Fish Habitat Models and Beyond

CHaMP Camp 2015, Advanced Modules Day 3

June 4, 2015

Philip Bailey, Joe Wheaton, Pete McHugh
(and Sara Bangen, Nick Bouwes, Carl Saunders, Eric Wall)

NORTH ARROW RESEARCH

Utah State University ECOGEOMORPHOLOGY & TOPOGRAPHIC ANALYSIS LABORATORY

Eco Logical Research, Inc. Science Driven Solutions

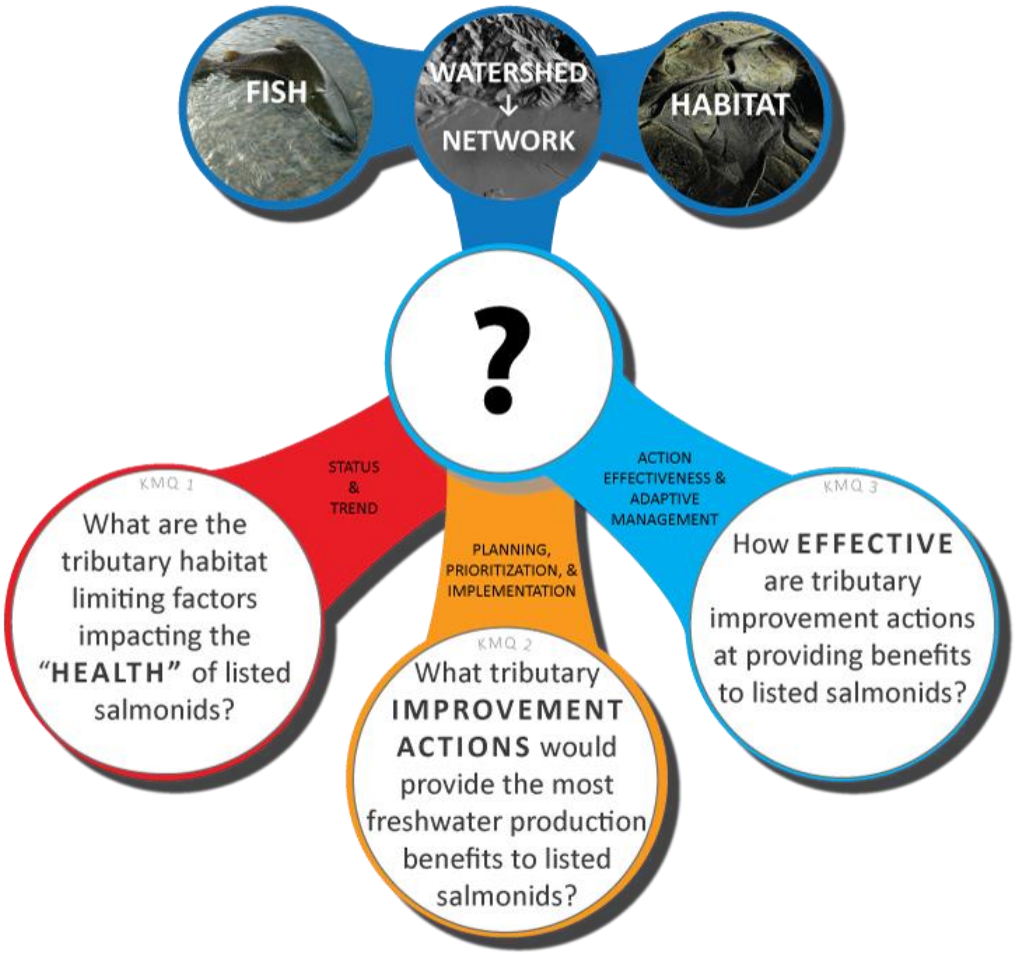
BONNEVILLE POWER ADMINISTRATION ISEMP CHaMP

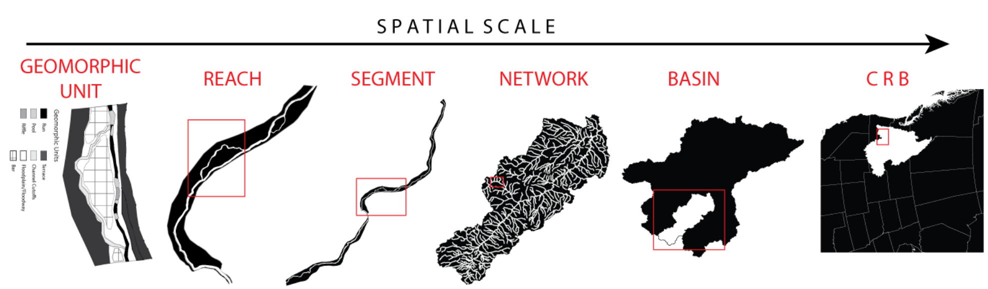
Fish Habitat Model Outline

- CHaMP Context
- Fish Habitat Model Backgrounder
  - HSC and FIS models
- Fish Habitat Model Software
  - Introduction
  - Exercises
- The Net Rate of Energy Intake (NREI) Model
- Life Cycle Models

Underlying Motivation

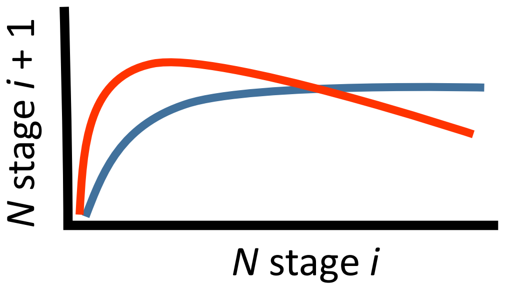
- How to improve habitat to bring about population benefits (the KMQs)?
- Answering KMQs requires:
  - Translation of CHaMP data into biological currency
  - A means to forecast benefits of restoration
- More broadly, a need for tools to estimate capacity





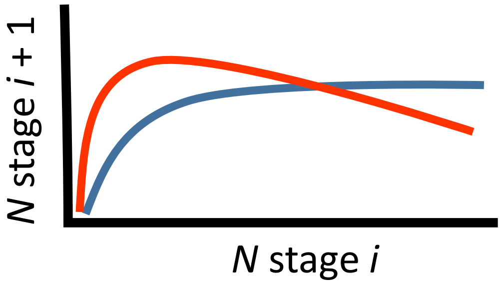
Estimating Habitat Capacity

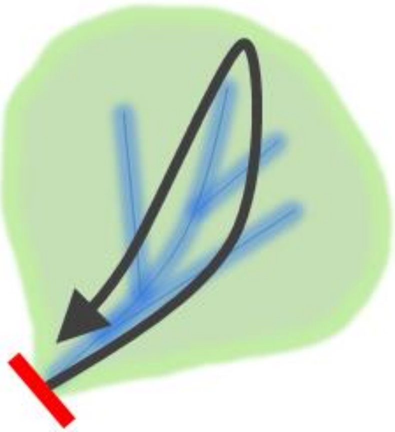
- What is meant by capacity?
- For which species/life stage?
- At what spatial scale?
- Why estimate capacity?
  - Habitat status & trends
  - Key input to LCMs
  - Others
- All have pros and cons



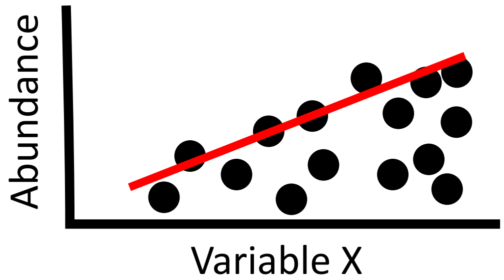
$$N_{i+1} = \frac{N_i}{\frac{1}{prod.} + \frac{1}{capacity} N_i}$$

Estimating Habitat Capacity



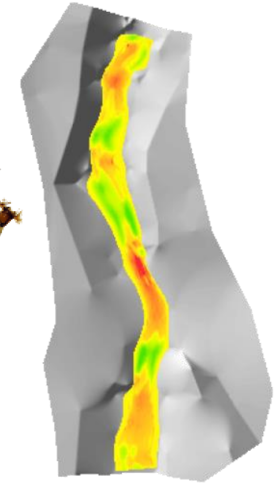


Population Models
Spawner-Recruit
(~Parken/Liermann)



Statistical Models
Quantile Regression
QR Forests

Areal Methods
Density-Area Product



Mechanistic (or Quasi-)
Net Rate of Energy Intake
Habitat Suitability Models
(WUA * space req'd)

Other Approaches
Expert-informed (e.g., EDT)
Indices (e.g., IP, HabRate)
Hybrid approaches

Method	Advantages	Disadvantages
Population models	- Integrative - Relevance to other 'H' - Established framework	- Hard-to-meet assumptions - Data needs - Bottleneck stage(s) unknown
Statistical models	- Generates FHR knowledge - Draws on existing data (?) - Gets the job done	- Design, extrapolation challenges - Narrow domain of use - Seeding level issues (?)
Areal methods	- Ties fish *N* to channel units - Gets the job done	- Design, extrapolation challenges - Uncertainty in density used (?) - Labor intensive
Habitat Suitability Models	- Explicit link to habitat - Platform for simulation - 'Limited' sampling required	- Design, extrapolation challenges - Limited accessibility - Narrow domain of use (not FIS) - Ignores productivity/food
NREI Models	- Explicit link to habitat, FOOD - Transferable - Platform for simulation - 'Limited' sampling required	- Design, extrapolation challenges - Limited accessibility

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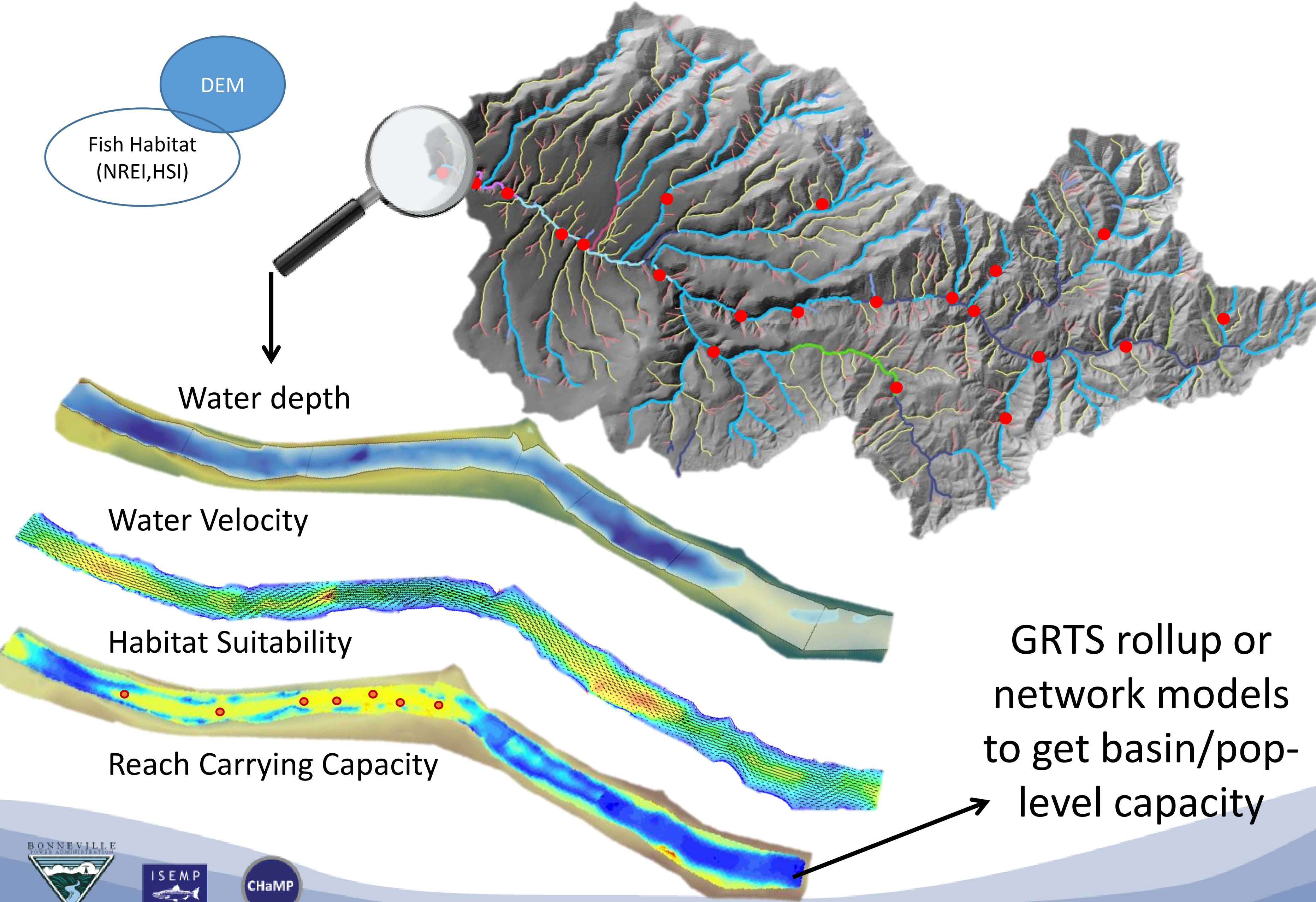
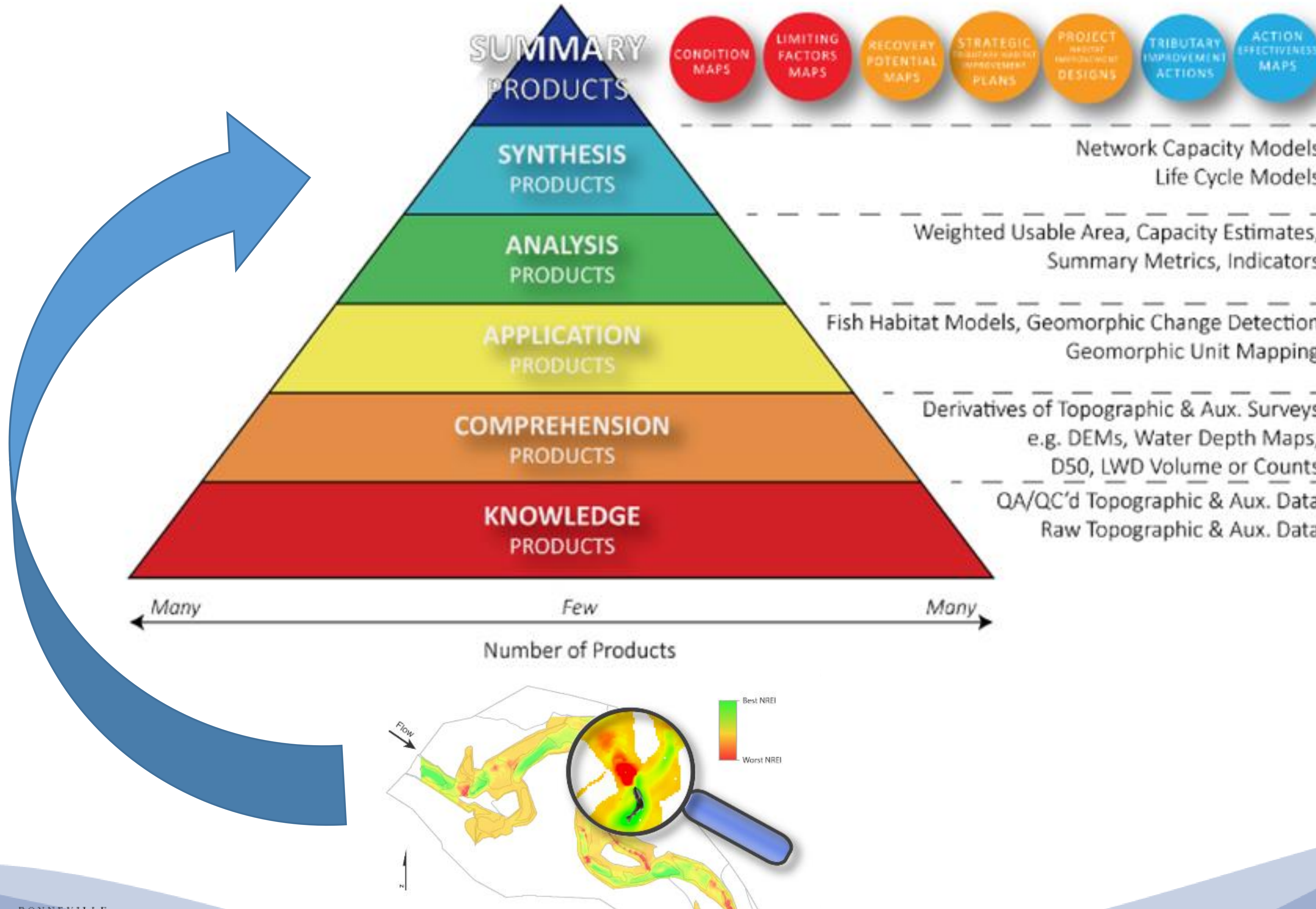
DEM based protocol→ HSI → Potential Spawner Capacity




SUMMARY PRODUCTS
CONDITION MAPS
LIMITING FACTORS MAPS
RECOVERY POTENTIAL MAPS
STRATEGIC PLANS
PROJECT DESIGNS
TRIBUTARY IMPROVEMENT ACTIONS
ACTION EFFECTIVENESS MAPS
SYNTHESIS PRODUCTS
Network Capacity Models
Life Cycle Models
ANALYSIS PRODUCTS
Weighted Usable Area, Capacity Estimates,
Summary Metrics, Indicators
APPLICATION PRODUCTS
Fish Habitat Models, Geomorphic Change Detection
Geomorphic Unit Mapping
COMPREHENSION PRODUCTS
Derivatives of Topographic & Aux. Surveys
e.g. DEMs, Water Depth Maps,
D50, LWD Volume or Counts
KNOWLEDGE PRODUCTS
QA/QC'd Topographic & Aux. Data
Raw Topographic & Aux. Data
Many
Few
Many
Number of Products
Flow
Best NREI
Worst NREI

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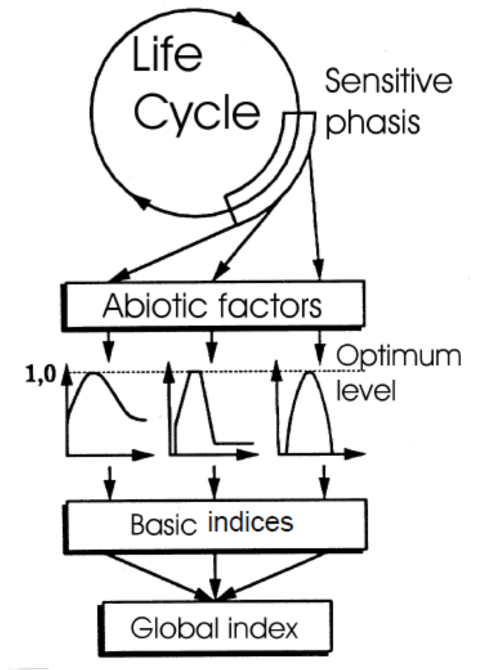
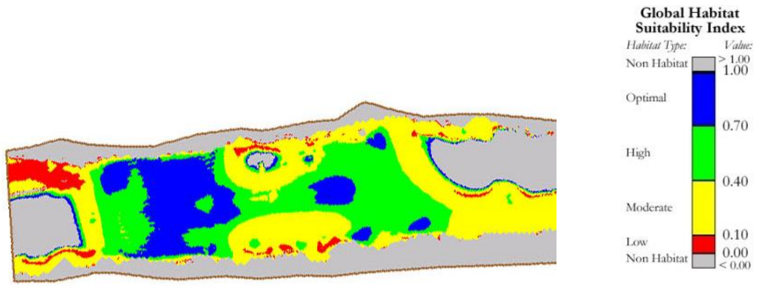
Habitat Suitability Modeling

What is a habitat suitability model?

- A model of **suitability of habitat** for specific species for either specific life-stages or functions
- Habitat is characterized by specific **abiotic variables**
- 'Model' can be applied at a point or over regions (e.g. cells/polygons) that have a unique combination of abiotic variables
- The 'model' can produce spatially variable results (e.g. in a GIS)
- The 'model' can produce temporal dynamics, if you have time series of abiotic inputs…



Building a classical fish *preferendum* model



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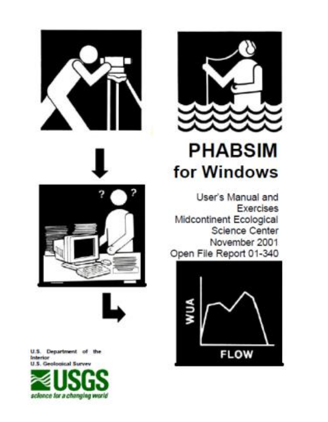
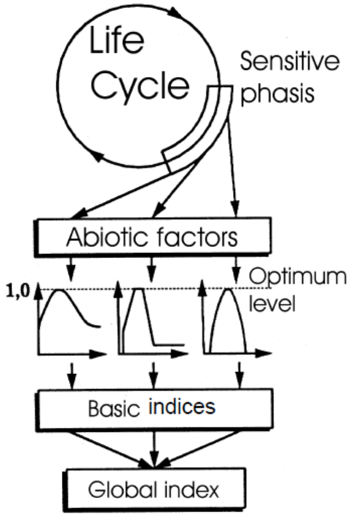
HABITAT SUITABILITY CURVES

- Habitat suitability curve classification…
- Once I got one… can I use it everywhere?





Building a classical fish *preferendum* model

In general, suitability curves have been classified according to the following categories (Bovee et al., 1998, pp. 73–78):

Category I Expert opinion or literature curves. These are typically derived from a consensus of experts' accumulated knowledge of habitat use by a species' life stage(s) or by evaluating habitat use information found in the professional literature.

Category II Habitat Utilization Curves. These are derived directly from observations of habitat use of the target life stage and species.

Category III Habitat Preference Curves. These are derived from observation data on habitat use corrected for habitat availability.

Transferability of Suitability Curves

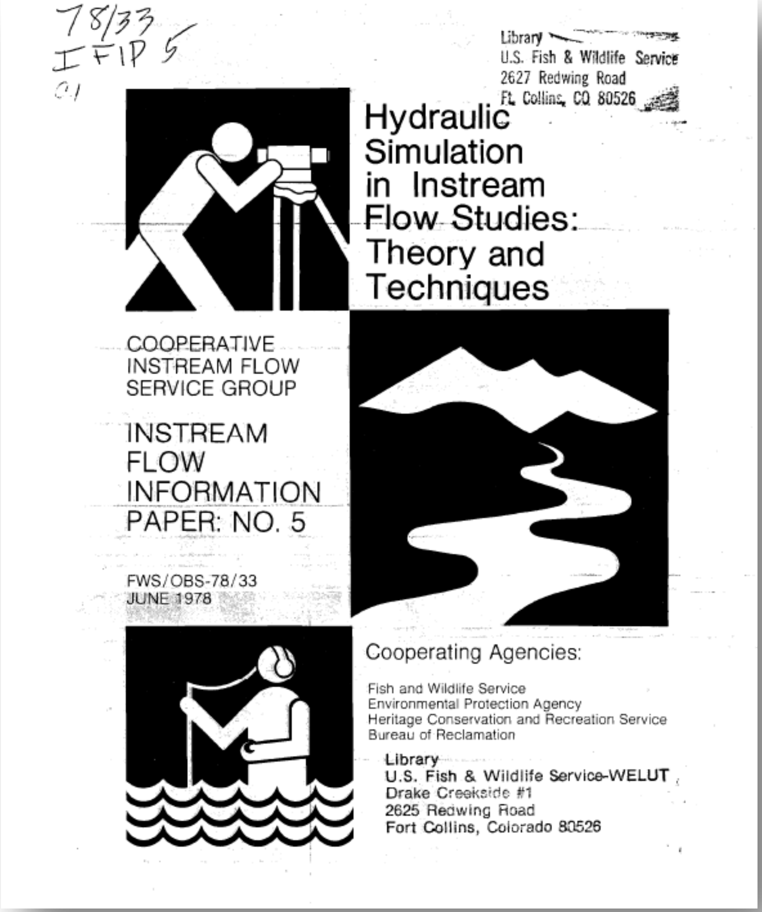
Regardless of how the data are collected, suitability curves will demonstrate some specificity to the stream(s) in which they were developed. With limited resource availability and the high cost associated with development of stream-specific suitability curves, use of HSC from other streams is common. Thus, checking for the appropriateness of the transfer is important. Avoiding development of study-specific HSC leads to considerable cost savings. The investigator must apply professional knowledge and judgment to evaluate if the source curves are meaningful for the current application and transferable. In the IFIM context, it is essential for all parties to agree on the HSC to be used for the study and to agree on their transferability. Thomas and Bovee (1993) and Groshen and Orth (1994) provide methods for quantitatively testing HSC transferability. Manly (1993) provides general guidance on modeling habitat selection by various animals.

http://www.fort.usgs.gov/Products/Publications/15000/15000.pdf

PHABSIM…

http://www.fort.usgs.gov/products/software/phabsim/

- Physical Habitat Simulation Software
- Technique developed in mid 1970s
- Most widely used ecohydraulic model
- This is an HSC technique… Can be applied in 1D, 2D or 3D


78/33
IFIP 5

Hydraulic Simulation in Instream Flow Studies: Theory and Techniques

COOPERATIVE INSTREAM FLOW SERVICE GROUP

INSTREAM FLOW INFORMATION PAPER: NO. 5

FWS/OBS-78/33
JUNE 1978

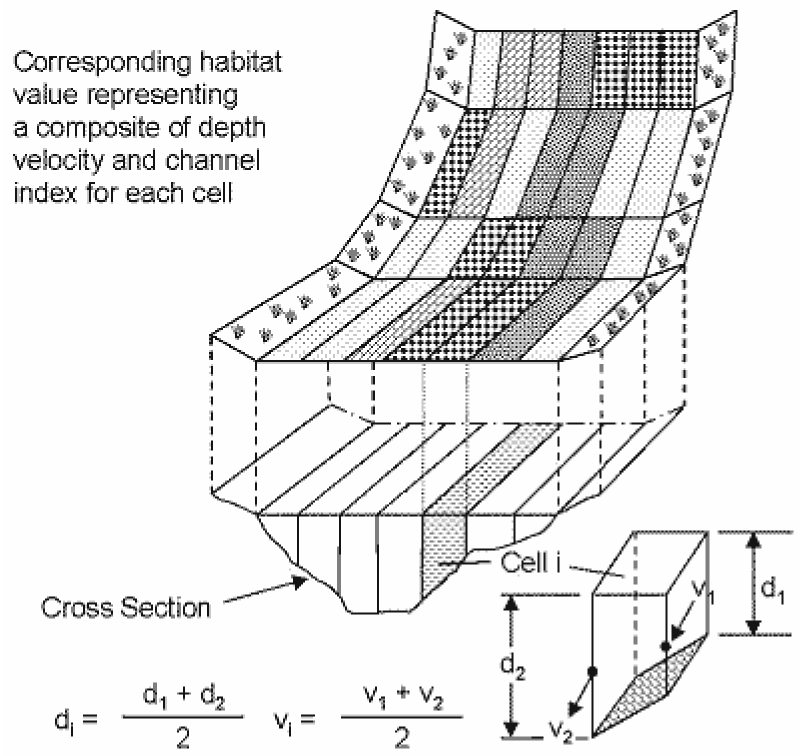
Cooperating Agencies:

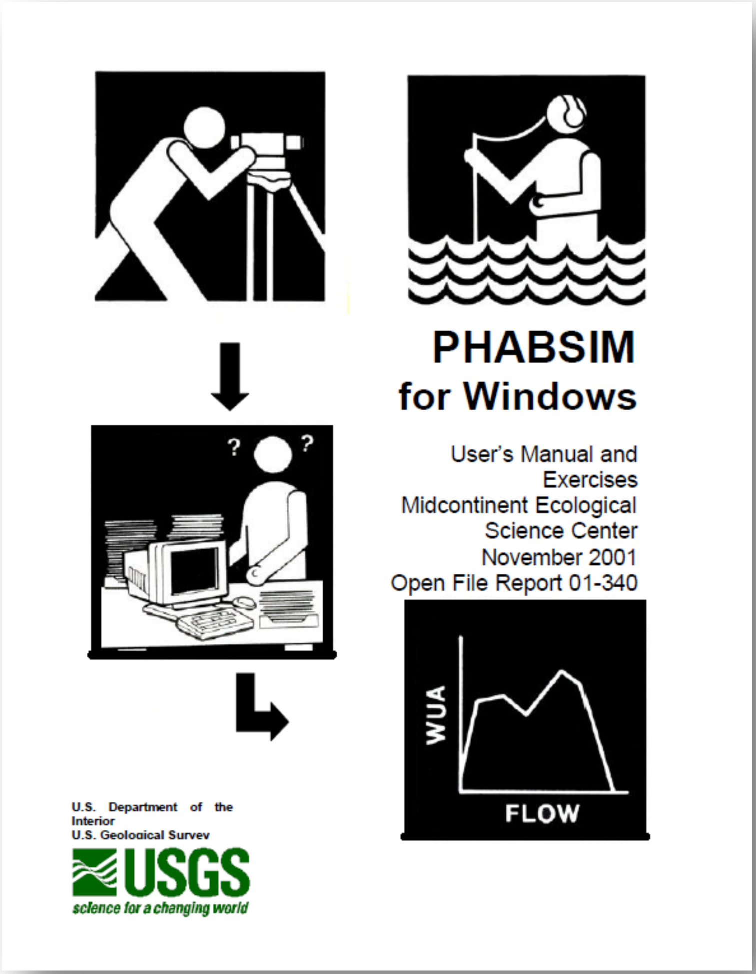
Fish and Wildlife Service
Environmental Protection Agency
Heritage Conservation and Recreation Service
Bureau of Reclamation

Bovee KD and Milhous R. 1978. *Hydraulic simulation in instream flow studies: theory and techniques. Instream Flow Information Paper 5.* FWS/OBS-78/33, U. S. Fish and Wildlife Service, Fort Colins, CO, 156 pp. Available at: http://www.fort.usgs.gov/Products/Publications/22457/22457.pdf

PHABSIM FOR ~~DOS ->~~ WINDOWS!

- Driven by a 1D Hydraulic Model





http://www.fort.usgs.gov/Products/Publications/15000/15000.pdf

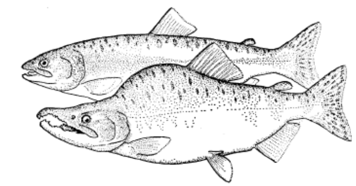
FROM THE LITERATURE…

- CAT I
- Lots of existing stuff out there (both HSCs and HSIs)

http://el.erdc.usace.army.mil/emrrp/emris/EMRIS_PDF/PinkSalmon.pdf

BIOLOGICAL REPORT 82(10.109)
AUGUST 1985

HABITAT SUITABILITY INDEX MODELS AND INSTREAM FLOW SUITABILITY CURVES: PINK SALMON



Fish and Wildlife Service
U.S. Department of the Interior

List of Habitat Suitability Index (HSI) models

http://el.erdc.usace.army.mil/emrrp/emris/emrishelp3/list_of_habitat_suitability_index_hsi_models_pac.htm

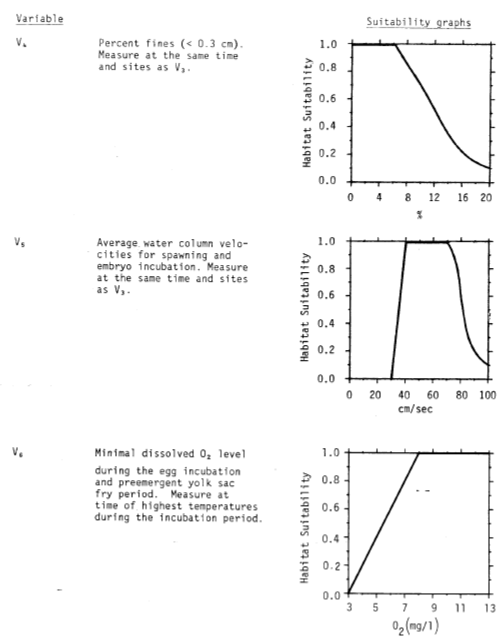
To view the information contained within the Blue Books in Adobe Acrobat Reader (.pdf) format, click on the corresponding .pdf icon.

HSI BLUE BOOK TITLES FWS/OBS Report #

INVERTEBRATES
- American Oyster (Gulf of Mexico) Pdf 82/10.57
- Brown Shrimp (N Gulf of Mexico) Pdf 82/10.54
- Hard Clam Pdf 82/10.77
- Littleneck Clam Pdf 82/10.59
- Pink Shrimp Pdf 82/10.76
- Red King Crab Pdf 82(10.153)
- White Shrimp (N Gulf of Mexico) Pdf 82/10.54

FISHES
- Alewife Herring Pdf 82/10.58
- American Shad Pdf 82(10.88)
- Arctic Grayling (Riverine Populations) Pdf 82(10.110)
- Atlantic Croaker (Juvenile) Revised Pdf 82(10.98)
- Bigmouth Buffalo Pdf 82/10.34
- Black Bullhead Pdf 82/10.14
- Black Crappie Pdf 82/10.6
- Blacknose Dace Pdf 82/10.41
- Blueback Herring Pdf 82/10.58
- Bluegill Pdf 82/10.8
- Brook Trout Pdf 82/10.24
- Brown Trout Pdf 82(10.124)
- Channel Catfish Pdf 82/10.2
- Chinook Salmon Pdf 82(10.122)
- Chum Salmon Pdf 82(10.108)
- Coho Salmon Pdf 82/10.49
- Common Carp Pdf 82/10.12
- Common Shiner Pdf 82/10.40
- Creek Chub Pdf 82/10.4
- Cutthroat Trout Pdf 82/10.5
- English Sole (Juvenile) Pdf 82(10.133)
- Fallfish Pdf 82/10.48
- Flathead Catfish Pdf 82(10.152)
- Gizzard Shad Pdf 82(10.112)
- Green Sunfish Pdf 82/10.15
- Gulf Flounder Pdf 82(10.92)
- Gulf Menhaden Pdf 82/10.23
- Inland Silverside Pdf 82(10.120)
- Lake Trout (Great Lakes Region) Pdf 82/10.84
- Largemouth Bass Pdf 82/10.16
- Longnose Dace Pdf 82/10.33

HSC



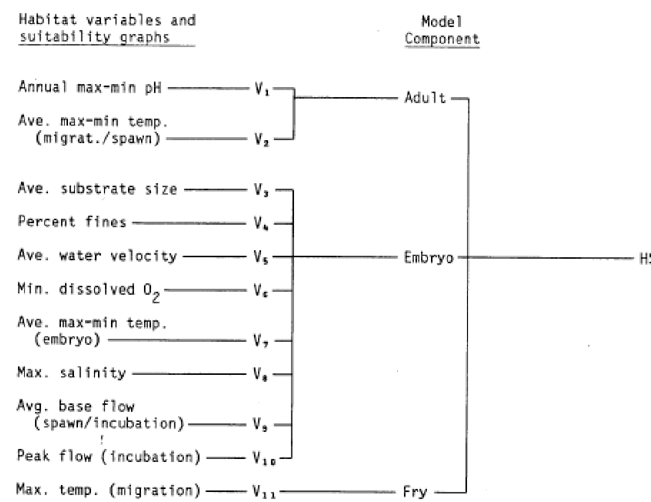


Figure 1. Diagram illustrating the relationship among model variables, components, and HSI.

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CHaMP

Habitat Suitability Modeling Terminology

- Is it a habitat suitability curve, habitat preference curve, habitat utilization curve, habitat availability curve or habitat suitability index?

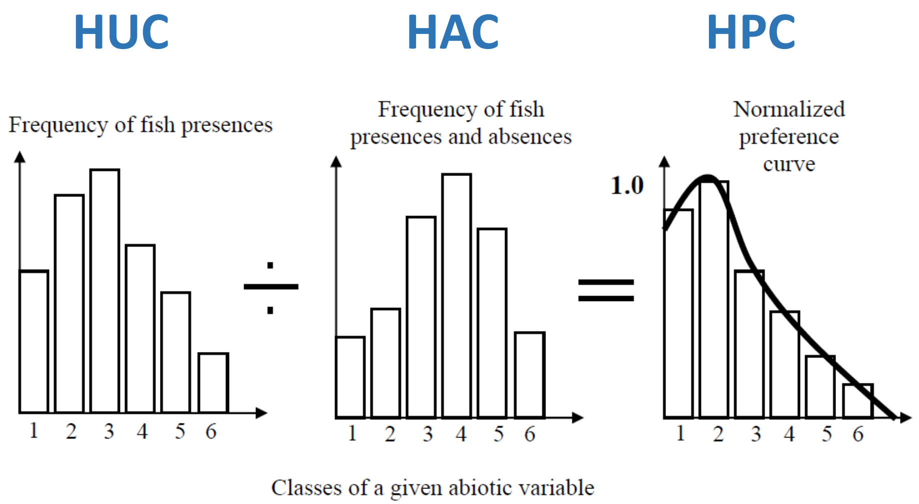
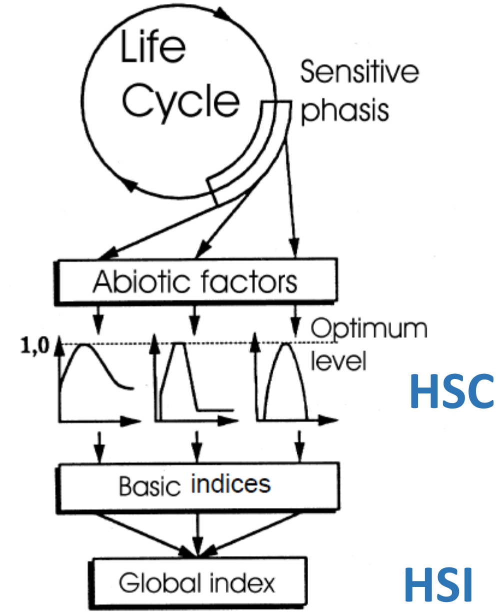


Figure 3 : The general methodology for establishing fish preference curves

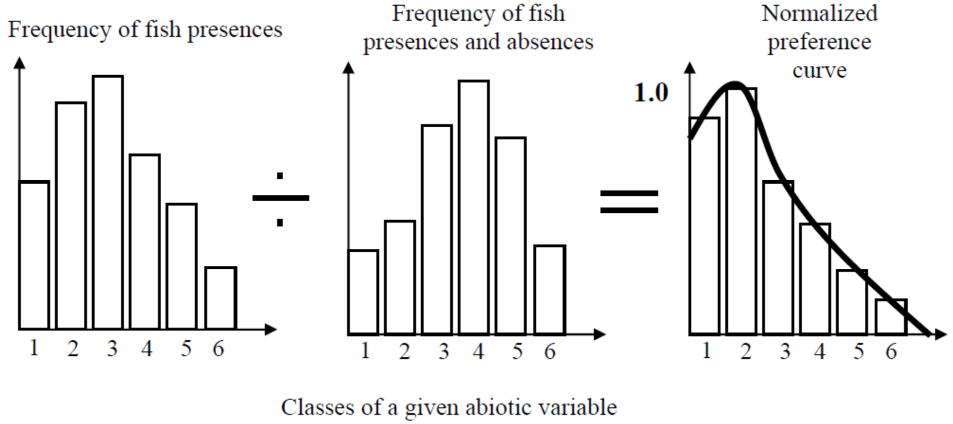


Building a classical fish *preferendum* model

- A HPC can be used for a HSC
- A HUC can be used for a HSC
- HSCs of different abiotic variables are combined to form a HSI

How to make a Habitat Preference Curve

- Make measurements of the abiotic variable of interest where you see the fish.
- Make histogram. Fit curve.
- Do inventory of all available habitat (turn into frequency of fish presence)
- Divide to get normalized preference



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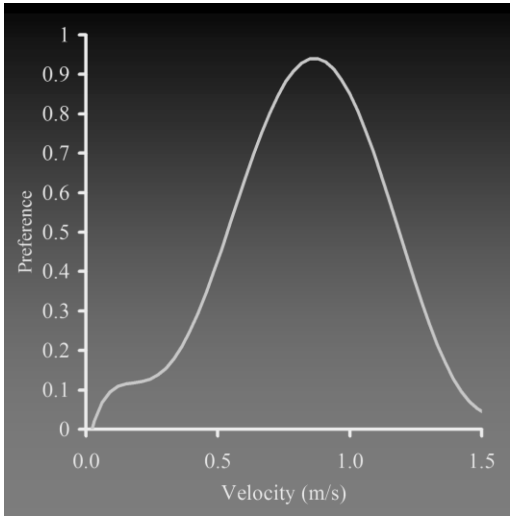
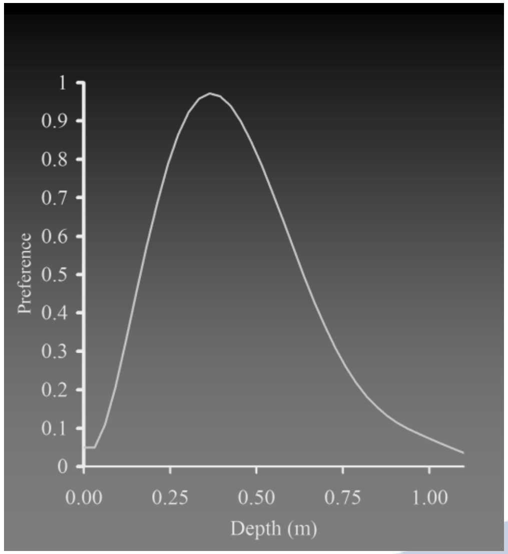
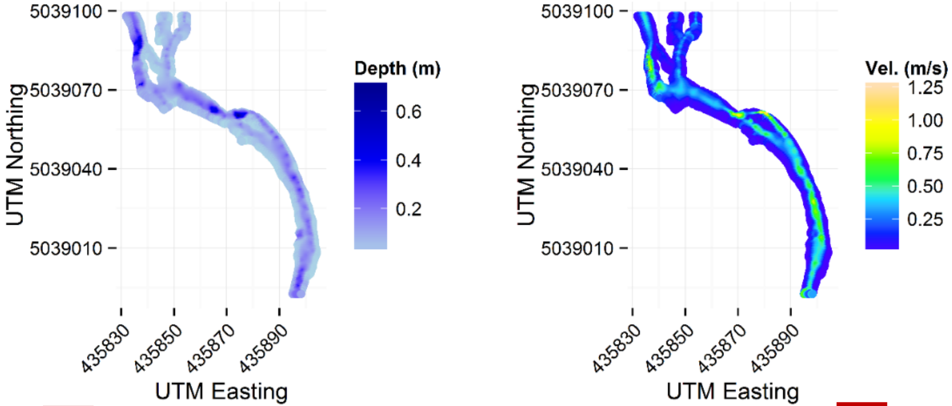




Using a Habitat Suitability Model

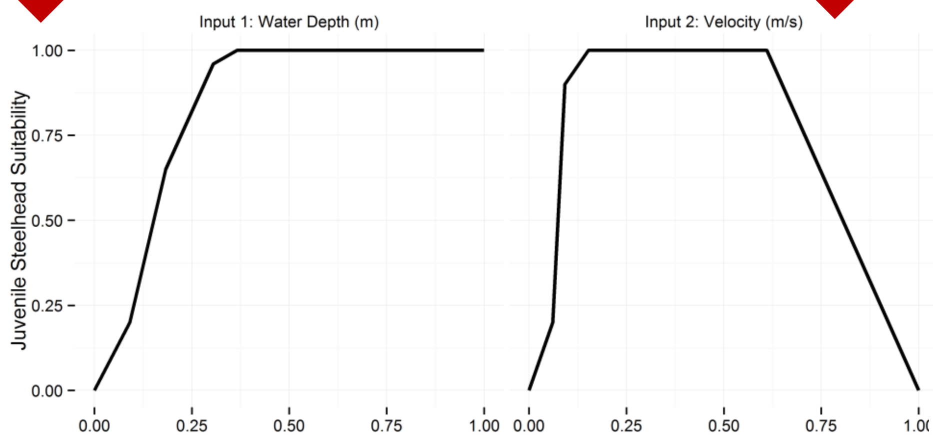
ABIOTIC INPUTS



- Data from topographic survey and hydraulic model

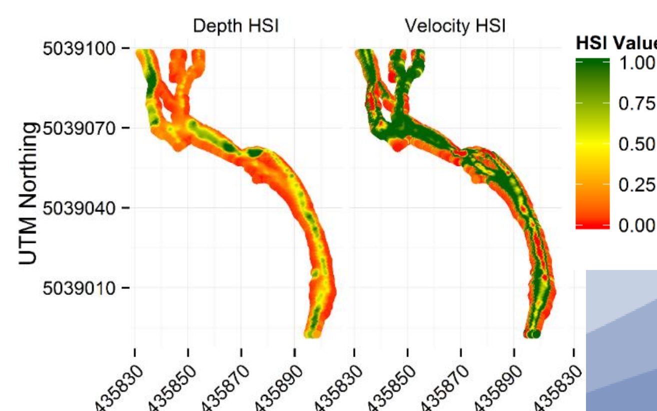
Apply curves to inputs

HSC PREFERENCE FUNCTIONS



- Preference curve (i.e., functions) from empirical study

Output ‘basic’ index

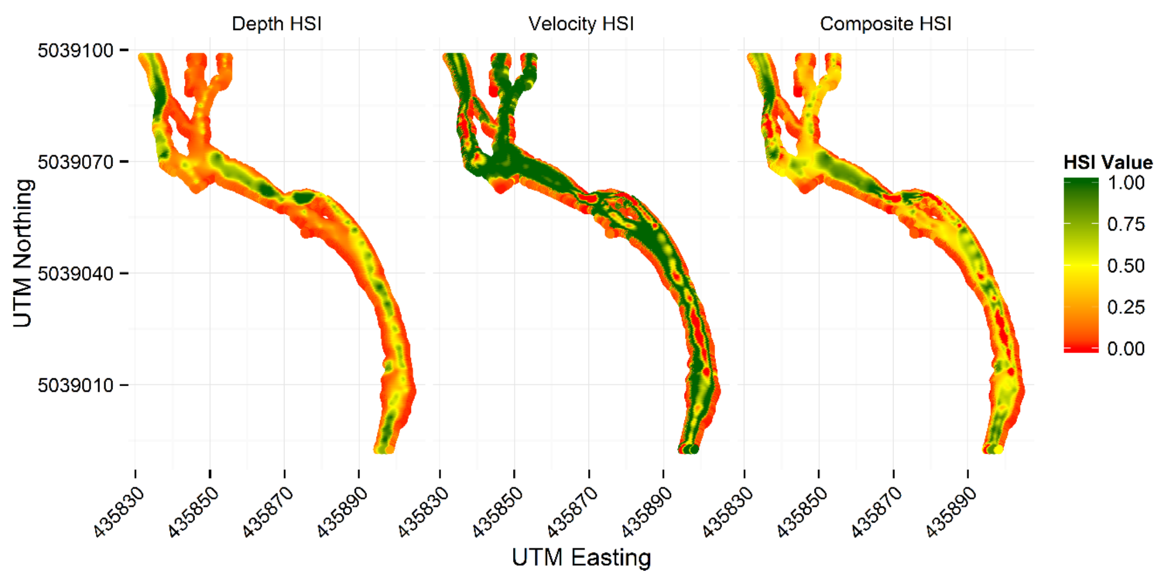


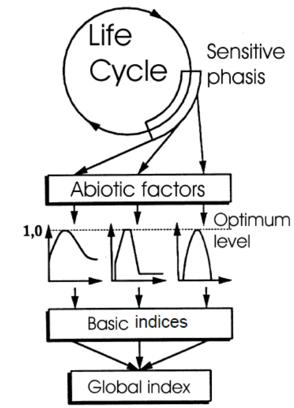
Convert to global habitat suitability index (HSI)

Combining basic indices into global, or composite, index

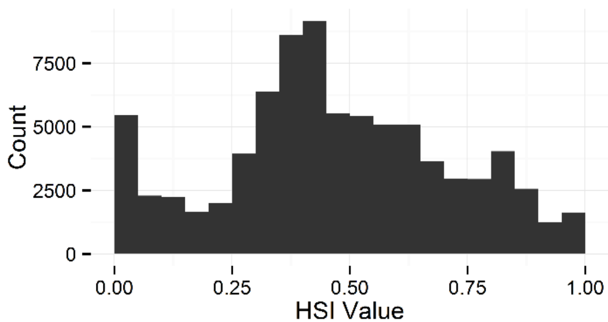
- Methods: product, minimum, maximum , geometric mean
- Geometric mean is most common:

$$Composite\ HSI = \sqrt{(DepthHSI\ * VelocityHSI)}$$





Building a classical fish *preferendum* model



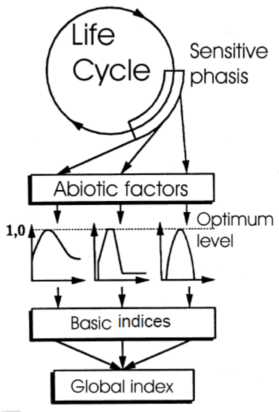
Habitat quality	Area (sq.m)
Poor	77.4
Low	248.0
Medium	339.1
High	165.9

HSI Modeling

What metrics can we derive from composite HSI?

- Weighted Usable Area (WUA)

$$WUA = \sum_{i=1}^{n} HSI_i * Area_i$$

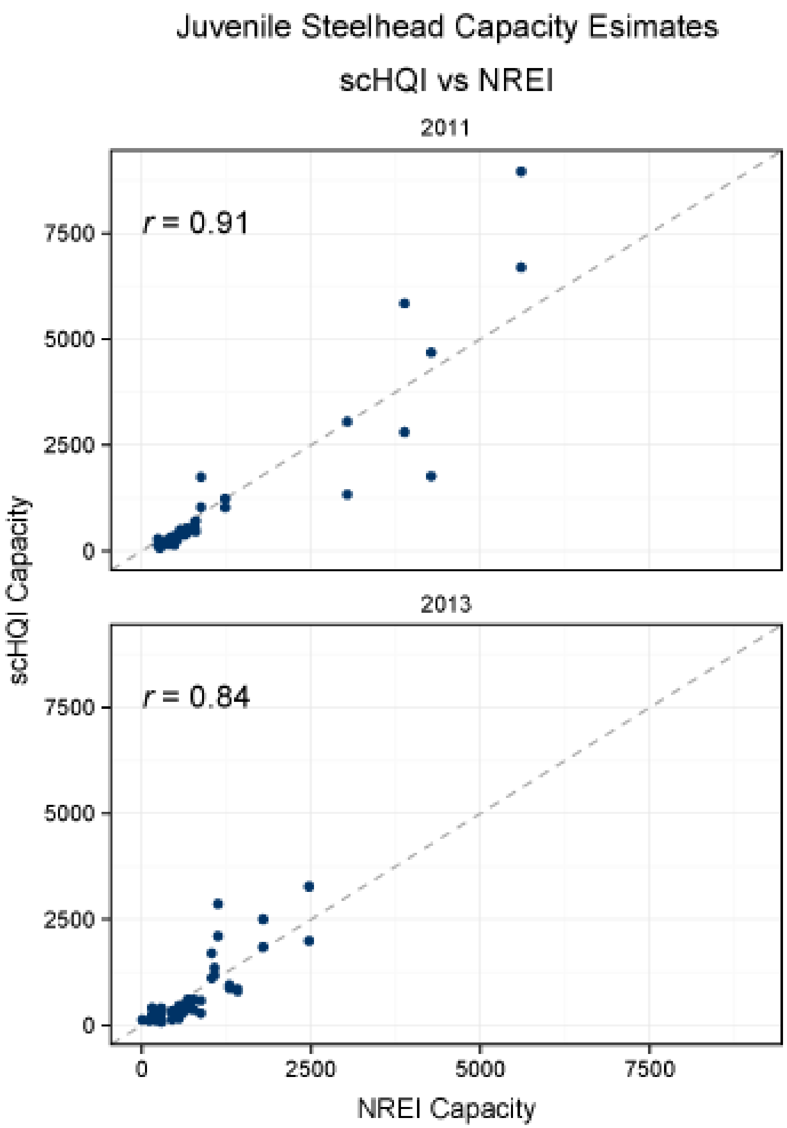


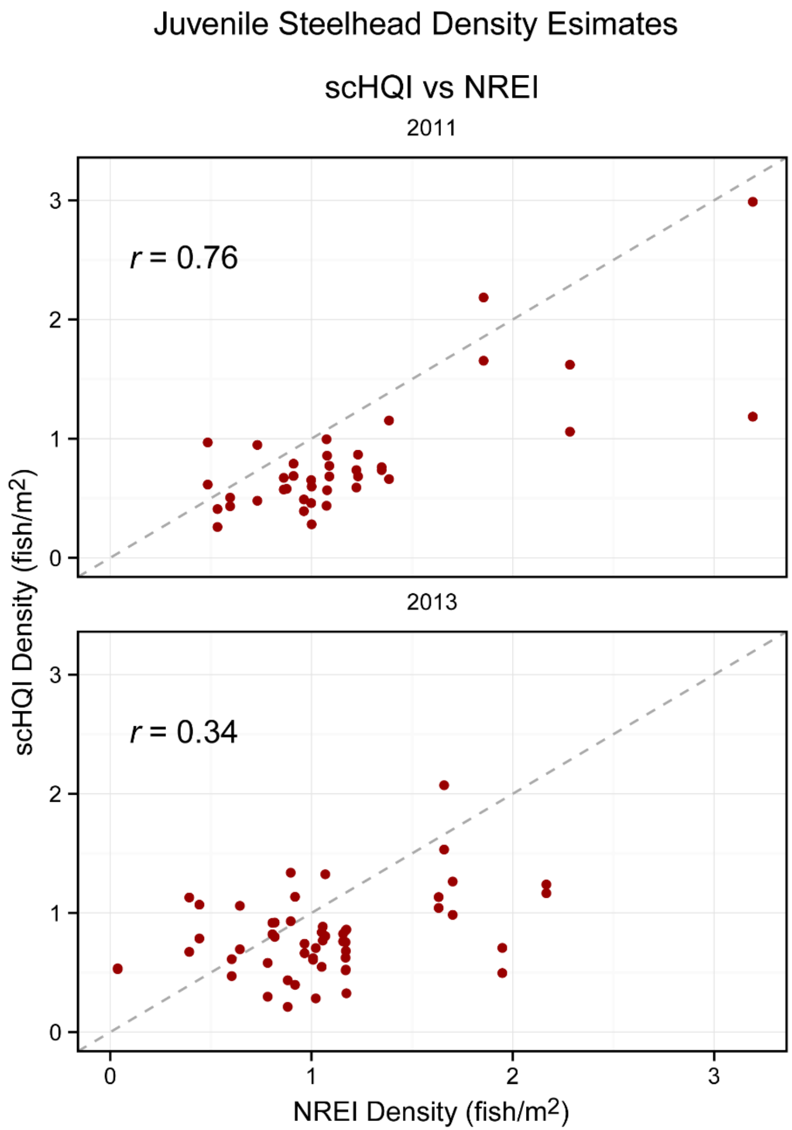
Building a classical fish *preferendum* model

- Weighted Usable Area : Wetted Area
  - Normalized, easier to compare among sites, basins
- Capacity Estimates
  - Juveniles:
    - WUA / Juvenile territory size
  - Redd capacity:
    - WUA / Redd area

HSI Modeling: Capacity & Density Estimates

How do estimates compare with other approaches?

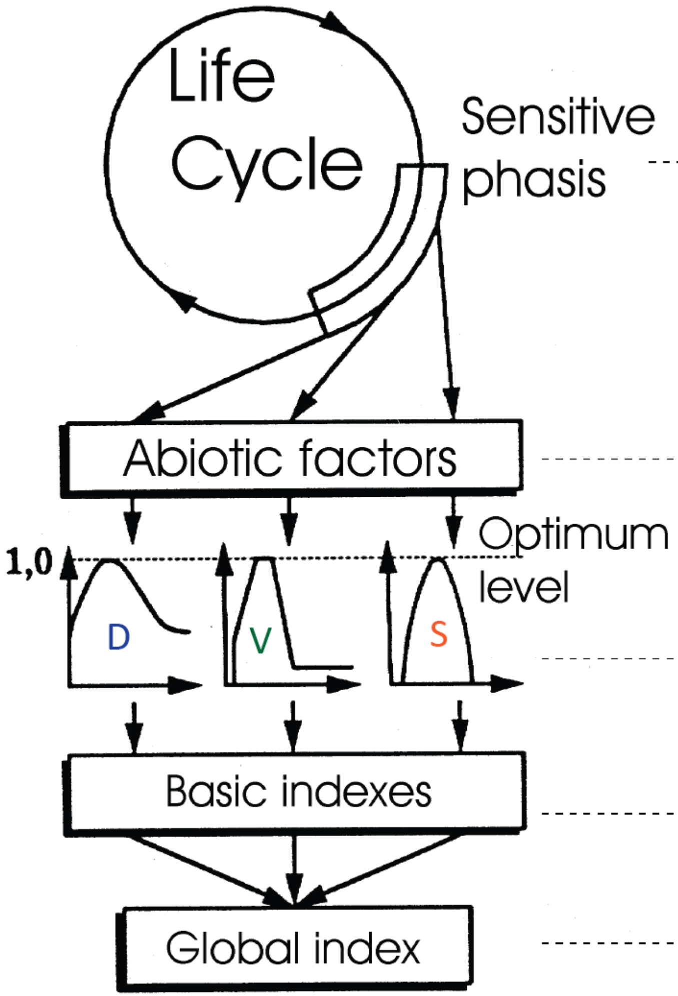




WEAKNESSES OF HSI BASED MODELS

- Habitat requirements described by precise functions (even though observations are rather imprecise)
- Independence of habitat parameters is assumed
- New parameters difficult to incorporate (i.e. other then velocity, depth substrate)
- Lots of field data needed (i.e. HSC from HUC & HAC)
- HSC are site specific….

HSI Model Structure:



CHaMP Implementation Example:

Spawning

Water Depth (D)	*Hydraulic Model Output*
Water Velocity (V)	*Hydraulic Model Output*
Substrate (S)	*Crew Estimates*

Suitability Curves — *From Literature*

Intermediate Index Scores for Each Input

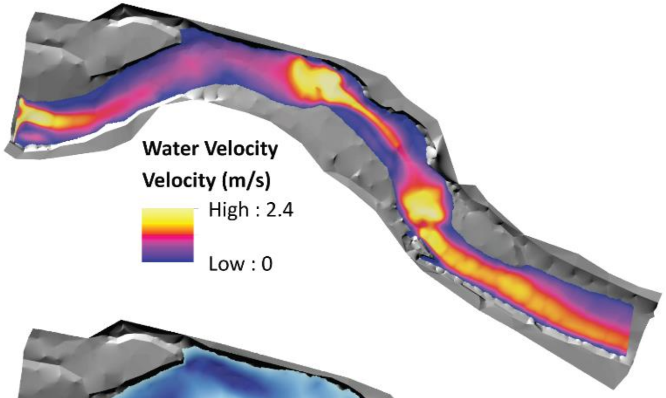
HSI Value — $HSI_i = {ID_i}^a * {IV_i}^b * {IS_i}^c$ *with* $a + b + c = 1.0$

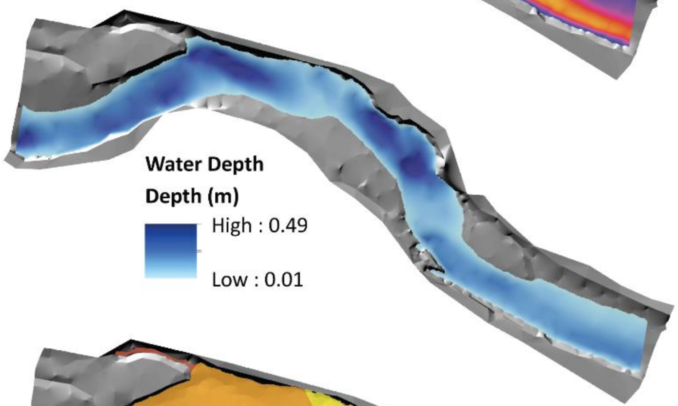
where: ID, IV, IS = basic index scores for water depth (D), water velocity (V), and substrate (S)
a, b, c = weights powering the basic indices and influencing the relative ecoloical importance given to each basic index in the model

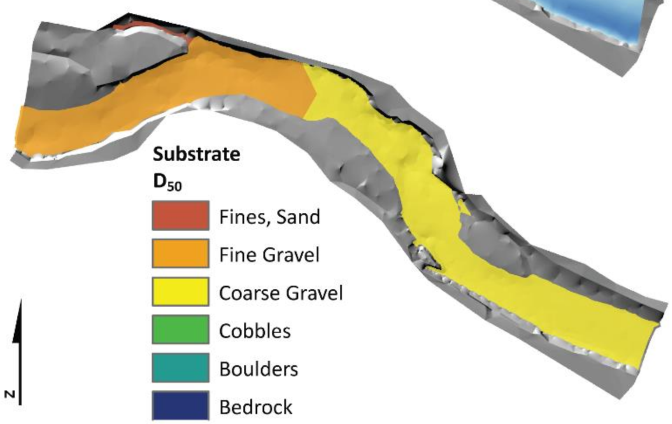
Entiat River, Entiat Basin, WA

ENT00001-2A9, Visit 1054, 2012

HSI Model Inputs

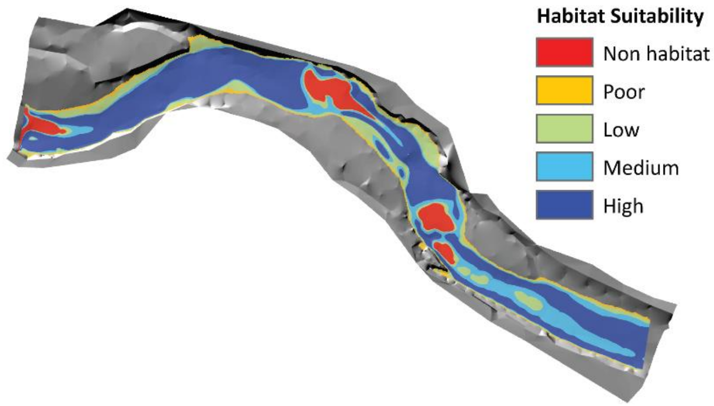


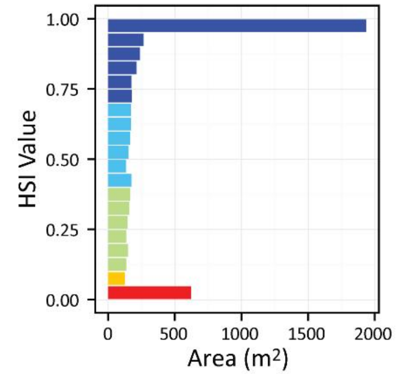




HSI Model Outputs

Steelhead Juvenile Habitat Suitability

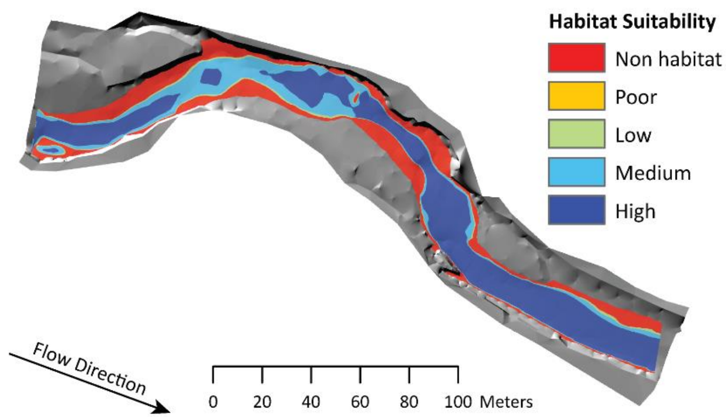


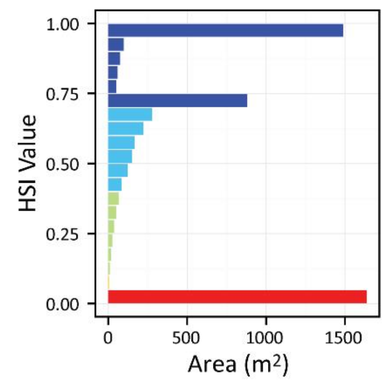


WUA: ***3,585 m²***

Normalized WUA: ***0.64***

Steelhead Spawner Habitat Suitability





WUA: ***3,020 m²***

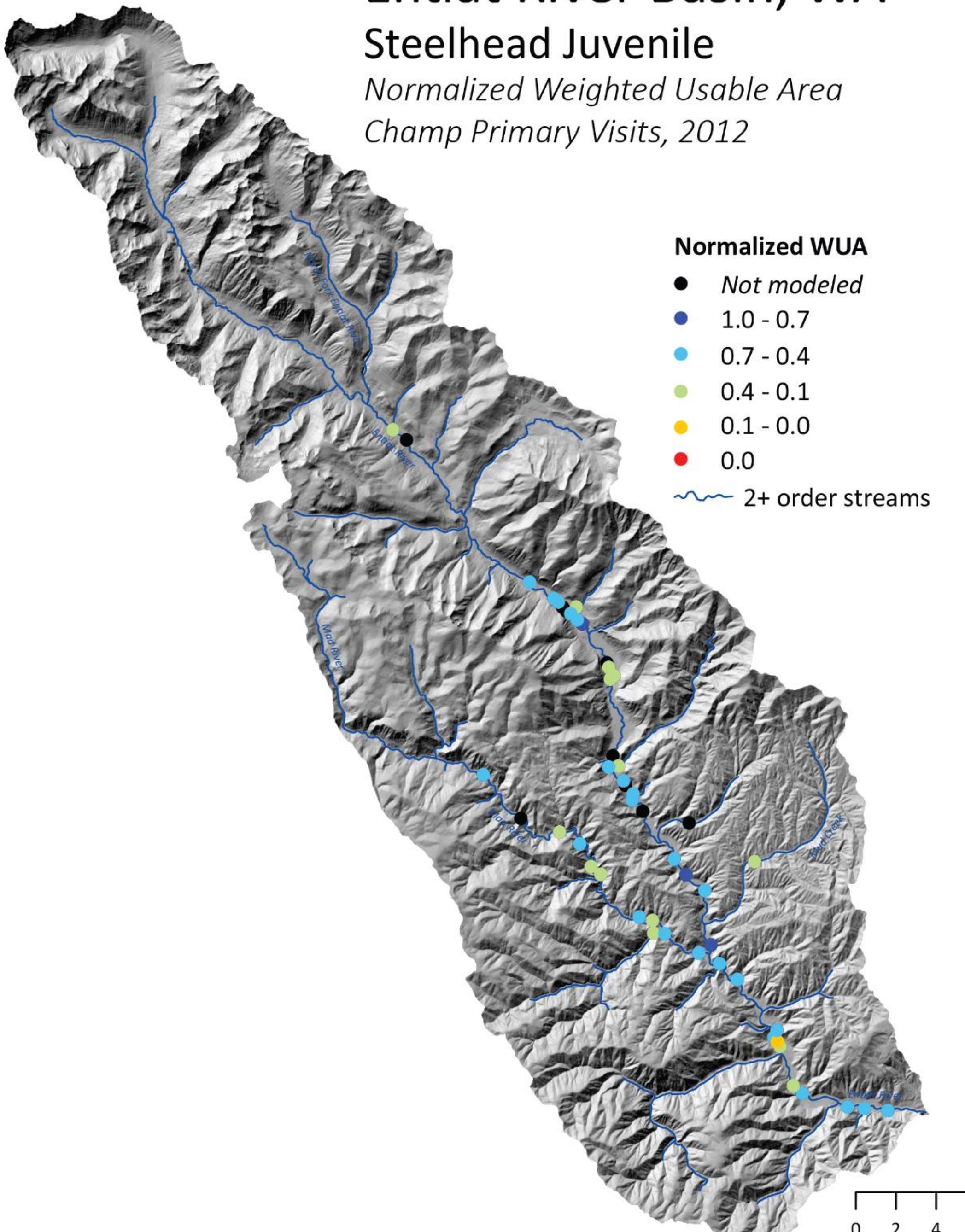
Normalized WUA: ***0.55***

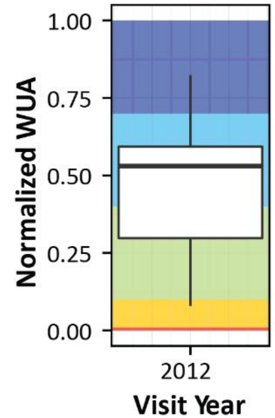
Entiat River Basin, WA

Steelhead Juvenile

Normalized Weighted Usable Area

Champ Primary Visits, 2012



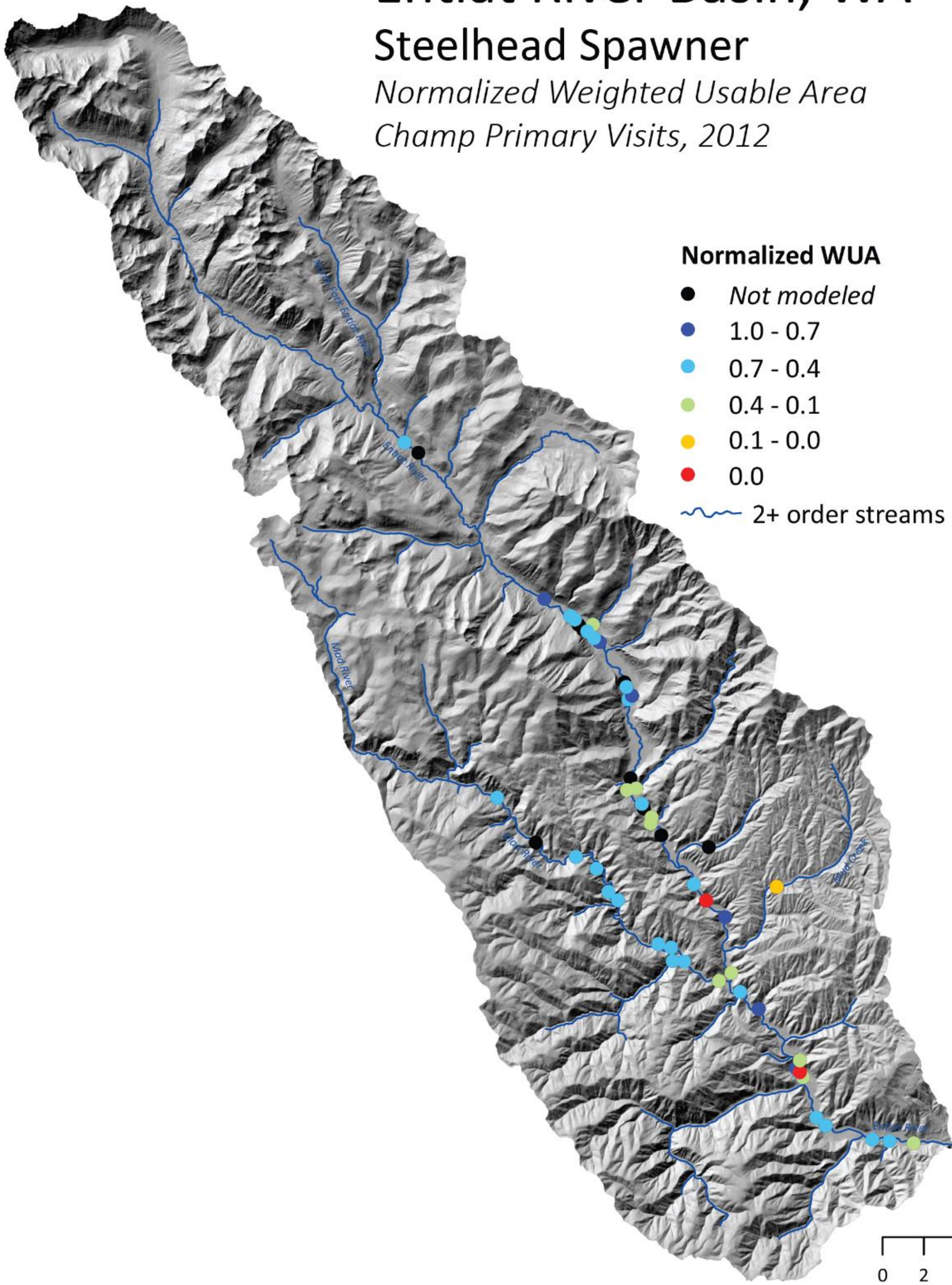


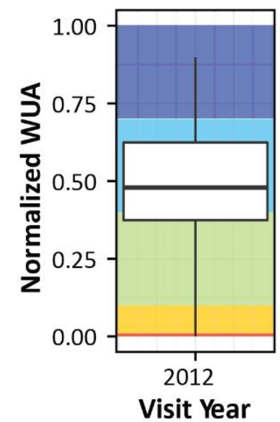
Entiat River Basin, WA

Steelhead Spawner

Normalized Weighted Usable Area

Champ Primary Visits, 2012

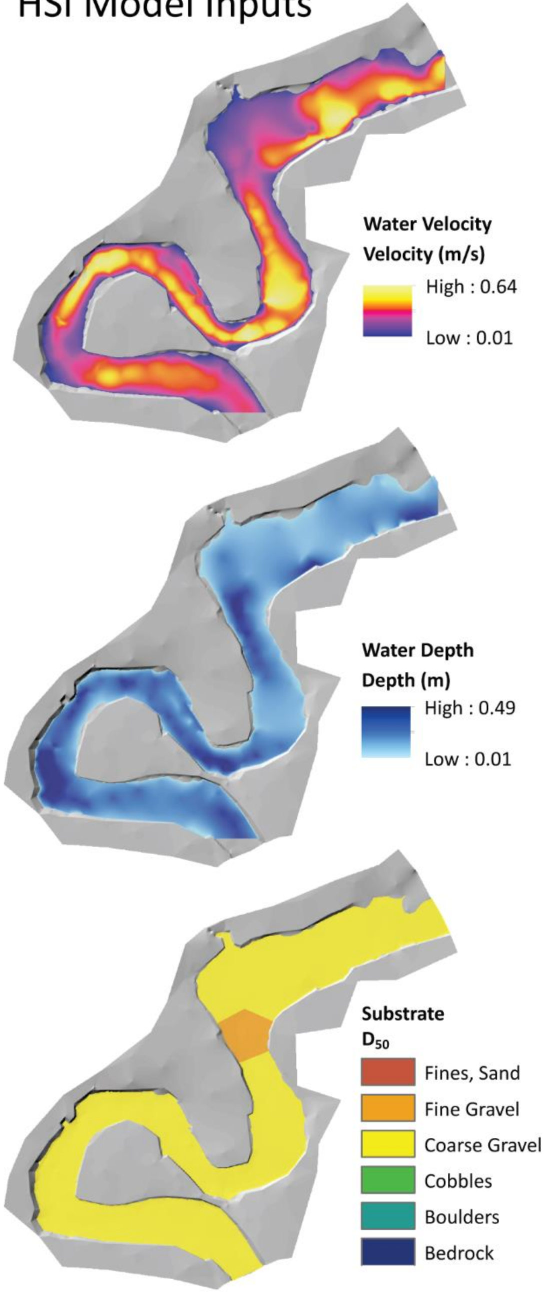




Big Springs, Lemhi Basin, ID

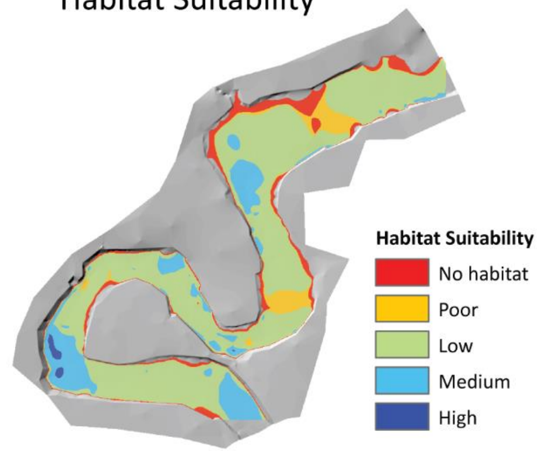
LEM00001-Big0Springs6, Visit 551, 2012

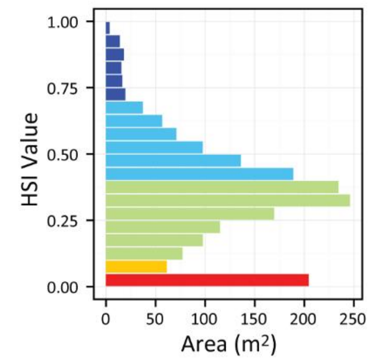
HSI Model Inputs



HSI Model Outputs

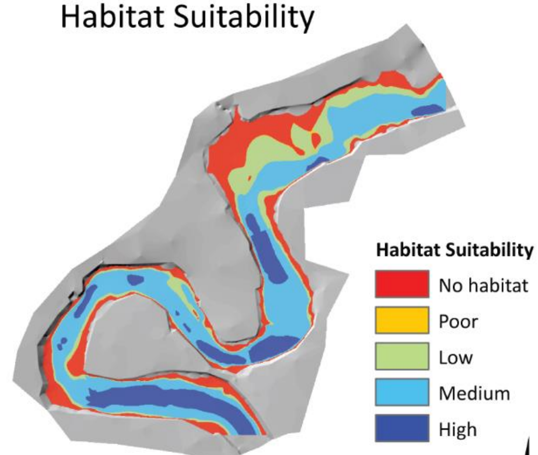
Chinook Juvenile Habitat Suitability

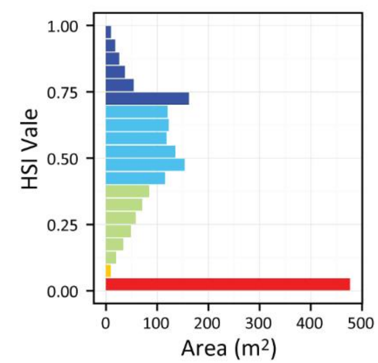




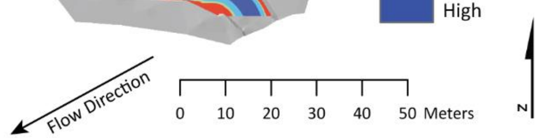
WUA: ***487 m²***
Normalized WUA: ***0.26***

Chinook Spawner Habitat Suitability





WUA: ***747 m²***
Normalized WUA: ***0.40***

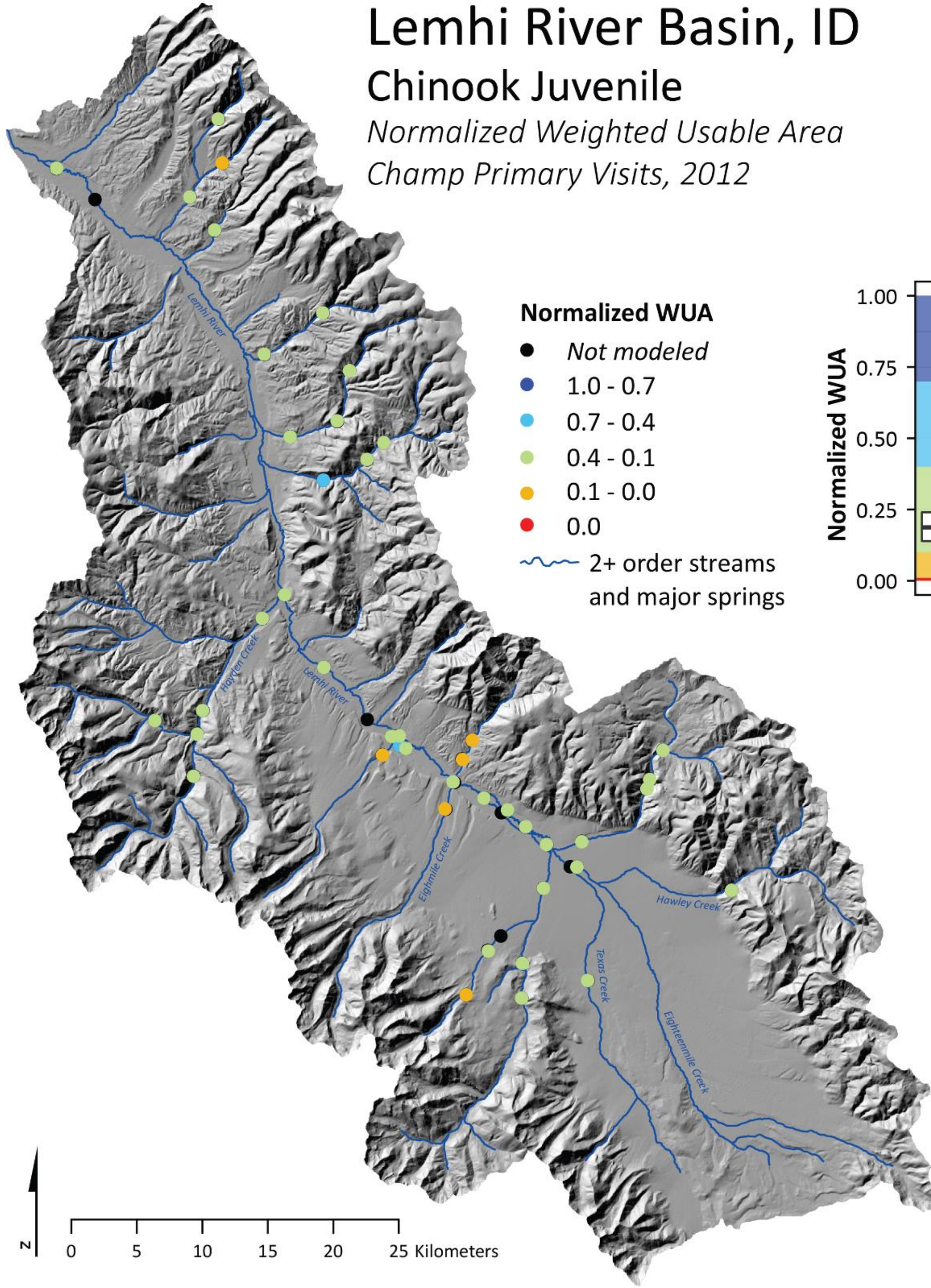


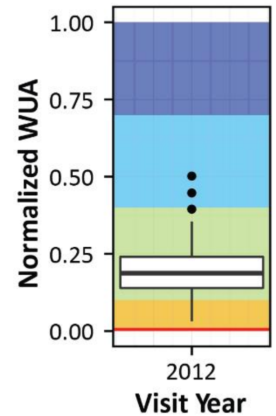
Lemhi River Basin, ID

Chinook Juvenile

Normalized Weighted Usable Area

Champ Primary Visits, 2012



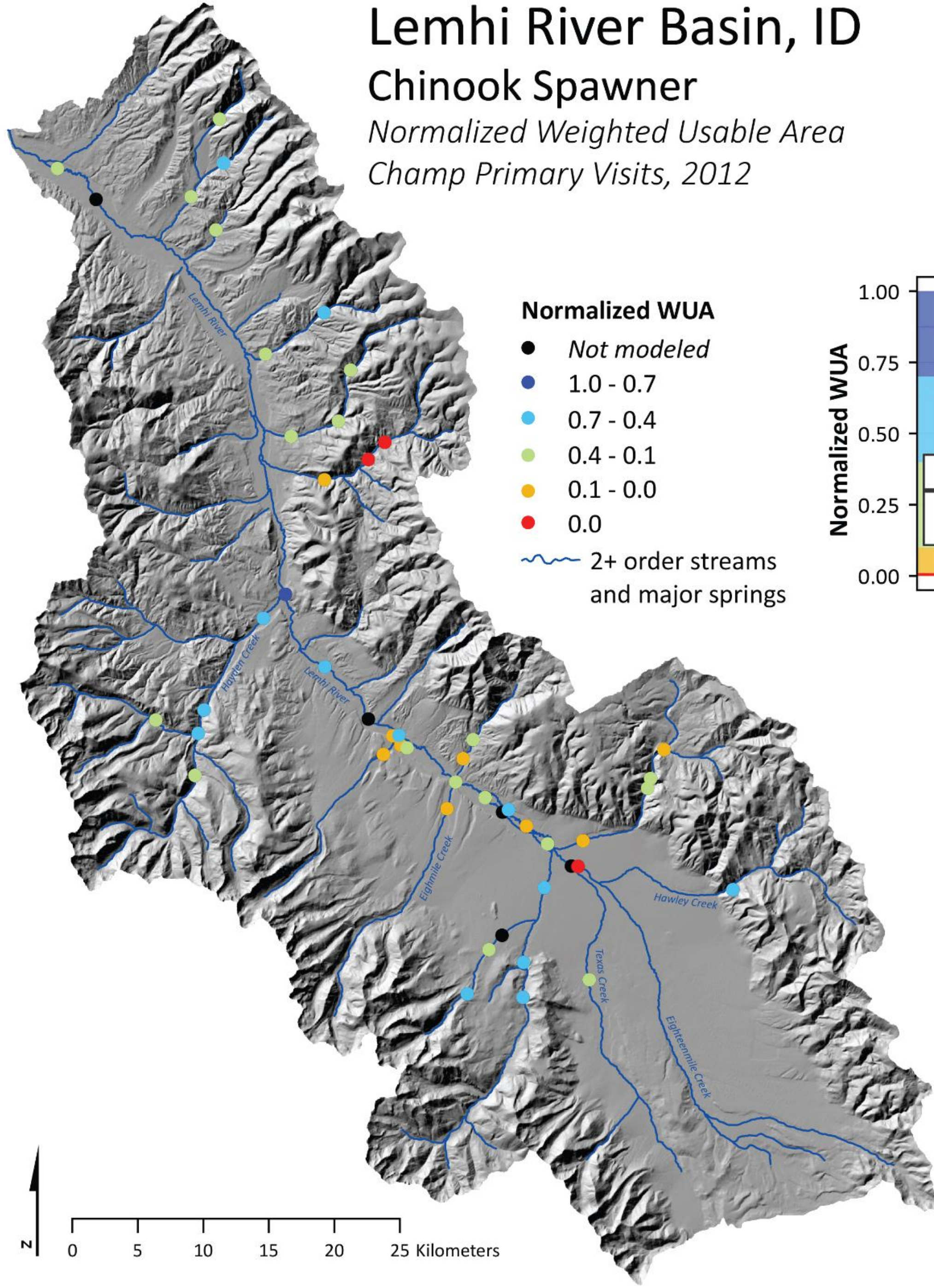


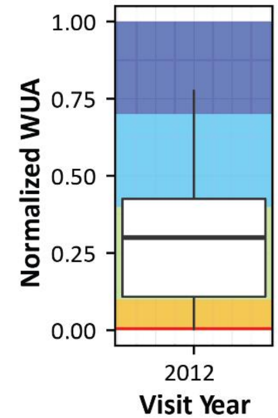
Lemhi River Basin, ID

Chinook Spawner

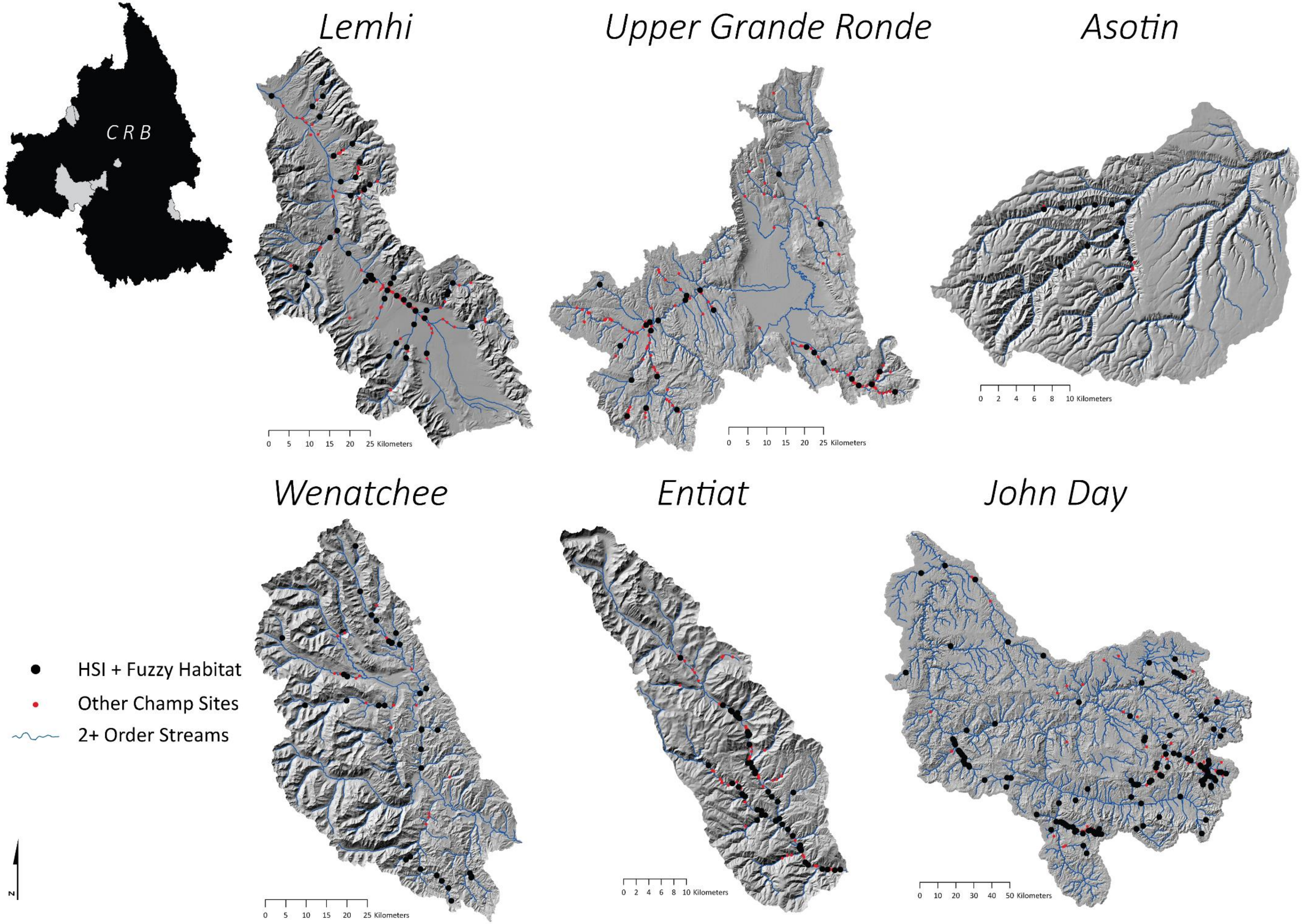
Normalized Weighted Usable Area

Champ Primary Visits, 2012

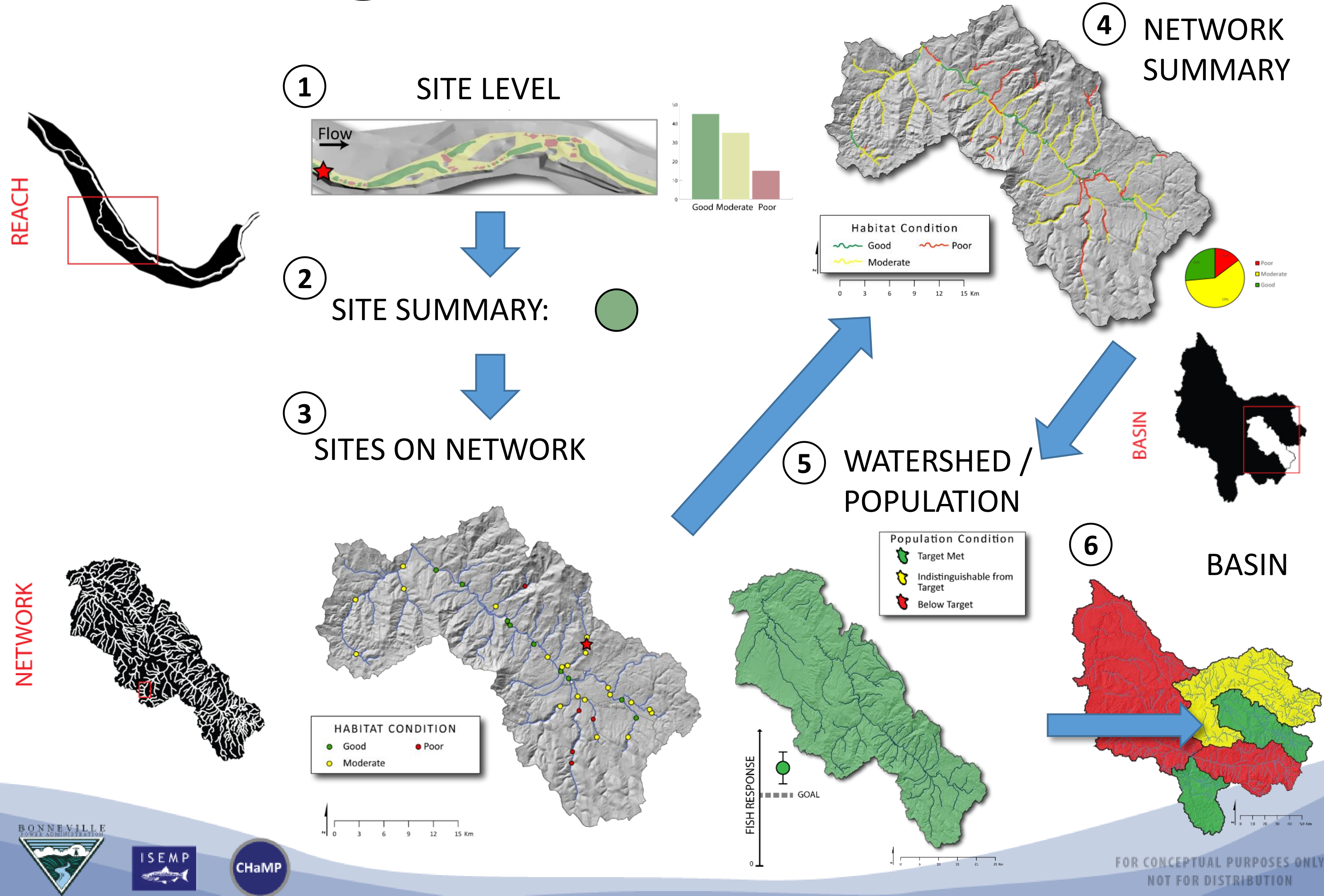




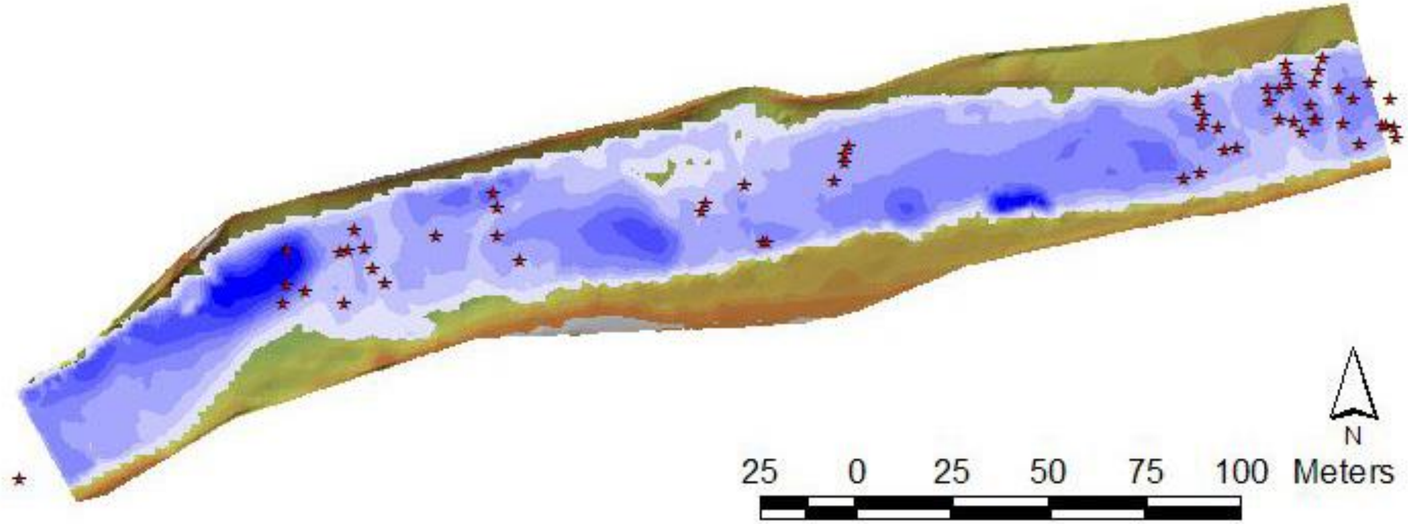
Champ HSI and Fuzzy Habitat Model Runs

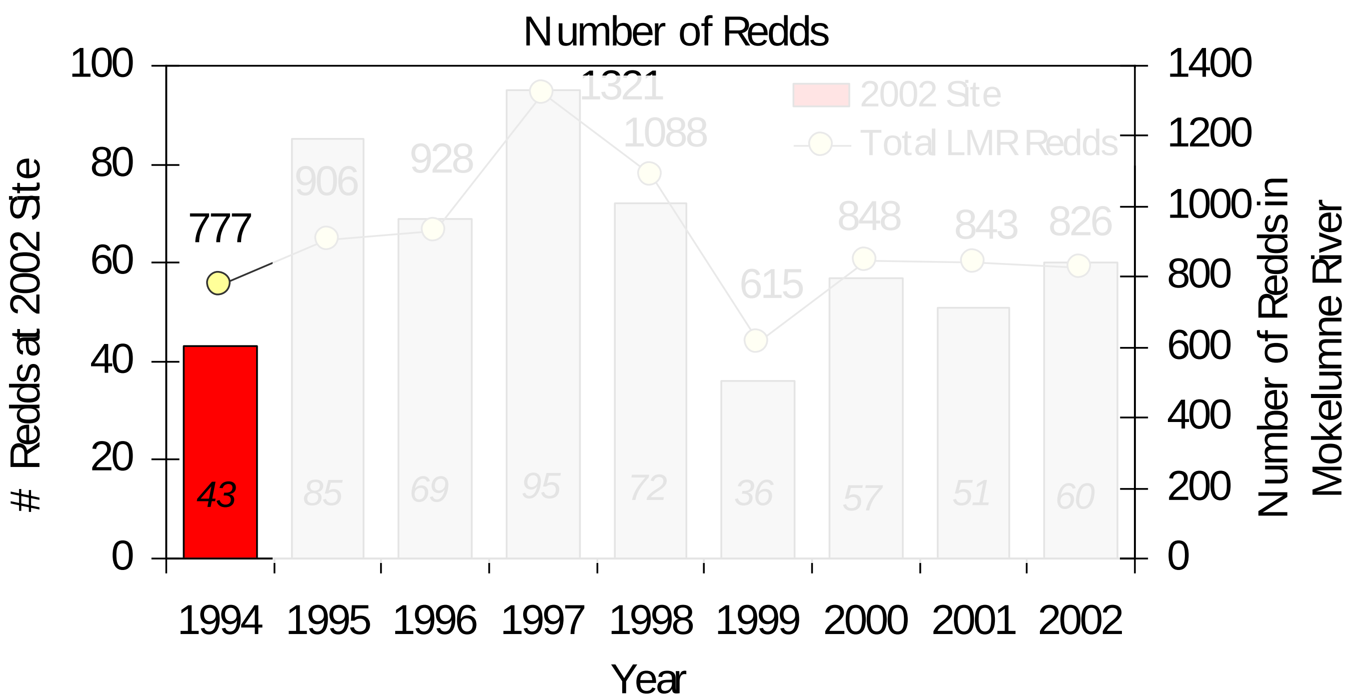


SO WE'RE @ 3… WORKING ON 4 & 5



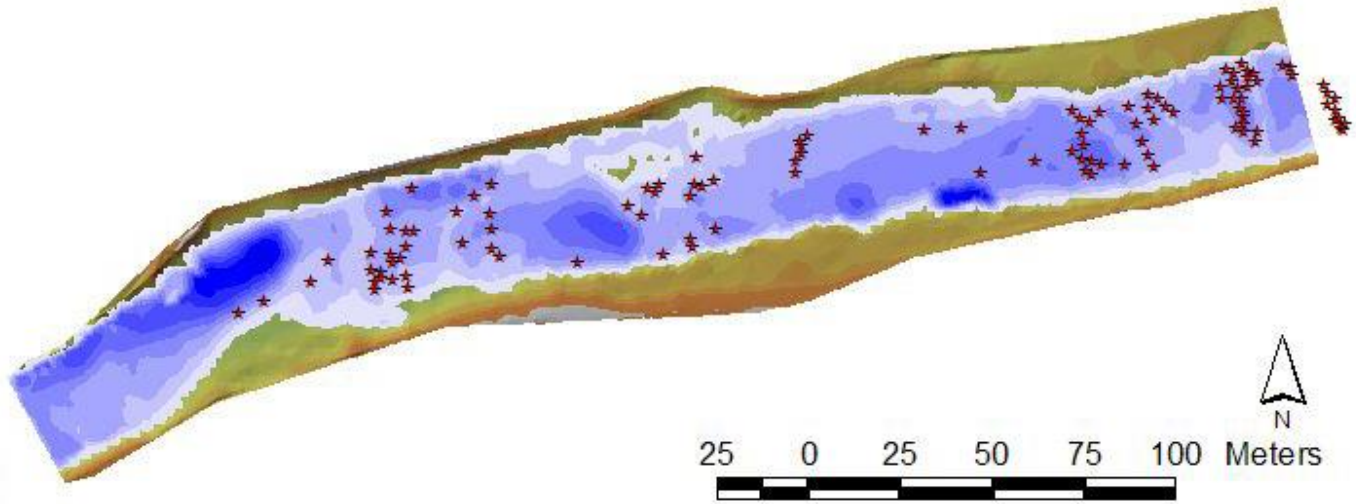
ANNUAL REDD SURVEY

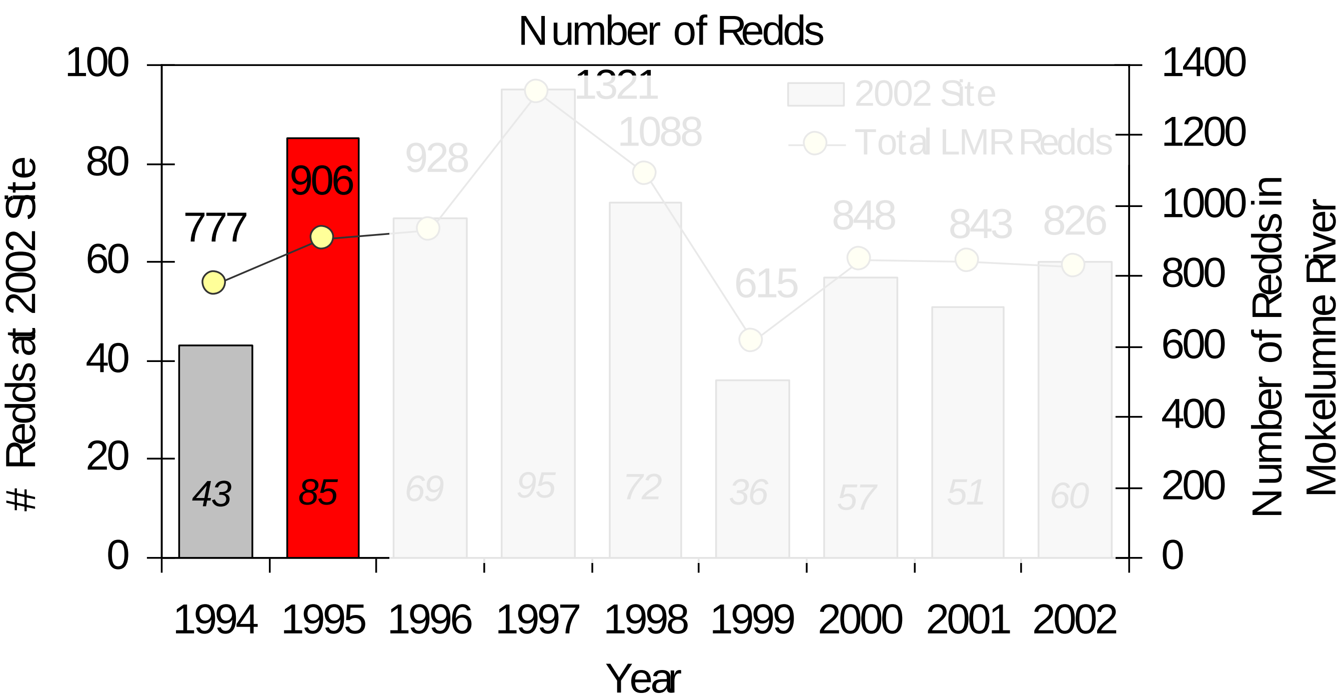




1994

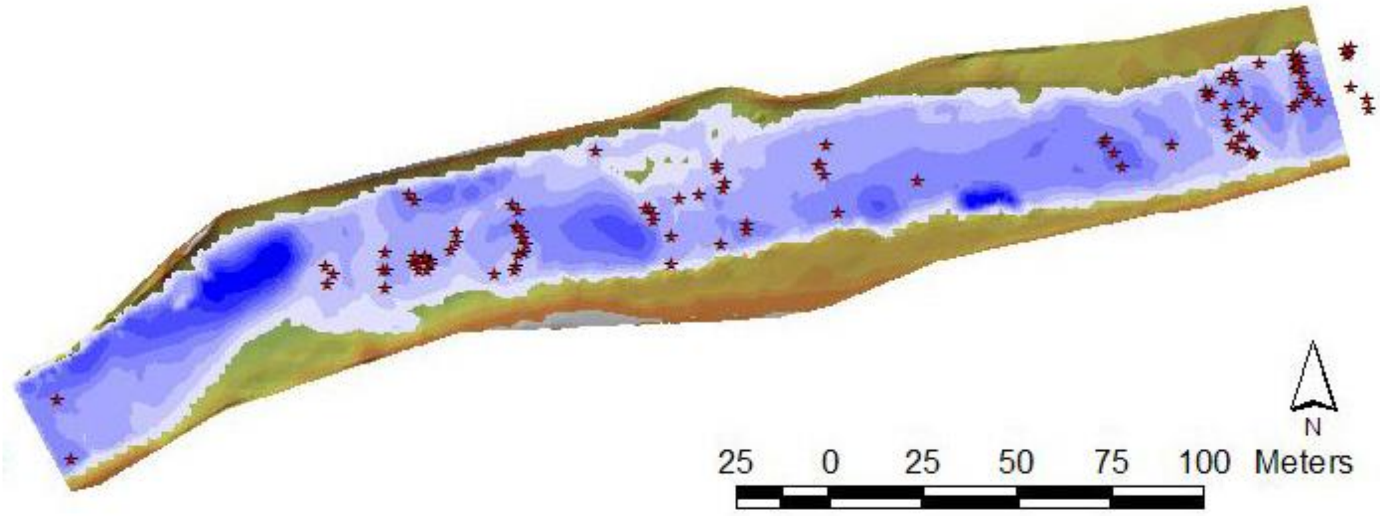
ANNUAL REDD SURVEY

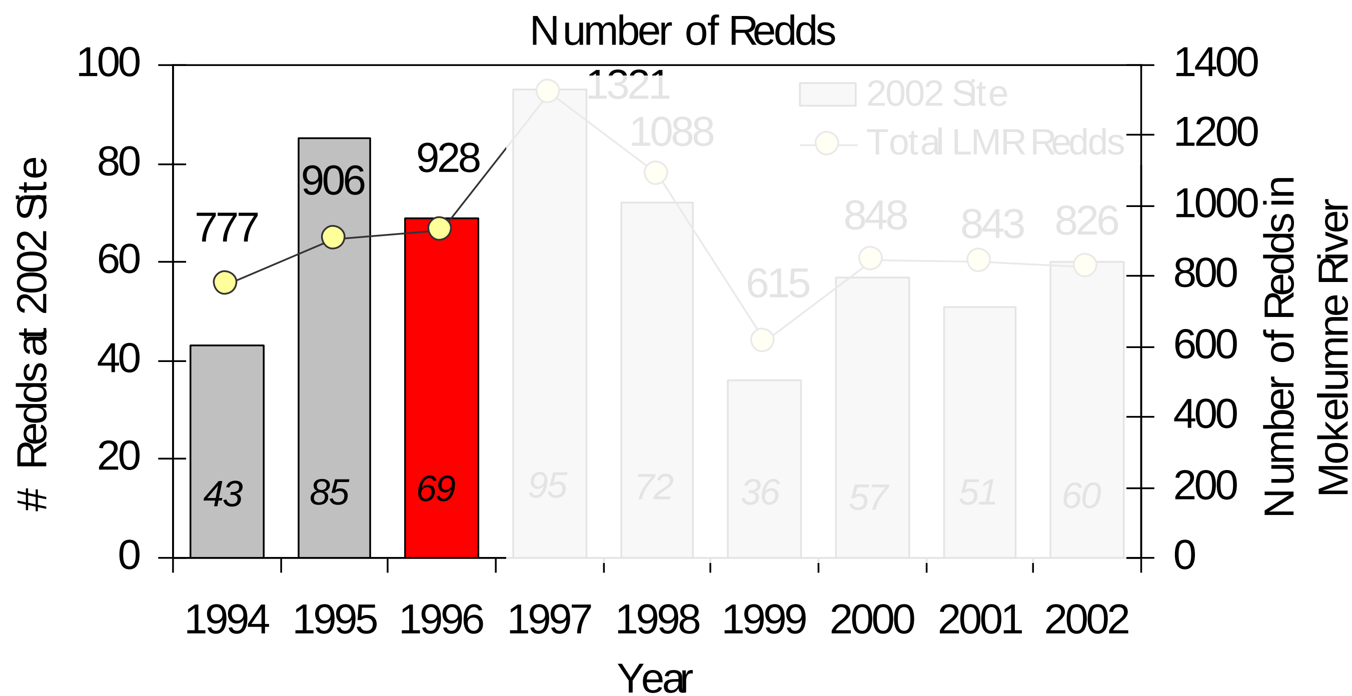




1995

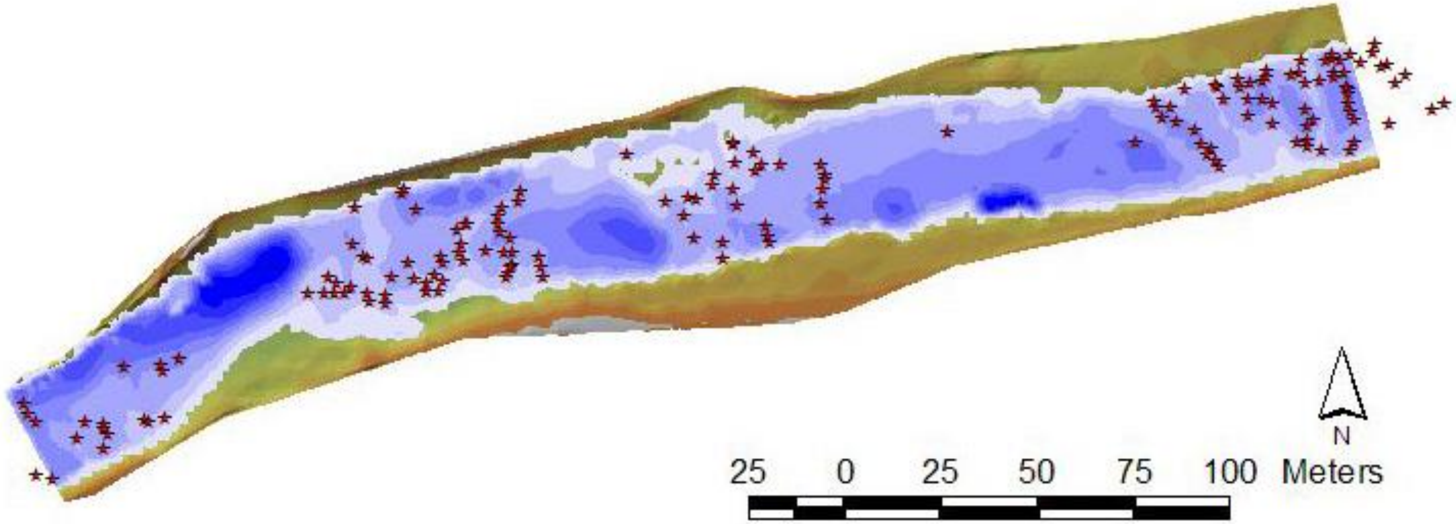
ANNUAL REDD SURVEY

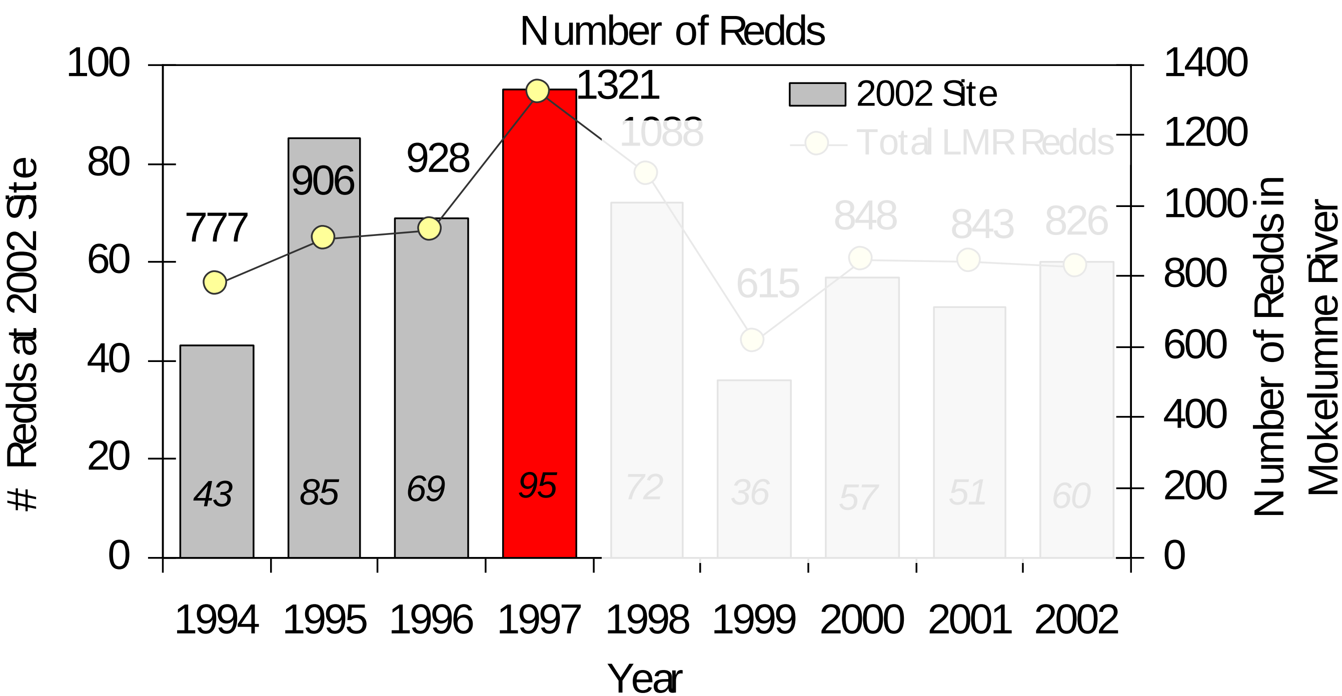




1996

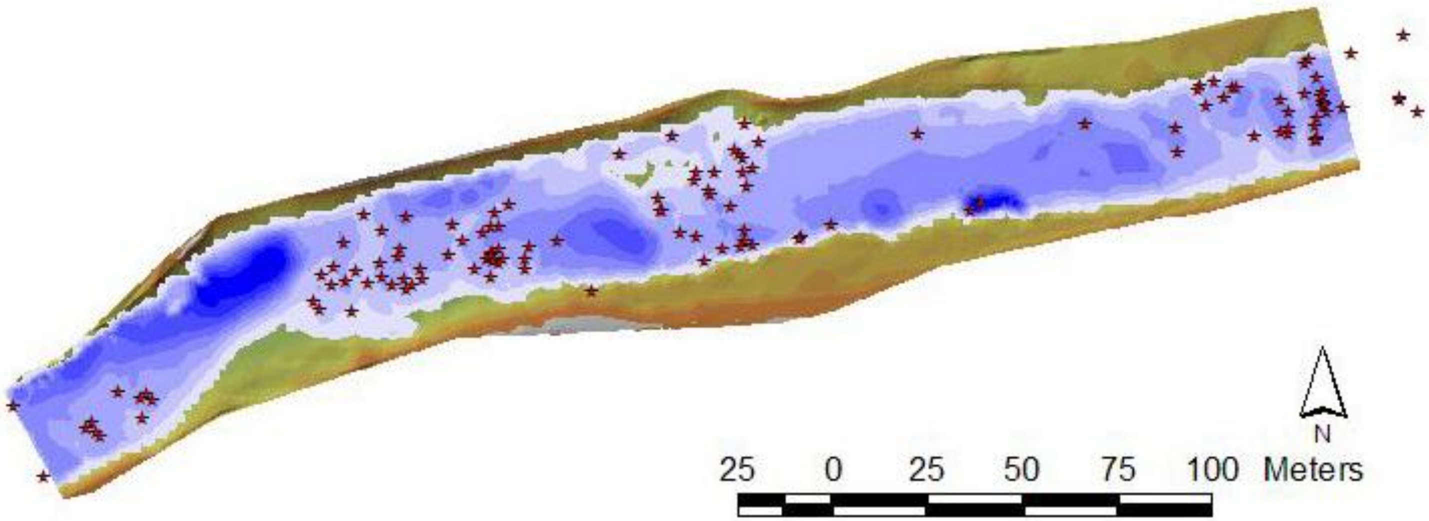
ANNUAL REDD SURVEY

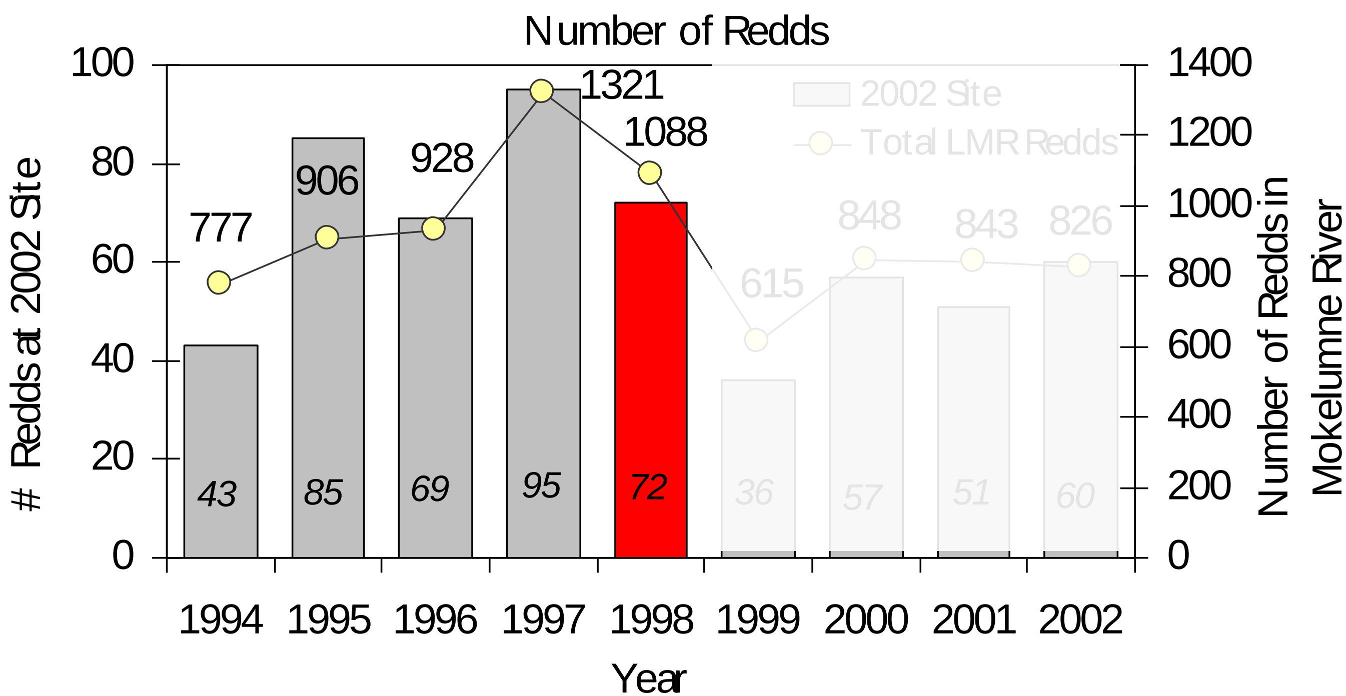




1997

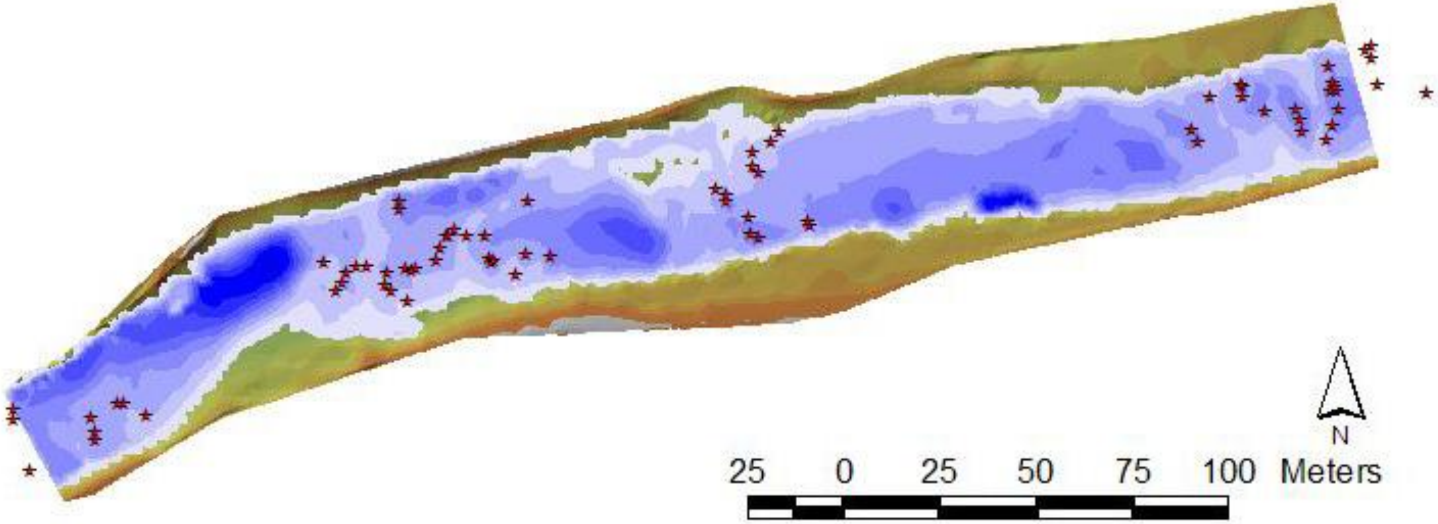
ANNUAL REDD SURVEY

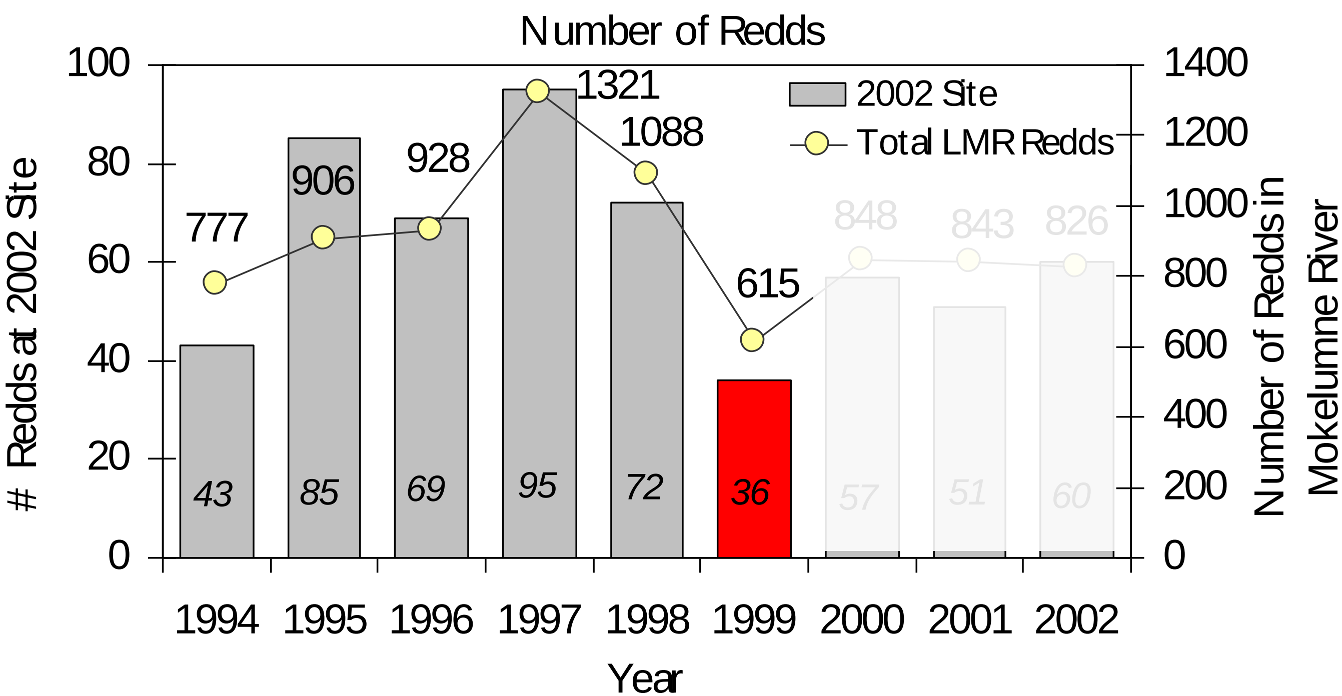




1998

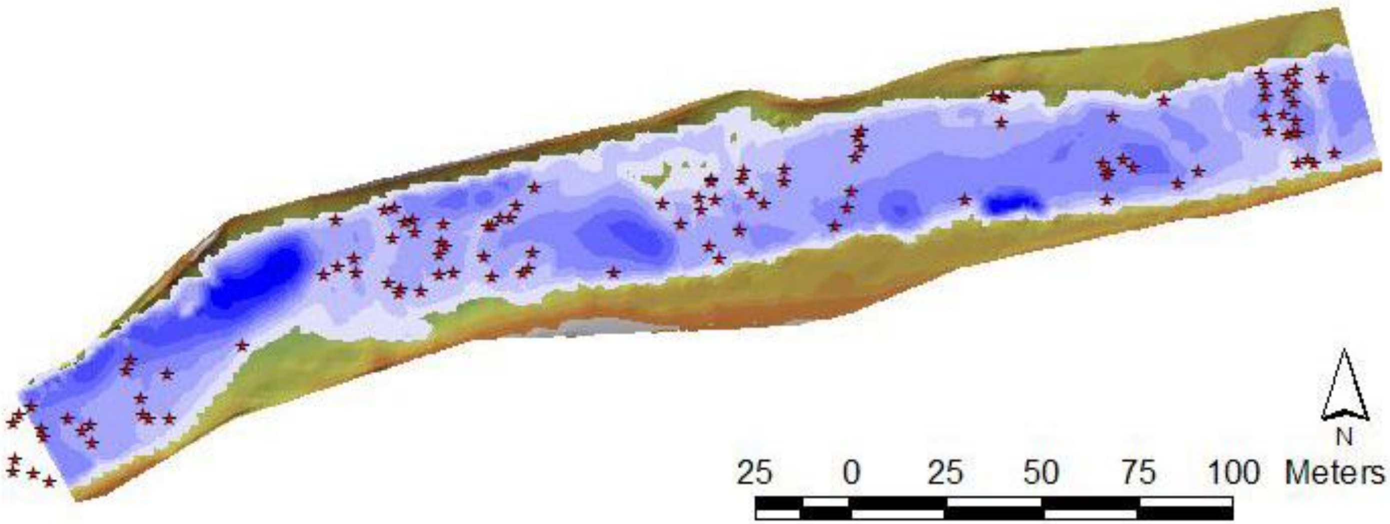
ANNUAL REDD SURVEY

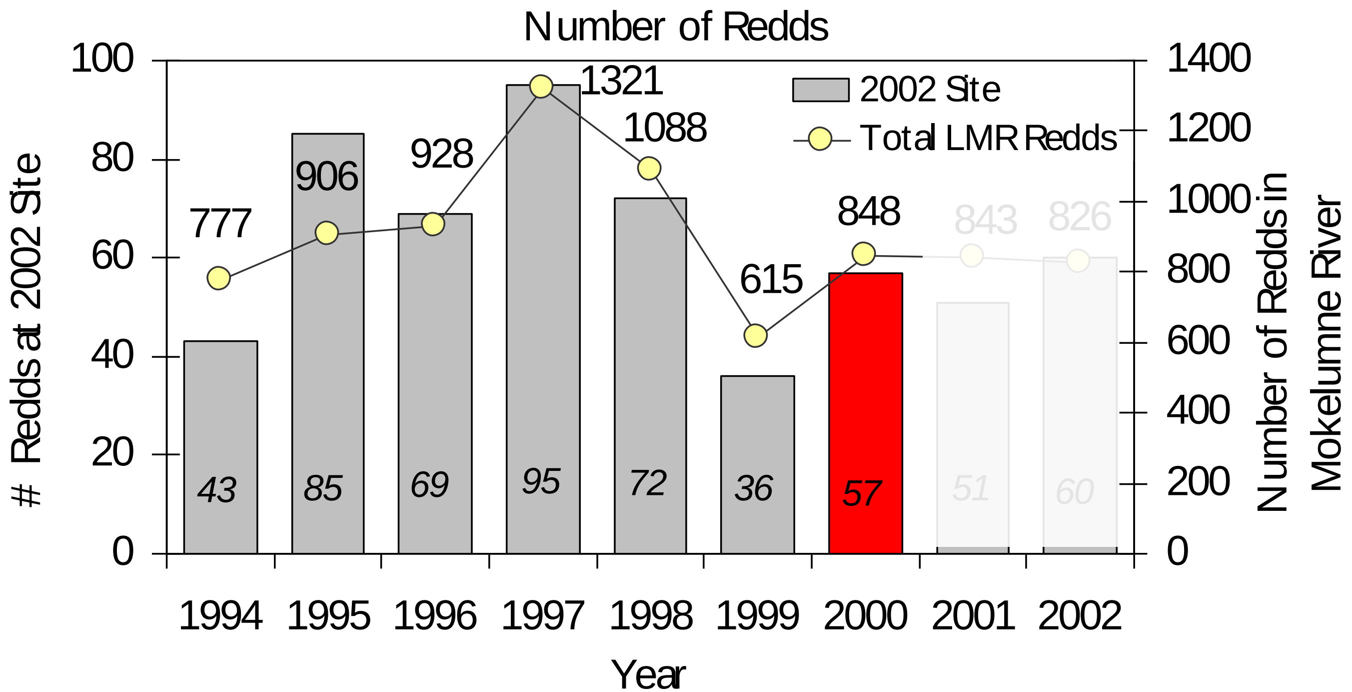




1999

ANNUAL REDD SURVEY

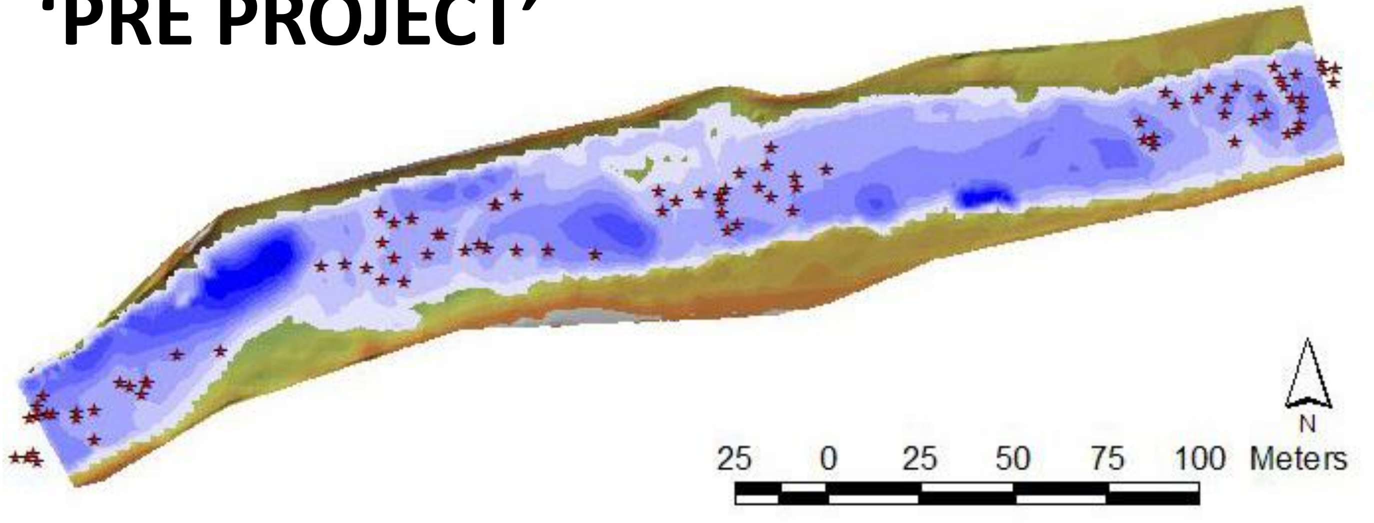


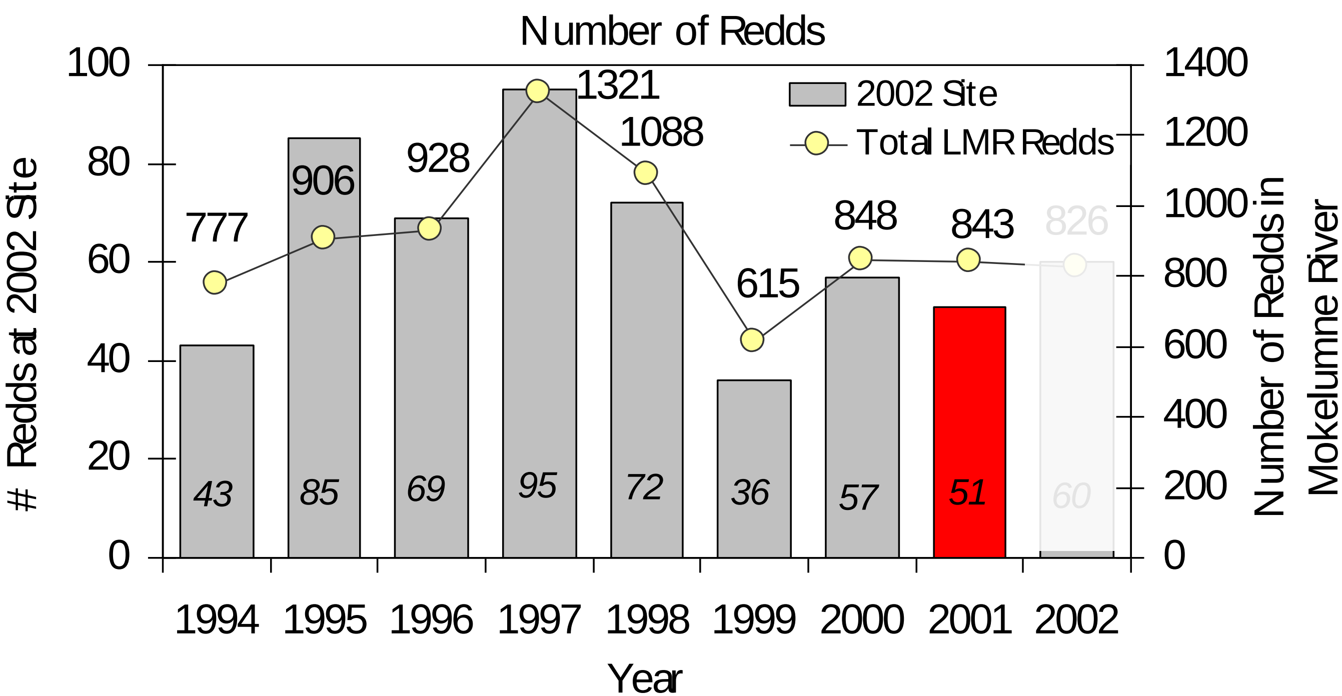


2000

ANNUAL REDD SURVEY

‘PRE PROJECT’

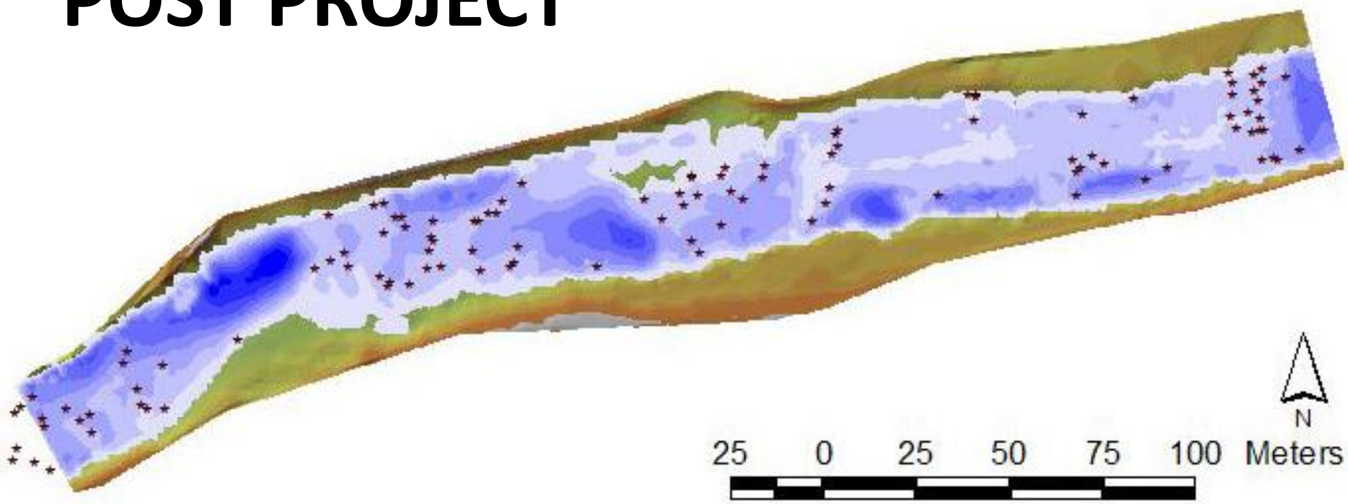


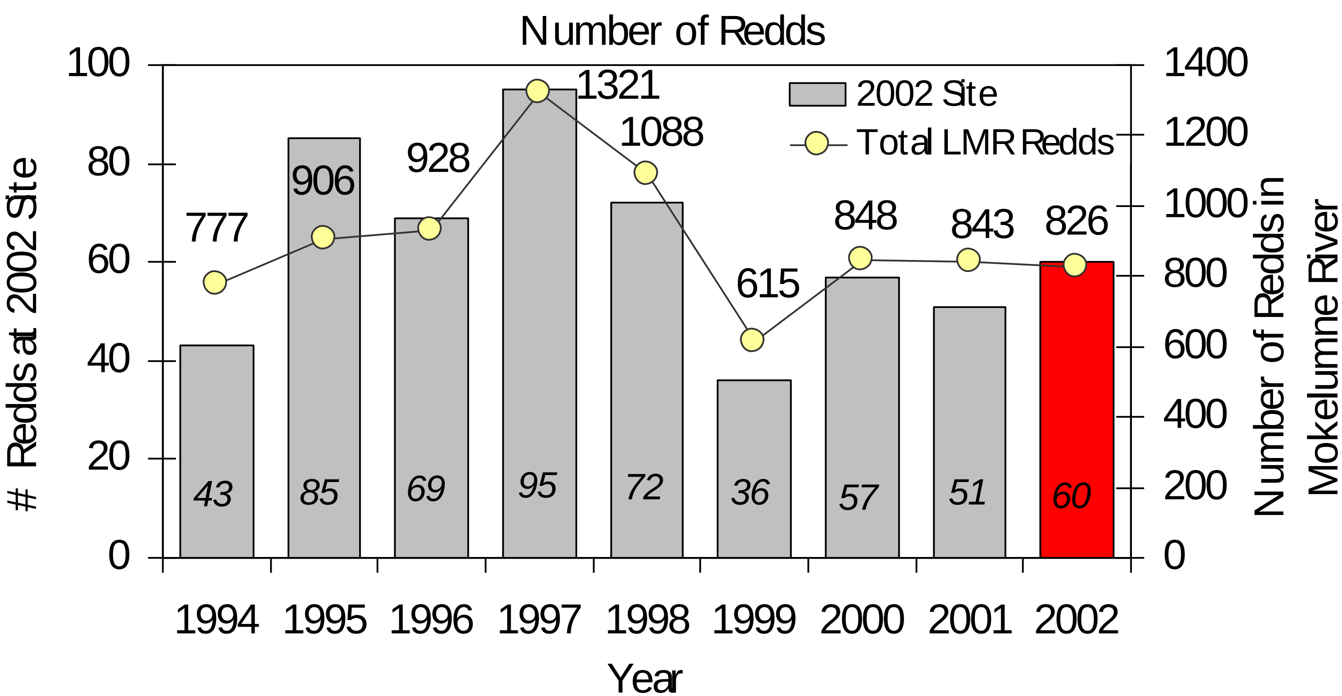


2001

ANNUAL REDD SURVEY

'POST PROJECT'





2002

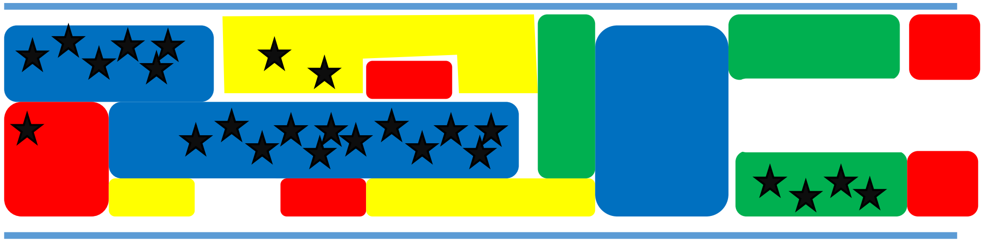
ELECTIVITY INDEX (EI) DEFINITION

Utilization-to-Available Ratio by habitat quality class

$$\%U_i = 100 \times \frac{\#\cdot redds_i}{total \cdot \#\cdot redds}$$

$$\%A_i = 100 \times \frac{bed\, area_i}{total \cdot area} \qquad EI = \frac{\%U_i}{\%A_i}$$

Example



EI > 1 indicates preference of habitat class I

EI< 1 indicates tolerance of habitat class i

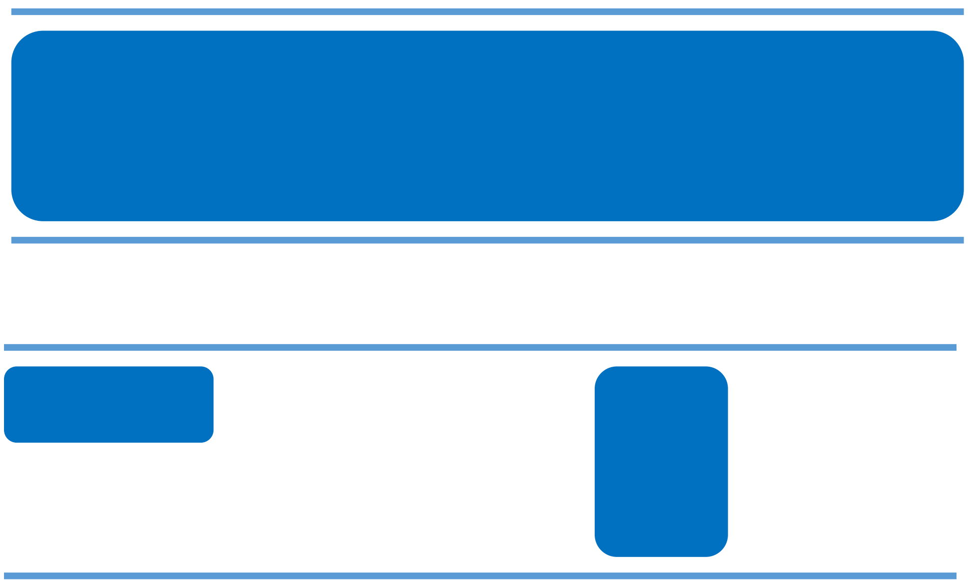
EI = 0 indicates no habitat of habitat class i

Habitat	# Stars	% stars	% area	EI
blue	18	72	35	2.06
green	4	16	15	1.07
yellow	2	8	20	0.40
red	1	4	15	0.27
white	0	0	15	0.00

From Pasternack (2011)

BIOVERIFICATION PERFORMANCE INDICATOR 1

- A pairing of a 2D model with HSCs must yield one or more habitat classes with EI>1 and one or more with EI<1. This indicates that it is predicting both preference and tolerance.
- Must take a risk to have specificity!



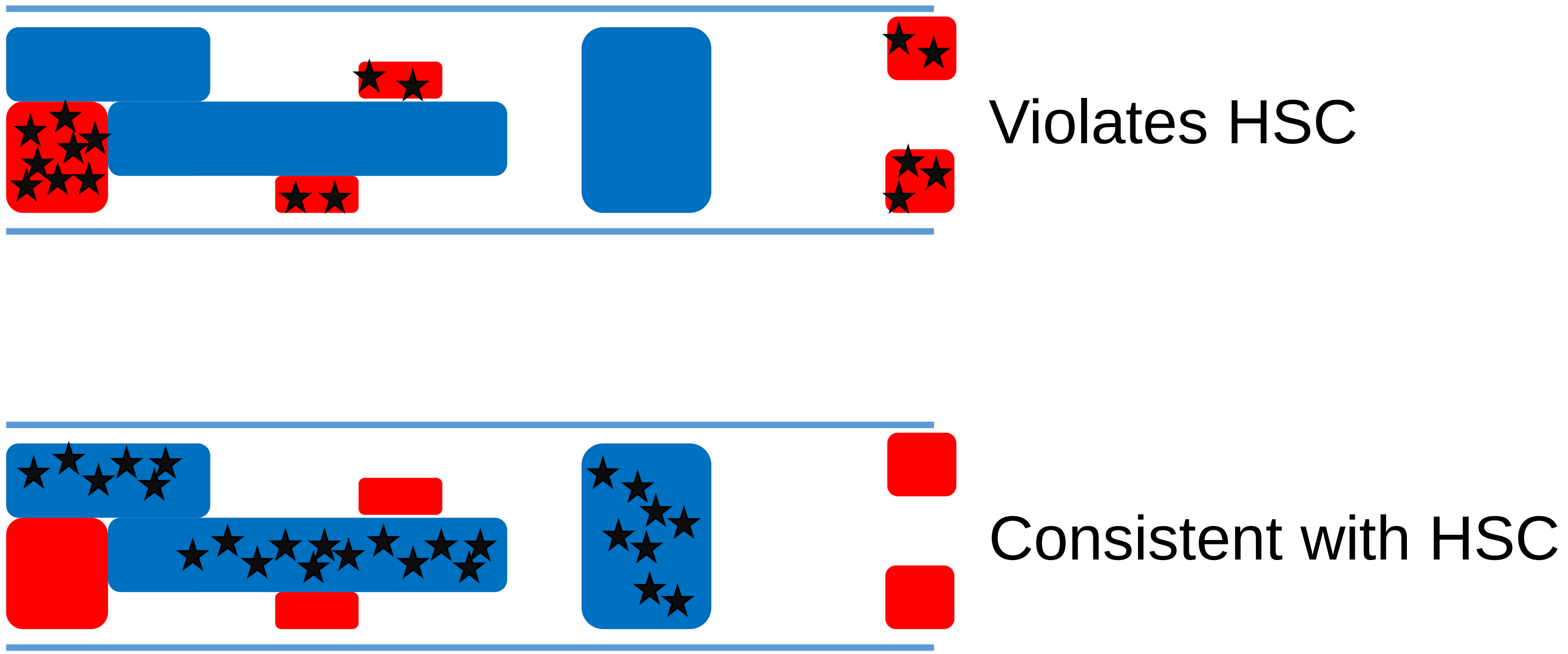
Trivial Prediction!

Risky Prediction!

From Pasternack (2011)

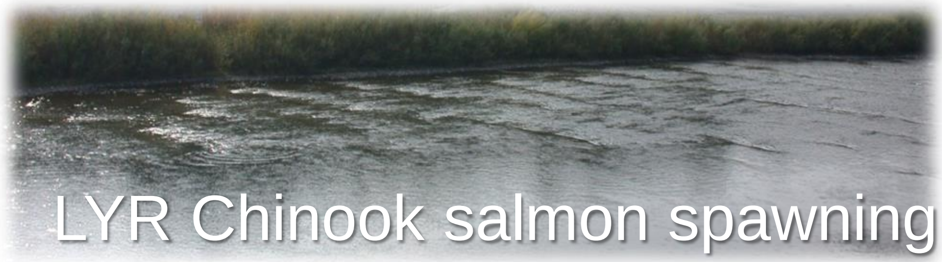
BIOVERIFICATION PERFORMANCE INDICATOR 2

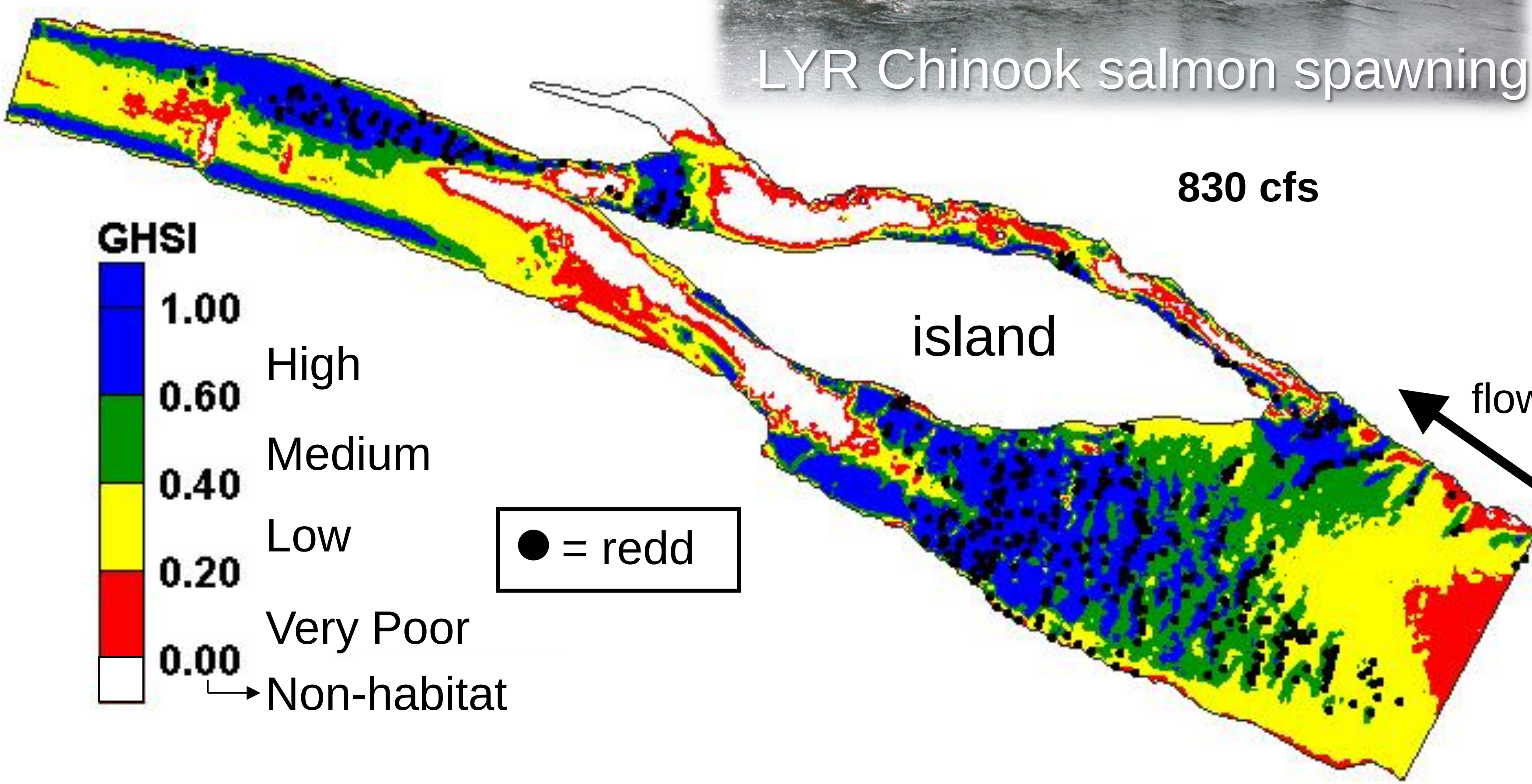
- Habitat classes with EI>1 must be those with high habitat index values and habitat classes with EI<1 must be those with low habitat index values.



From Pasternack (2011)

EXAMPLE OF BIOVERIFICATION

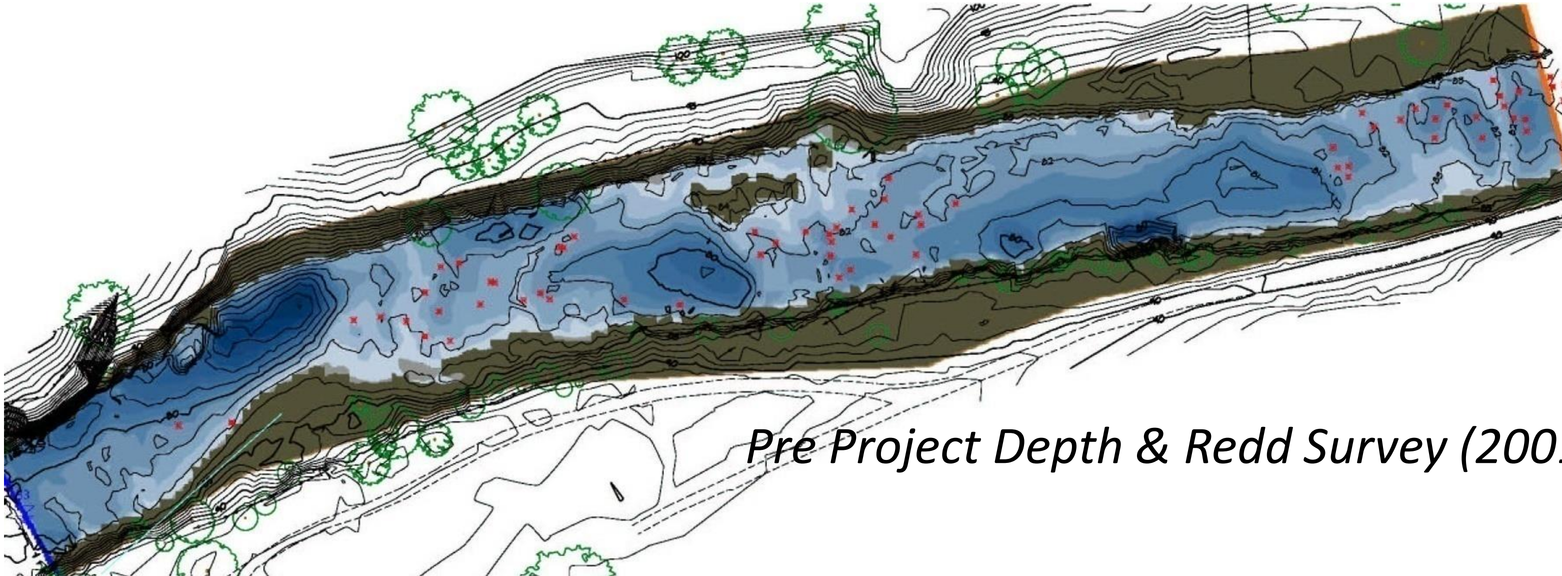




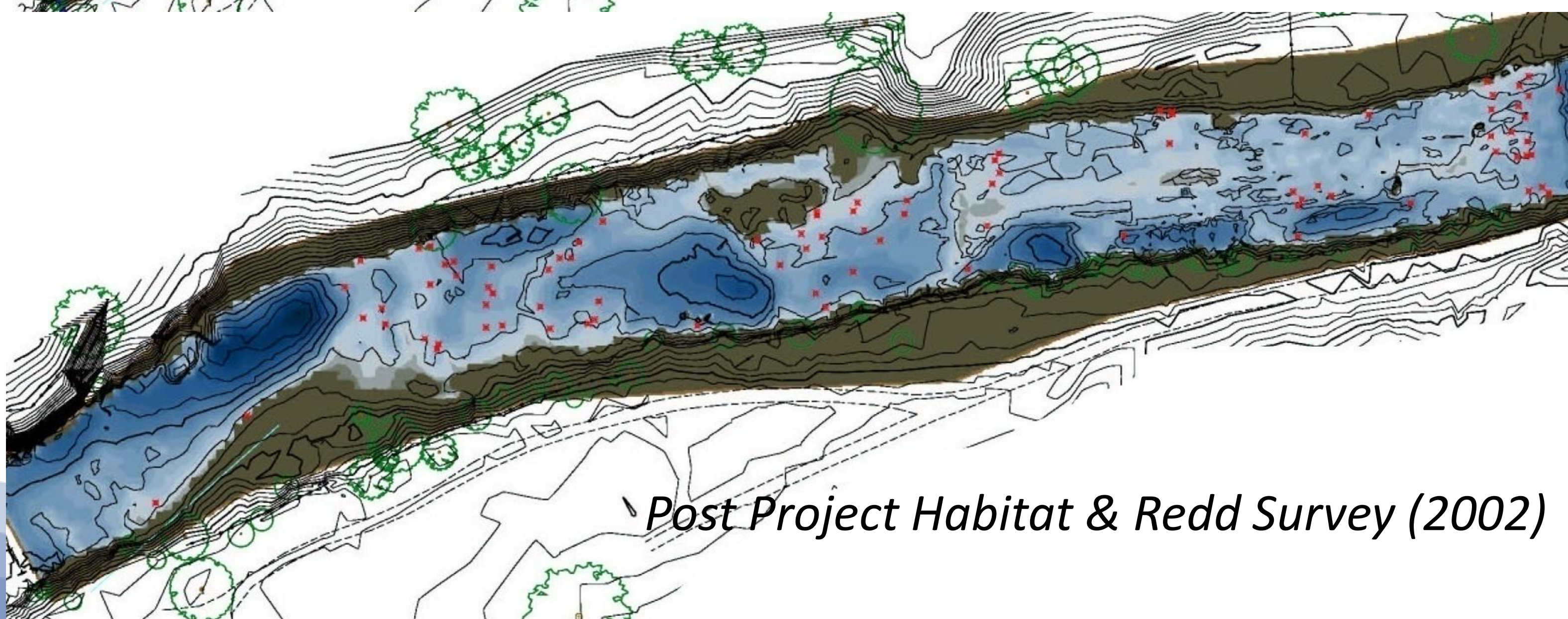
From Pasternack (2011)

PRE VS. POST PROJECT ASSESSMENT

Hydraulic Model Results



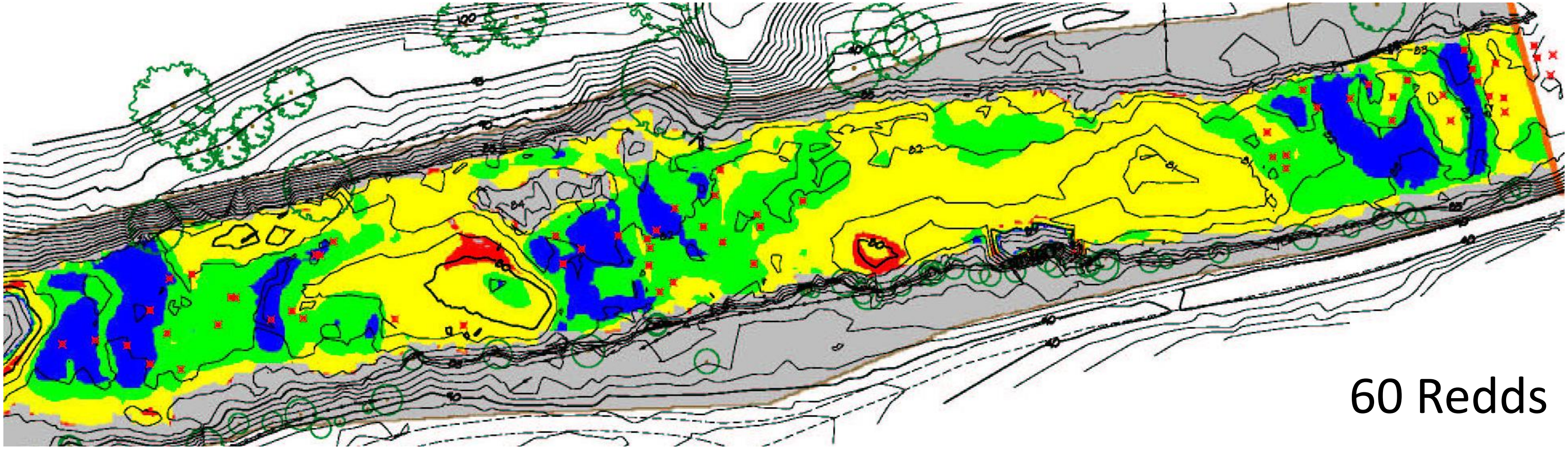
Pre Project Depth & Redd Survey (2001)



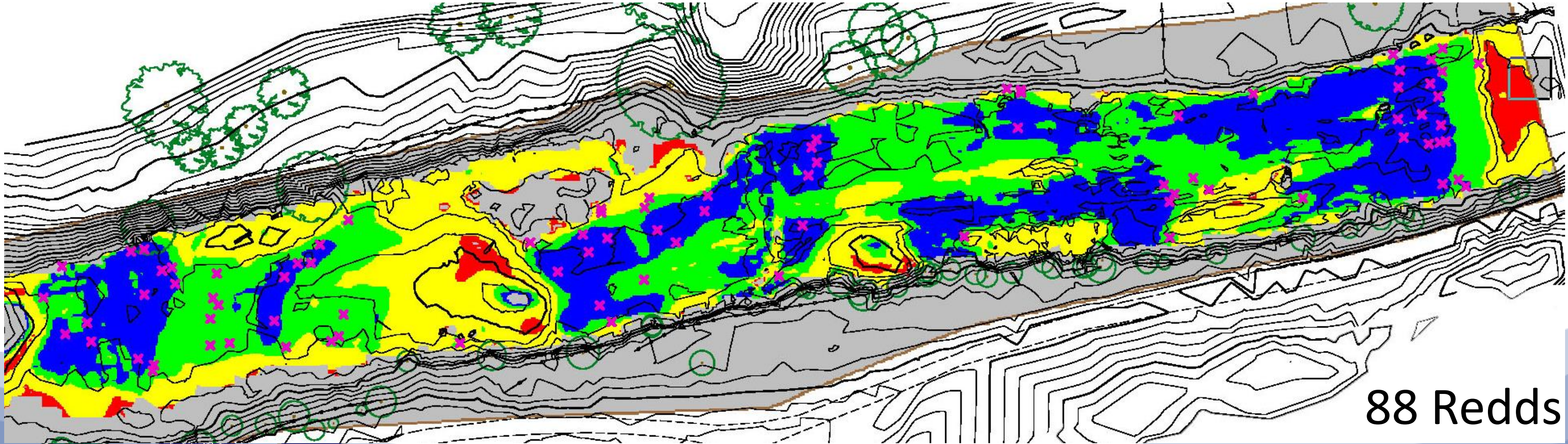
Post Project Habitat & Redd Survey (2002)

LONG TERM MONITORING

2001 & 2002 Redd Surveys



60 Redds



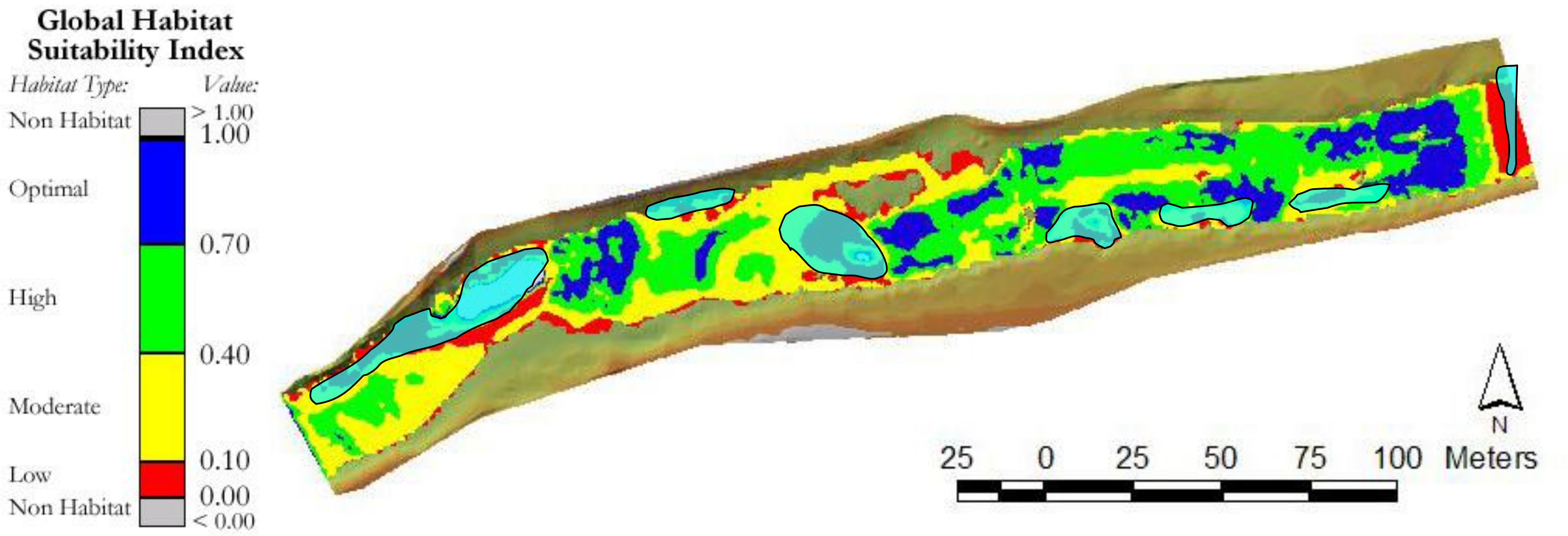
88 Redds

Post Project Habitat & Redd Survey (2002)

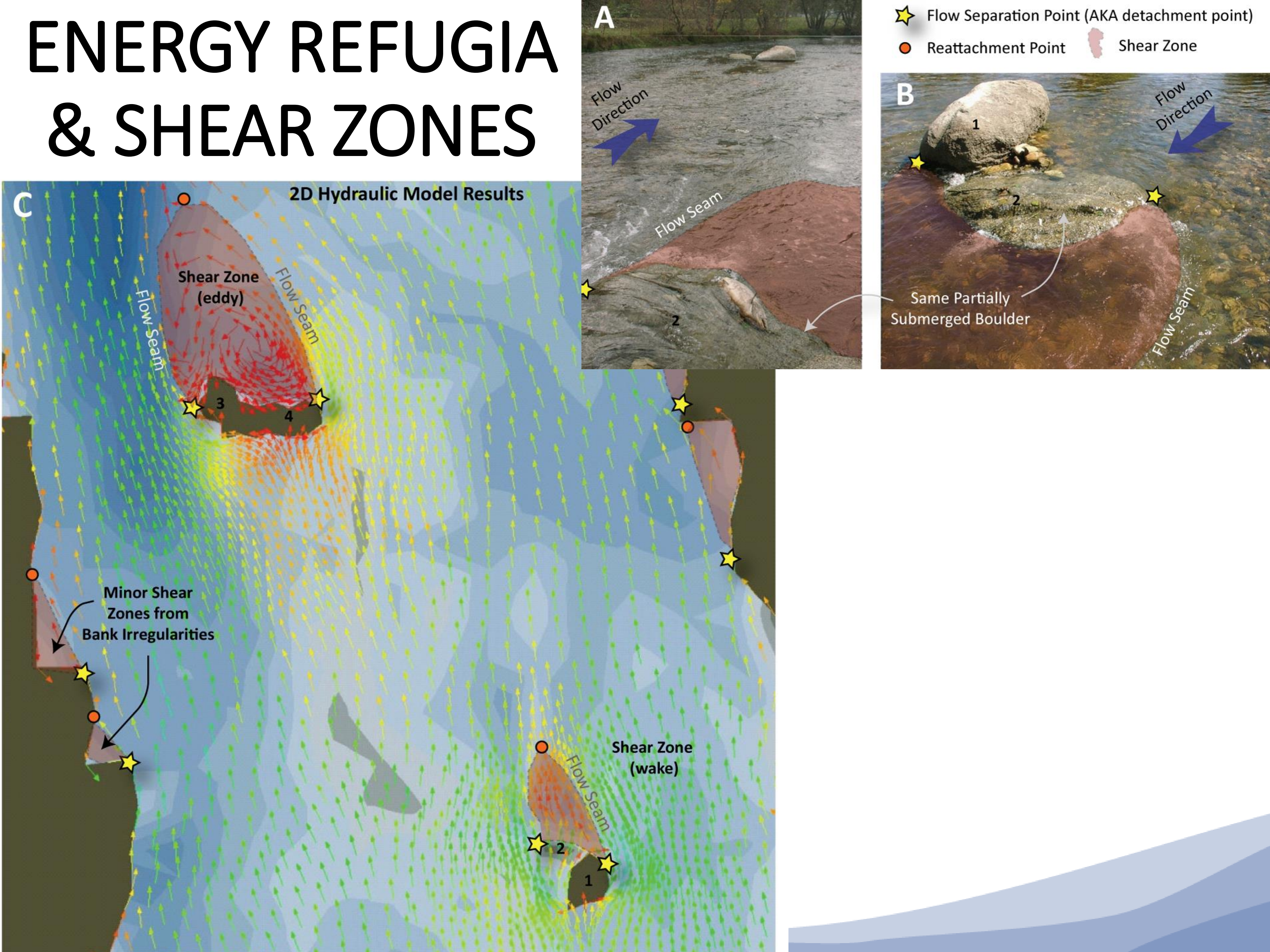
AVAILABILITY MATTERS

1. How many distinct units (counts) and what size are they (area)?
    - Too small? → Not usable, or too patchy.
    - Too big? → Homogenous

2. Are distinct units in close (1-10 m) proximity to "good" spawning habitat?



ENERGY REFUGIA & SHEAR ZONES



THREE TYPES OF REFUGIA…

1. **Predation** Refugia – (Cover) Protection from Predation
2. **Energy** Refugia - Resting Areas (i.e. shear zones)
3. **Thermal** Refugia – Get away from the mean!

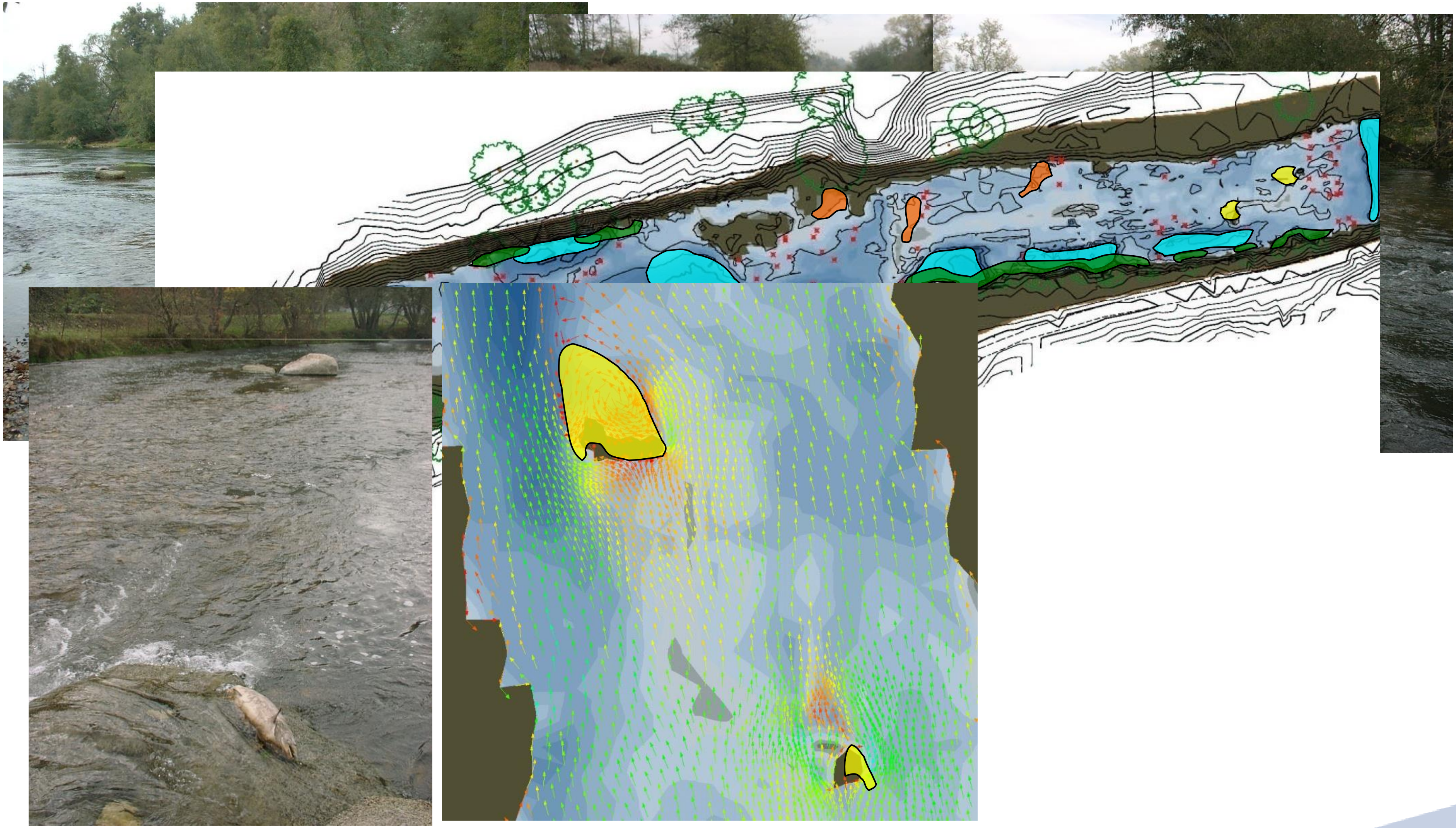
Predation Refugia from:

- Bank Vegetation
- LWD
- Boulders
- Deep Pools

Engergy Refguia from Shear Zones induced by:

- Irregular Banks
- LWD
- Boulders
- Bed Forms

DEFINING HABITAT HETEROGENEITY - REFUGIA



IS HETEROGENEITY IMPORTANT TO A SPAWNING FEMALE SALMON?

Habitat Heterogeneity is usually assumed to support species diversity (assumed to be good).

What are specific ecological benefits of habitat heterogeneity to spawning salmonids?

BONNEVILLE POWER ADMINISTRATION

ISEMP

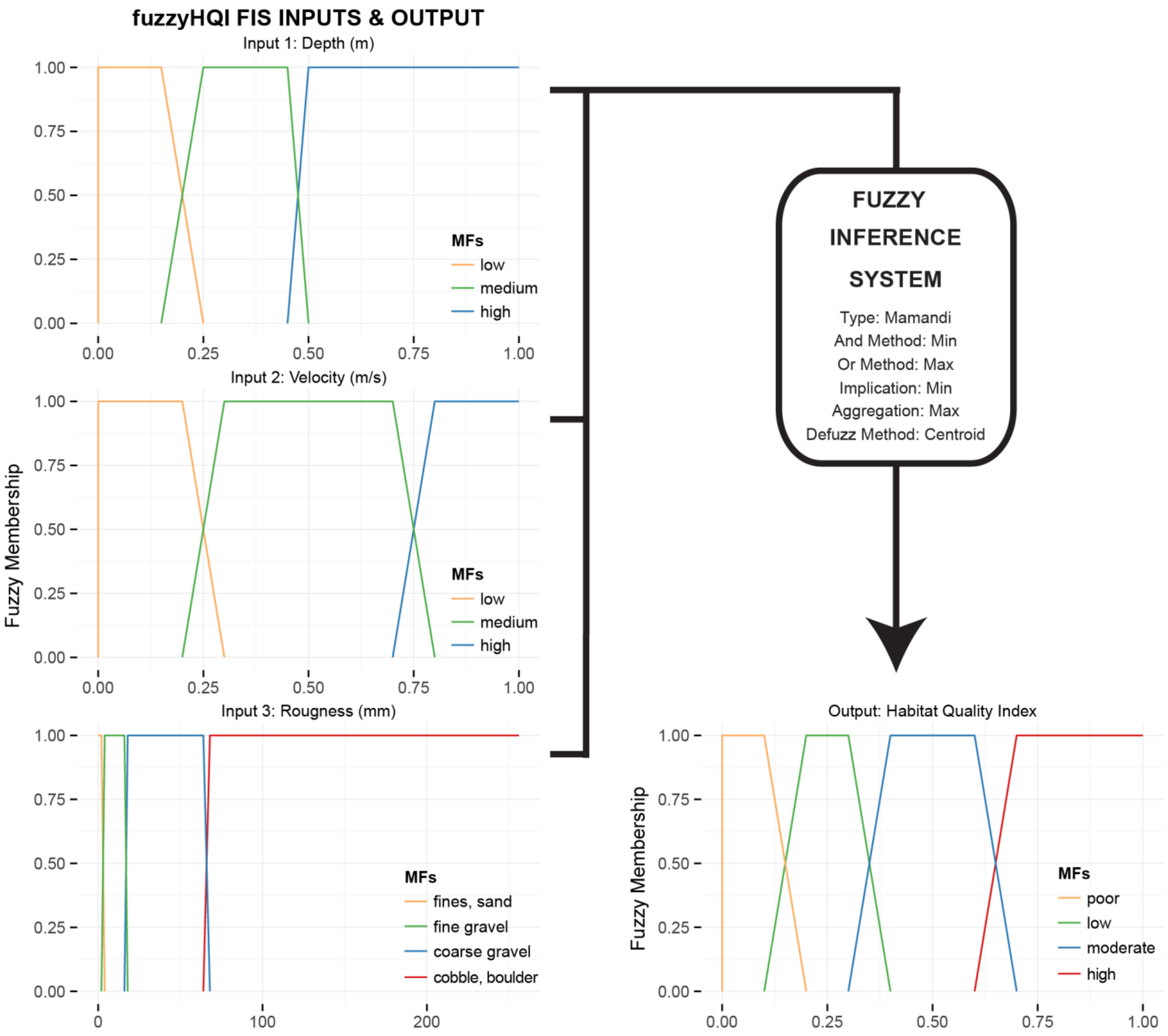
CHaMP

Fuzzy Habitat Models

ADVANTAGES:

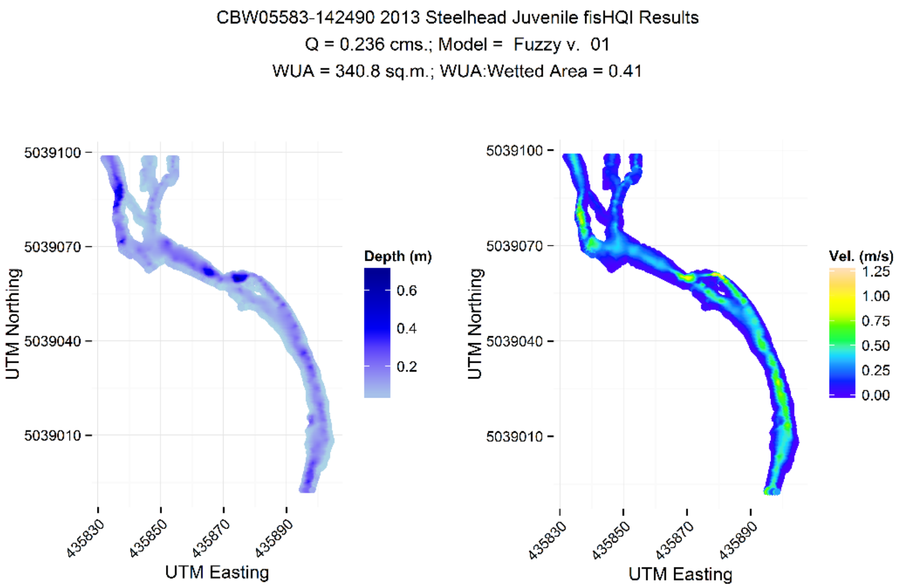
- Knowledge about ecological linkages is **imprecise**
- Fuzzy logic calculations consider **multivariate effects** (no assumption of independence)
- **New parameters** incorporated easily
- **Few observations** needed
- Calculation is **understandable** (no black box effect)
- High **flexibility** and adaptability
- Results often validate better then traditional HSI

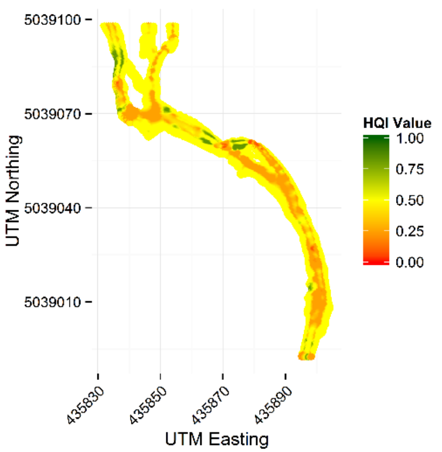
Fuzzy approach to HSI Modeling

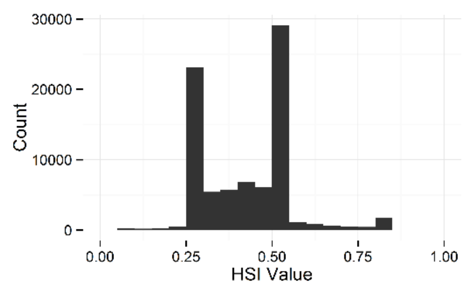


Fuzzy Habitat Model

Example Output:

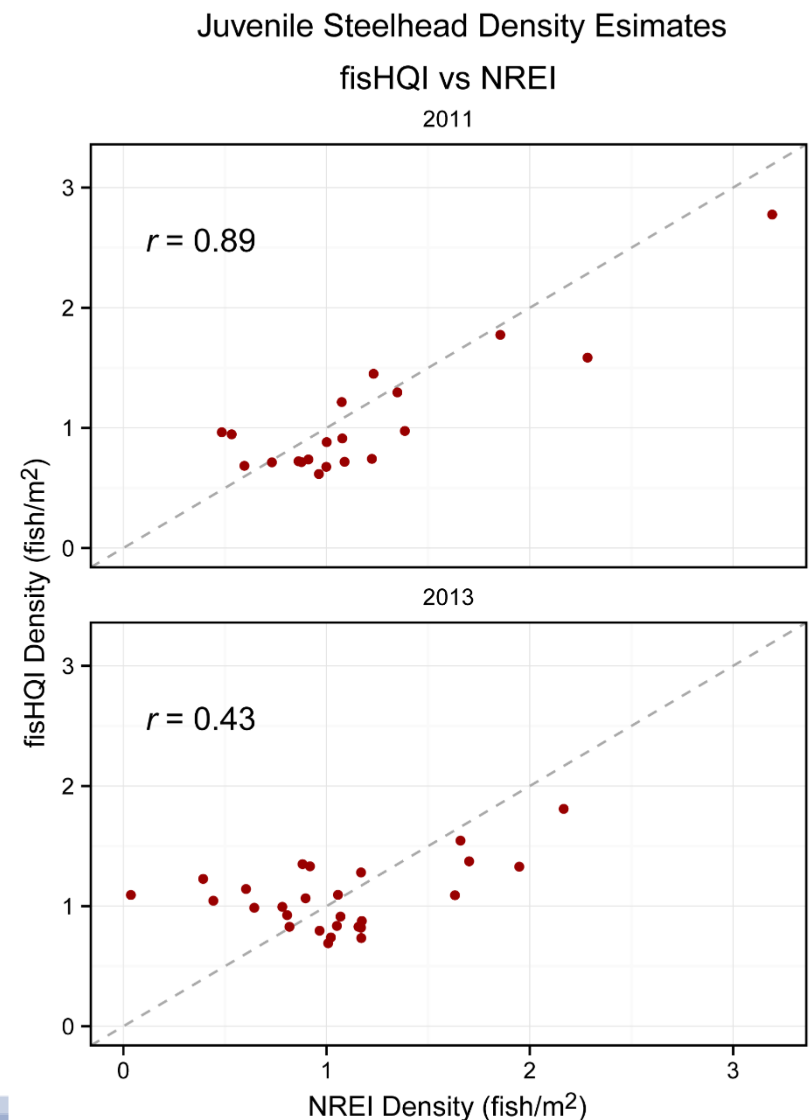






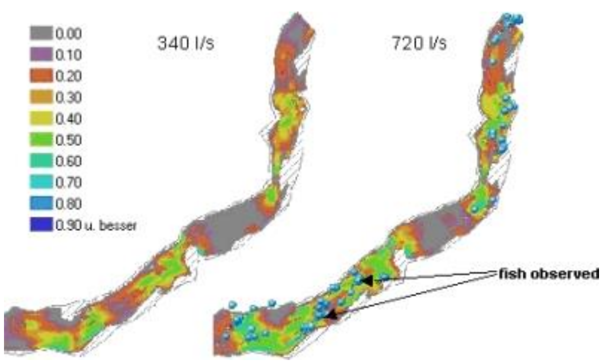
Habitat quality	Area (sq.m)
Poor	0.3
Low	104.6
Medium	215.0
High	21.0

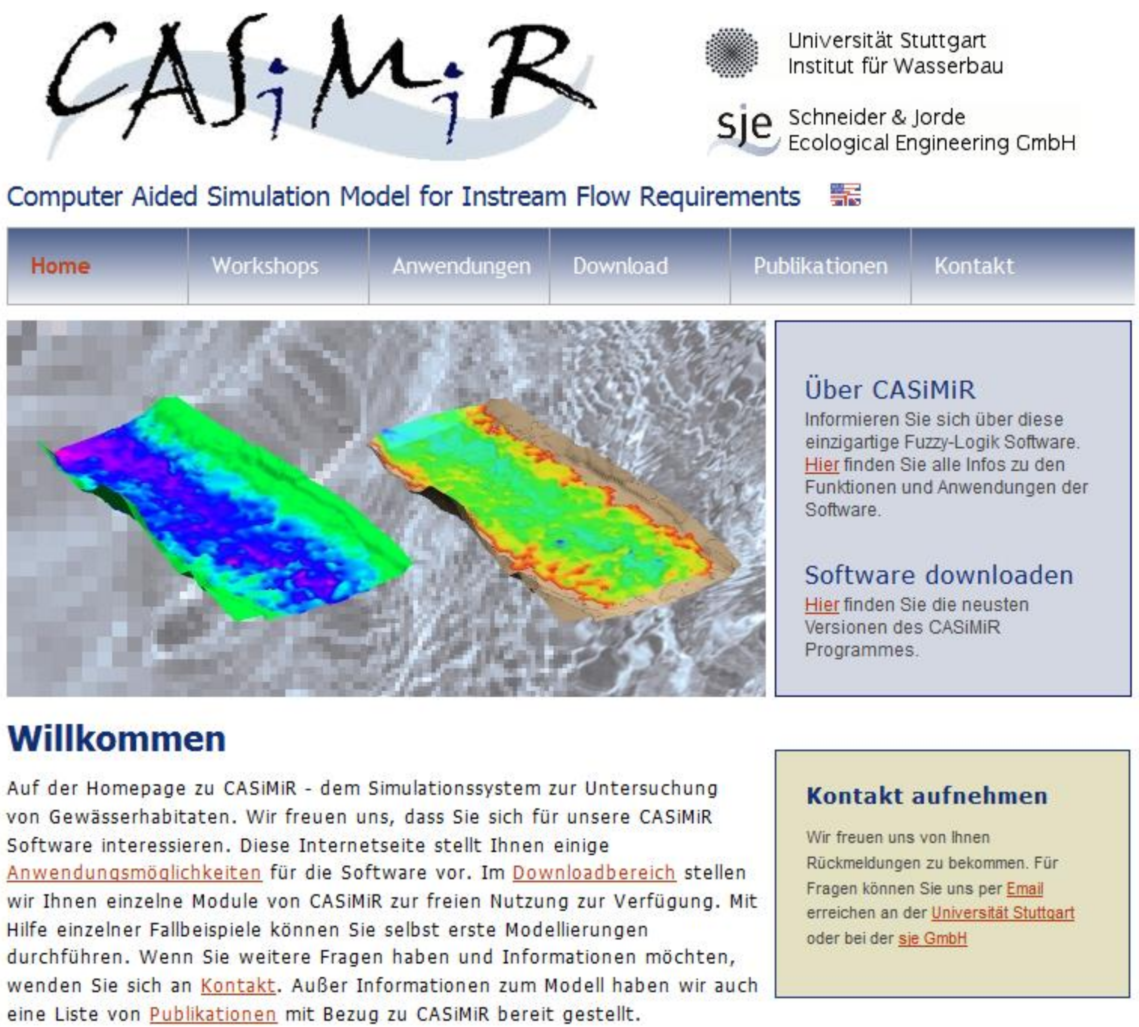
Fuzzy vs. NREI Density Estimates:



CASiMiR

- There is an English version…





HELP PLEASE

Chinook Juvenile Habitat Suitability

Respondent Information:

* Required

Name: *

Organization: *

Position: *

This survey form consists of 64 questions, one for each rule in the fuzzy habitat model. The number of rules is based on the number of unique input category combinations (4 water depth categories * 4 velocity categories * 4 grain size categories = 64 rules).

Continue »

5% completed

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Email

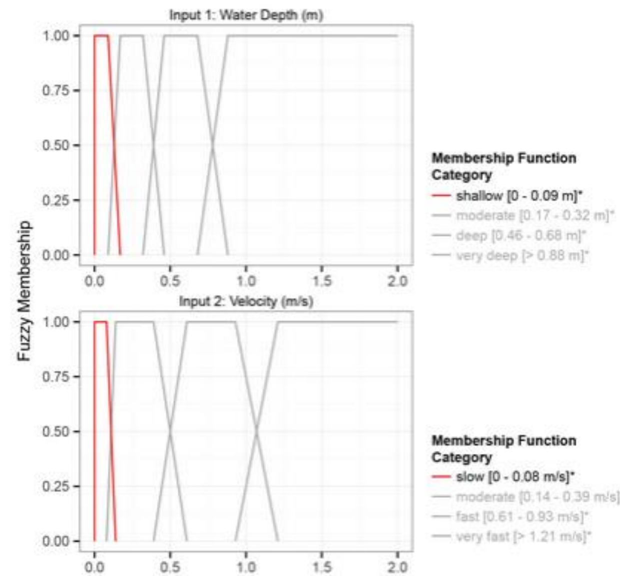
Sara.Bangen@gmail.com

Chinook Juvenile Habitat Suitability

* Required

Chinook Juvenile Habitat Suitability

Rules for SHALLOW water depth & SLOW velocity:



* *Values that have full membership (i.e., membership = 1) in a specified category (e.g., 'shallow'). Values not included in any of these ranges have partial membership in 2 categories.*

1. If water depth is SHALLOW & velocity is SLOW & grains size is FINES/SAND [< 2 mm], then habitat suitability is: *

2. If water depth is SHALLOW & velocity is SLOW & grains size is FINE GRAVEL [2 - 16 mm], then habitat suitability is: *

3. If water depth is SHALLOW & velocity is SLOW & grains size is COARSE GRAVEL [16 - 64 mm], then habitat suitability is: *

4. If water depth is SHALLOW & velocity is SLOW & grains size is COBBLE/BOULDER [> 64 mm], then habitat suitability is: *

« Back Continue »

11% completed

Fish Habitat Model Outline

- CHaMP Context
- Fish Habitat Model Backgrounder
  - HSC and FIS models
- Fish Habitat Model Software
  - Introduction
  - Exercises
- The Net Rate of Energy Intake (NREI) Model
- Life Cycle Models

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NREI & Beyond

- Foraging models 101
- CHaMP NREI adaptation
    - Inputs, outputs, structure, etc.
    - Workflow: from field data to model output
    - Model performance
- Sample of NREI applications
    - Indicator of habitat quality
    - Restoration design and evaluation
    - Life cycle models

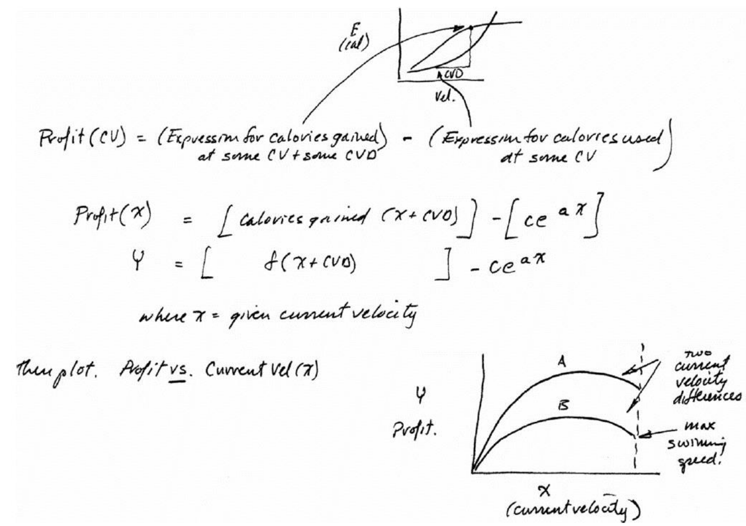
Eric Wall

Nick “the Beav” Bouwes

Method	Advantages	Disadvantages
Population models	- Integrative - Relevance to other 'H' - Established framework	- Hard-to-meet assumptions - Data needs - Bottleneck stage(s) unknown
Statistical models	- Generates FHR knowledge - Draws on existing data (?) - Gets the job done	- Design, extrapolation challenges - Narrow domain of use - Seeding level issues (?)
Areal methods	- Ties fish *N* to channel units - Gets the job done	- Design, extrapolation challenges - Uncertainty in density used (?) - Labor intensive
Habitat Suitability Models	- Explicit link to habitat - Platform for simulation - 'Limited' sampling required	- Design, extrapolation challenges - Limited accessibility - Narrow domain of use (not FIS) - Ignores productivity/food
NREI Models	- Explicit link to habitat, FOOD - Transferable - Platform for simulation - 'Limited' sampling required	- Design, extrapolation challenges - Limited accessibility

Drift-foraging Models Backgrounder

- Origins in basic fish ecology:
  - Why do fish use particular habitats? Fausch, Hughes
- An energetic cost-benefit perspective on habitat
  - Costs = holding a station
  - Benefits = food delivery
- Direct link to growth (~fitness)
- In practice, complexity varies widely

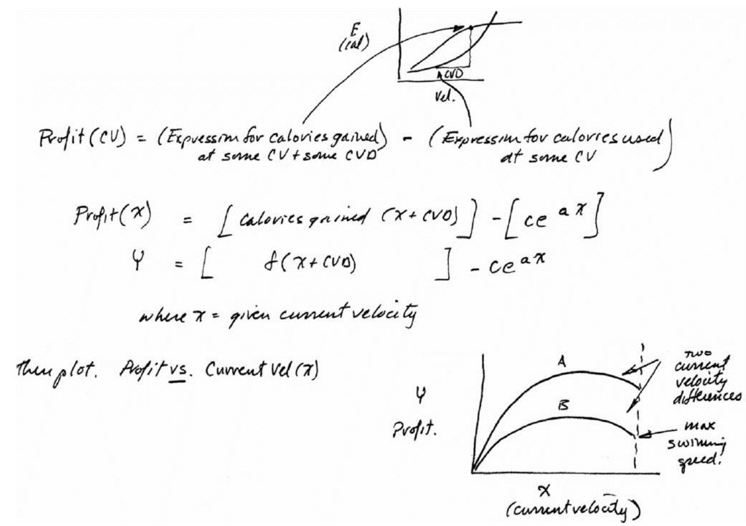


Fausch 2014, Env. Biol. Fish.

Drift-foraging Models Backgrounder

Elements of the NREI 'model'

- Physical model: provides the depth/velocity landscape
- Foraging model: defines a fish's ability to detect/capture prey
- Bioenergetics model: Energy accounting tool (swimming, metabolism); some allometry
- Drift model: defines prey (drift) abundance in space
- Often simplified

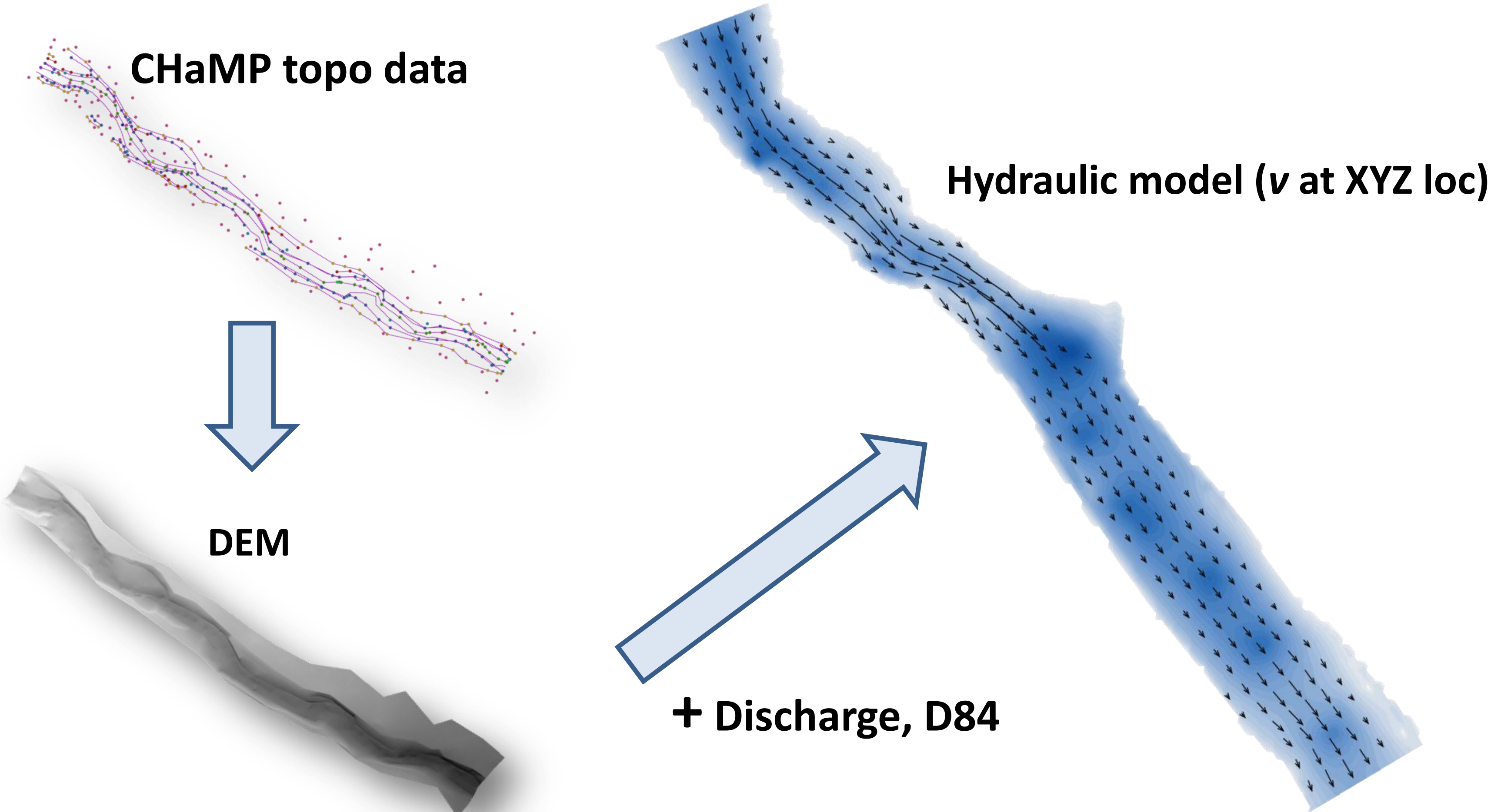


Fausch 2014, Env. Biol. Fish.

NREI & Beyond

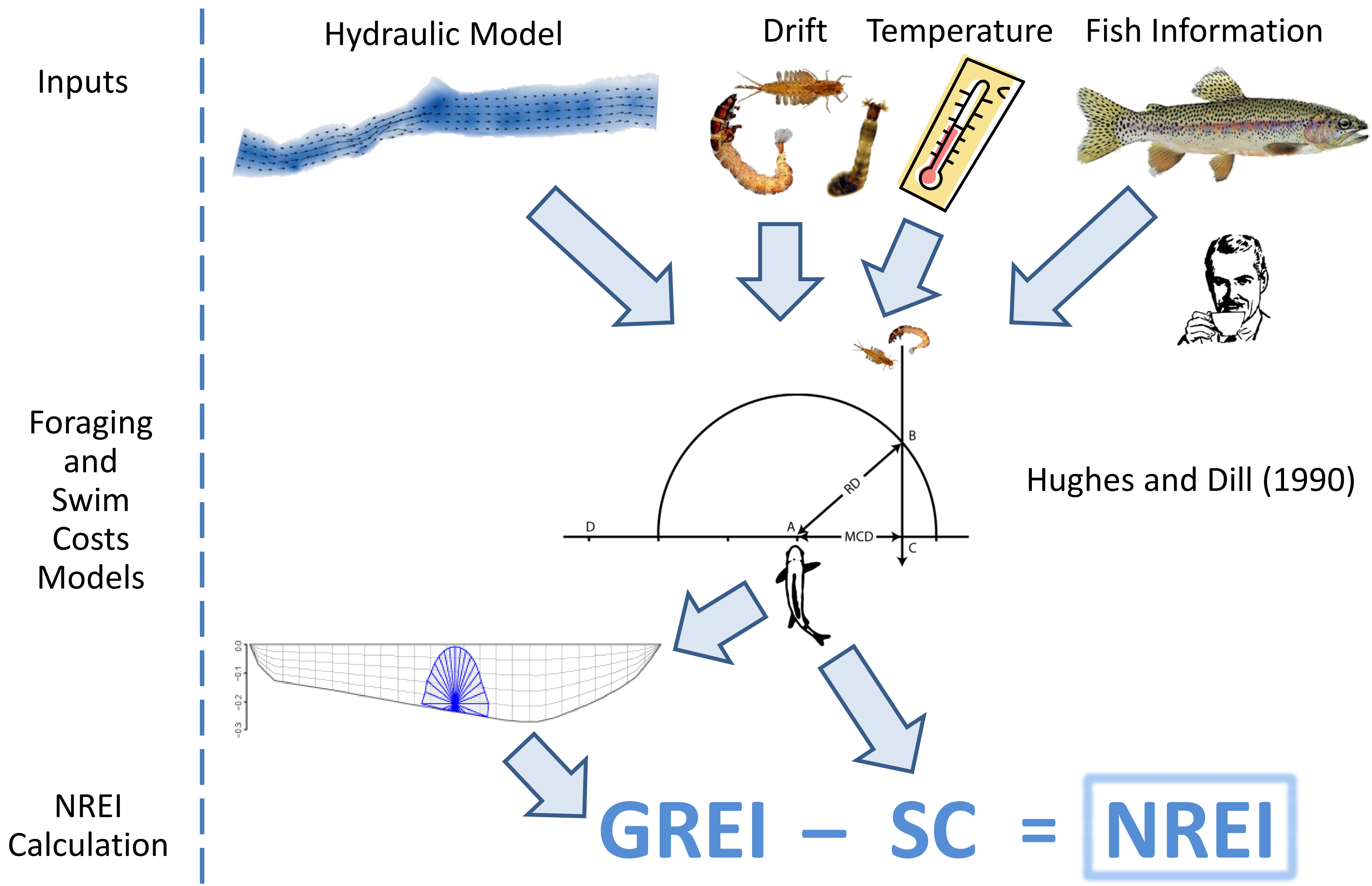
- Foraging models 101
- CHaMP NREI adaptation
  - Inputs, outputs, structure, etc.
  - Workflow: from field data to model output
  - Model performance
- Sample of NREI applications
  - Indicator of habitat quality
  - Restoration design and evaluation
  - Life cycle models

From CHaMP Field Data to NREI Predictions



CHaMP

From CHaMP Field Data to NREI Predictions

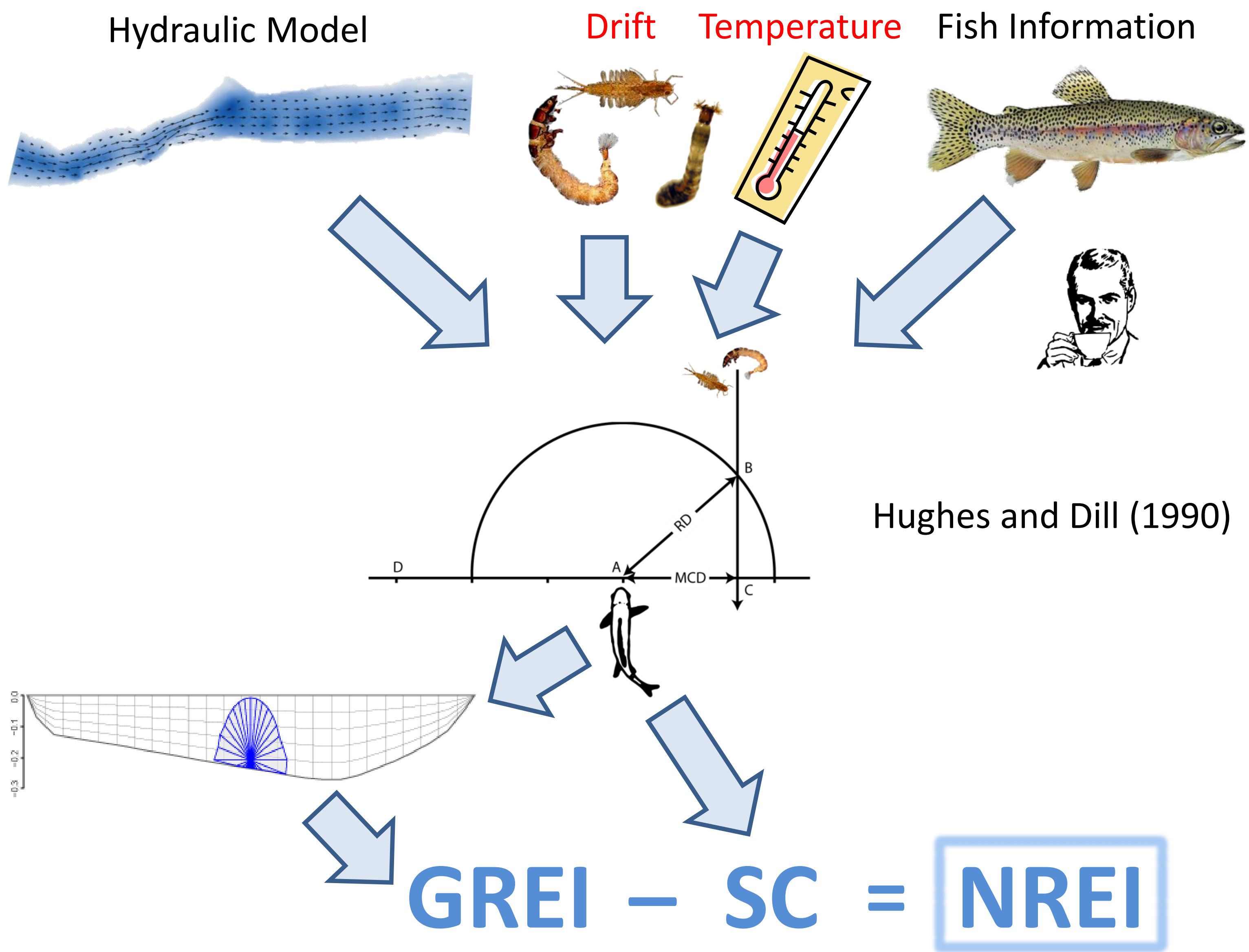


From CHaMP Field Data to NREI Predictions

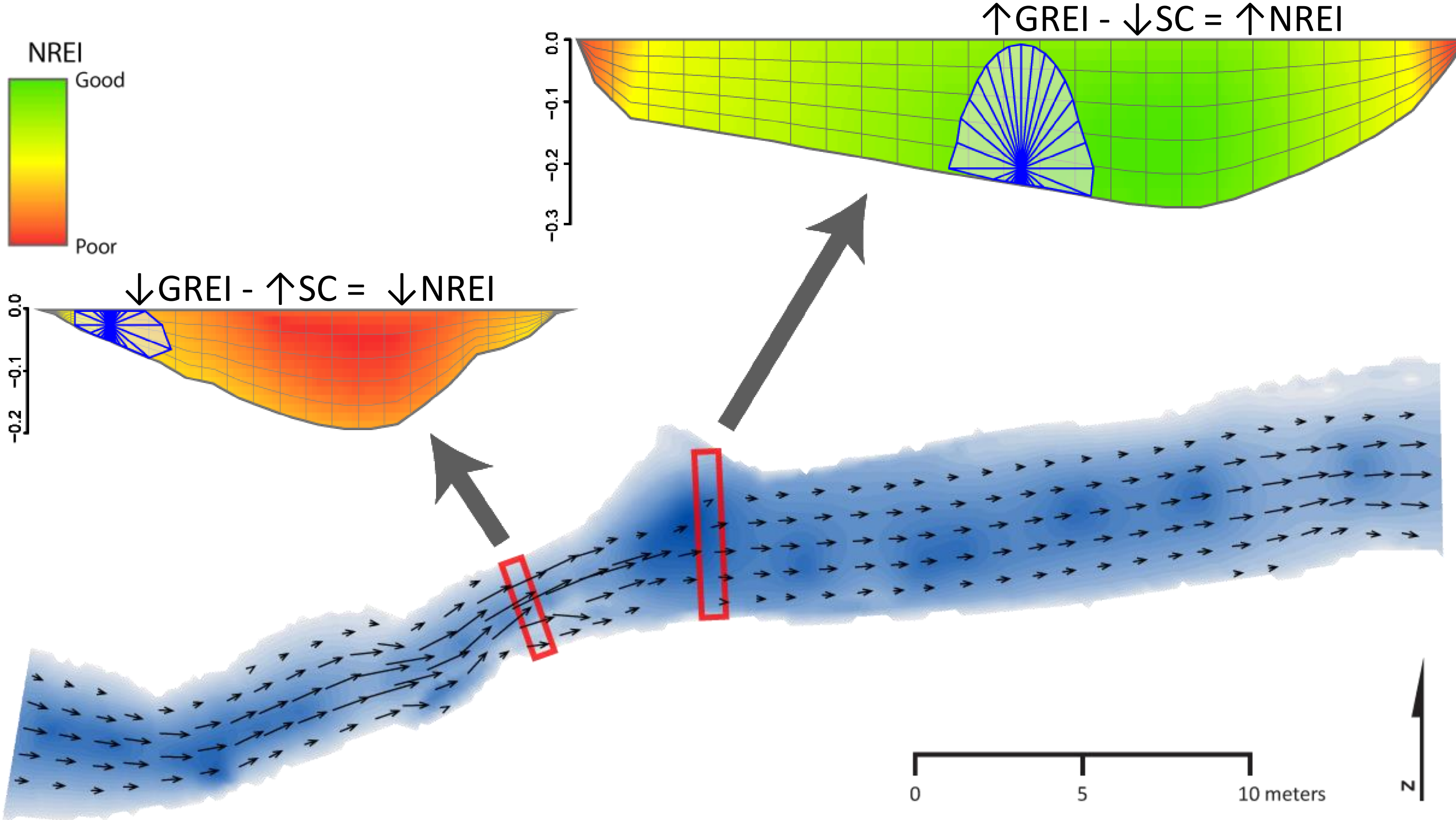
Inputs

Foraging and Swim Costs Models

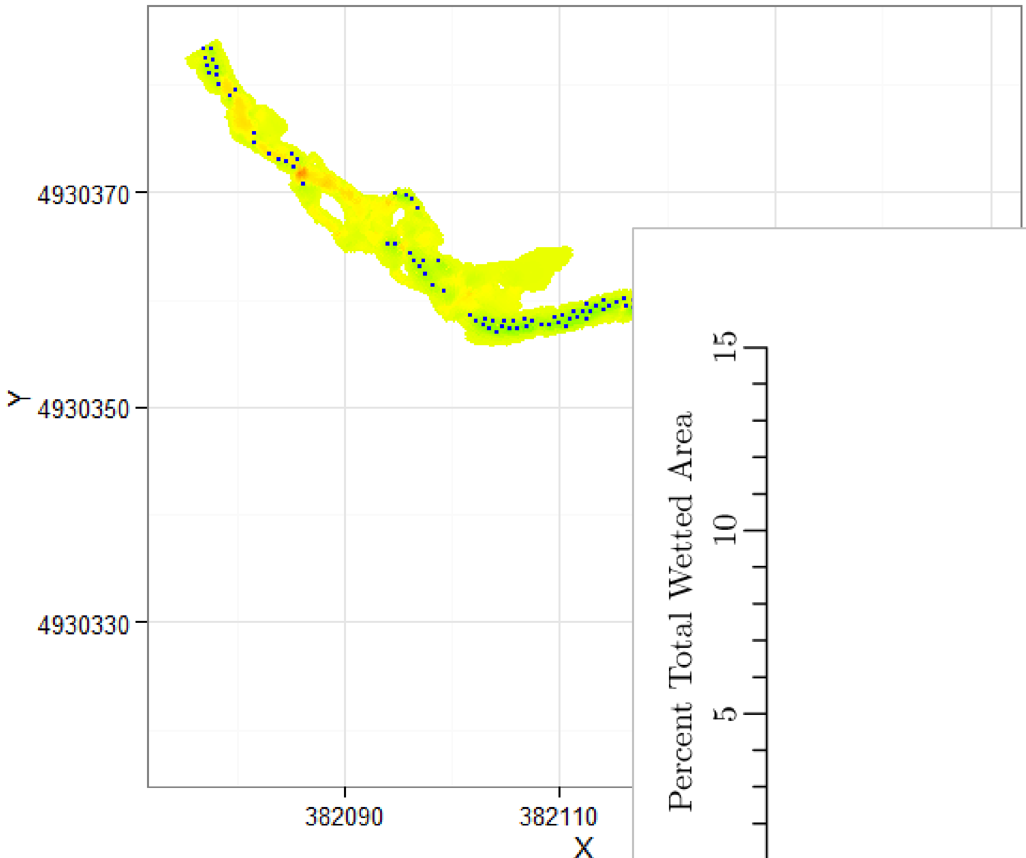
NREI Calculation



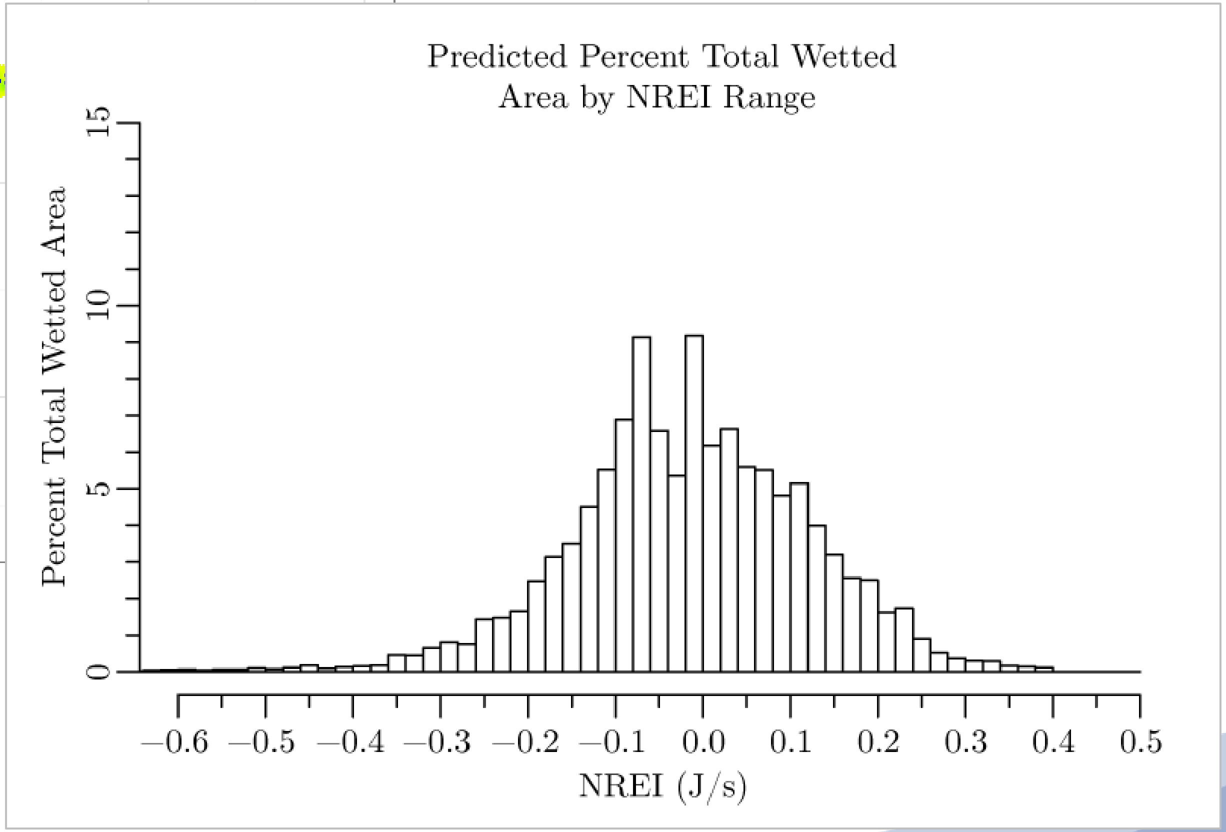
Visualization: NREI for Contrasting Cross Sections



NREI-based Site Maps and Distributions



A biologically meaningful habitat status & trends indicator…

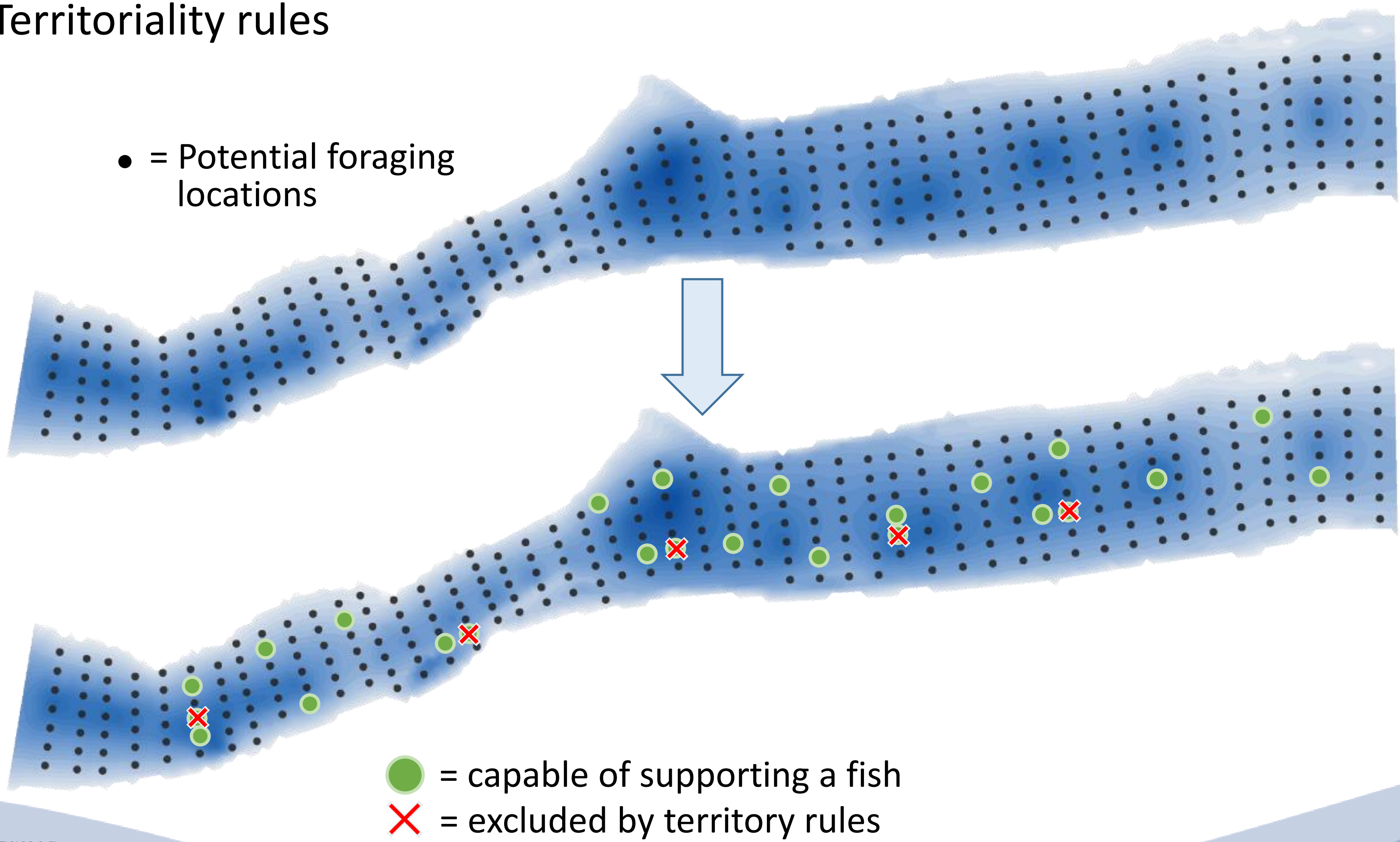


From NREI to Reach Capacity

Additional info needs:

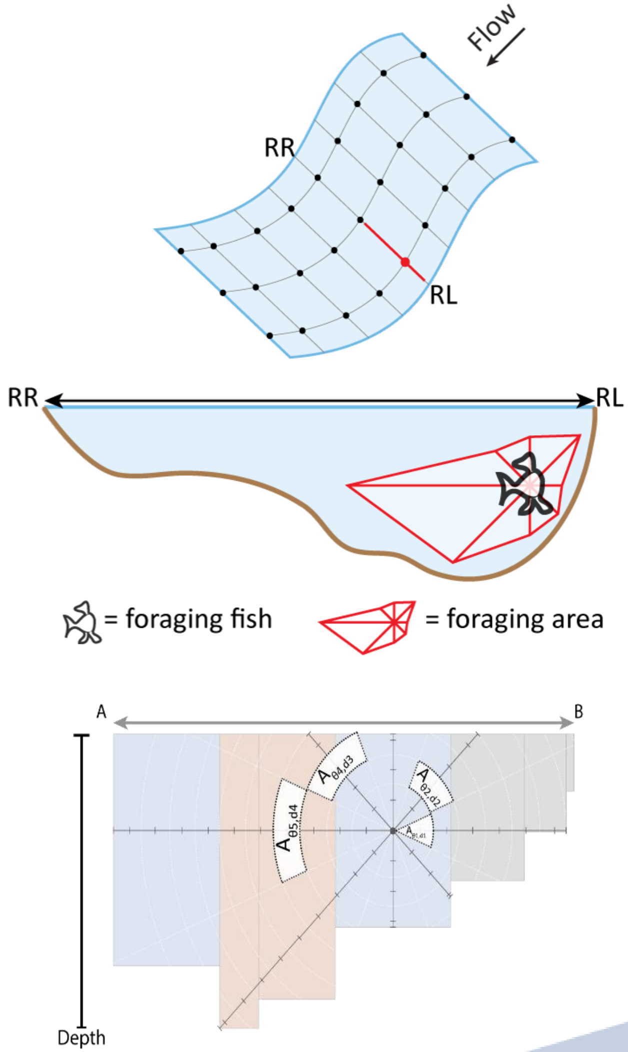
NREI Threshold

Territoriality rules



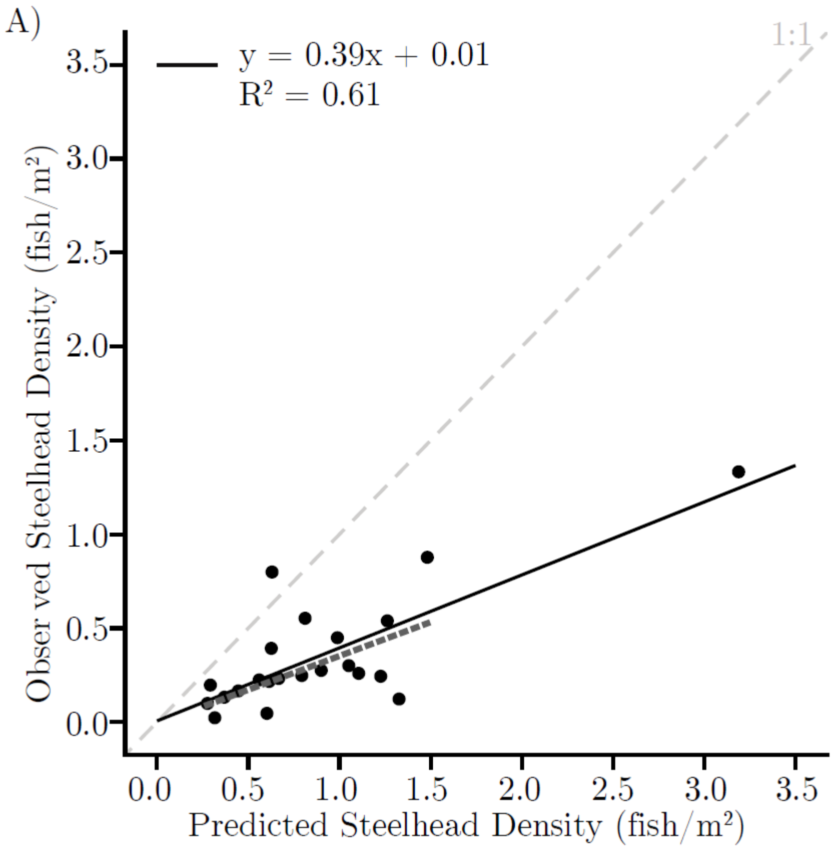
Some CHaMP NREI Specs

- CHaMP adaptations:
  - Physical model: Delft3D, with post-processing improvements
  - Foraging model: Hughes; implementation improvements
  - Bioenergetics model: Wisc. Model
  - Drift model: Not modeled (uniform)
- Implemented in R
- Now runs at drift-temp combos:
  - Temperatures ranging 6-26°C
  - Drift concentrations 0.01-5.00 ind/m^3
- Substantially more efficient, now 10s of minutes per site (vs. 100s-1000s)



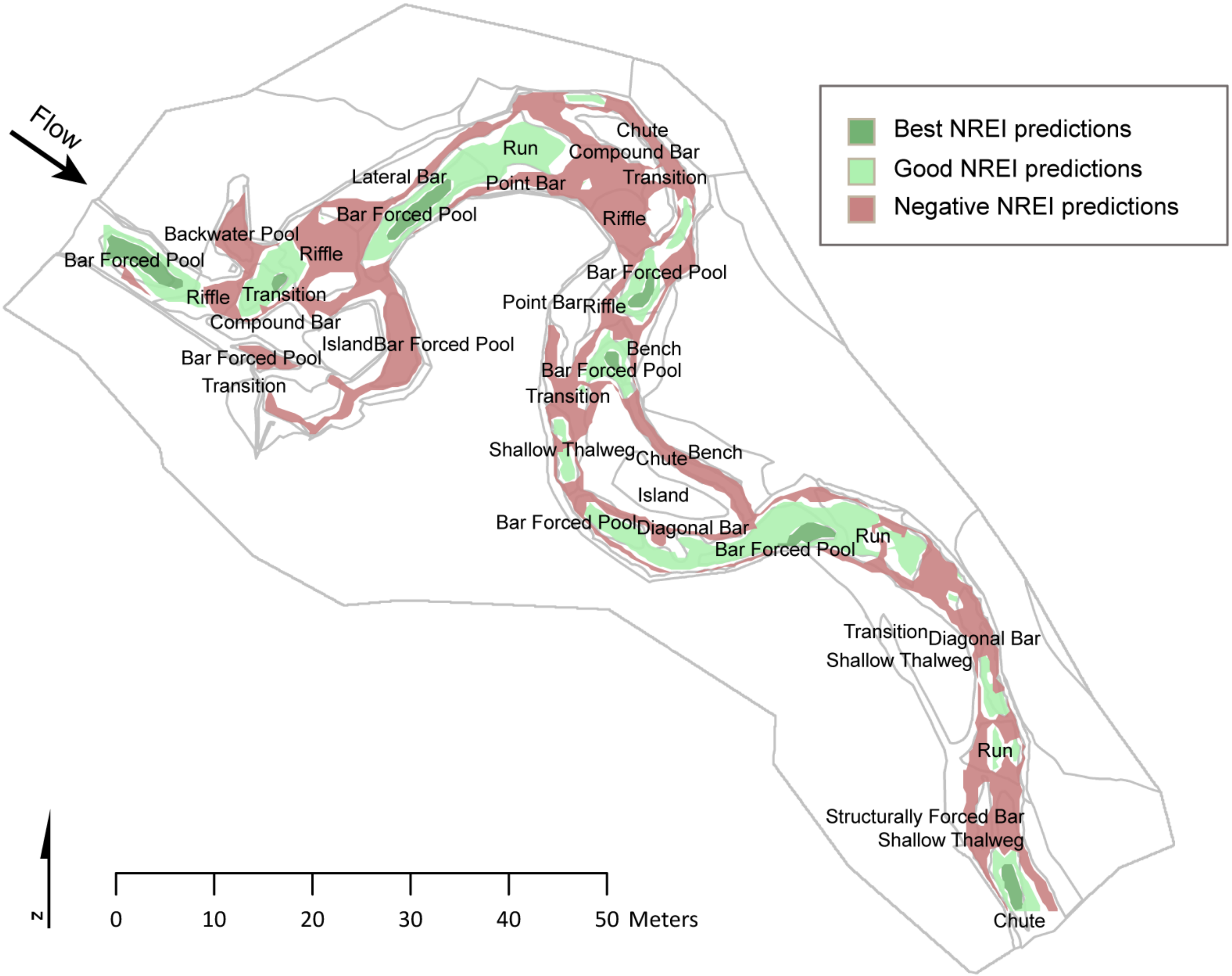
How Well Does NREI Perform?

Asotin & John Day



- Accounts for ~2/3 of variation in *O. mykiss* abundance
- But…predictions generally exceeded observations
- CHaMP-wide evaluation coming soon

How Well Does NREI Perform?



Status of CHaMP-wide NREI Implementation

- Existing NREI runs:
  - 196 unique visit IDs have been run
  - Asotin (4 y), Entiat (2012), John Day (3 y), Lemhi (2012)
- Goal: $\geq$ 1 run per CHaMP site by July (1K+), run remaining (i.e., repeat) visits (~ 1K+) thereafter
- Leaps towards production/metric mode:
  - Code and algorithm efficiencies (Wall, Nahorniak)
  - Cloud computing
  - Lookup table (drift/temp combo) now standard

Remaining Tasks, Questions, Decisions

- Sensitivity analysis underway, including:
  - Assessment of base parameters and functions
  - Evaluation of key modeling decisions:
    - What is a relevant bottleneck temperature?
    - Is a current threshold (NREI>0) the right one?
    - Multi-species and/or multi-age systems
    - Territoriality rules
- Can we model/predict NREI inputs?
  - Temperature (MODIS)
  - Drift…or proxies thereof
- Beyond: Predicting NREI-based capacity as fxn of globally available attributes

NREI & Beyond

- CHaMP context
- Foraging models 101
- CHaMP NREI adaptation
    - Inputs, outputs, structure, etc.
    - Workflow: from field data to model output
    - Model performance
- Sample of NREI applications
    - Indicator of habitat quality
    - Restoration design and evaluation
    - Life cycle models

Ex 1: NREI & Restoration Design & Monitoring

<u>Restoration actions affecting NREI:</u>

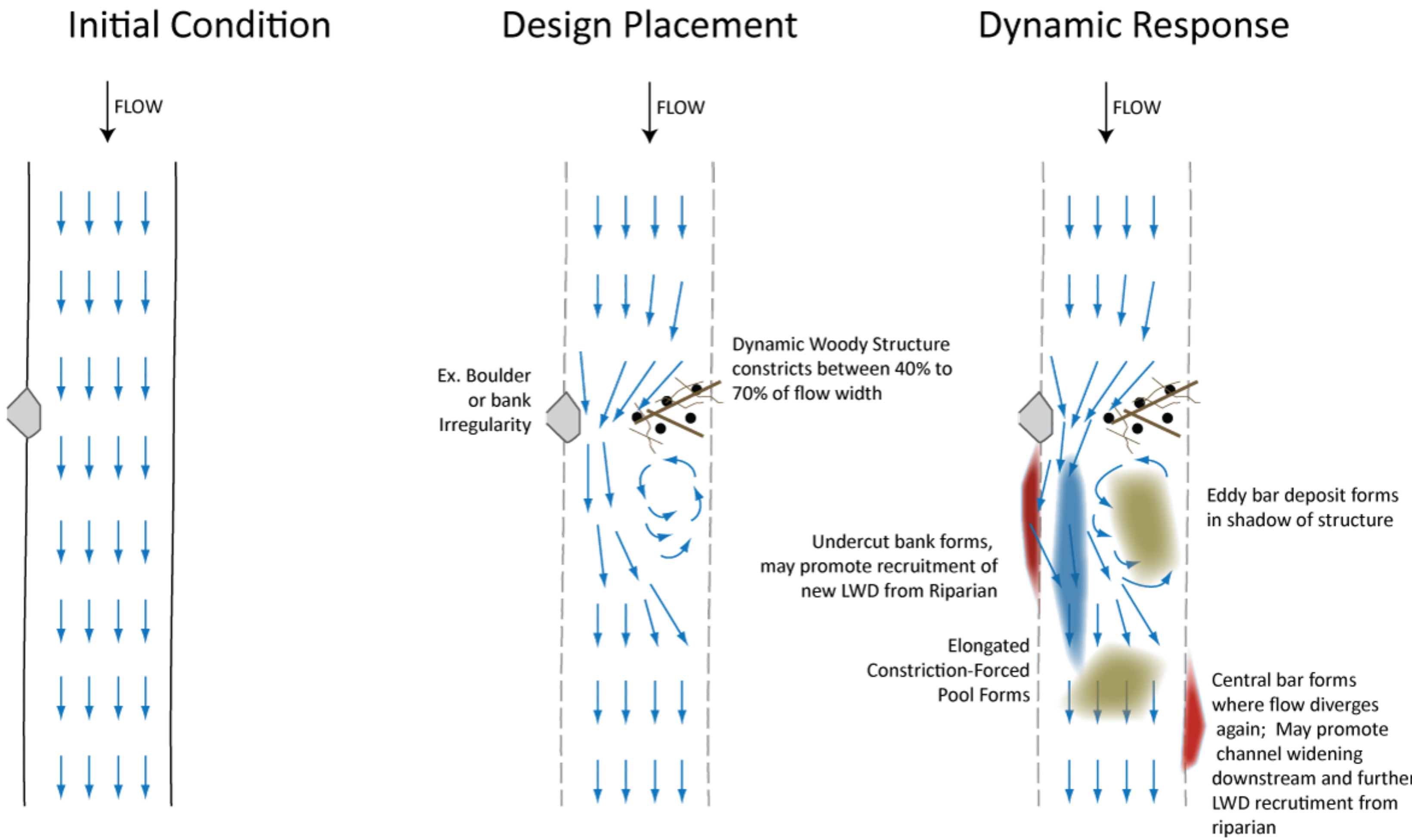
- Adding hydraulic complexity
- Reducing summer temperatures
- Restoring flow
- Actions impacting productivity (?)

Ex 1: NREI & Restoration Design & Monitoring

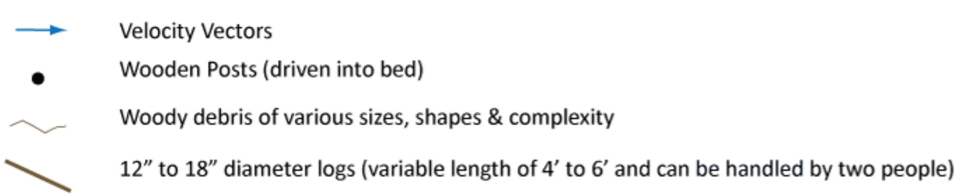
Catherine Cr. RM37 – restoration site near Union

TYPICAL HDLWD STRUCTURES

Hypothesized Response to HDLWD

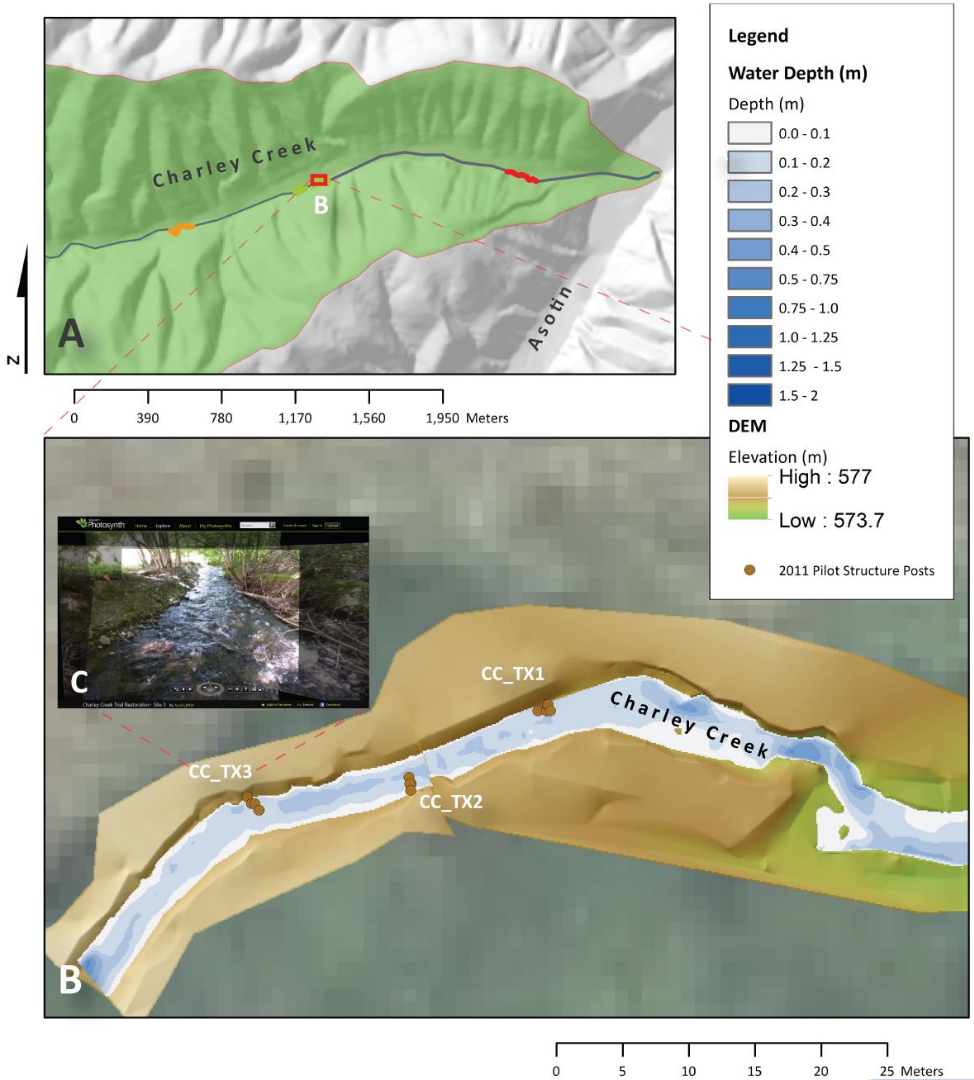


LEGEND



PILOT OR AEM TESTING VS. DESIGN STAGE

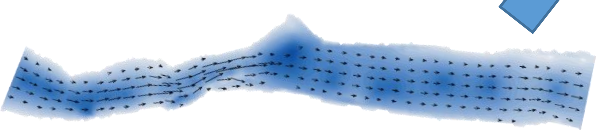
- Do we have to build it to test it?



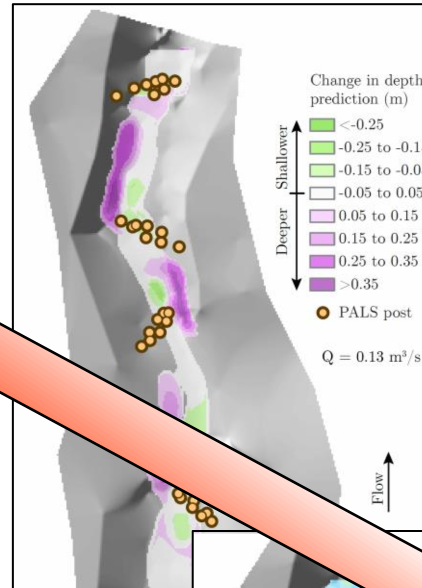
Ex 1: NREI & Restoration Design & Monitoring

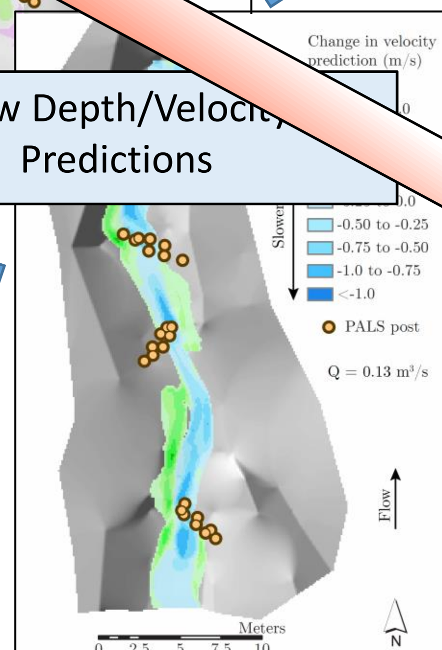
Expected effect of action(s) on topography

Modify DEM

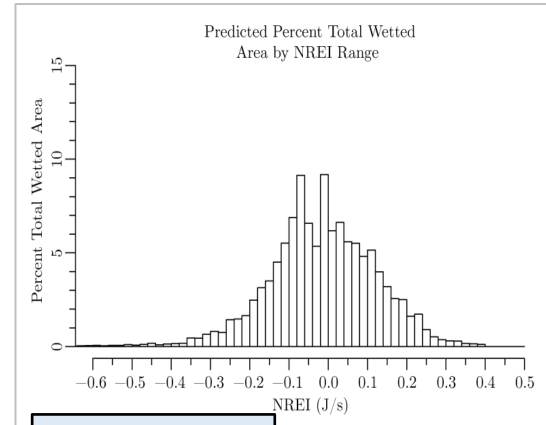


Run Hydraulic Model





New Depth/Velocity Predictions



Run NREI

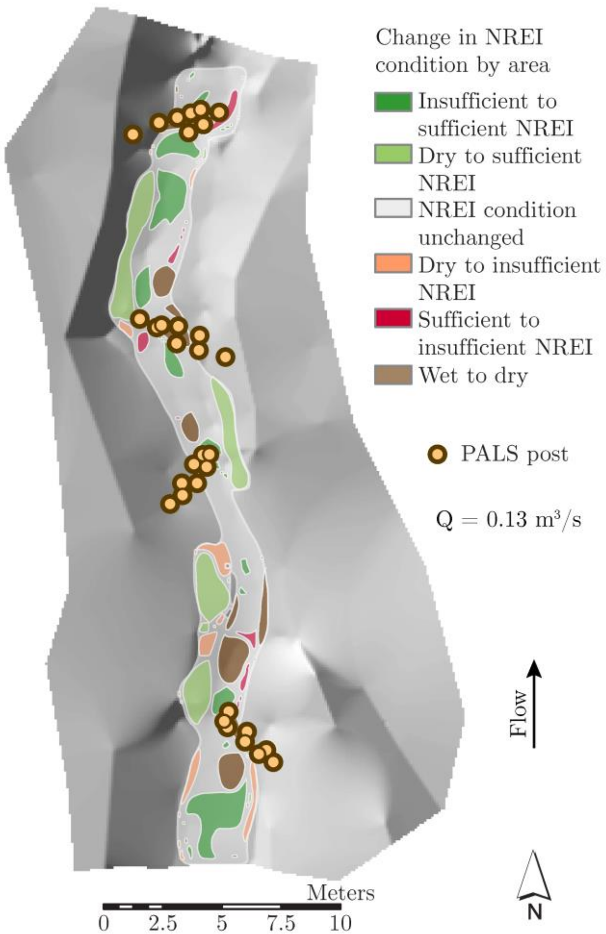
Evaluate
Choose
Do
Monitor
Learn

Ex 1: NREI & Restoration Design & Monitoring

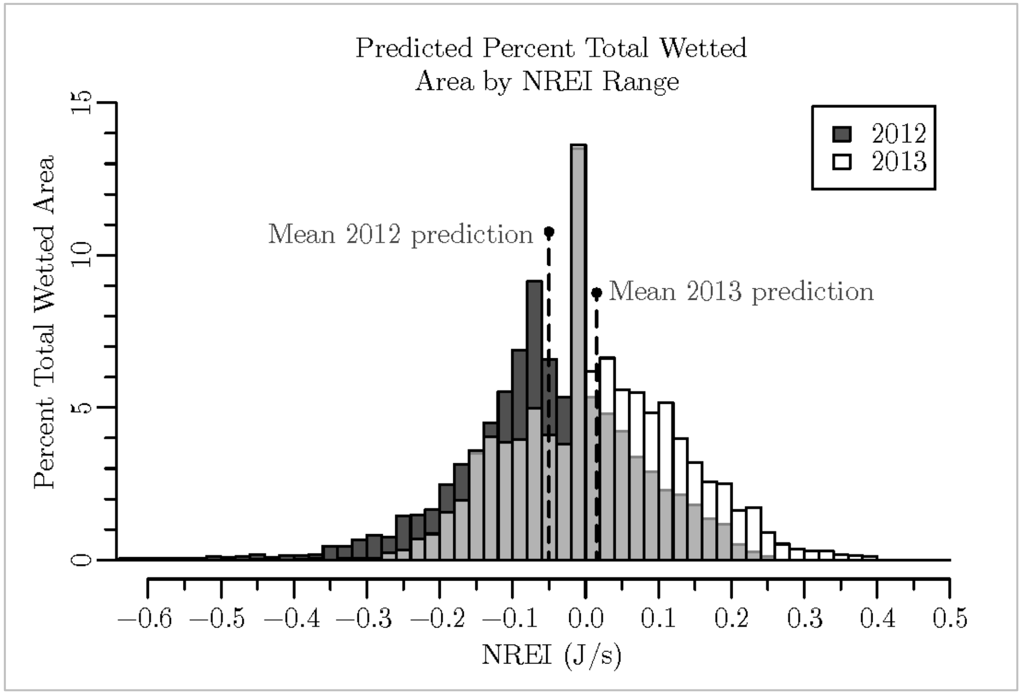
BONNEVILLE POWER ADMINISTRATION ISEMP CHaMP

Tracking site values over time

NREI change map (2012 → 2013)



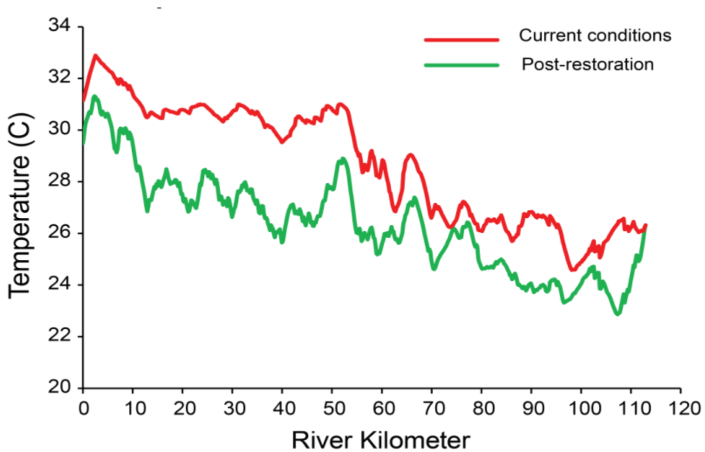
NREI distributions (2012 and 2013)



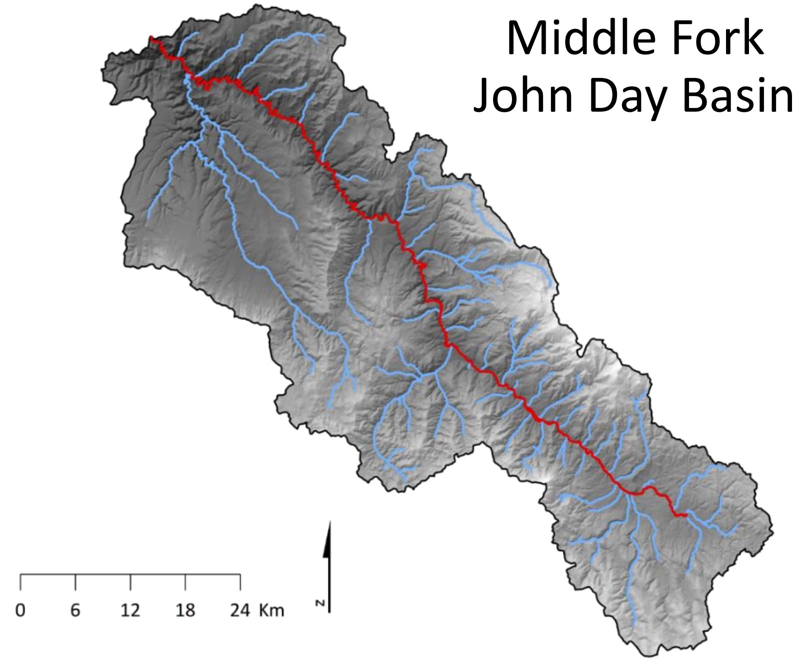
Ex 1: NREI & Restoration Design & Monitoring

Also useful for evaluating benefits of temperature-focused restoration actions…

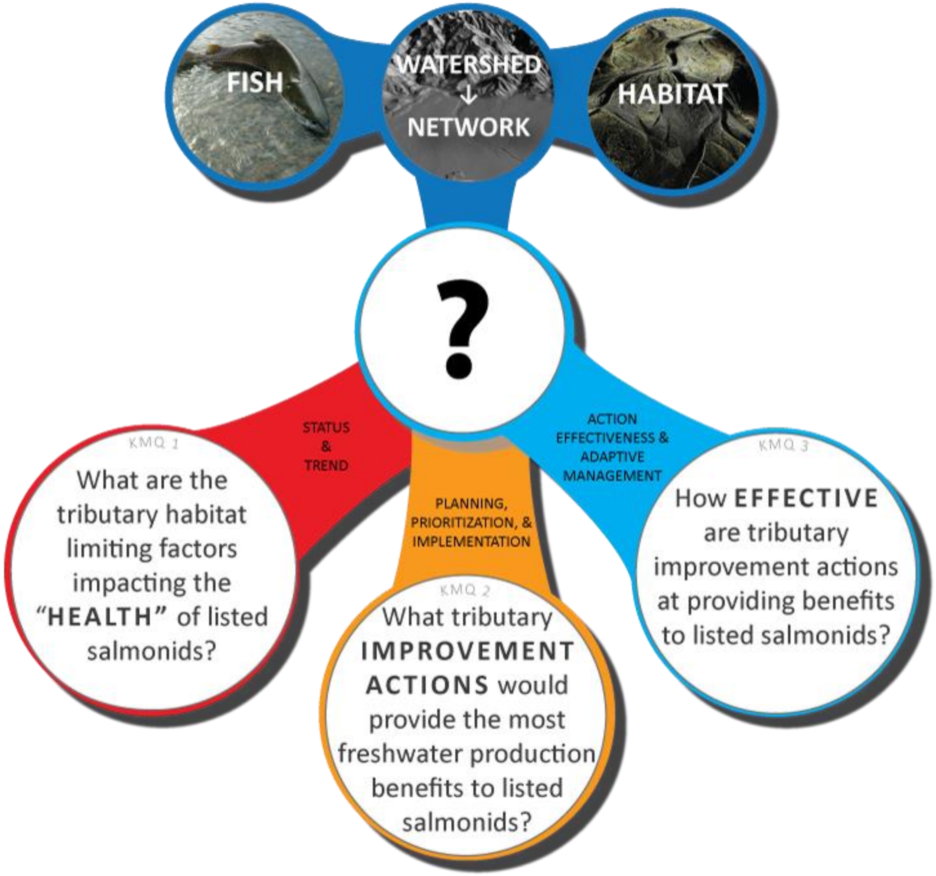
ODEQ Heat Source Model Results



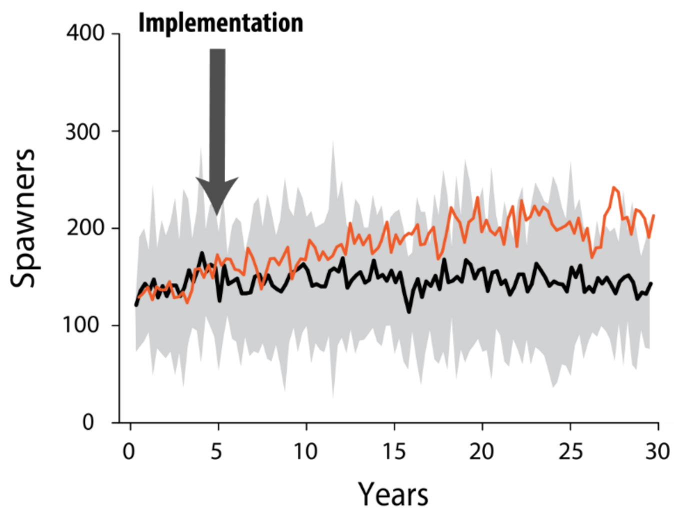
Middle Fork
John Day Basin



Ex 2: Life Cycle Models



- NREI & extrapolation process can translate planned actions into population currency
- LCMs tell us what this means for future population status (KMQ2)? Also, benchmark for KMQ3…



ISEMP Watershed Model

Habitat Modification Effects on Salmonid Population Dynamics

Matt Nahorniak

titative framework for the analysis of habitat and hatchery practices on Pacific salmon

Rishi Sharma[a,*], Andrew B. Cooper[b,1], Ray Hilborn[c]

[a] Columbia River Inter-Tribal Fish Commission, 729 NE Oregon Street, Suite 200, Portland, OR 97232, USA
[b] Quantitative Ecology and Resource Management, University of Washington, Box 351720, Seattle, WA 98195-1720, USA
School of Aquatic and Fishery Sciences, University of Washington, Box 355020, Seattle, WA 98195-5020, USA

Received 26 June 2003; received in revised form 8 July 2004; accepted 28 July 2004

The Shiraz model: a tool for incorporating anthropogenic effects and fish–habitat relationships in conservation planning

Mark D. Scheuerell, Ray Hilborn, Mary H. Ruckelshaus, Krista K. Bartz, Kerry M. Lagueux, Andrew D. Haas, and Kit Rawson

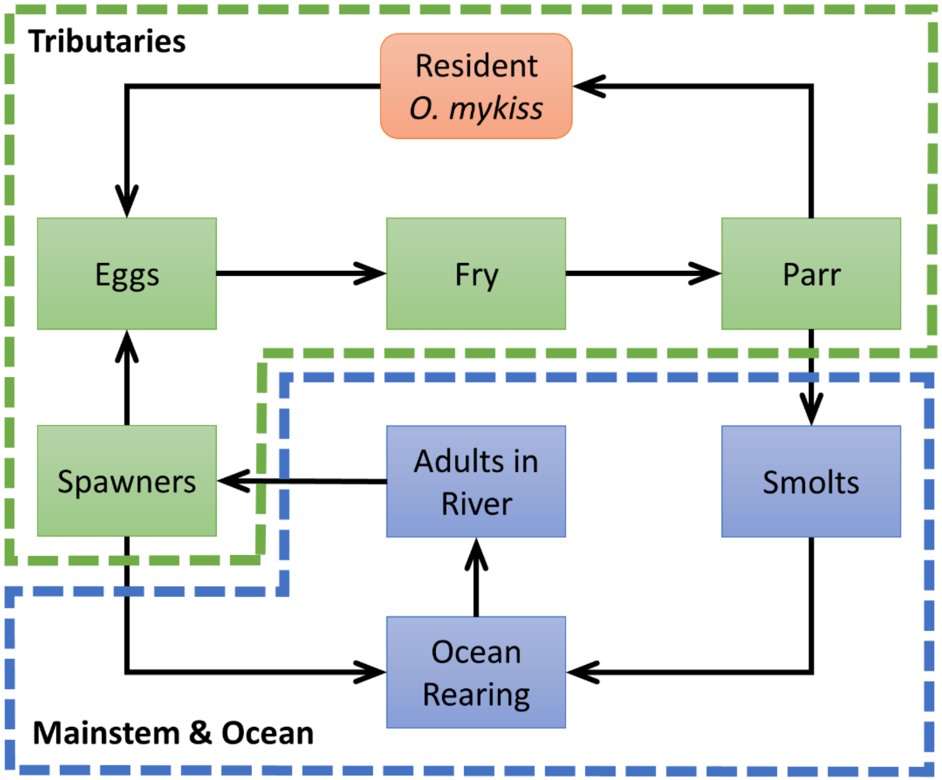
Optimal Stock Size and Harvest Rate in Multistage Life History Models

Elie Moussalli and Ray Hilborn[1]

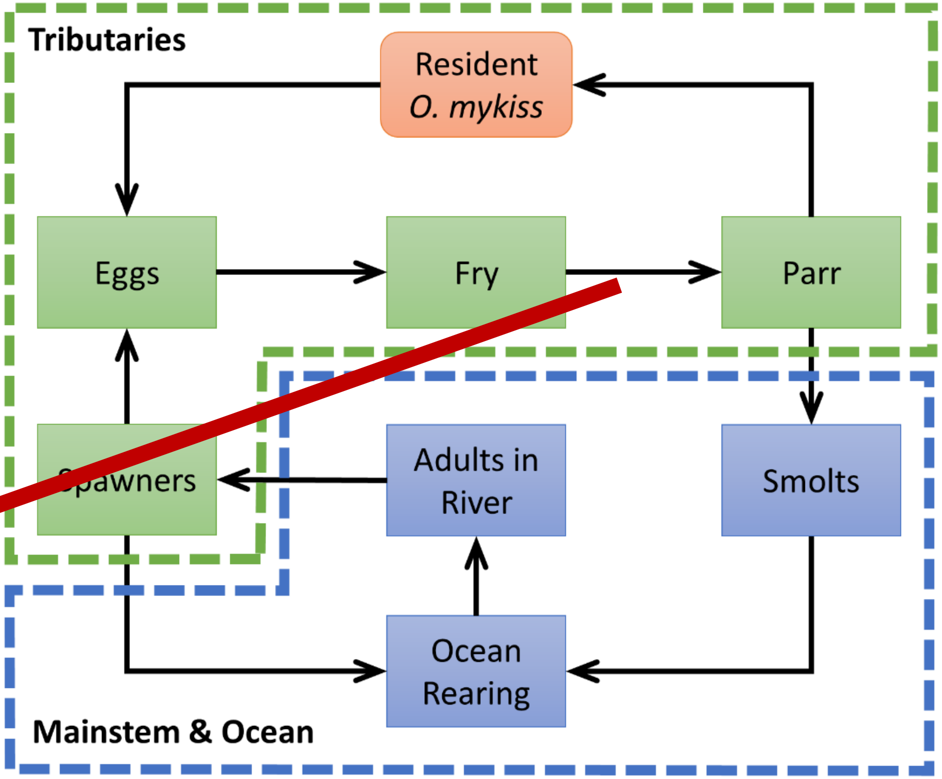
Institute of Animal Resource Ecology, University of British Columbia, Vancouver, B.C. V6T 1W5

Moussalli, E., and R. Hilborn. 1986. Optimal stock size and harvest rate in multistage life history models. Can. J. Fish. Aquat. Sci. 43: 135–141.

Middle Fork John Day O. mykiss Life Cycle Model

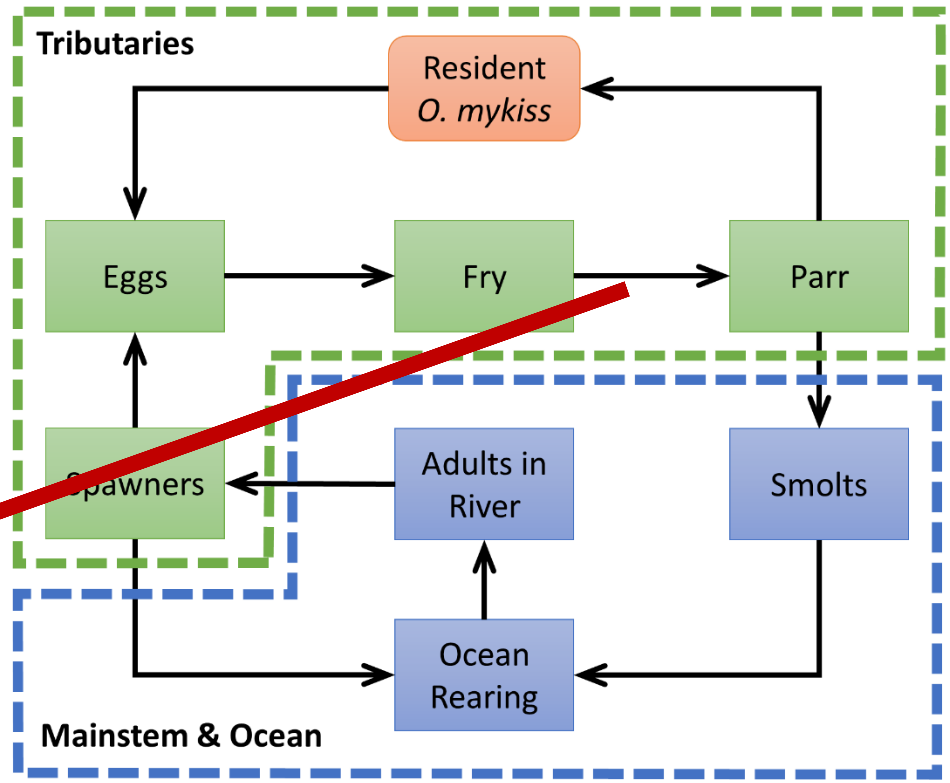


Middle Fork John Day O. mykiss Life Cycle Model

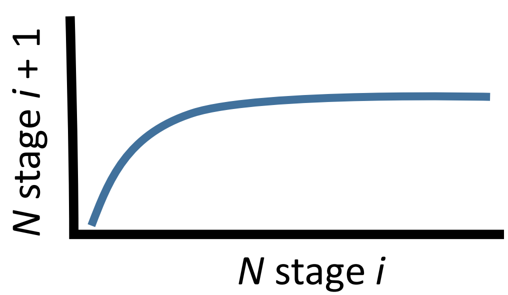


S_i = realized survival, fxn of stage-specific productivity & carrying capacity parameters (Beverton-Holt form)

Middle Fork John Day O. mykiss Life Cycle Model



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



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

Estimating base model parameters

Freshwater survival

- Egg-to-fry: link to CHaMP data using pub'd X vs. S relation.
- Fry-to-parr: backed out
- Parr & pre-smolt: ISEMP PIT-tag data (Barker model ests)
- Smolt (trap to JDA): CJS est's

Total fw survival constrained to stay within trap sm/sp estimates

Freshwater capacity

- Egg/spawner: HSI/FIS
- Fry: infinite (placeholder)
- Parr: NREI and HSI models
- Presmolt: NREI and HSI
- Smolt: infinite

Estimating base model parameters

Adult productivity & capacity

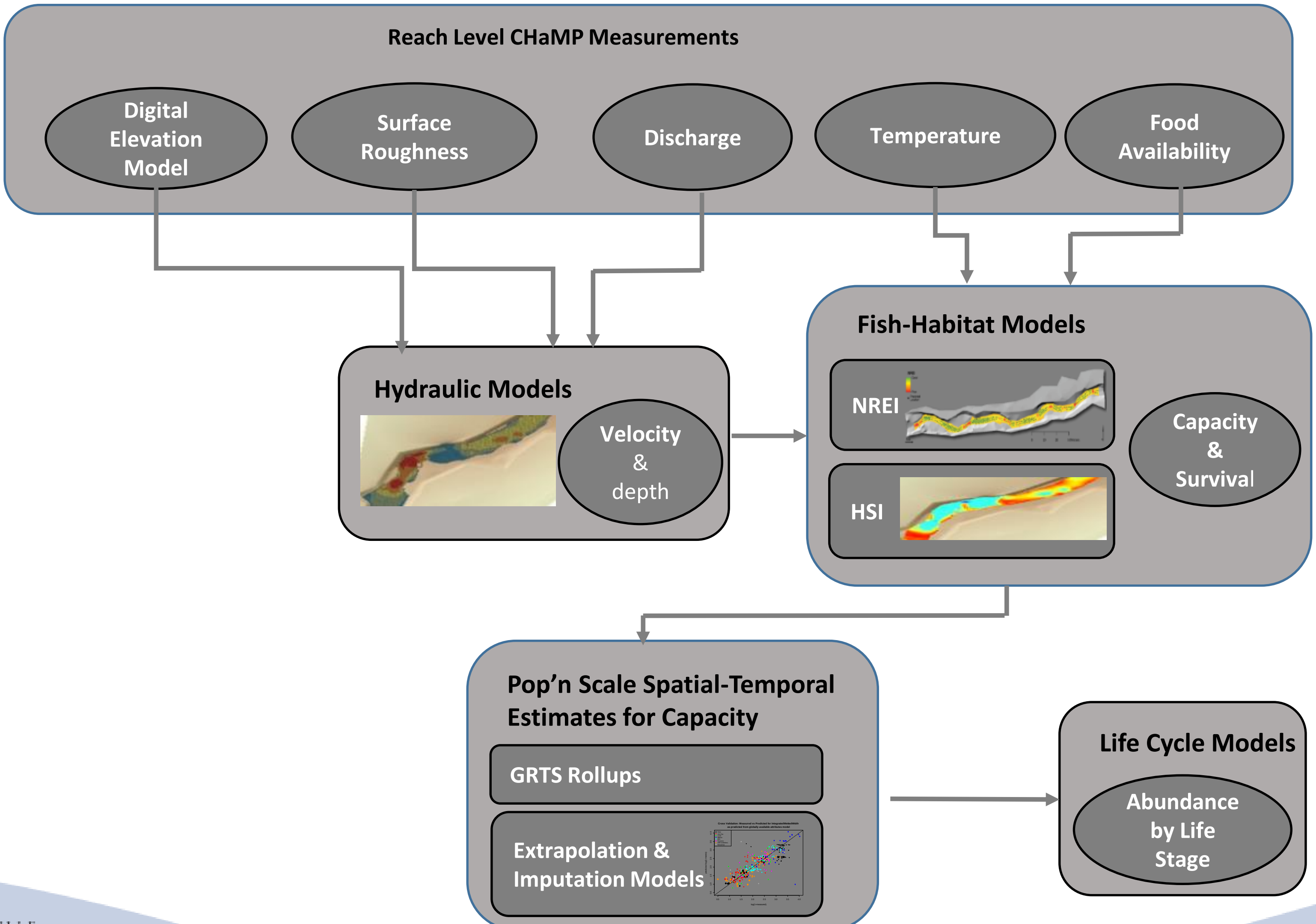
- JDA-to-BON SARs: CSS est's for wild John Day steelhead
- BON-to-spawning grounds, modeled at 60-80%
- Ocean adult capacity taken as infinite

Other model parameters

- Outmigration & return prob.
- Fecundity, pub'd relations
- Probability of resident LH, and associated gender bias
- Post-spawn survival
- Hatchery influence
- Inter-population movement
- Stochastic components

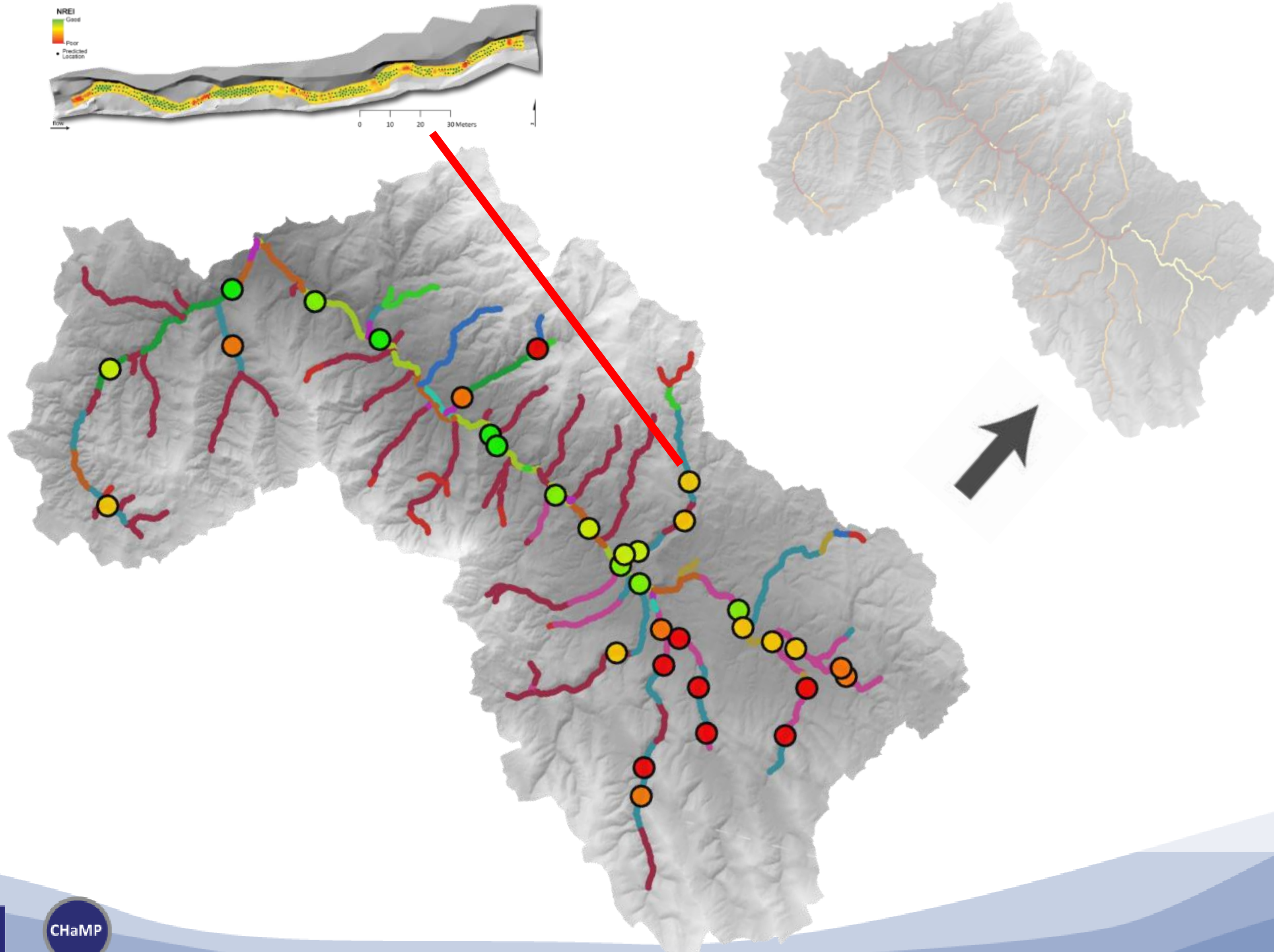
LCMs integrate info across RME projects

But…



Reach Level CHaMP Measurements
Digital Elevation Model
Surface Roughness
Discharge
Temperature
Food Availability
Hydraulic Models
Velocity & depth
Fish-Habitat Models
NREI
HSI
Capacity & Survival
Pop'n Scale Spatial-Temporal Estimates for Capacity
GRTS Rollups
Extrapolation & Imputation Models
Life Cycle Models
Abundance by Life Stage

Network model: carrying capacity

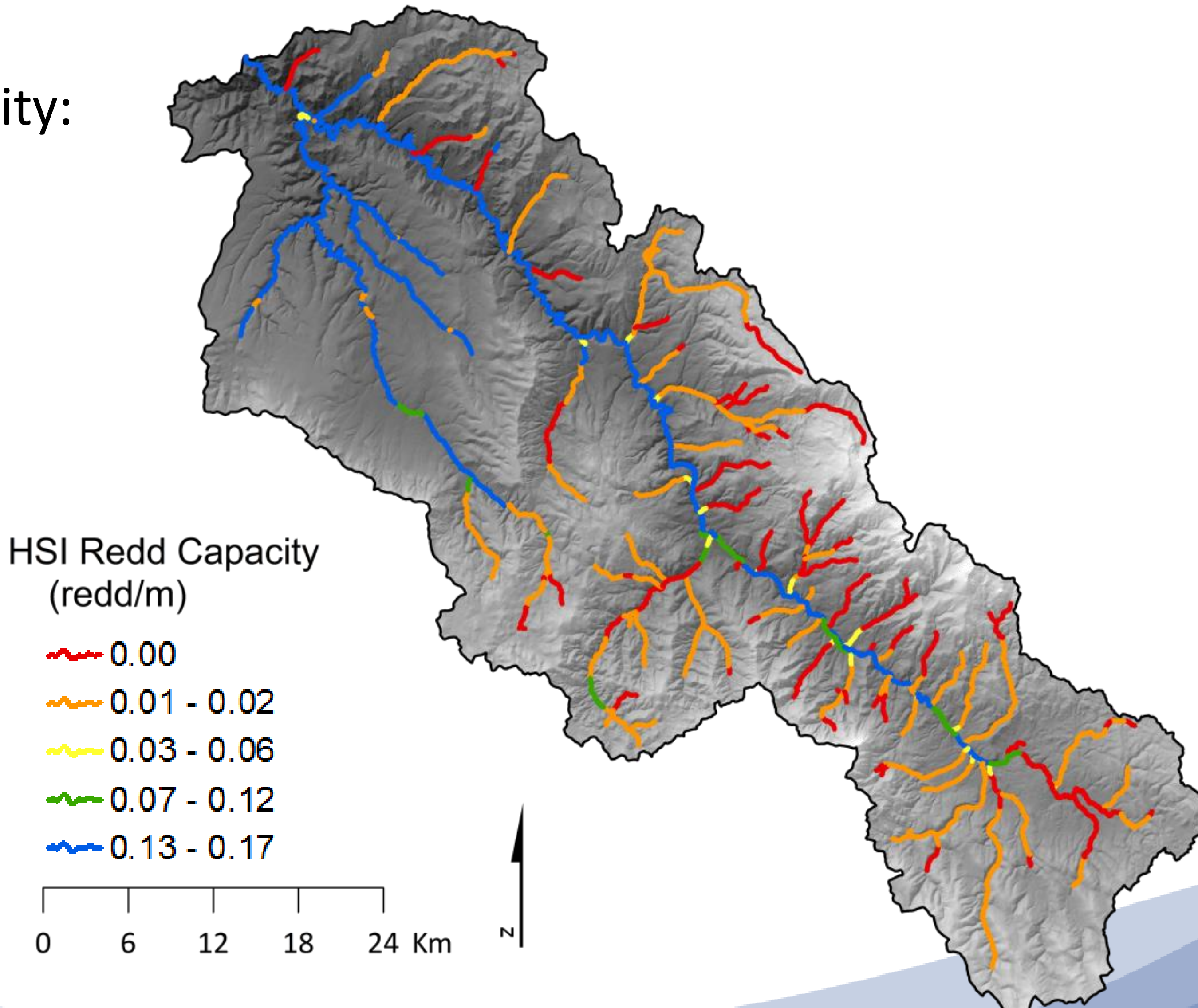


BONNEVILLE POWER ADMINISTRATION
ISEMP
CHaMP

Steelhead adult capacity

Watershed capacity:

ca. 41,000 redds



Steelhead juvenile capacity

Watershed age-0 parr (60 – 99 mm) capacity: 3.7 parr/m

Watershed 1+ pre-smolt (≥100 mm) capacity: 2.7 pre-smolt/m

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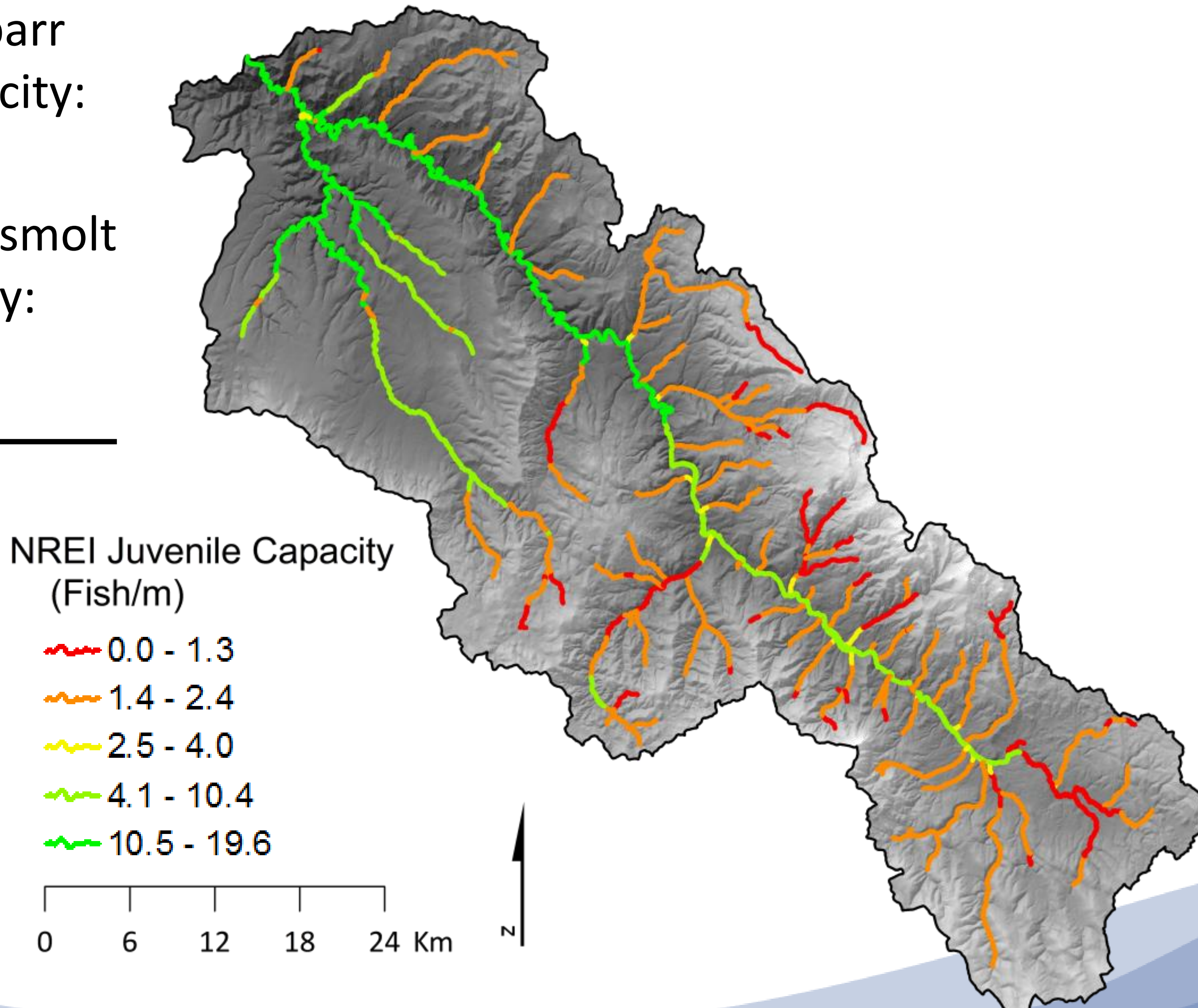
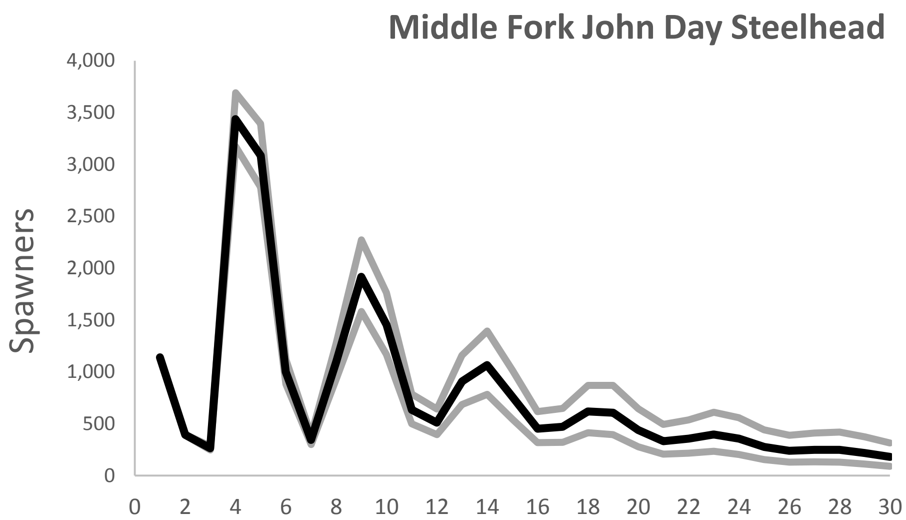
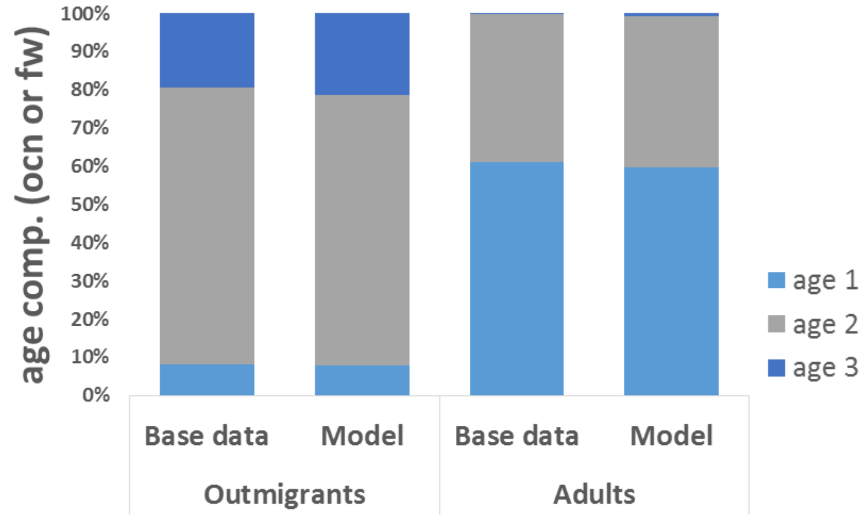
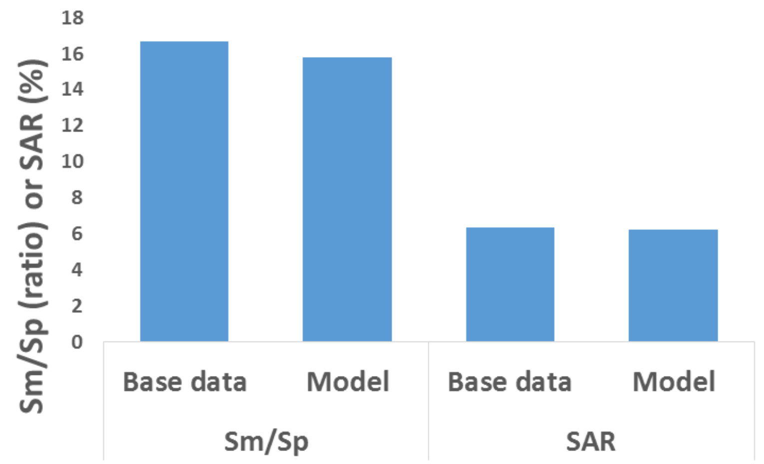
ca. 4 million



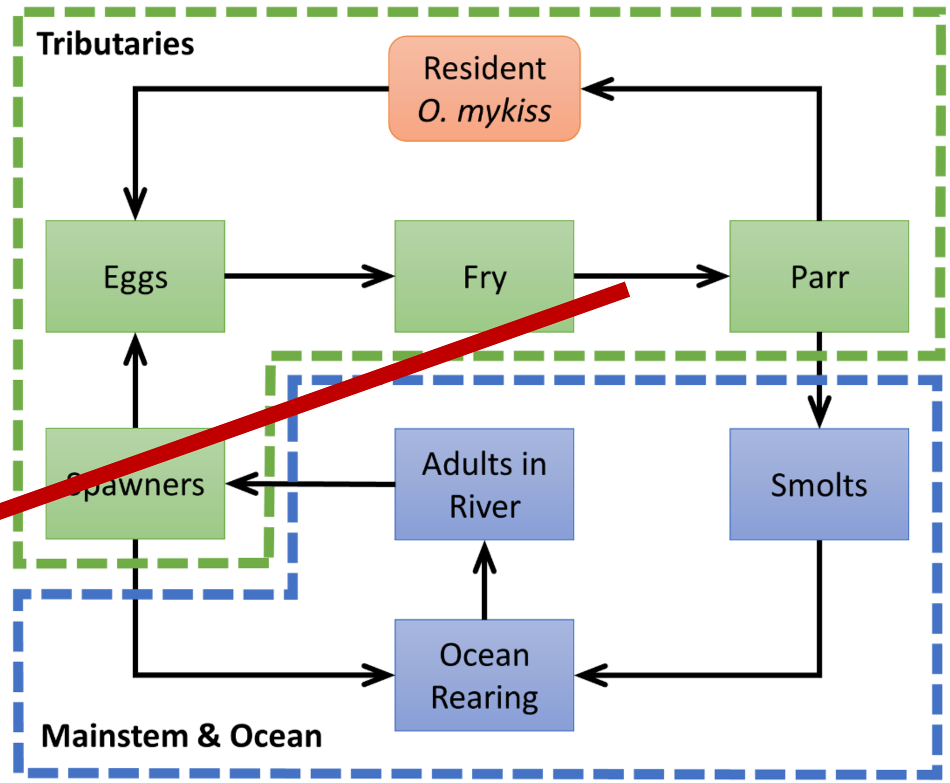
Does the model behave as it should?



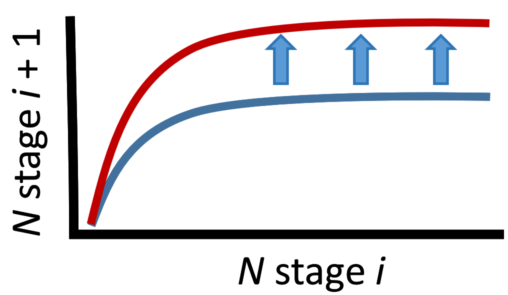




Middle Fork John Day O. mykiss Life Cycle Model

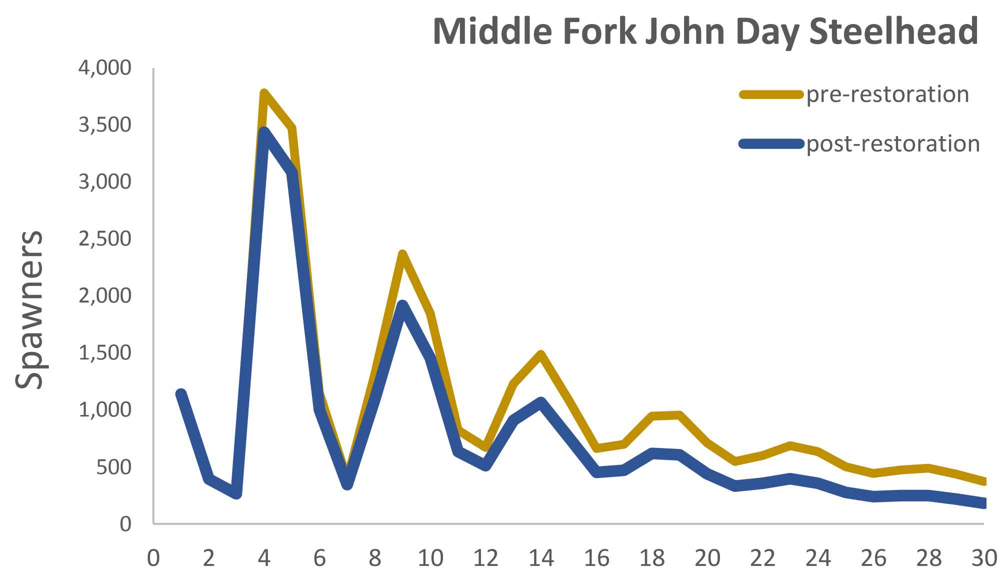


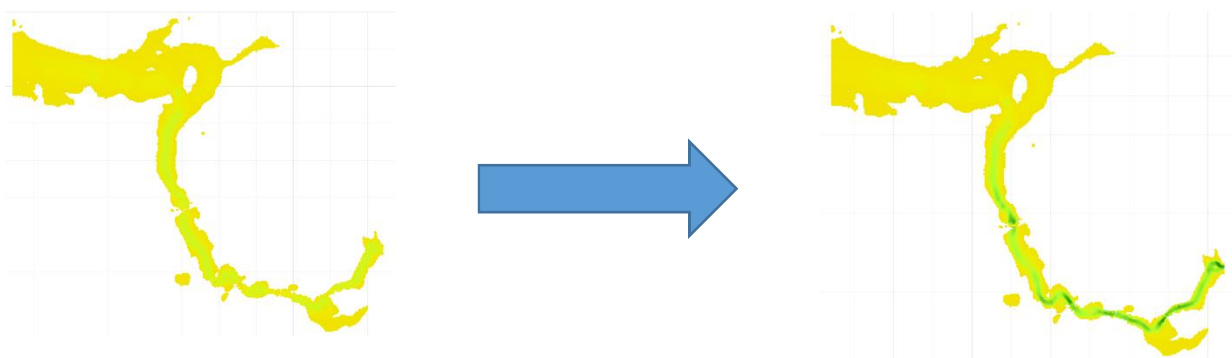
S_i = realized survival, fxn of stage-specific productivity & carrying capacity parameters (Beverton-Holt form)



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

A simple restoration scenario…





Next Steps for LCMs

- Complete MF John Day *O. mykiss* model:
  - Finish extrapolation
  - Run base & two scenarios
  - Complete manuscript (documentation)
- Adapt to other basins?
  - Build a linked JD Basin-wide model
  - Tucannon River
- Compare to other models?