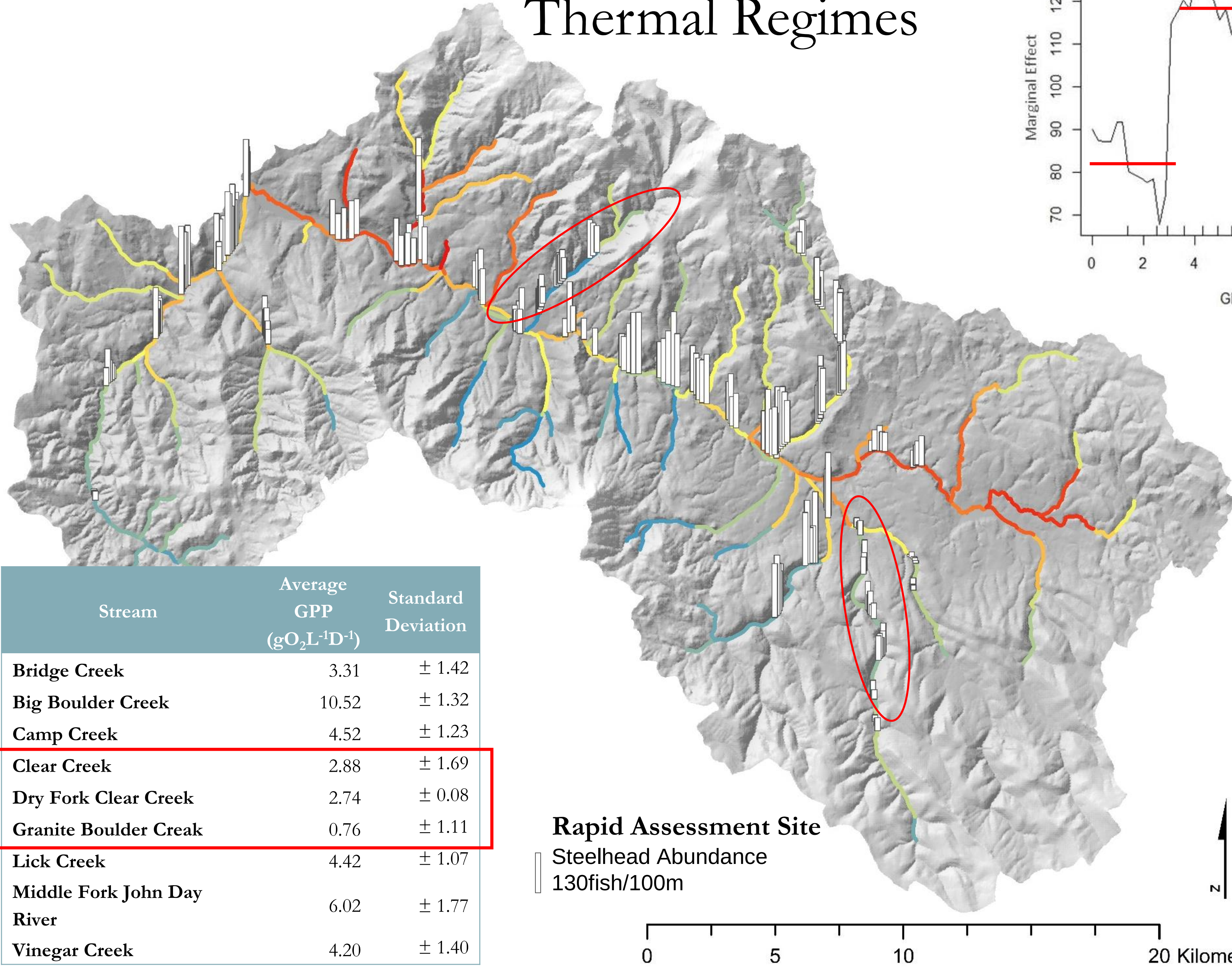
Partial Dependence Plots:
River Styles-Production Model



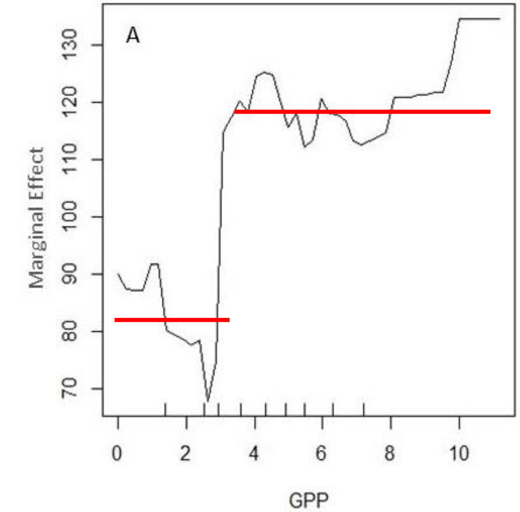
Stream Production and Thermal Regimes



Stream	Average GPP ($gO_2L^{-1}D^{-1}$)	Standard Deviation
Bridge Creek	3.31	± 1.42
Big Boulder Creek	10.52	± 1.32
Camp Creek	4.52	± 1.23
Clear Creek	2.88	± 1.69
Dry Fork Clear Creek	2.74	± 0.08
Granite Boulder Creak	0.76	± 1.11
Lick Creek	4.42	± 1.07
Middle Fork John Day River	6.02	± 1.77
Vinegar Creek	4.20	± 1.40



Stream Production and Thermal Regimes



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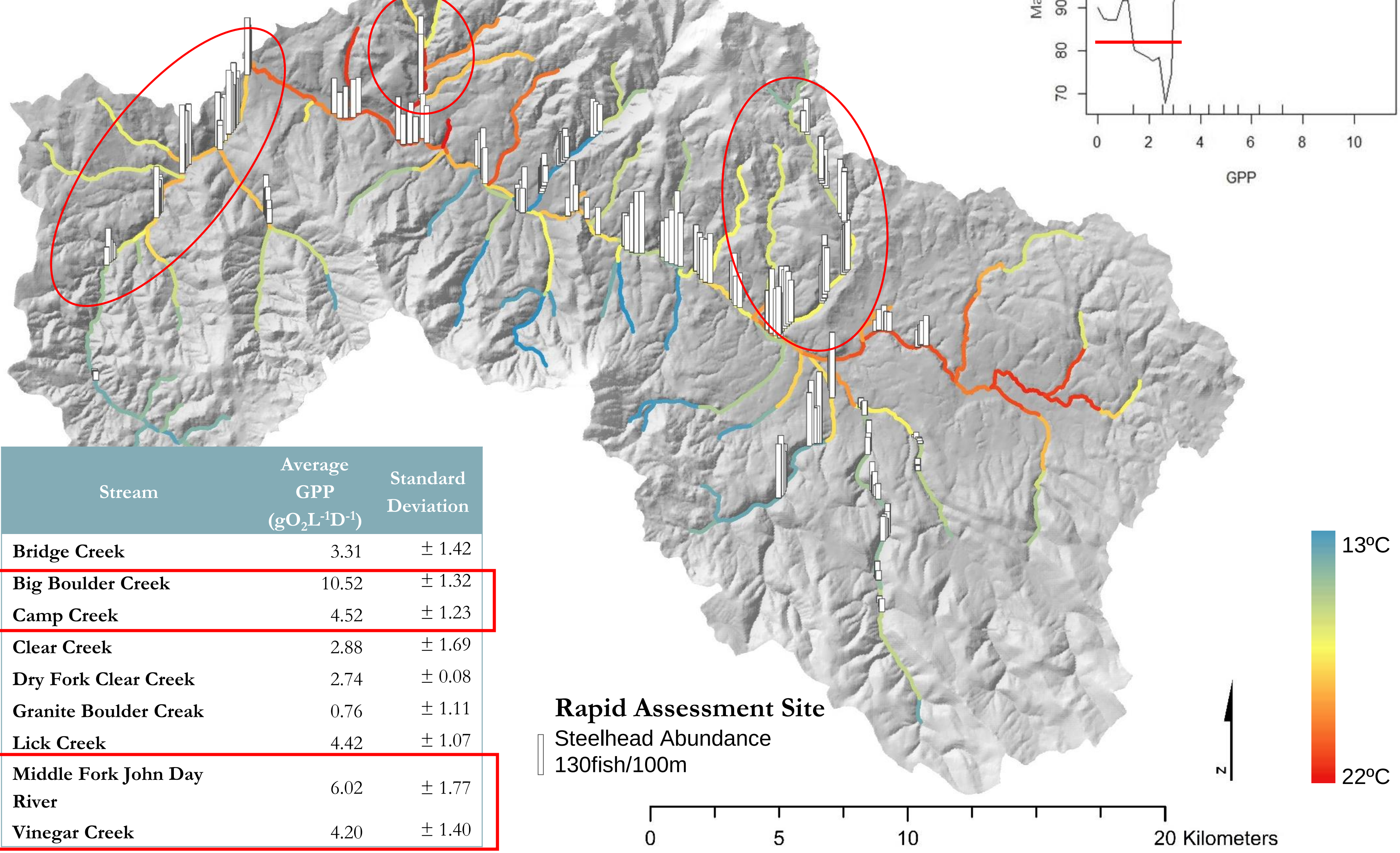
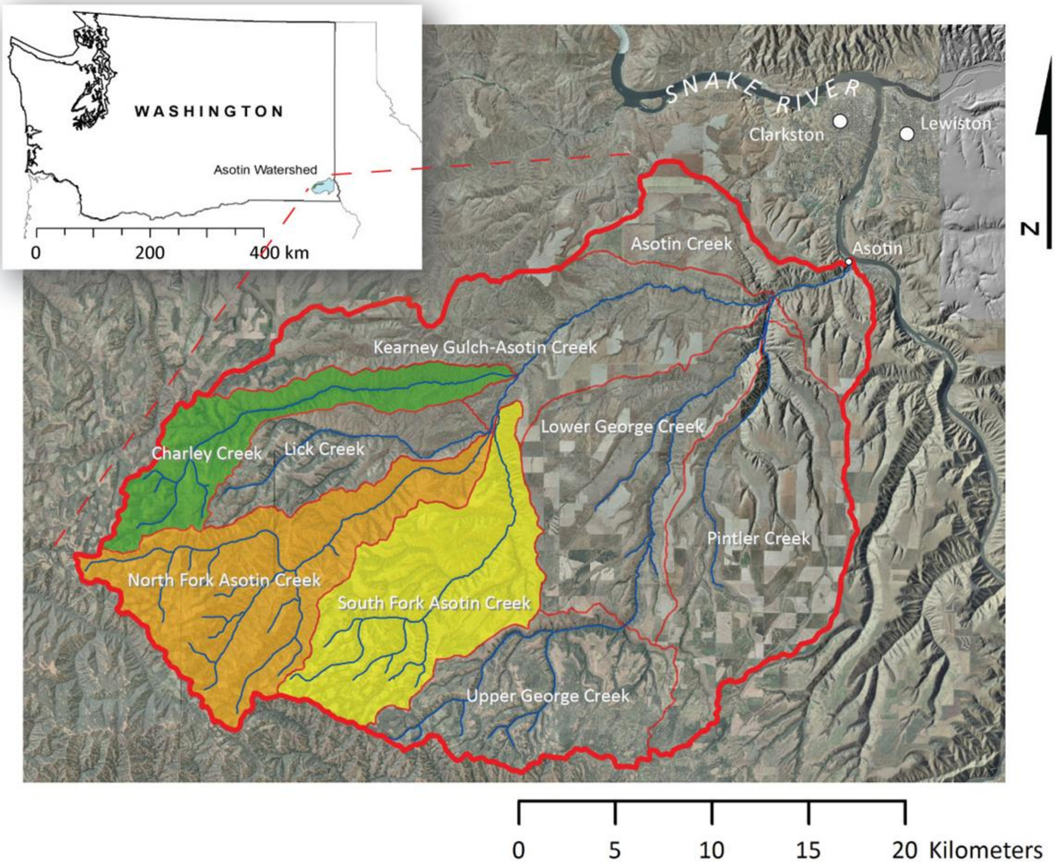


Summary

- Rapid assessment bridged gap in spatial extent
  - Expanded the proportion of the watershed surveyed by 8-fold
  - Surveys allow for surveying of previously unsurveyed River Styles and tributaries
- Validated River Styles using field measured physical habitat variables
- Using River Styles to describe physical habitat improve the models of steelhead abundance
  - Steelhead abundance responded to morphological differences among the different River Styles
- Stream production was the most important variable influences fish abundance
  - Temperature and production was strongly correlated
  - Direct and indirect effect of temperature
- Network Models in conjunction with high resolution surveys allow for more complete understanding of variability across the riverscape

Asotin Creek Intensively Monitored Watershed (IMW) and Watershed Assessment



wild steelhead refuge

Location of Asotin Creek Intensively Monitored Watershed in southeast Washington. Three colored tributaries comprise the IMW study area: Charley Creek (Green), North Fork (Orange), South Fork (Yellow).

Restoration Method

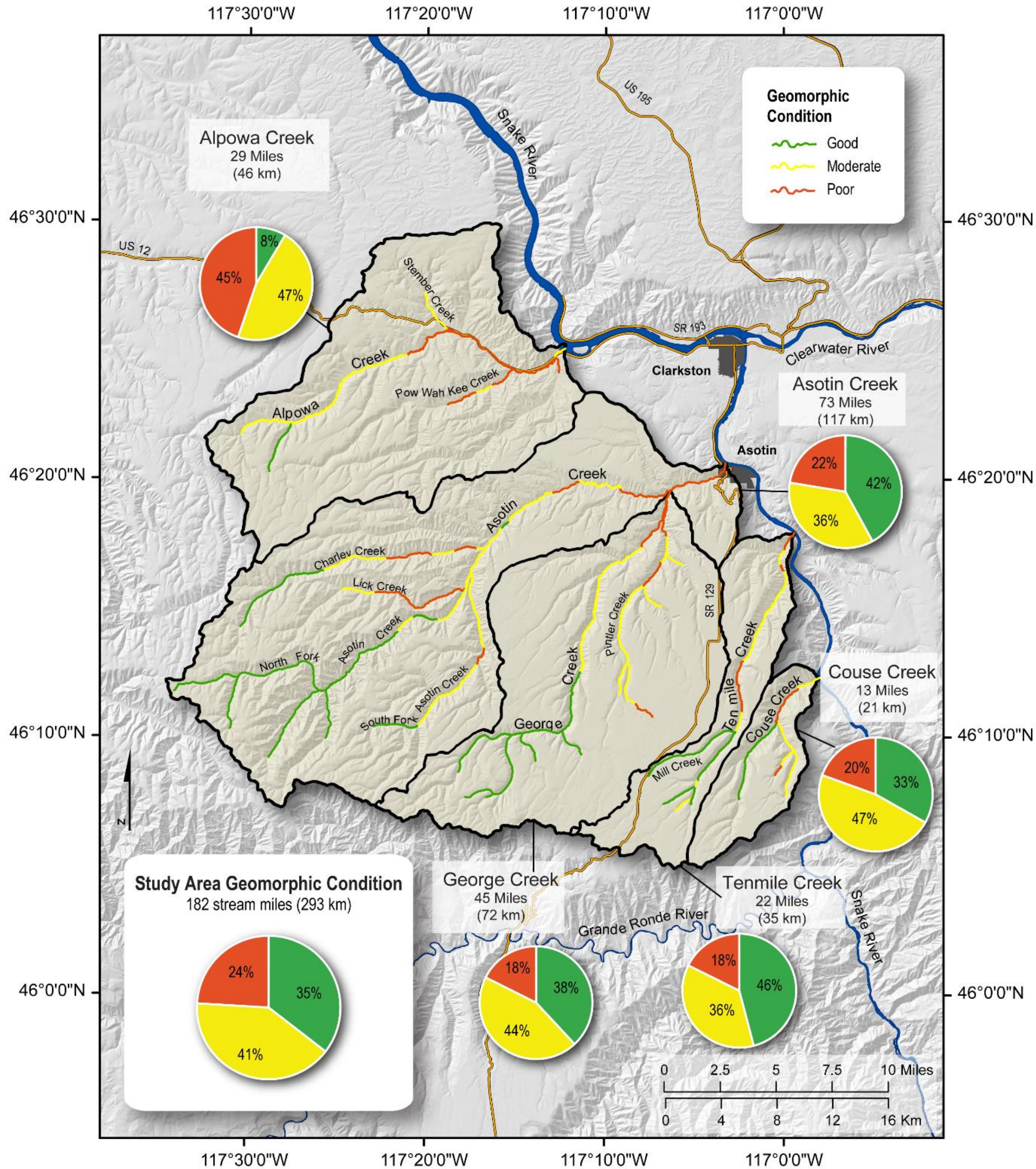
Simulate a tree

Post Assisted Log Structures (PALS)

Restoration Method
Construction stats

- 14 km's treated (39%)
- ~700 structures
- 3-5/100m
- Hand built

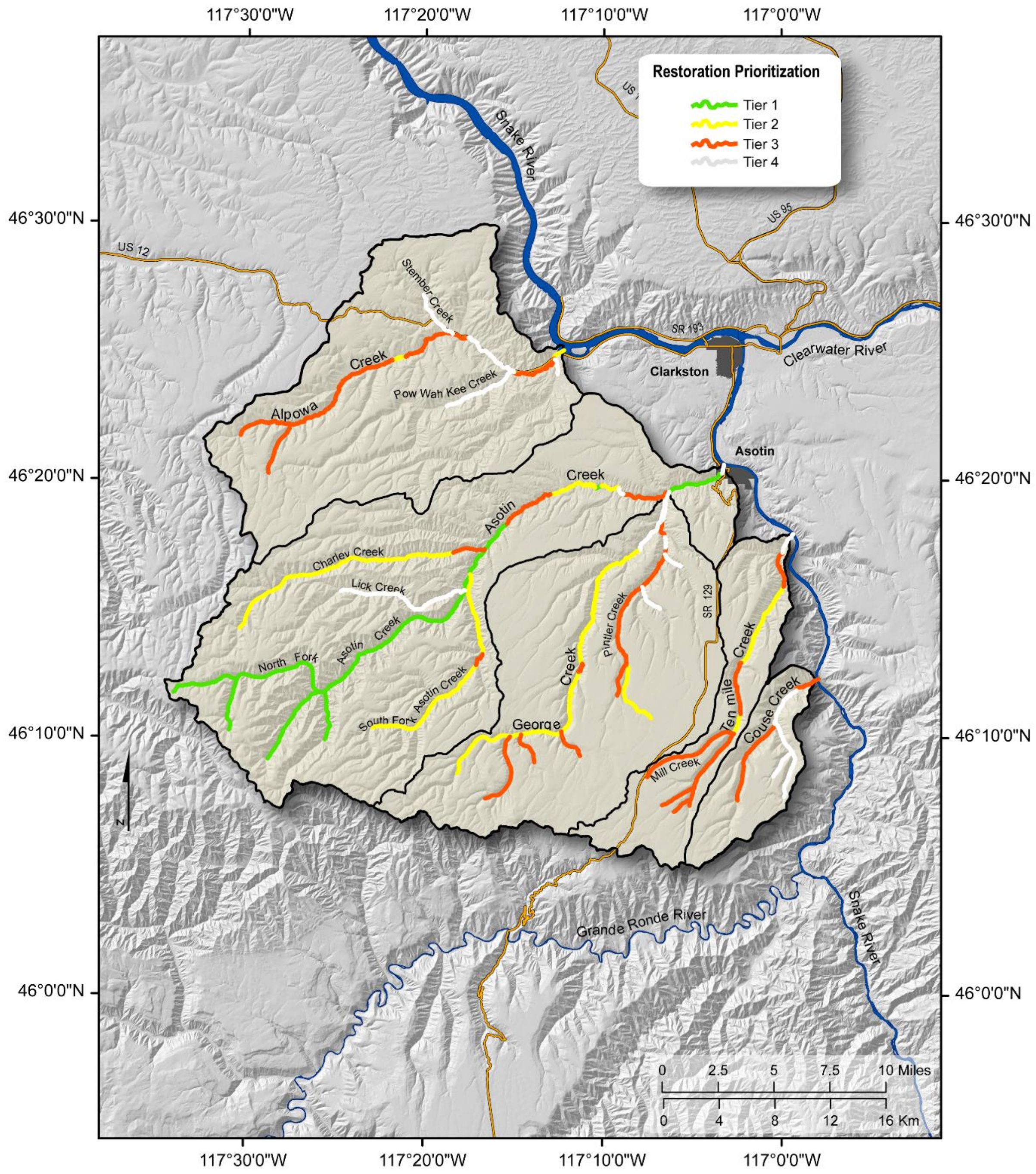
Geomorphic Assessment – Report 1



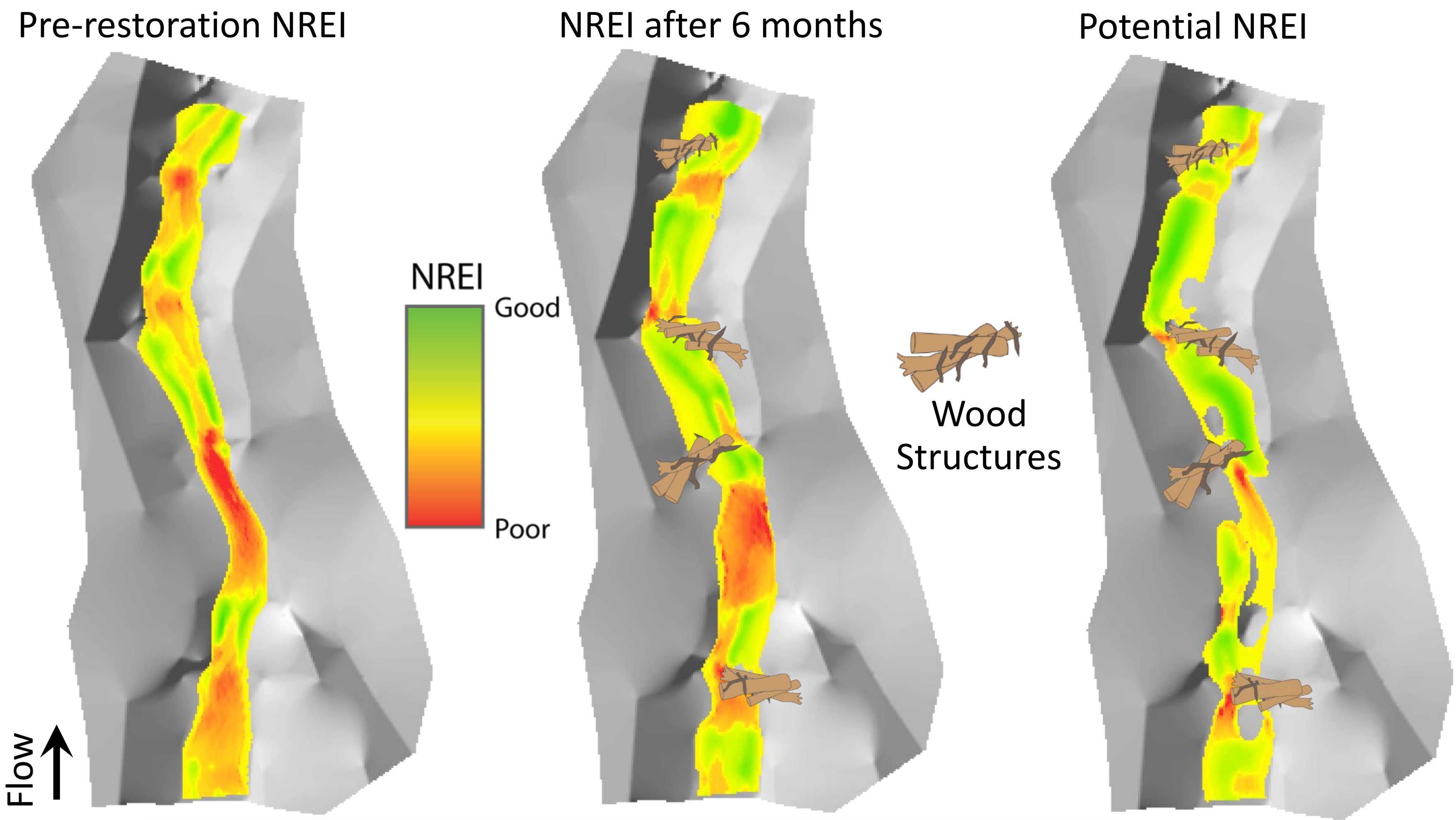
Conceptual Restoration Design & Project Area Descriptions – Report 2

Components

- Geomorphic
- Fish Capacity
- Cost
- Fish Distribution
- Water Quality & Quantity



Evaluating and planning stream restoration

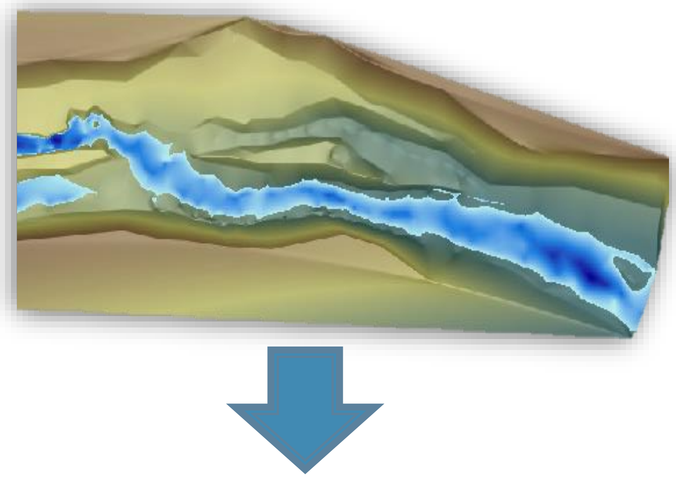


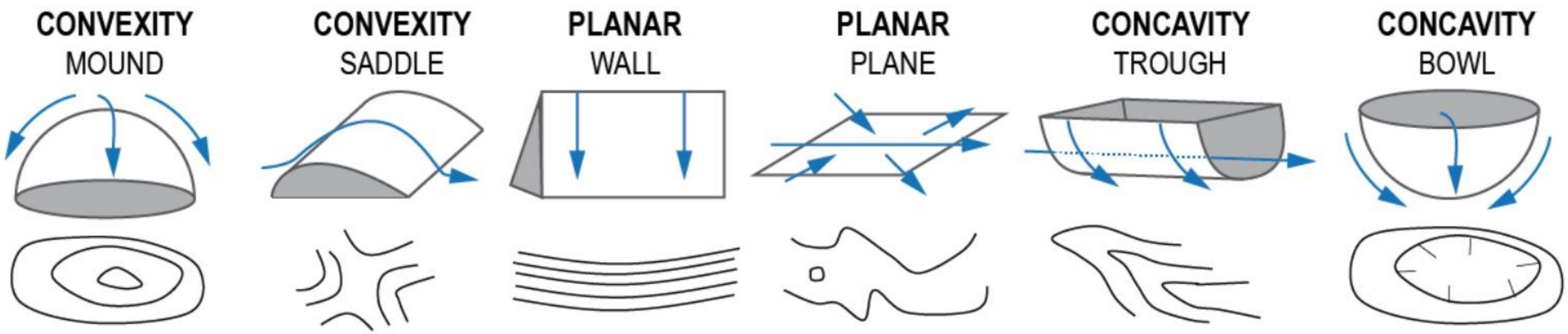
Design and monitoring of woody structures and their benefits to juvenile steelhead (*Oncorhynchus mykiss*) using a net rate of energy intake model *Can. J. Fish. Aquat. Sci. 2017*

C. Eric Wall, Nicolaas Bouwes, Joseph M. Wheaton, Stephen N. Bennett, W. Carl Saunders, Pete A. McHugh, and Chris E. Jordan

Restoration Effectiveness
Geomorphic Unit Delineation Tool (GUT)

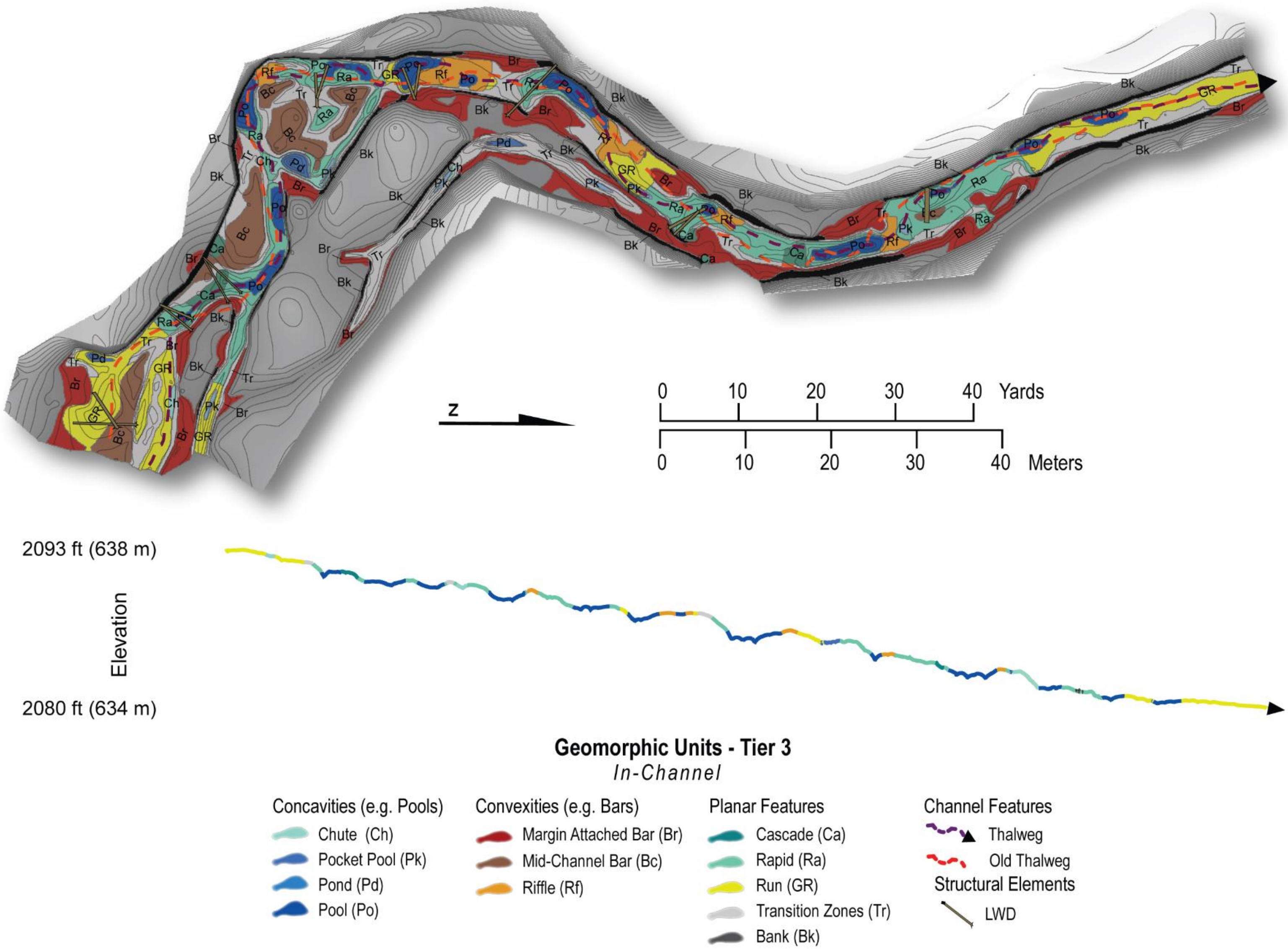
Digital elevation Model

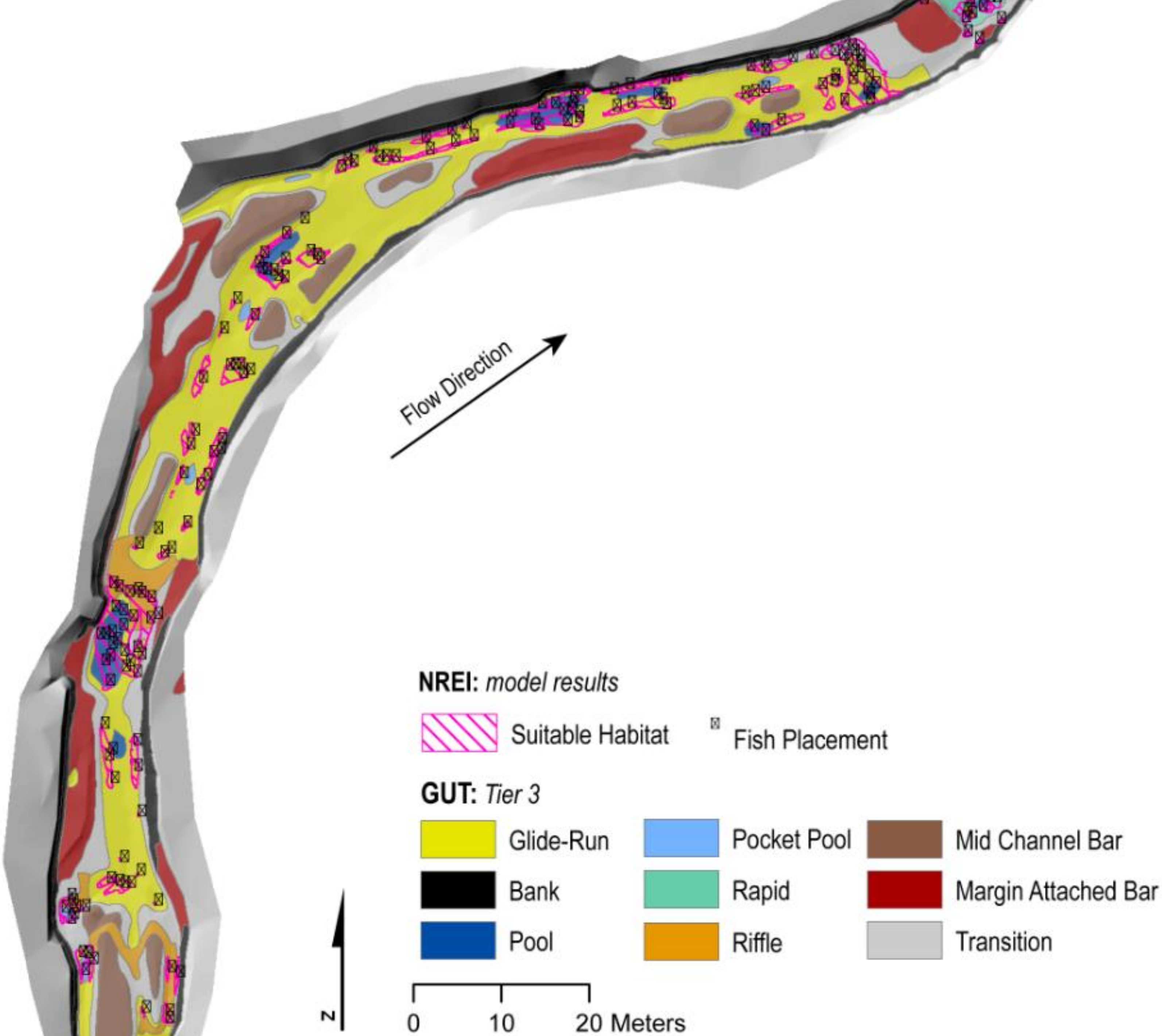




Tier 2 geomorphic units based on topographic signature

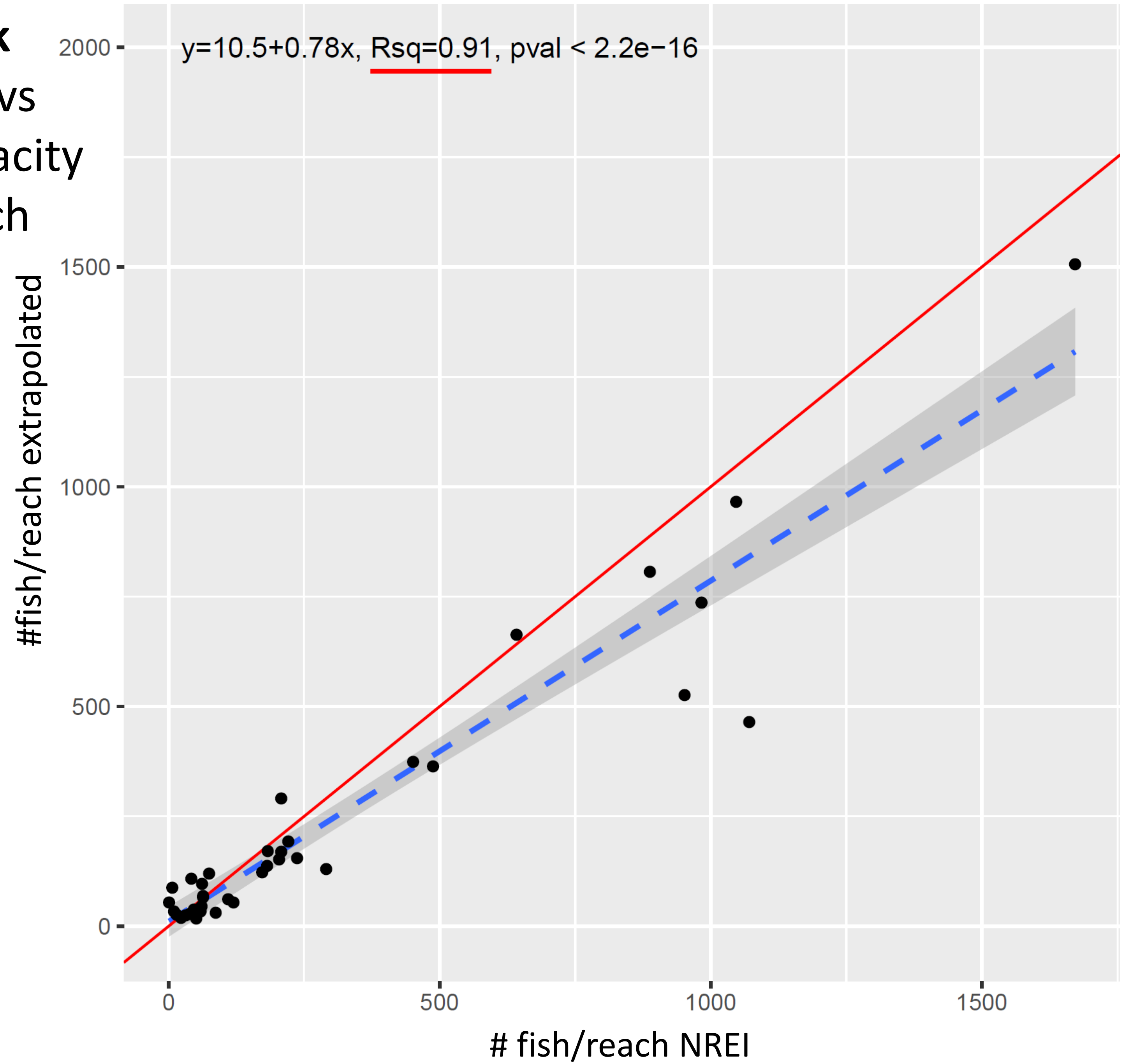
Restoration Effectiveness
Tier 3 geomorphic units




Flow Direction
NREI: model results
Suitable Habitat
Fish Placement
GUT: Tier 3
Glide-Run
Pocket Pool
Mid Channel Bar
Bank
Rapid
Margin Attached Bar
Pool
Riffle
Transition
N
0
10
20 Meters

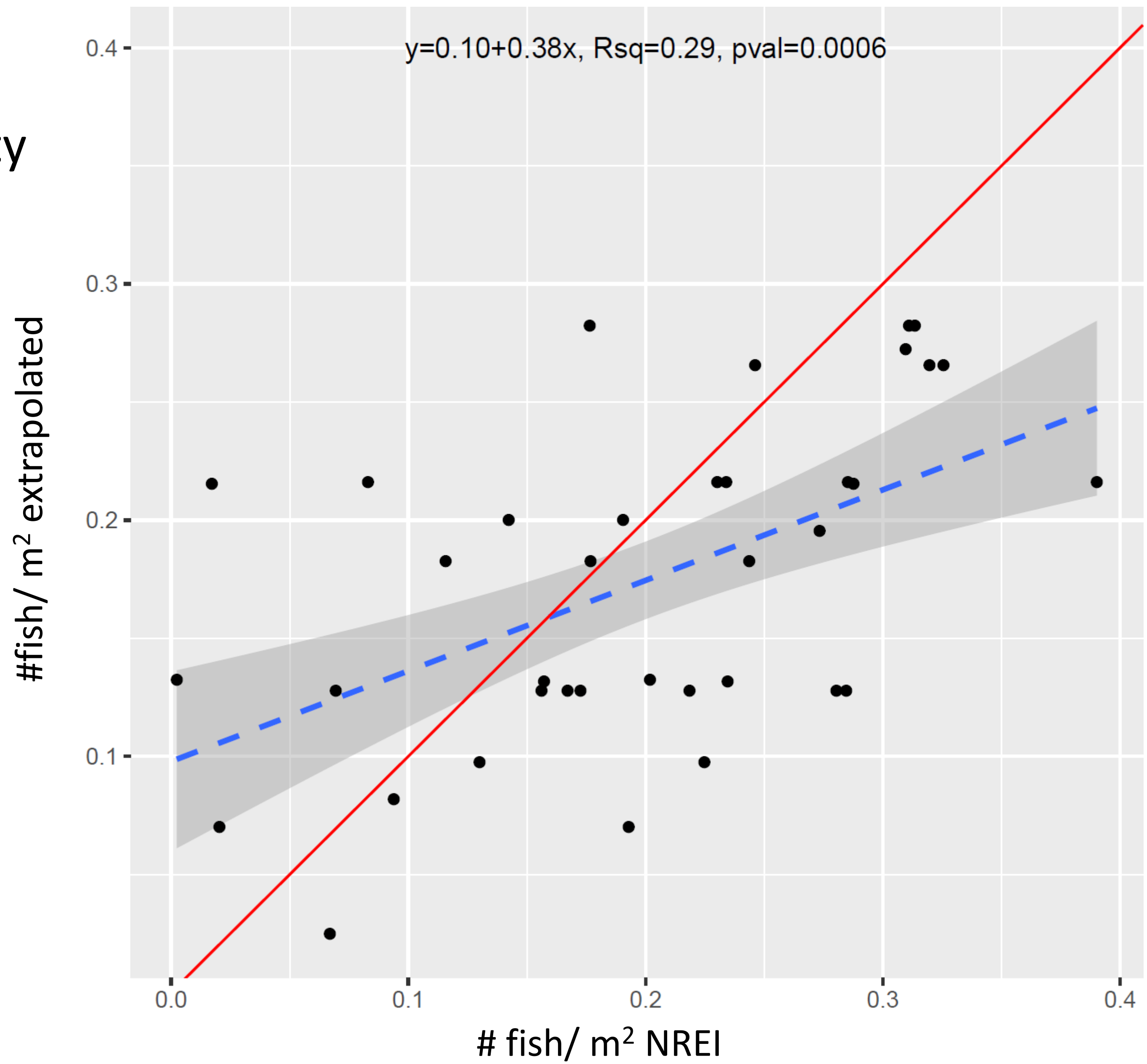
Asotin Creek

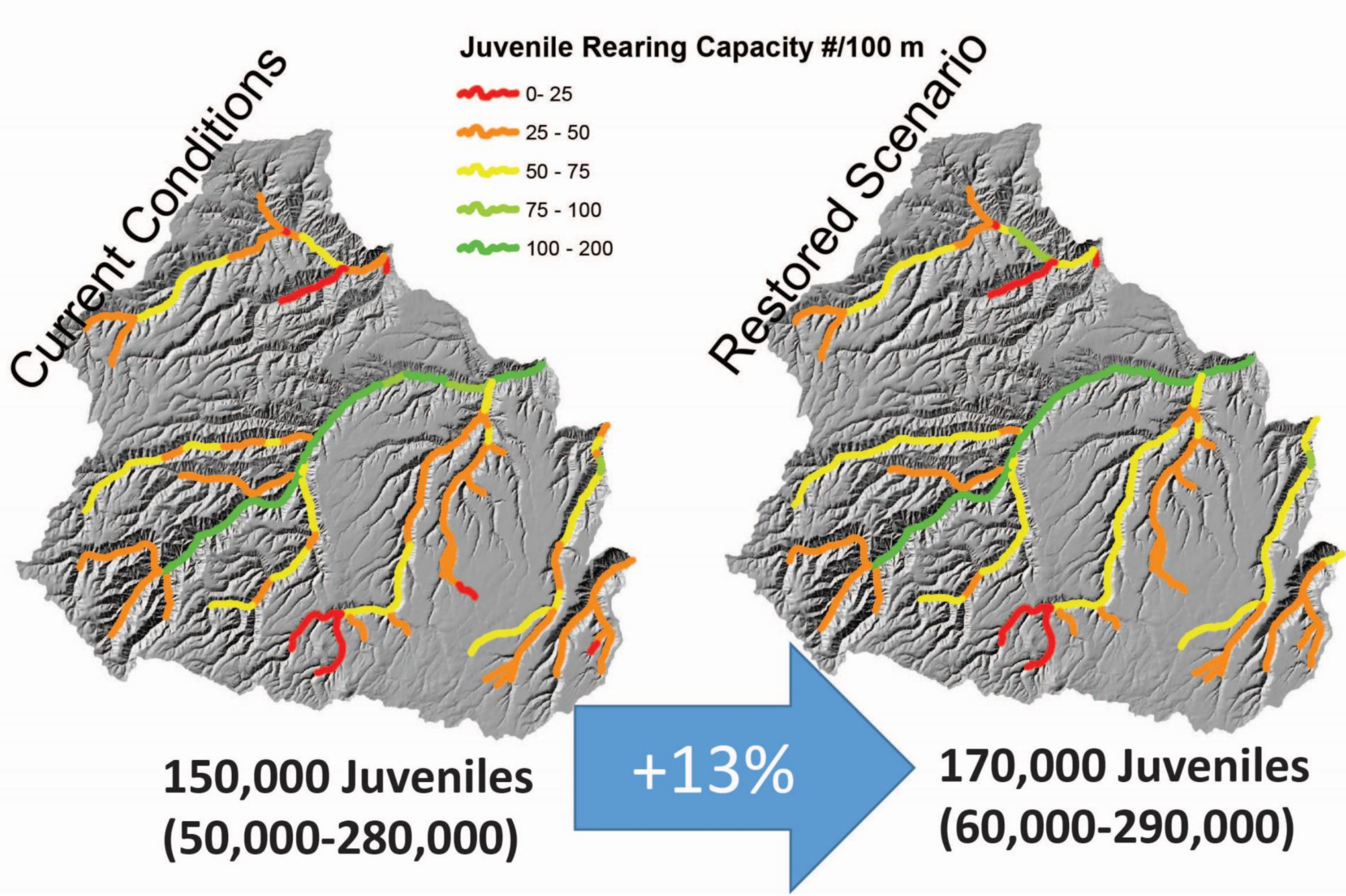
NREI capacity vs Extrapolate capacity no. fish / reach



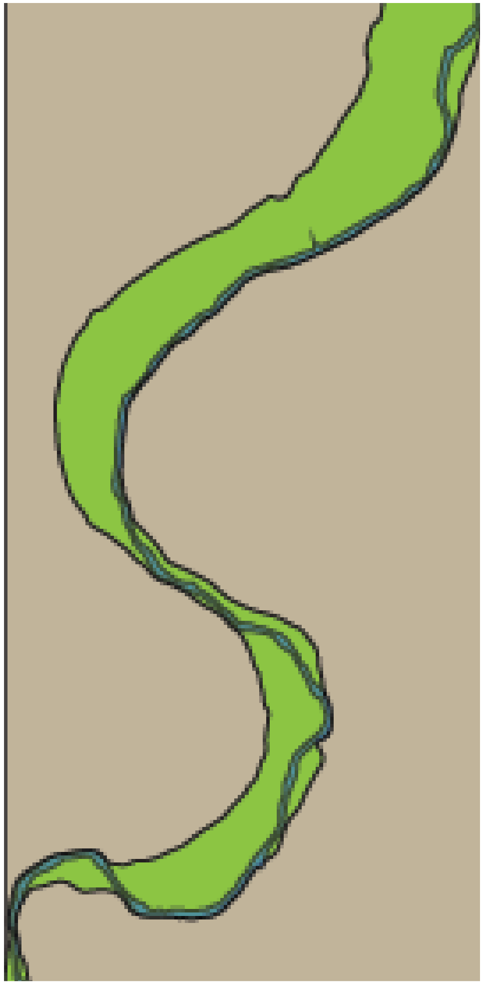
Asotin Creek

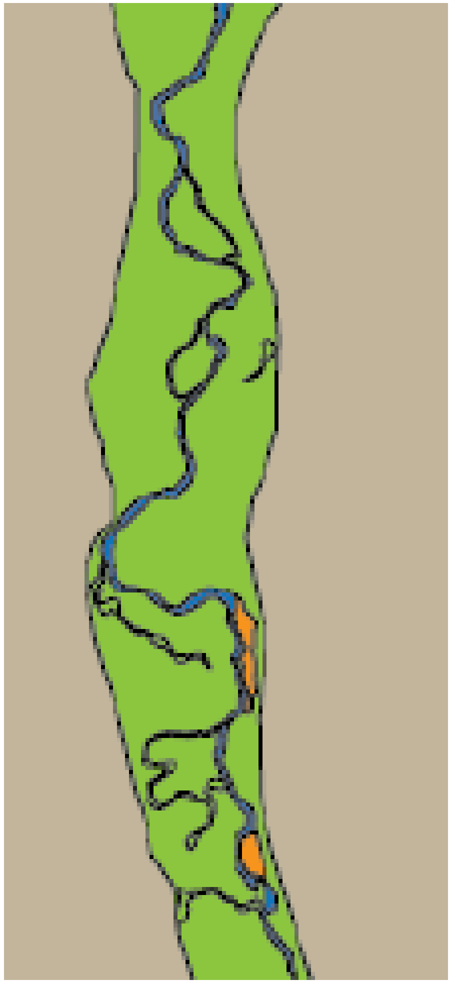
NREI capacity vs Extrapolate capacity no. fish / m^2




Juvenile Rearing Capacity #/100 m
0- 25
25 - 50
50 - 75
75 - 100
100 - 200
Current Conditions
Restored ScenariO
150,000 Juveniles
(50,000-280,000)
+13%
170,000 Juveniles
(60,000-290,000)

Single to multi-threaded provides biggest changes in fish capacity





STEELHEAD RESPONSE TO INCREASE IN BEAVER DAMS AND BDAs

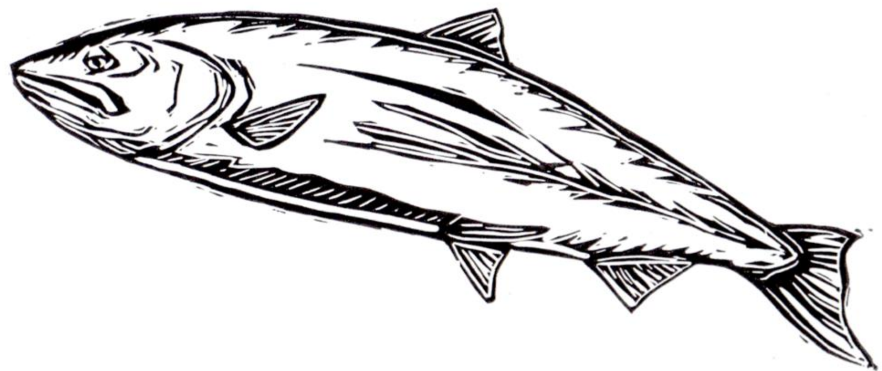
168% increase in abundance
52% increase in survival
172% increase in production

228% increase in stream area

Life - Cycle Model for upper Grande Ronde and Catherine Creek Spring Chinook

Evaluation of Habitat Restoration and Population Recovery Strategies

December 2018



Eco Logical Research

Nick Weber & Nick Bouwes
Bend OR and Providence UT

The Columbia River Inter-tribal Fish Commission

Casey Justice & Seth White
Portland OR

Restoration and climate scenarios in the upper Grande Ronde and Catherine Creek

Weber et al. 2018

TABLE 14. SCENARIOS MODELED AFTER JUSTICE ET AL. (2017). FOR LCM INPUTS, EACH SCENARIO IS REPRESENTED AS A PROPORTION INCREASE OR DECREASE IN SUMMER PARR REARING AND SPAWNER CAPACITY.

Scenario Abbreviation	Description
Curr	Baseline model calibrated using 2010 temperature, climate, vegetation, and hydrologic conditions
Clim	Air temperature and streamflow set to 2080s climate projections.
ClimVeg	2080s climate projections and vegetation set to potential cover and height at 75 years.
ClimPoolsVeg	2080s climate projections, vegetation set to potential cover and height at 75 years, and restoration resulting in increase in pool habitat.

Population response to modeled scenarios in the upper Grande Ronde and Catherine Creek

Weber et al. 2018

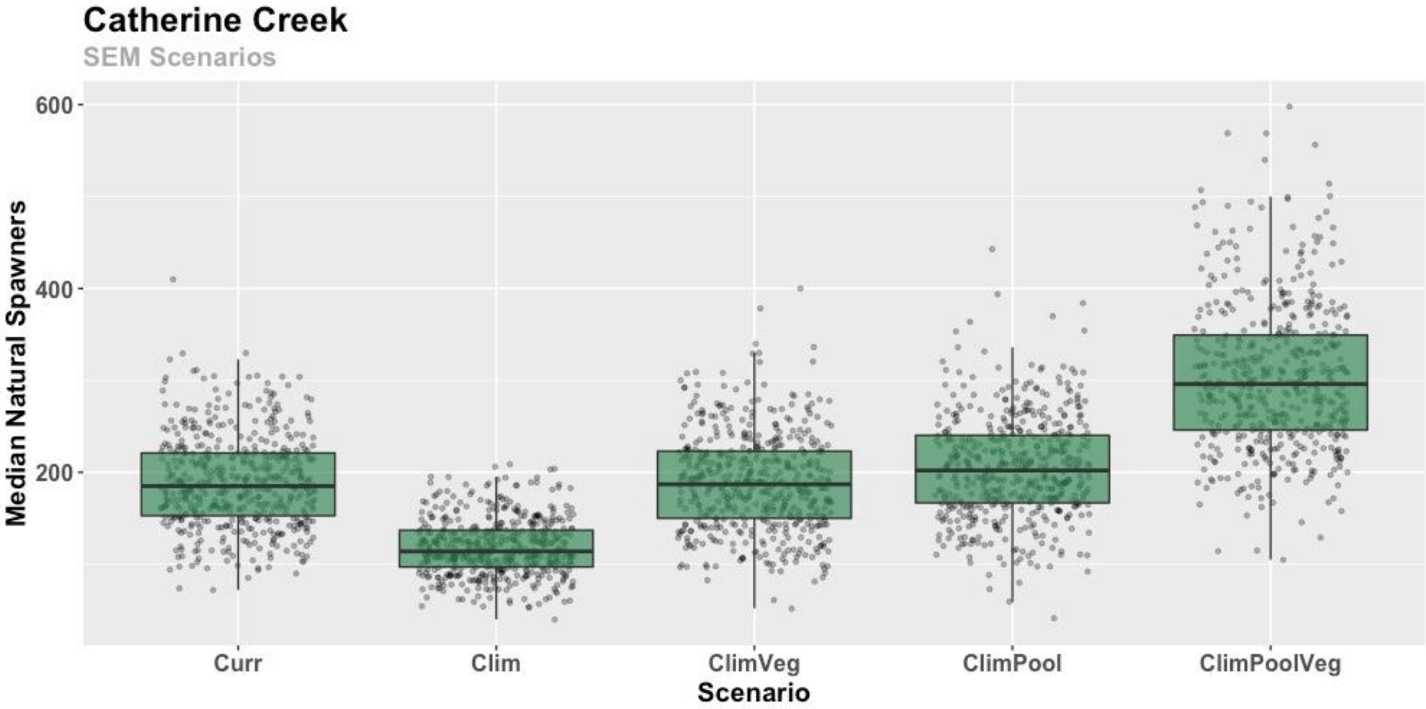


Figure 14. Median population size of Catherine Creek natural origin spawning Chinook based on restoration and climate scenarios described by the structural equation model relationships. Median population size is from 500 model simulations and assumes discontinuation of hatchery supplementation.

Population response to modeled scenarios in the upper Grande Ronde and Catherine Creek

Weber et al. 2018

TABLE 17. MEDIAN POPULATION SIZE OF NATURAL ORIGIN SPAWNING CHINOOK FOR 500 MODEL ITERATIONS OF RESTORATION SCENARIOS DESCRIBED BY THE SEM SCENARIOS. ALSO SHOWING RELATIVE DIFFERENCE OF EACH SCENARIO TO THE CURRENT CONDITIONS ('CURR') AND QUASI EXTINCTION RISK (PQER).

			Cease Supplementation		
Population	Scenario		Median Natural Spawners	Relative to Curr	QER
UGR	Curr		17	-	0.968
	Clim		4	-76%	1
	ClimVeg		20	18%	0.982
	ClimPool		5	-71%	0.998
	ClimPoolVeg		20	18%	0.952
CC	Curr		185	-	0.028
	Clim		114	-38%	0.15
	ClimVeg		187	1%	0.04
	ClimPool		202	9%	0.022
	ClimPoolVeg		296	60%	0.002

Linking models across scales to assess restoration potential for a threatened population of steelhead (Oncorhynchus mykiss) in the Middle Fork John Day River, Oregon

Middle Fork John Day River IMW Meeting

John Day, OR– April 13th, 2016

UtahStateUniversity
ECOGEOMORPHOLOGY & TOPOGRAPHIC ANALYSIS LABORATORY

EcoLogical Research

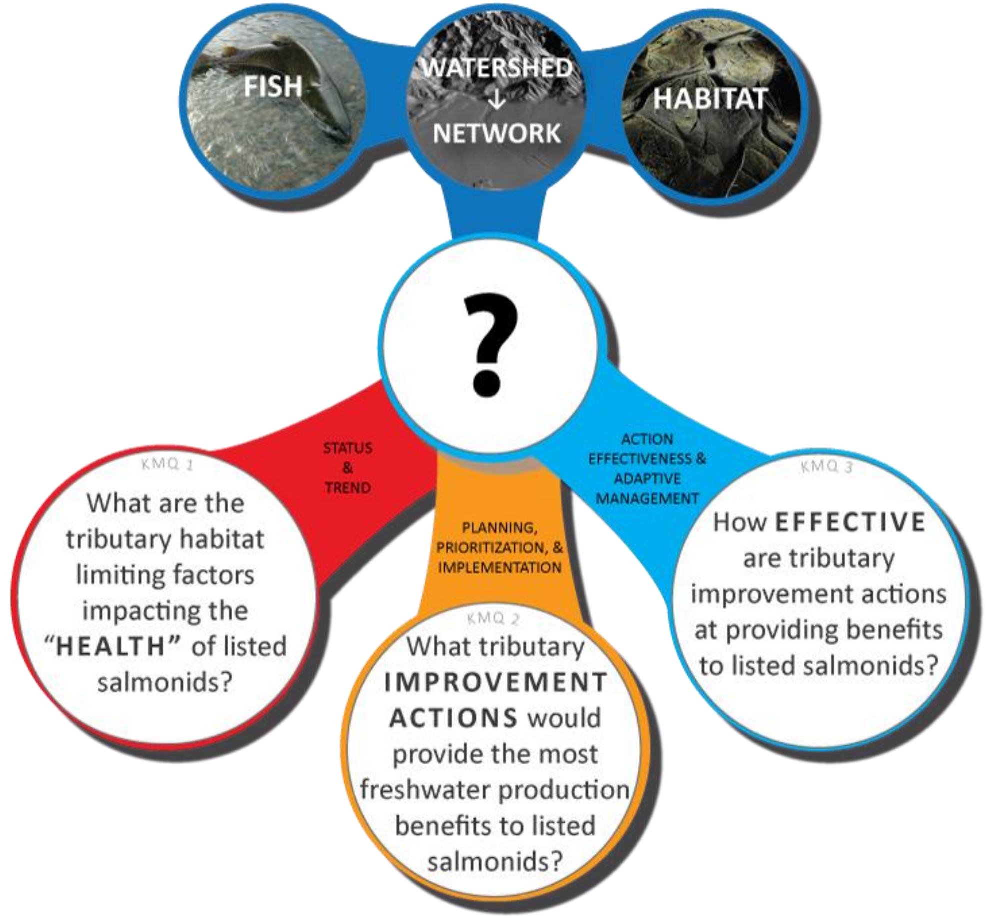
Carl Saunders

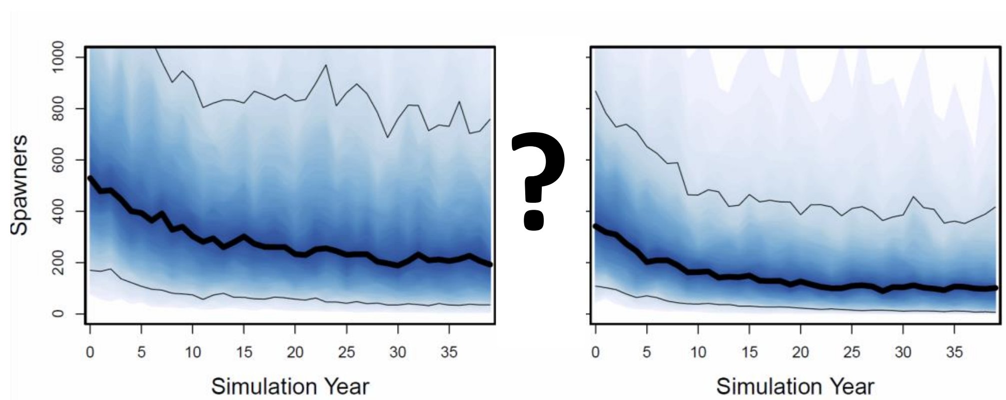
Collaborators:

Pete McHugh , Eric Wall, Sara Bangen, Nick Bouwes, Matt Nahorniak, Joe Wheaton, Chris Jordan, Ian Tattam, Jim Ruzycki

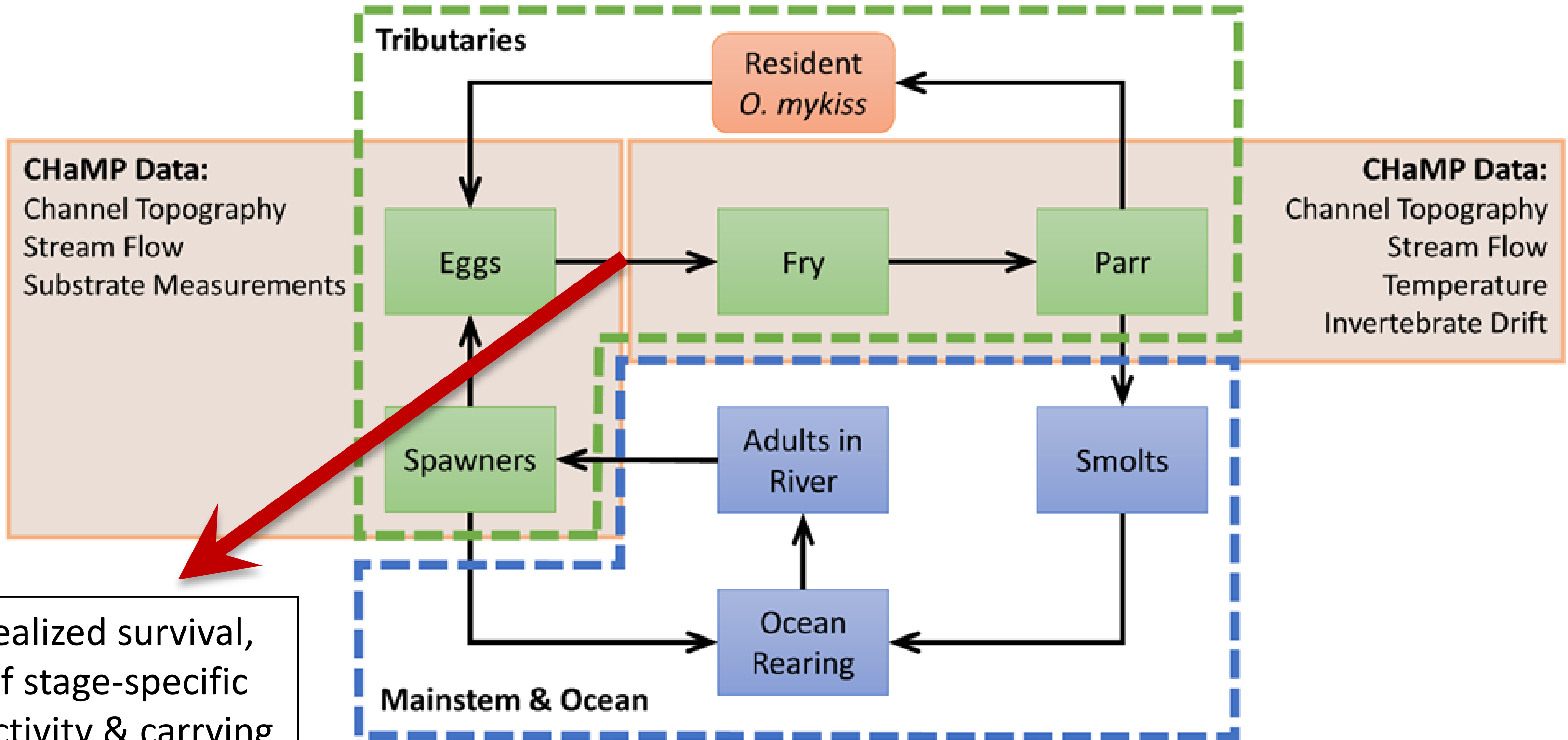
Life-cycle models

- What's the current viability of steelhead in MF John Day?
- How will they benefit from:
  - Thermal improvements due to riparian restoration & flow acquisition projects?
  - In-stream structure additions aimed at increasing rearing capacity?
- How do answers to these ?s vary across a range of model assumptions?
- Evaluate reach-scale restoration project effects for salmon populations

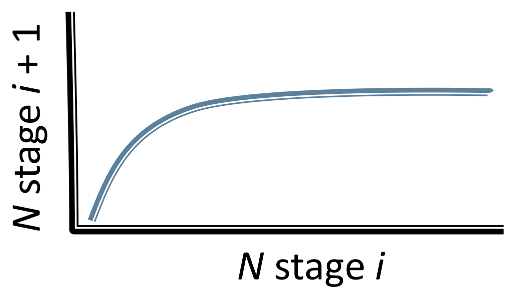




Incorporating NREI-based capacity change into LC models

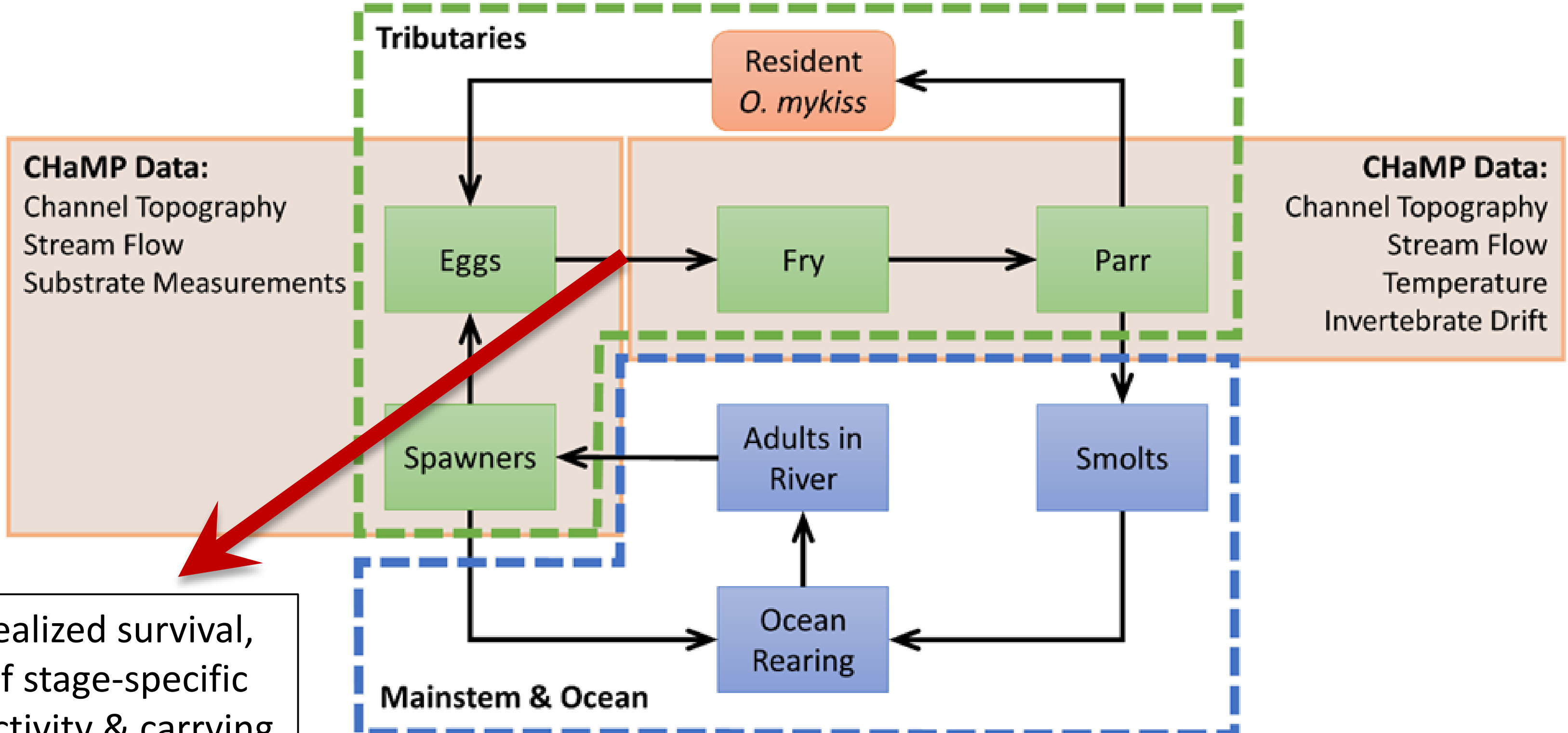


Si = realized survival, fxn of stage-specific productivity & carrying capacity parameters (Beverton-Holt form)

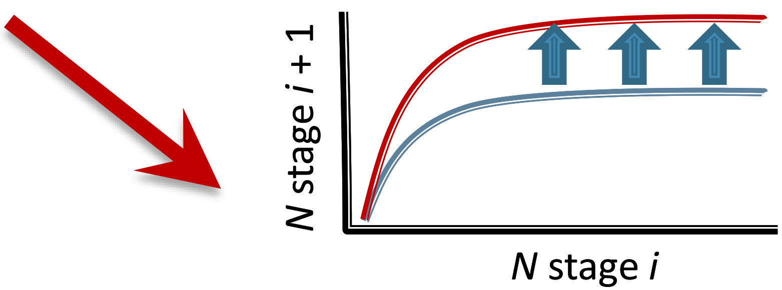


$$N_{i+1} = \frac{N_i}{\frac{1}{prod.} + \frac{1}{capacity} N_i}$$

Incorporating NREI-based capacity change into LC models

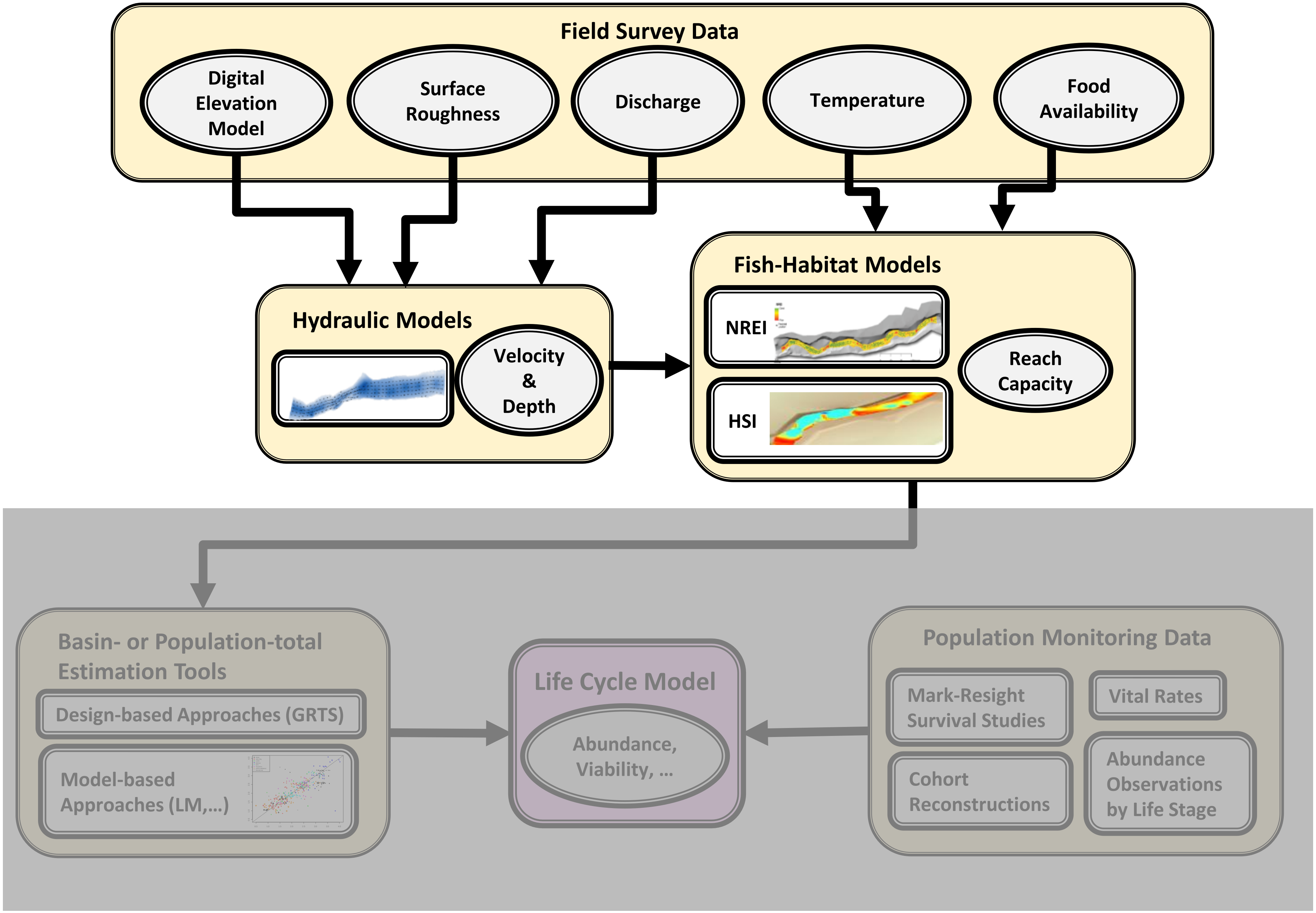


Si = realized survival, fxn of stage-specific productivity & carrying capacity parameters (Beverton-Holt form)



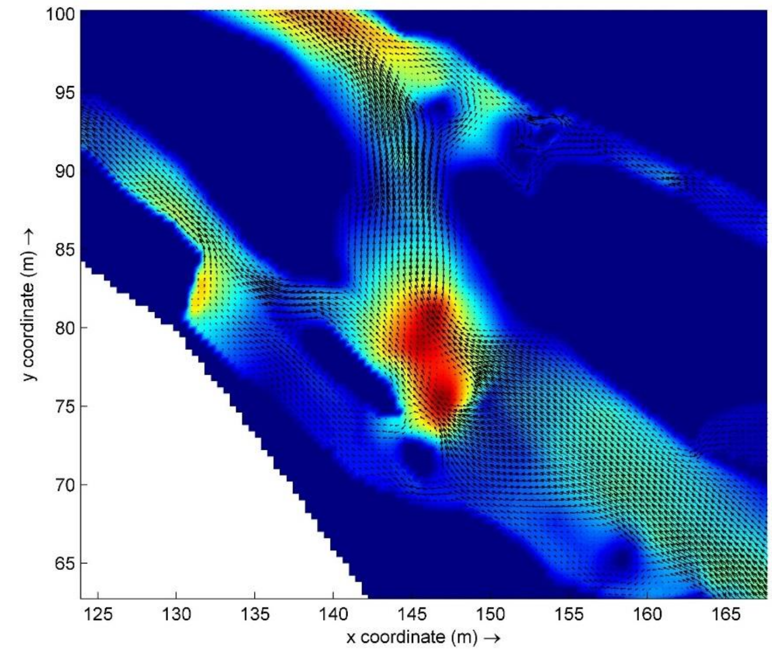
$$N_{i+1} = \frac{N_i}{\frac{1}{prod.} + \frac{1}{capacity} N_i}$$

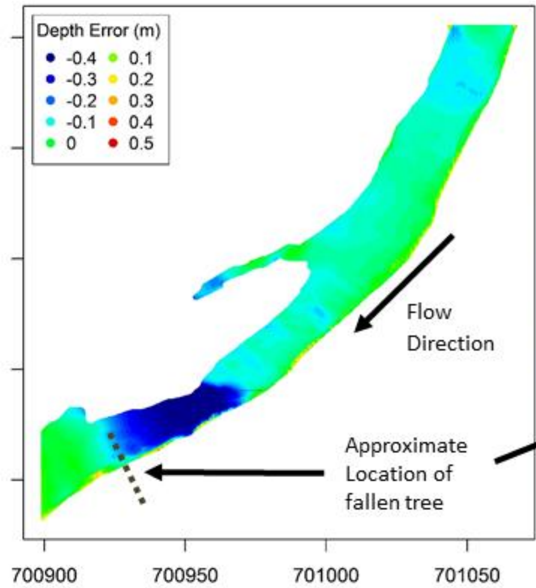
LCM workflow



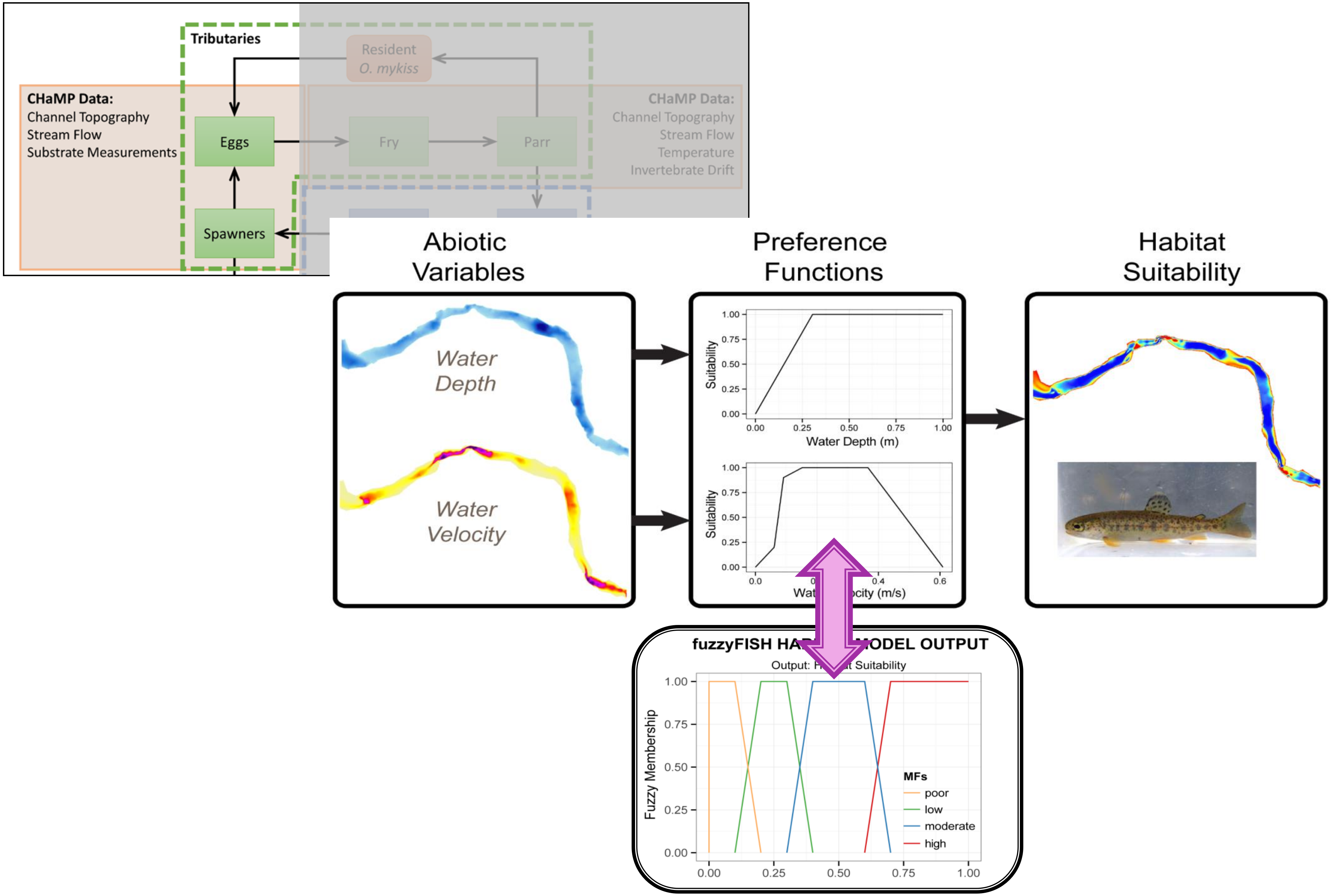
Hydraulic modelling

- Base flow discharge, 10-cm resolution
- Delft-3D and R
- Inlet Q, outlet water level as boundary conditions
- Validation/error checking stage to identify ‘problems’
- Output = D & V rasters, inputs to habitat models
- Capability for modeling porous structures…

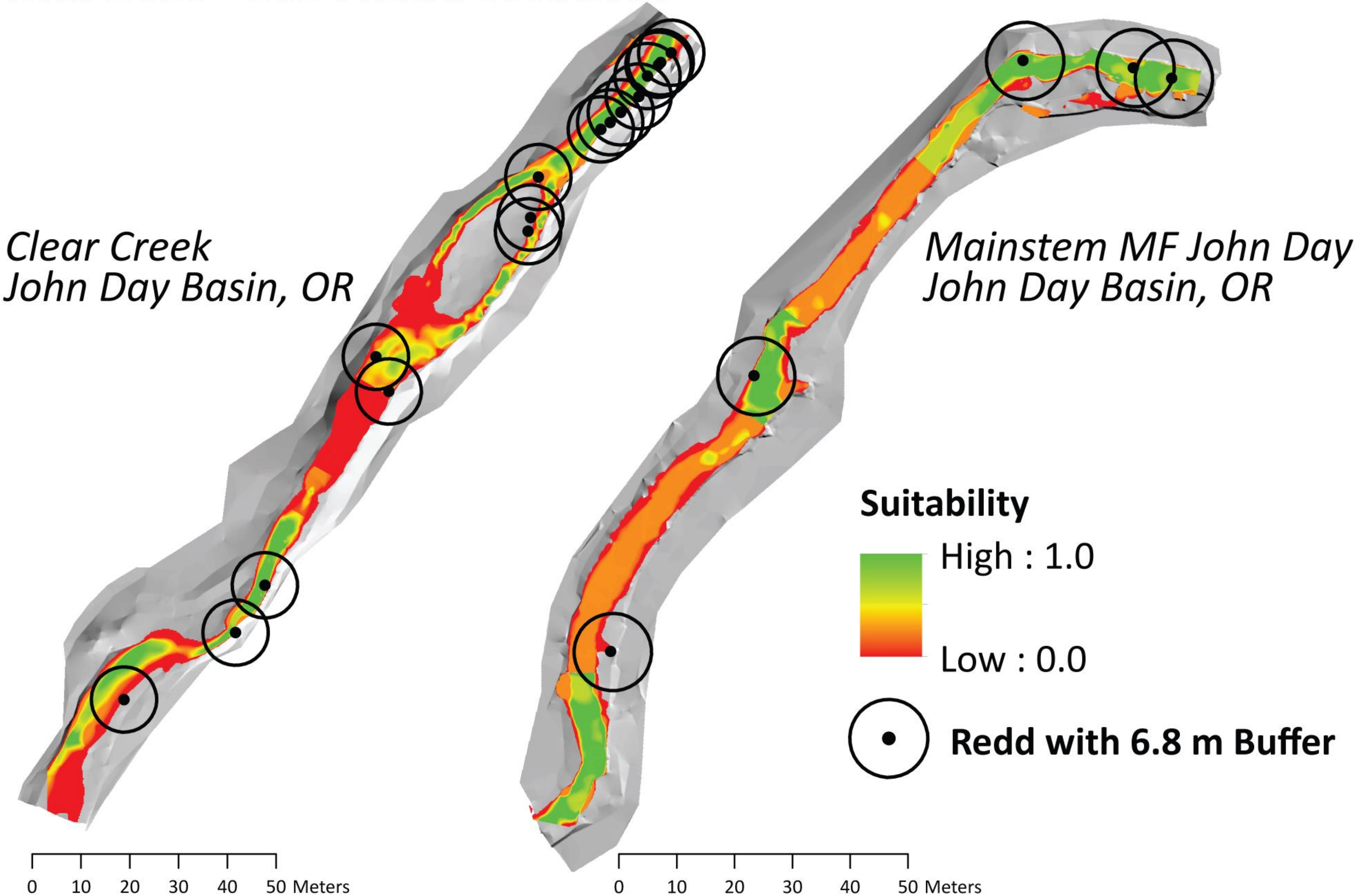




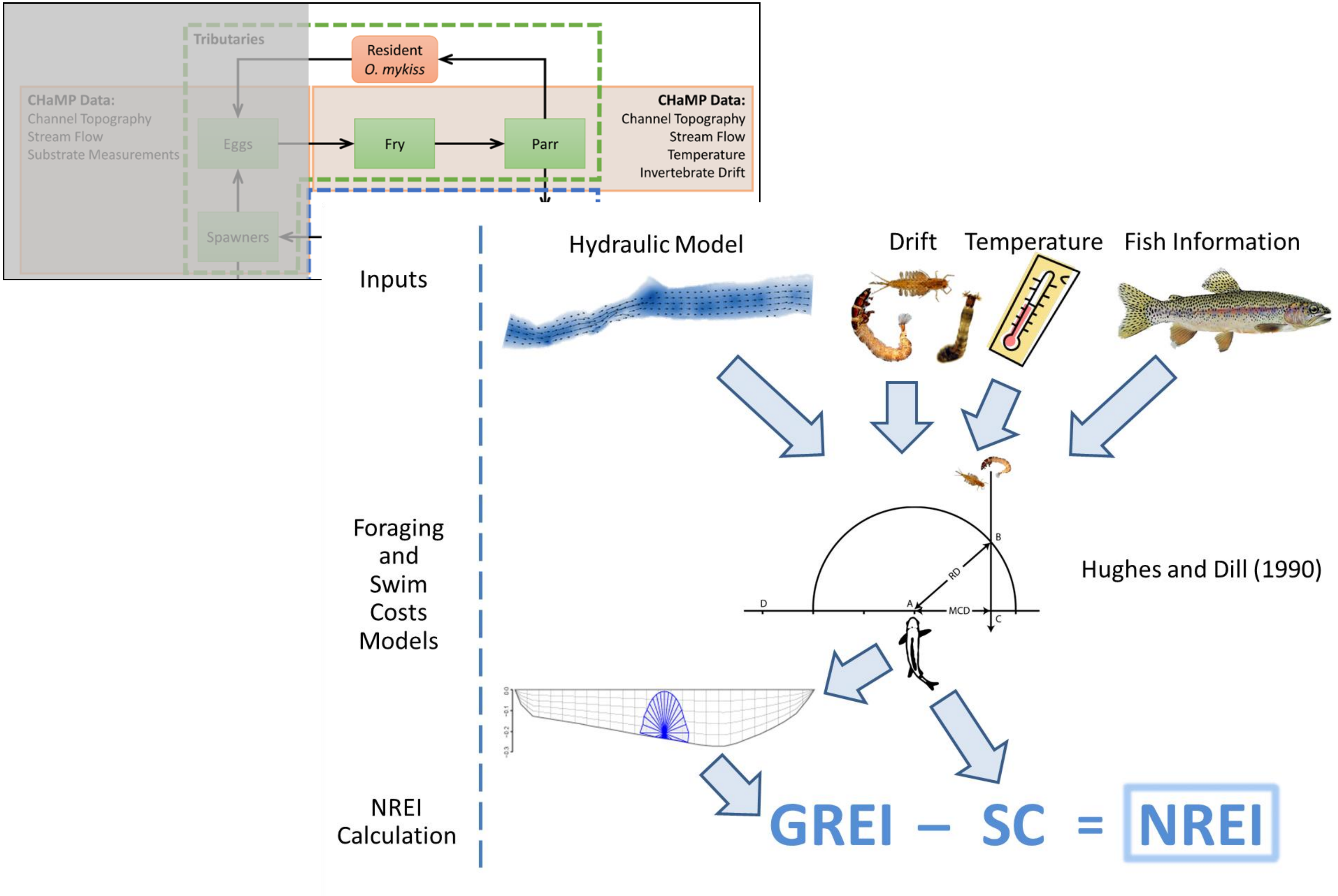
Habitat Suitability Models: egg capacity



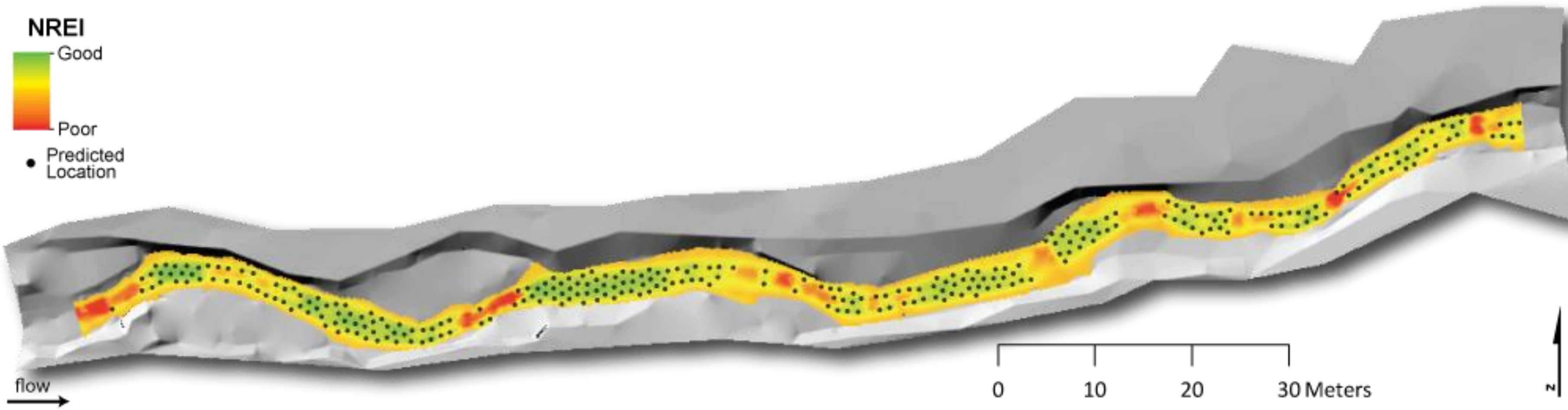
Chinook Spawner Fuzzy Habitat Suitability Model Predictions with 2013 - 2014 Redd Locations



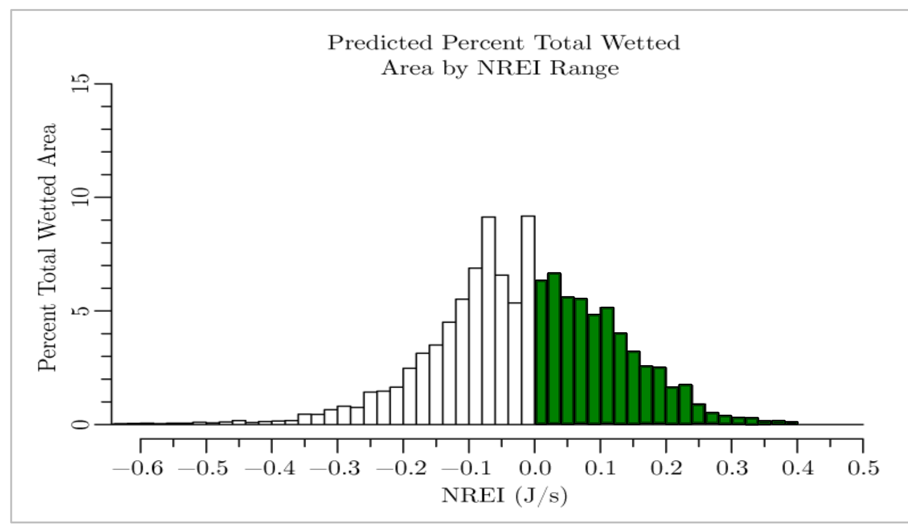
NREI Models: juvenile capacity



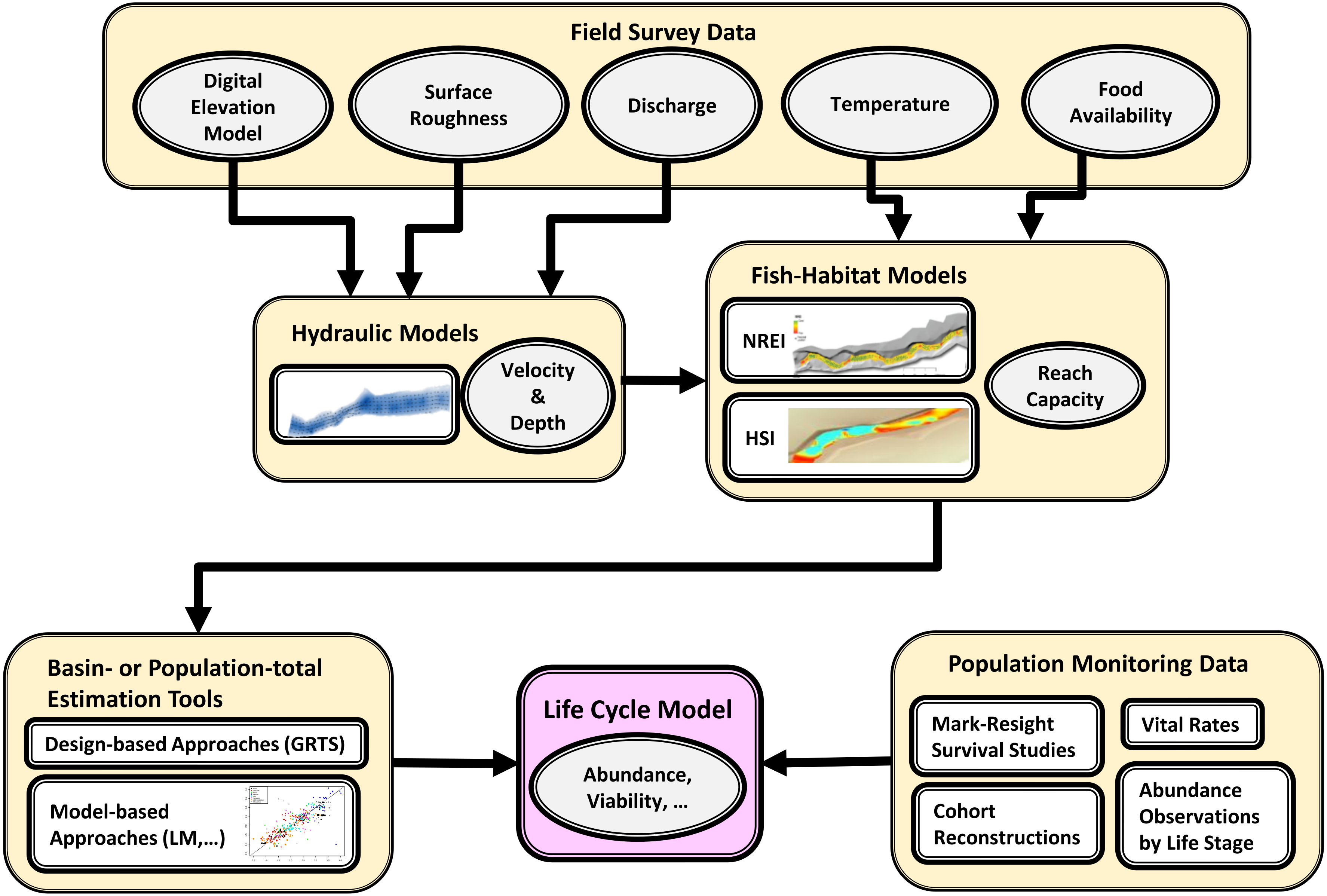
NREI-based site maps and distributions



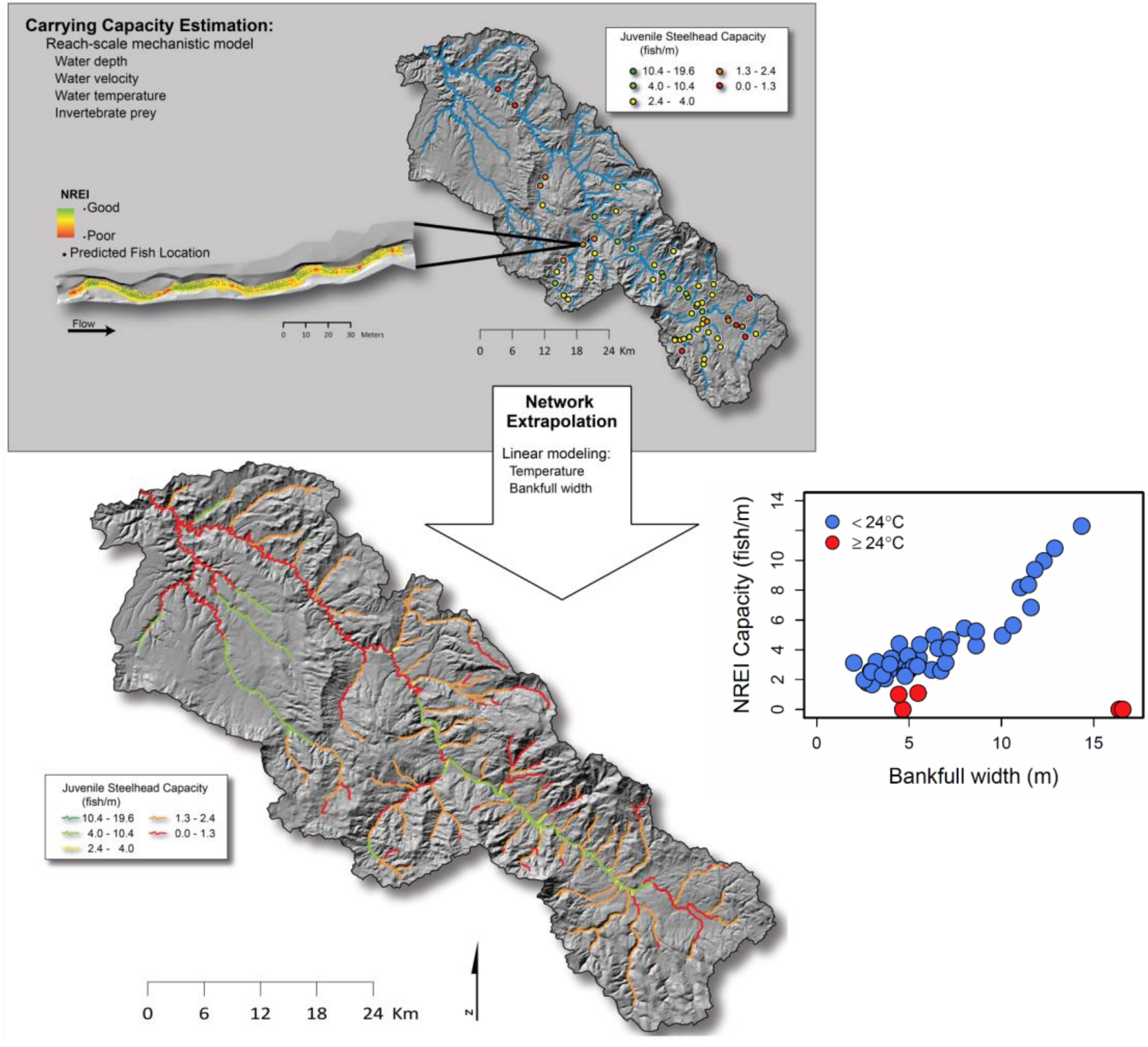
- Fish occupy positions with NREI > 0
- Size-specific territory size accounts for competitive exclusion from adjacent foraging locations
- Carry capacity = $\sum occupied\ foraging\ locations$



LCM workflow



Network Extrapolation: juvenile capacity



MFJD restoration scenarios (KMQ2)…

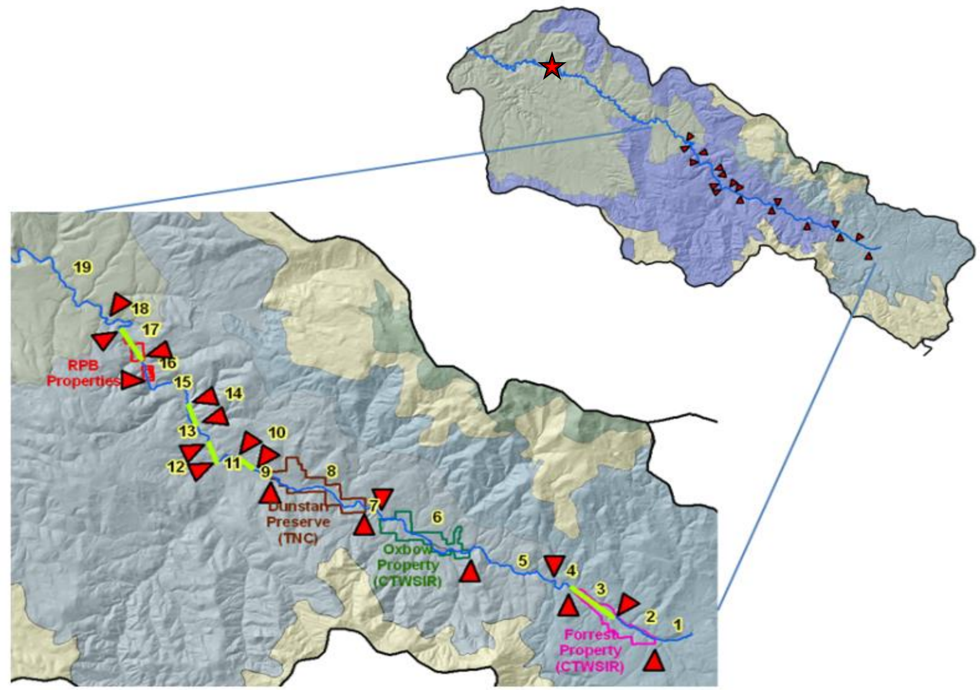
Riparian shading

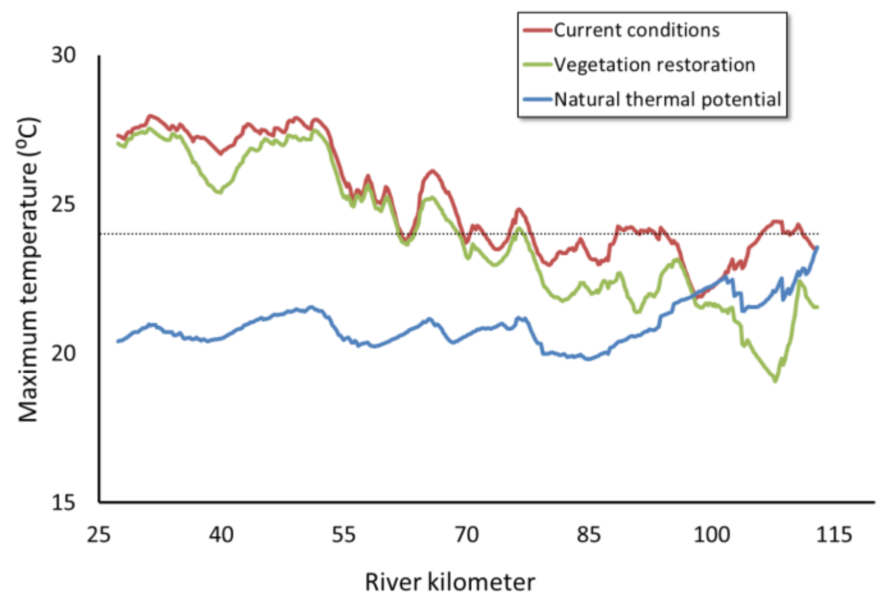
Structural additions

Temperature restoration:

- Mainstem temperature reduction
  - Restore riparian vegetation
  - Natural Thermal Potential

- Use NREI to model effect on carrying capacity
- Adjust survival to account for temperature reductions
- Evaluate
  - + Capacity
  - + Productivity
  - + Capacity & Productivity

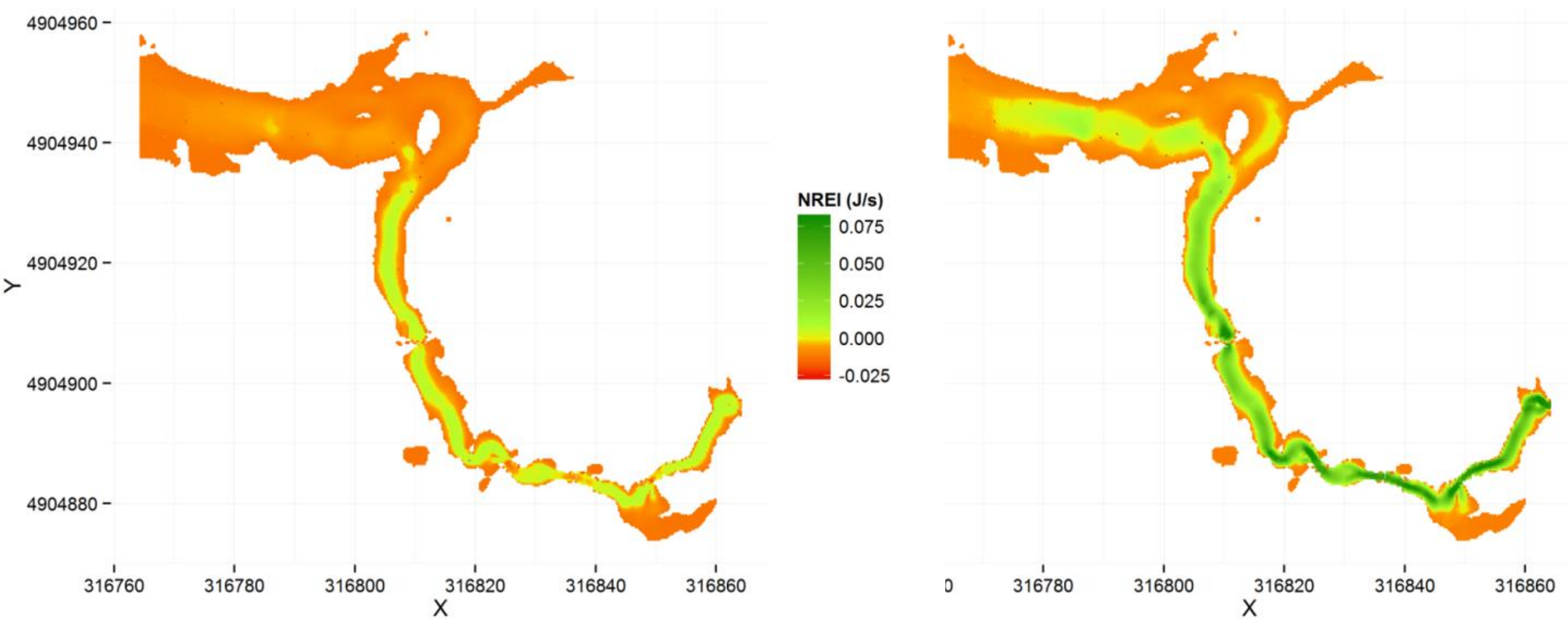




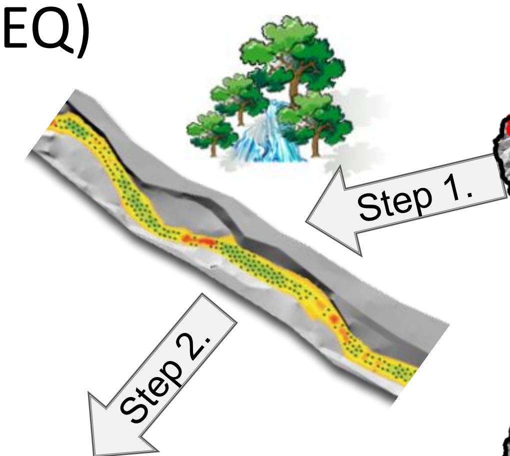
NREI prediction for 4^{o} C reduction temperature for mainstem CHaMP reach (NTP restoration scenario)

Current July temperature (24^{o} C)

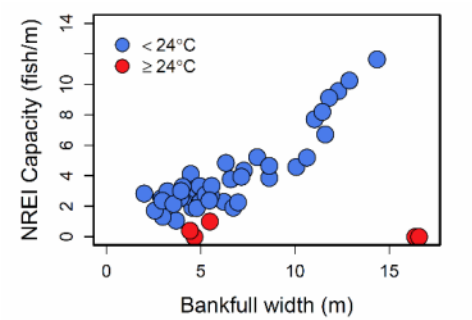
Reduced July temperature (20^{o} C)



O. mykiss capacity benefits of thermal restoration from Heat Source (ODEQ)

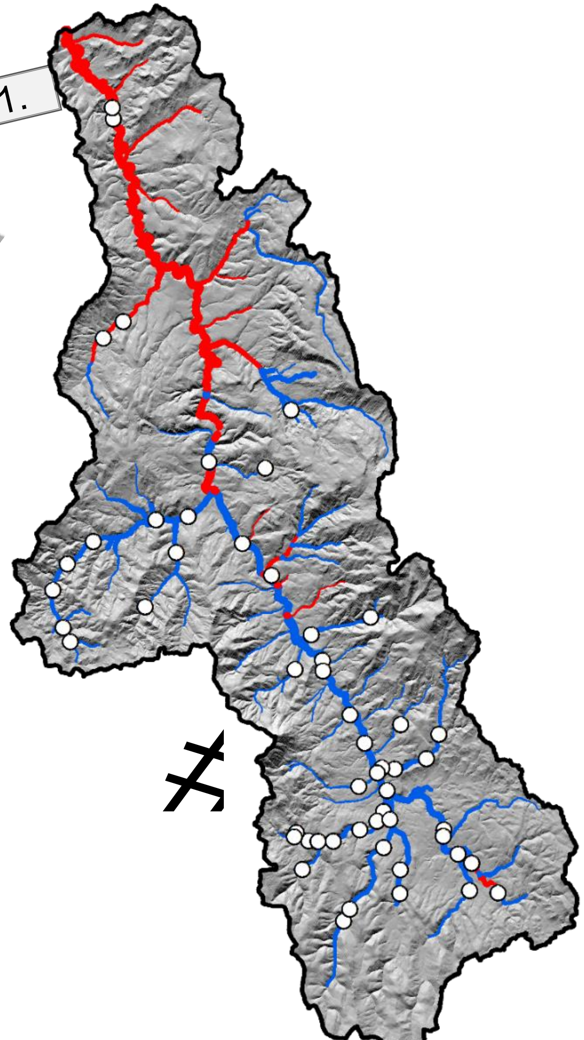


Site	NREI cap.	Hab. var 1	Hab. var 2	…	Hab. var *p*
1	y_1	x_{11}	x_{21}	…	x_{p1}
2	y_2	x_{12}	x_{22}	…	x_{p2}
⋮	⋮	⋮	⋮	…	⋮
n	y_n	x_{1n}	x_{2n}	…	x_{pn}



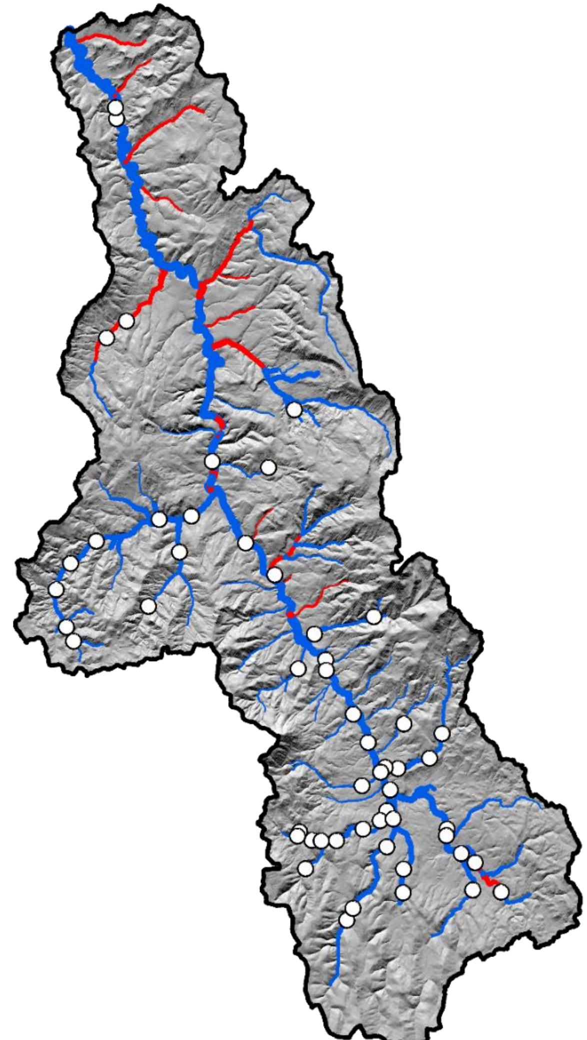
$$\widehat{y_i} = \widehat{\beta_0} + \widehat{\beta_1}x_1 + \cdots + \widehat{\beta_p}x_p + e_i$$

$$Capacity = \sum_{i=1}^{n} \widehat{y_i}$$



Present Capacity = 1.17 M

Baseline input for LCM



Climax Capacity = 1.89 M

Restored Capacity = 1.28 M

Scenario inputs for LCM

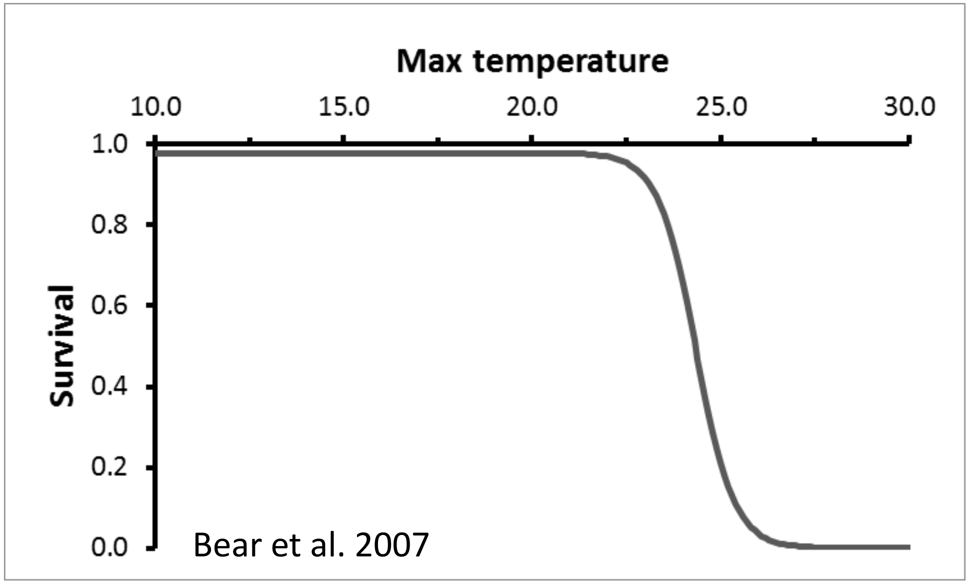
Step 3.

Restoration impact on survival:

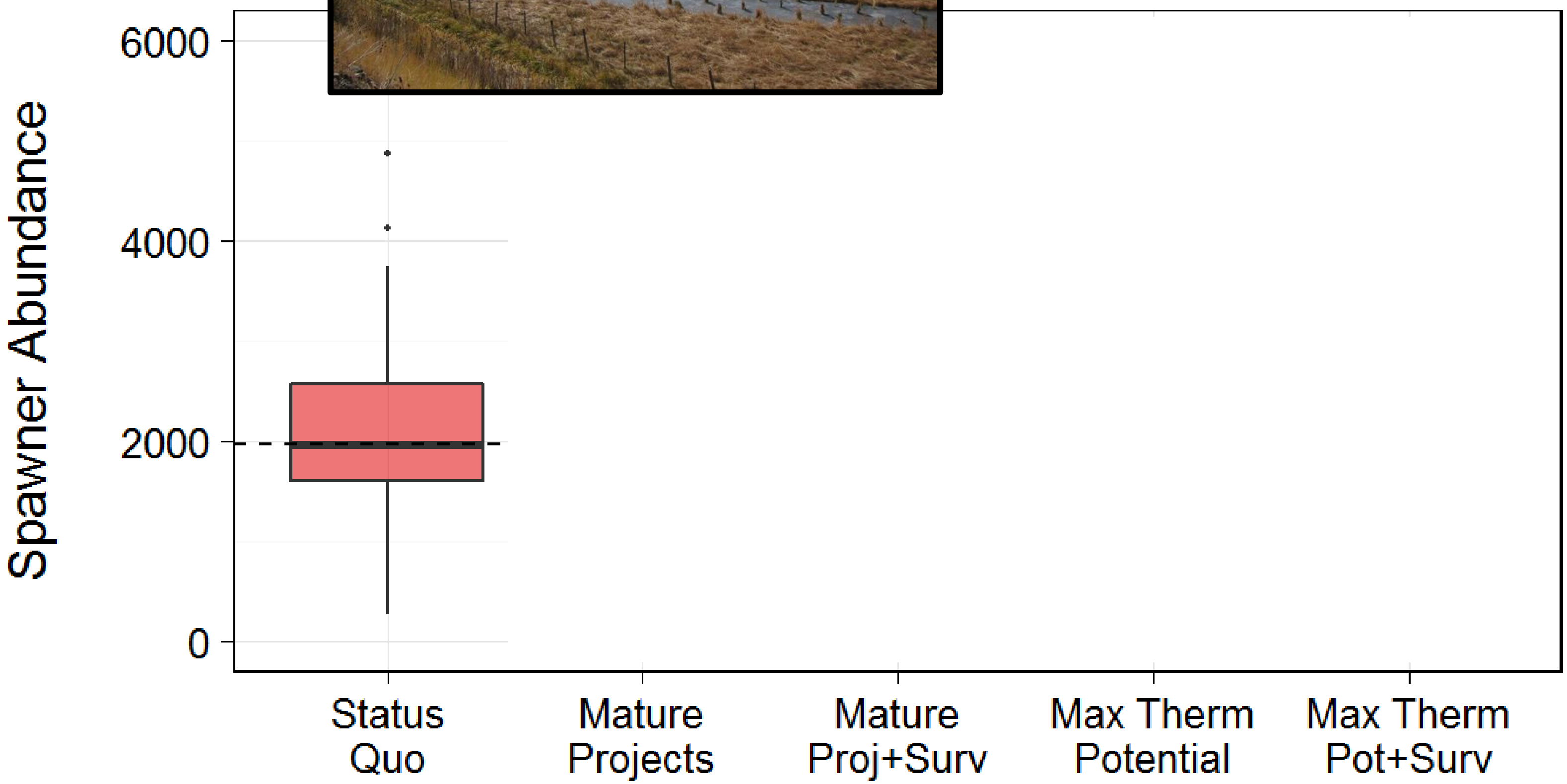
- Use Bear et al 2007 to estimate 60 d survival (S) for each scenario
- Estimate temp. dependent survival for all mainstem reaches (n = 115)
- Calculate adjustment as:

$$base\ S\ x\ \frac{restored\ S}{base\ S}$$

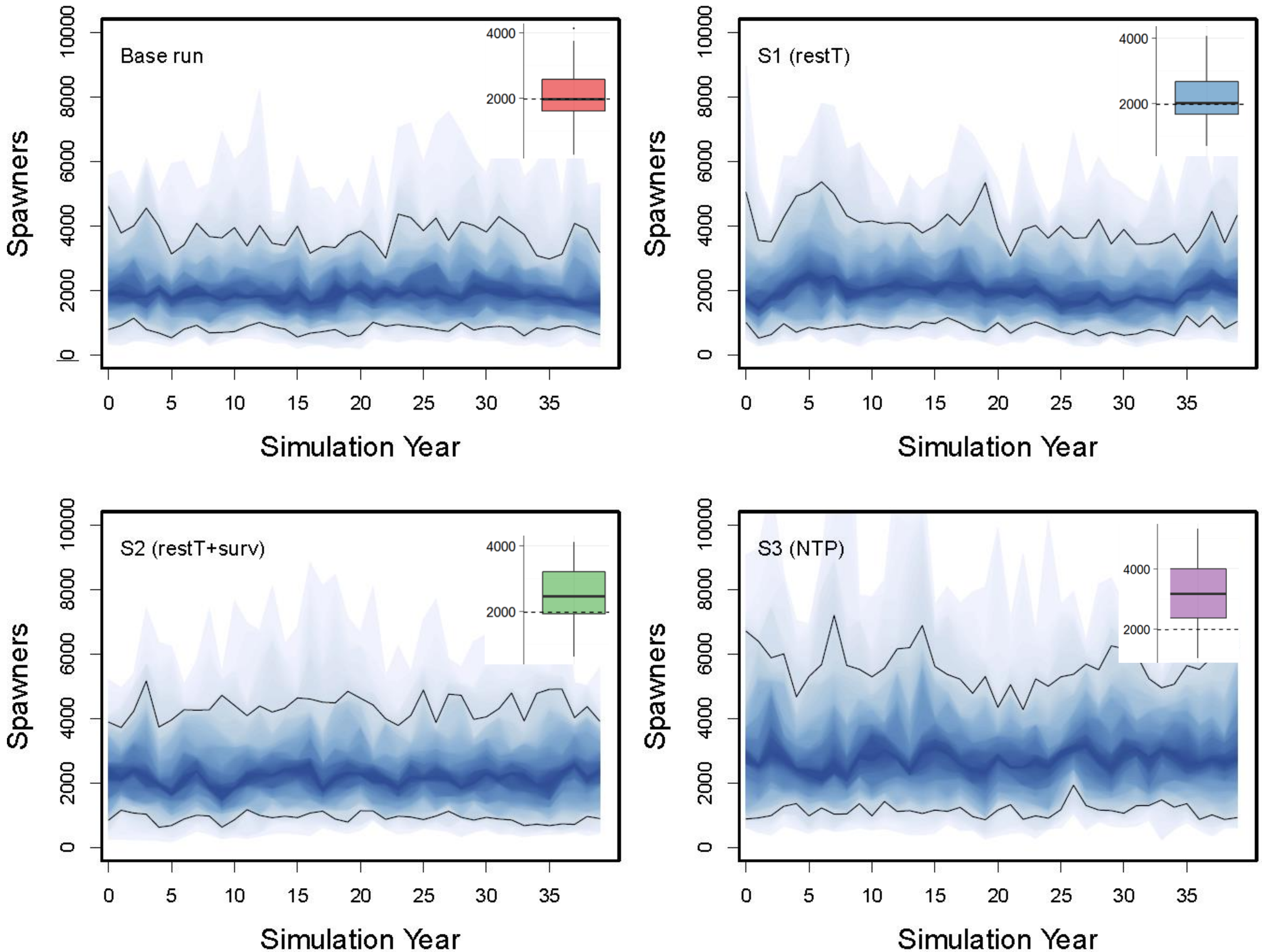
Vegetation restoration: 1.02
Natural Thermal Potential: 1.13



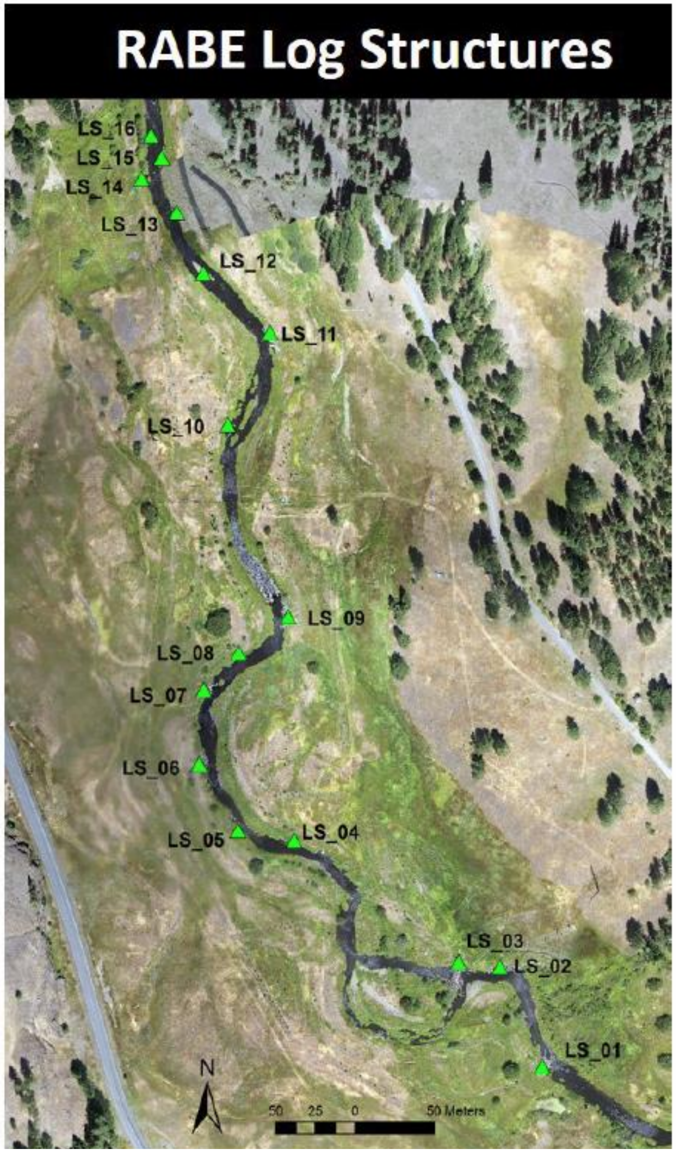
Benefits of thermal restoration



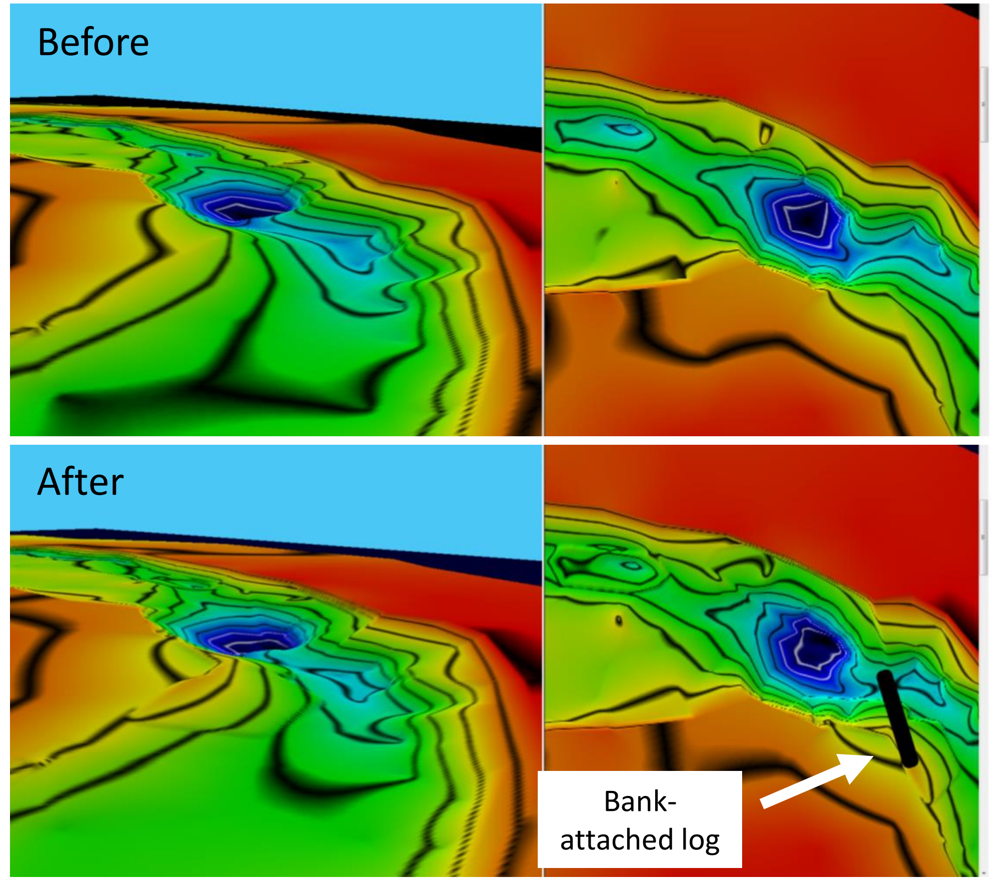
Vegetation restoration (~1.5º C reduction)



Modelling benefits of structures (mainstem, Camp Cr)



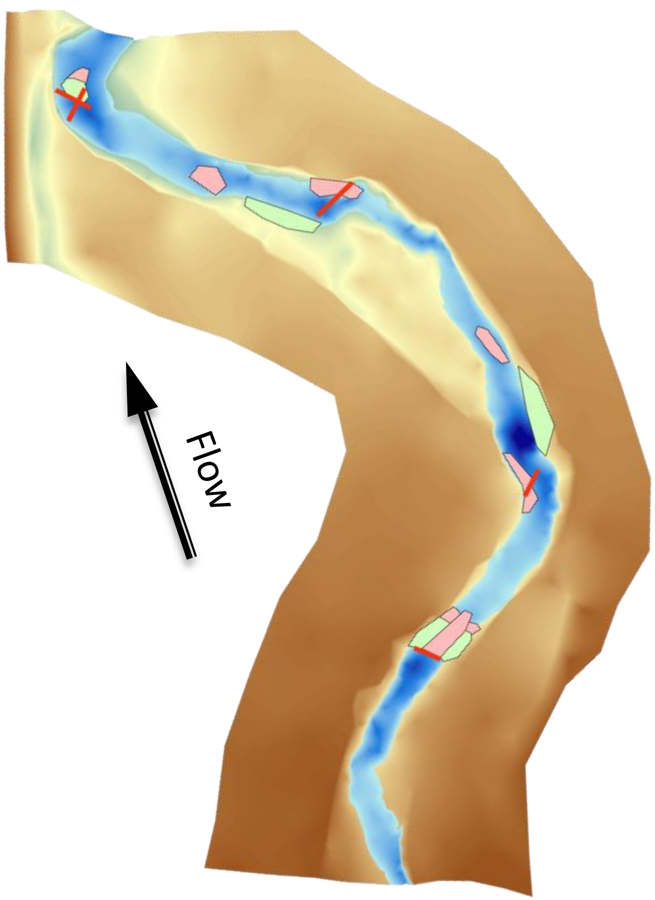
Duffin (2015) U of O Thesis

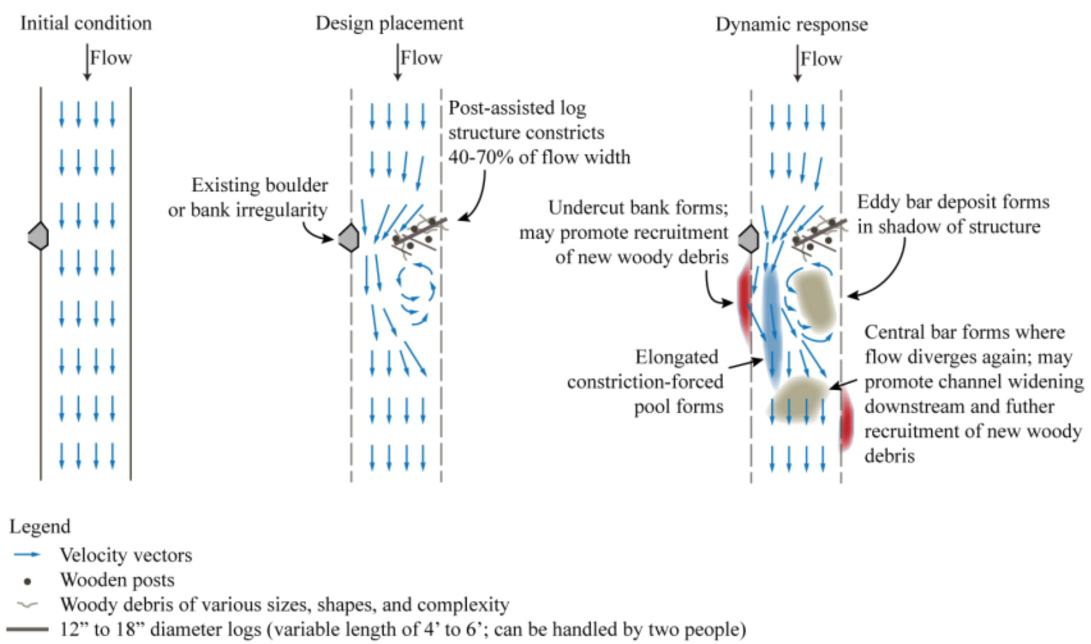


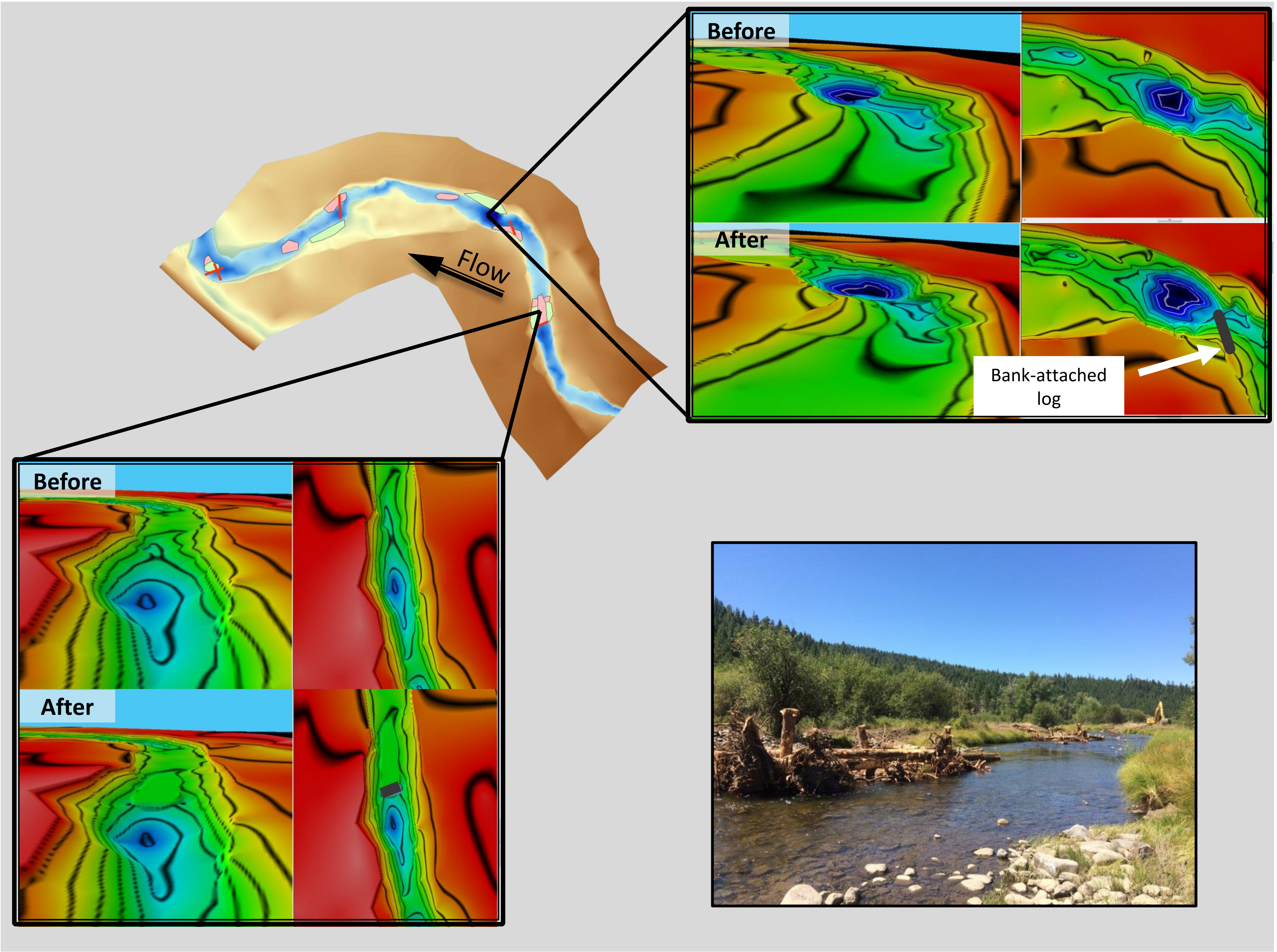
Alter DEMs → Re-run Delft & habitat models → Network model → Re-run LCM

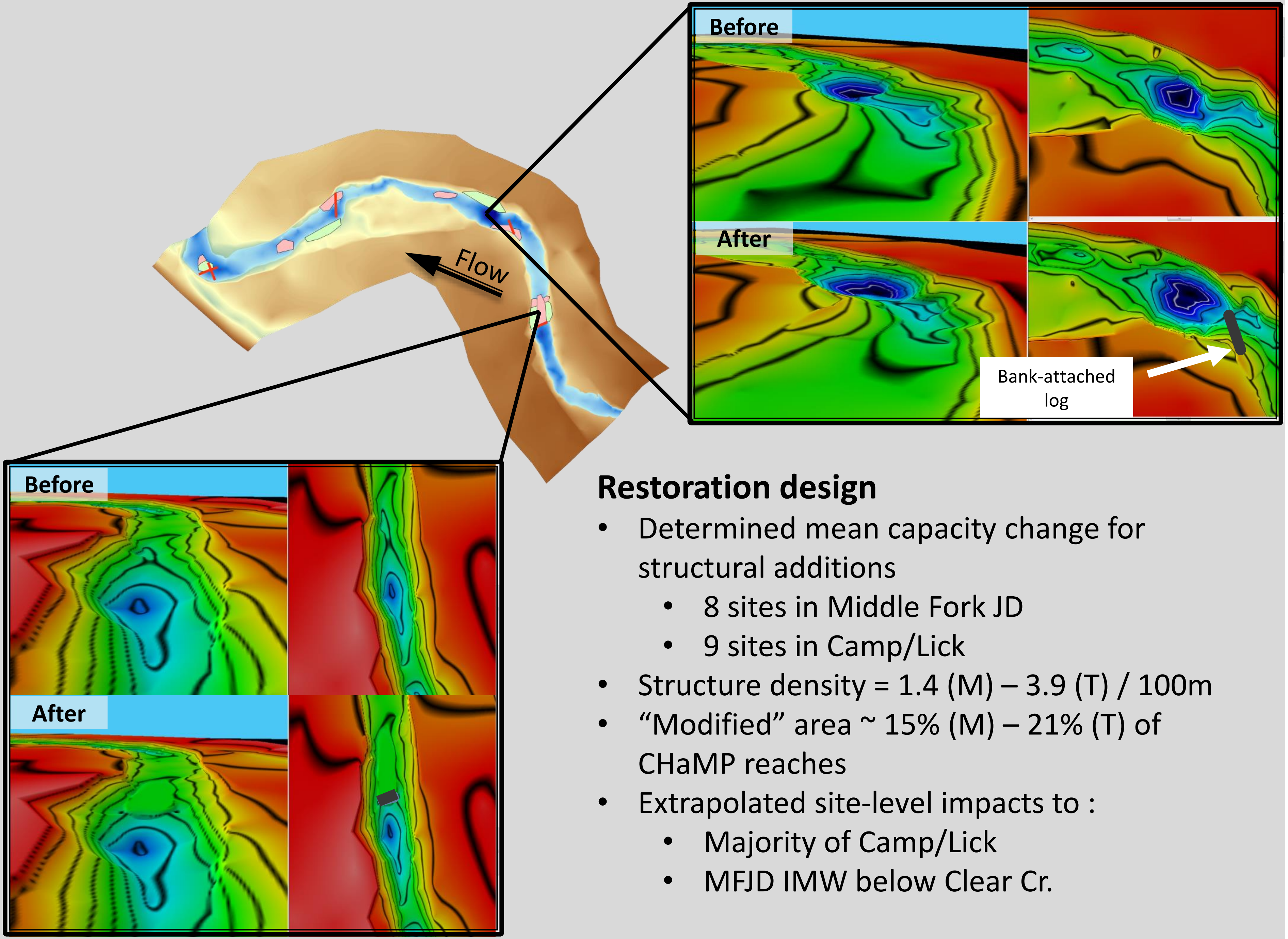
Restoration of channel structure

Map affected areas post structure addition






Flow
Before
After
Bank-attached
log
Before
After

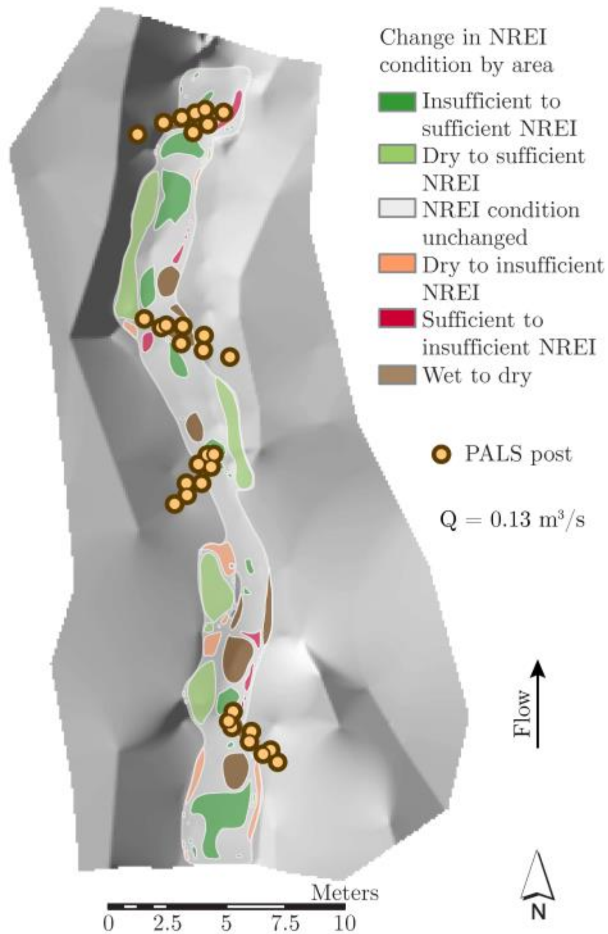


Restoration design

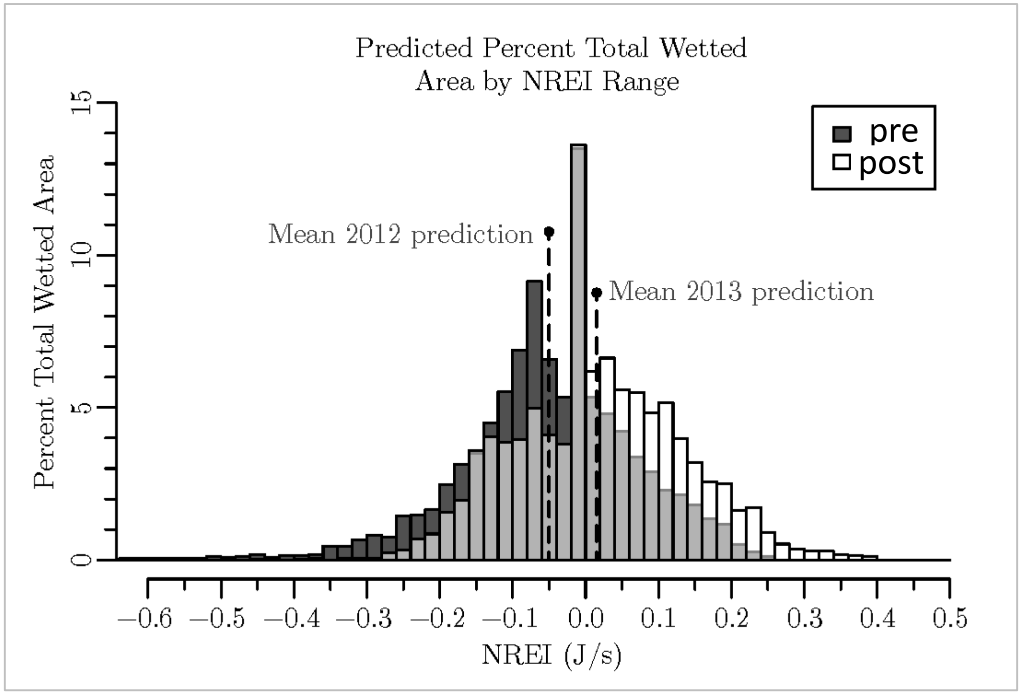
- Determined mean capacity change for structural additions
  - 8 sites in Middle Fork JD
  - 9 sites in Camp/Lick
- Structure density = 1.4 (M) – 3.9 (T) / 100m
- “Modified” area ~ 15% (M) – 21% (T) of CHaMP reaches
- Extrapolated site-level impacts to :
  - Majority of Camp/Lick
  - MFJD IMW below Clear Cr.

Restoration of channel structure

NREI change map (pre→ post)

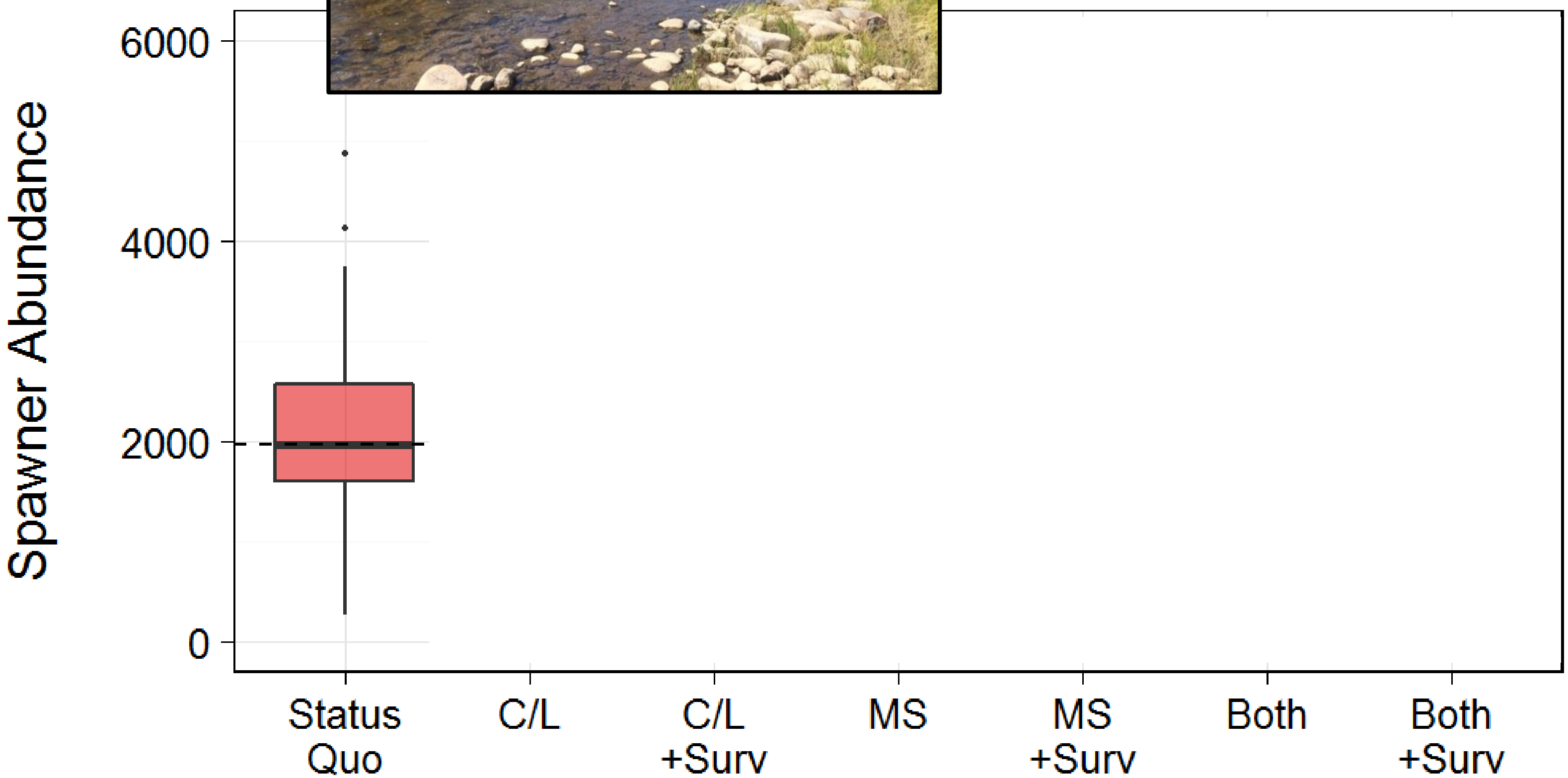


NREI distributions (pre→ post)



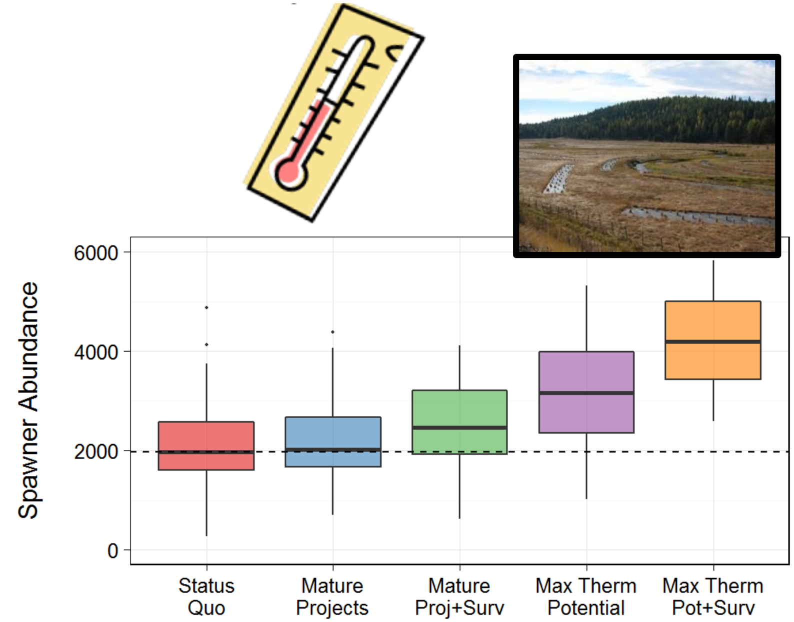
- Model proportional effect on survival for tributary and mainstem habitat

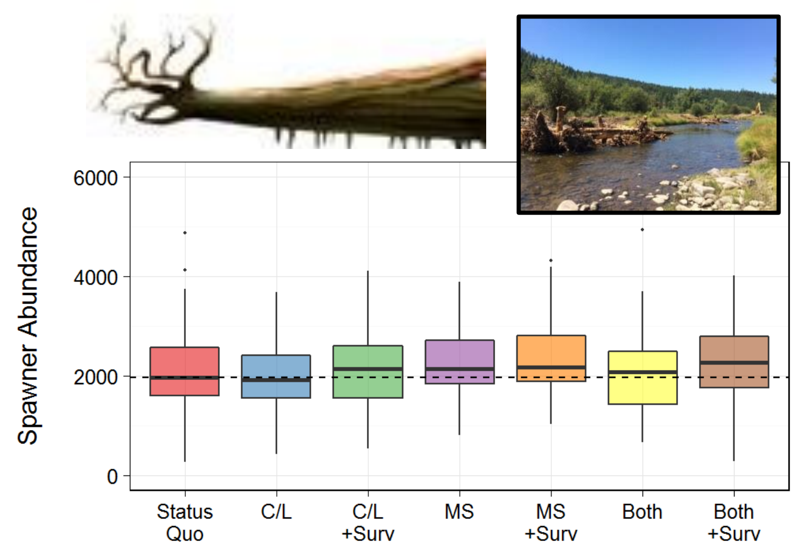
Benefits of instream structures



Restoration summary

- Capacity effects of restoration were minor
- As modeled, survival effects caused greatest spawner increases
- 1.04 – 2.16 times more spawners under temperature restoration
- 1 – 1.1 time more spawners with structural restoration
- LCM provide means to evaluate site-scale restoration effects on population





Conclusions

- LCM provide means to evaluate site-scale restoration effects on population
  - View impact of local restoration efforts as well as impact of IMW
- Base parameterization of LCM for MFJD is consistent with recent monitoring data for steelhead population
- Use of mechanistic models (HSI and NREI) provides means to evaluate effects of habitat alterations