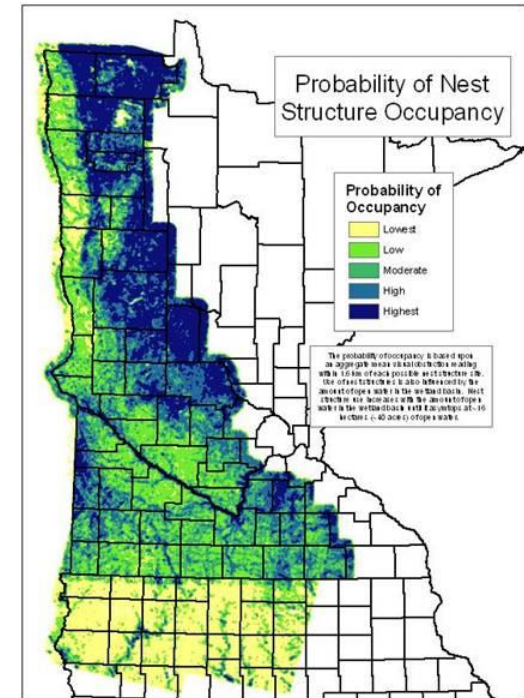


Watershed Sciences 4930 & 6920

Advanced GIS

HABITAT MODELING

Joe Wheaton



HOUSEKEEPING

- Labs 8 & 9
- Thursday... Slop for today
 - Podcast or Lecture?
- After Spring Break... Two more lectures (one is a demo)
- Project Class...
 - Same time slot... T TH 10:30 -1:00ish
 - No labs
 - Meet in Quinney Library Lab
 - Come prepared with some ideas for a project



TODAY'S PLAN



I. Introduction to Habitat Models

II. Habitat Models

I. HSI – Suitability Based Models

I. Fish example

II. Fuzzy-Logic Based Models

I. Beaver Example

III. Bioenergetics Based Models

I. Fish Example

III. Lab – Habitat Occupancy Model

I. Ungulates (Cows)...

WHAT IS A HABITAT MODEL?

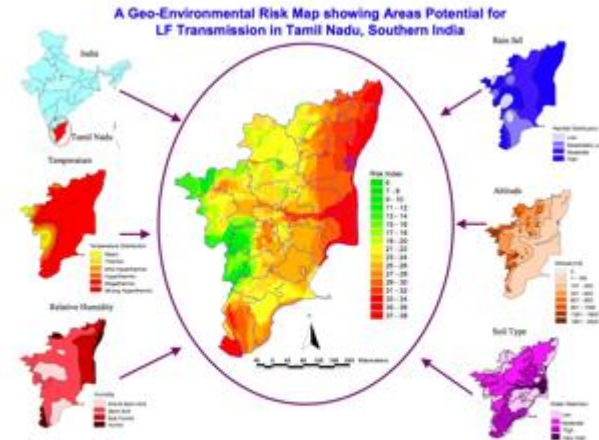
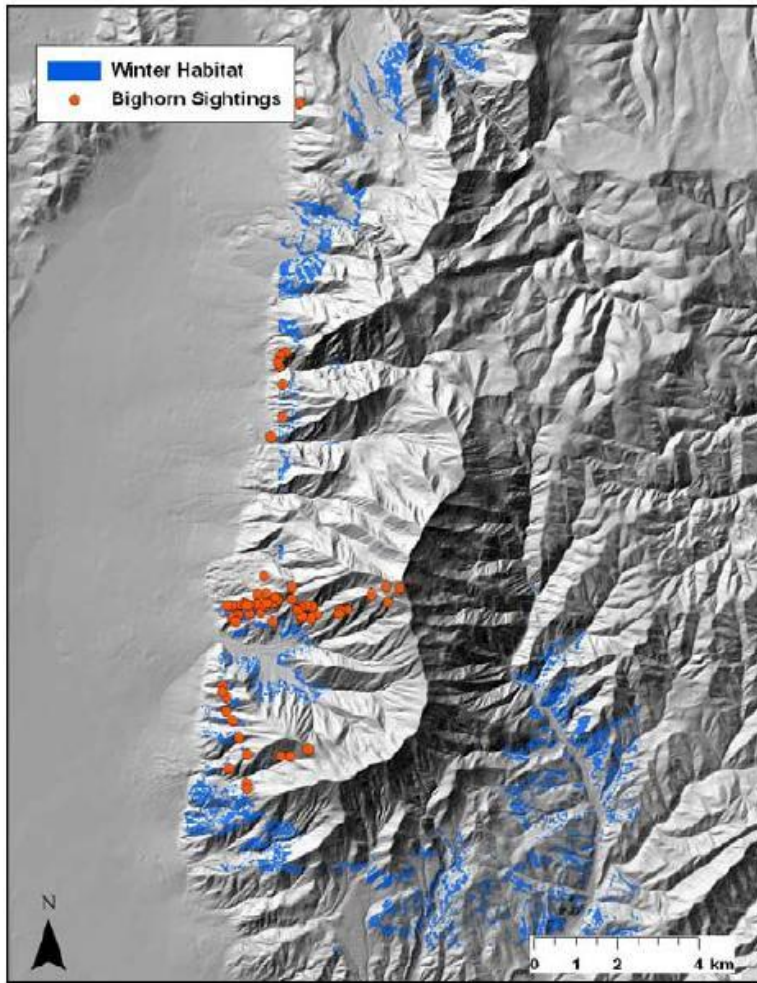


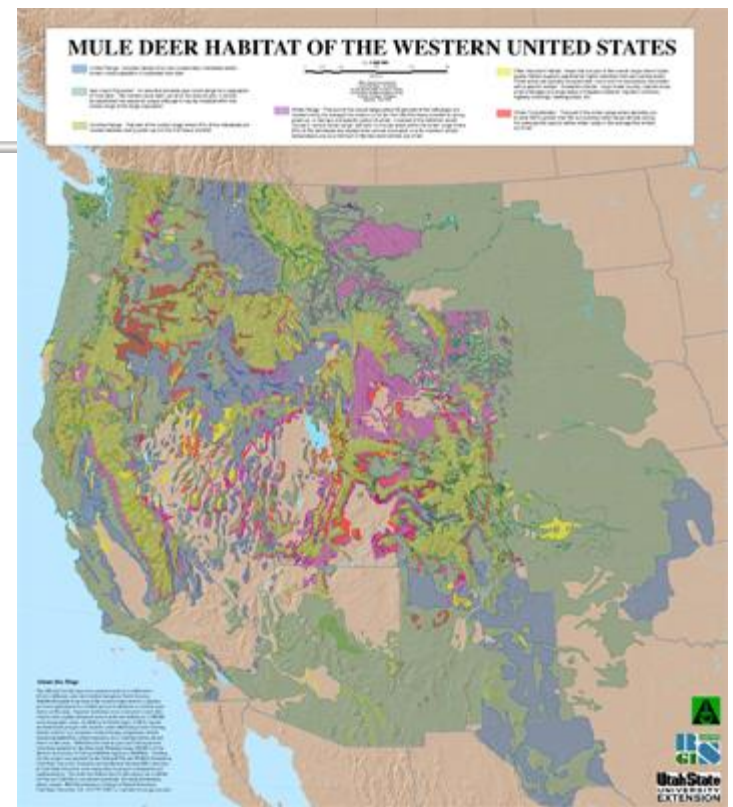
Figure 1: Relative risk of lymphatic filariasis transmission in Tamil Nadu, Southern India. From Sebasan S. et al. (2006).

- Spatial prediction of either:
 - Binary availability of specific habitat
 - Relative quality of available habitat

HABITAT MODELS CAN..

Take form of:

- Availability models
- Range models
- Capacity models
- Movement models
- Bioenergetics models

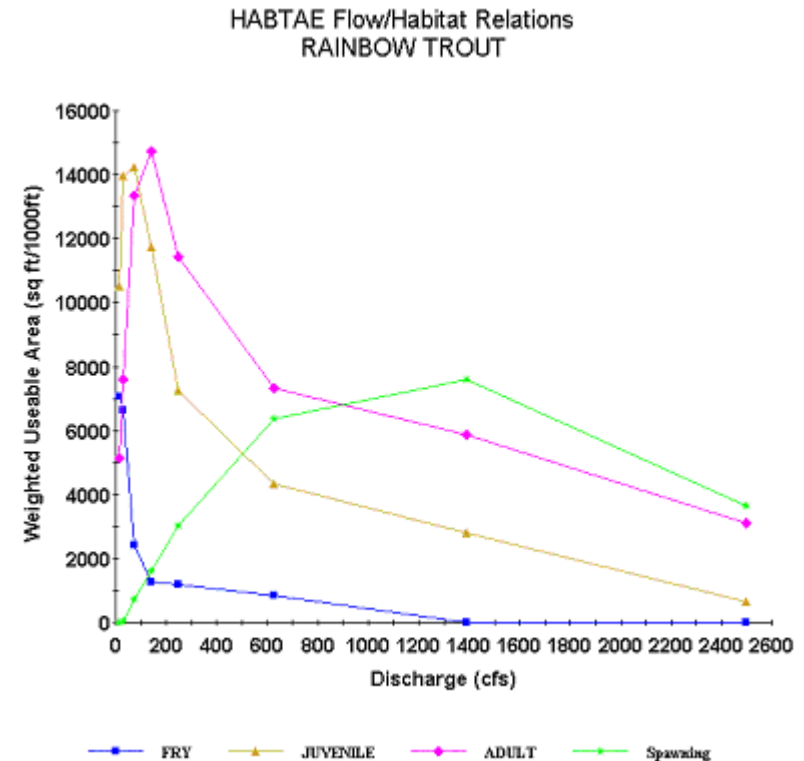


Spatial Model can be:

- Vector based
- Raster based
- Agent based

CAREFUL... WHAT DOES MODEL PREDICT?

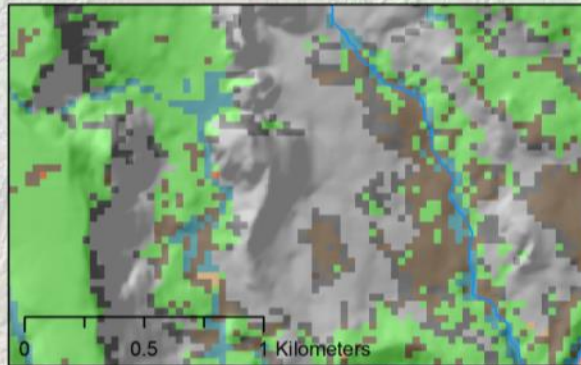
- What species?
- What lifestage(s)?
- Is it time-dependent?
- Is it a:
 - Probability of use
 - Capacity to support
 - 'Quality'
- Is 'high' quality habitat accessible?



IS THIS A HABITAT MODEL?

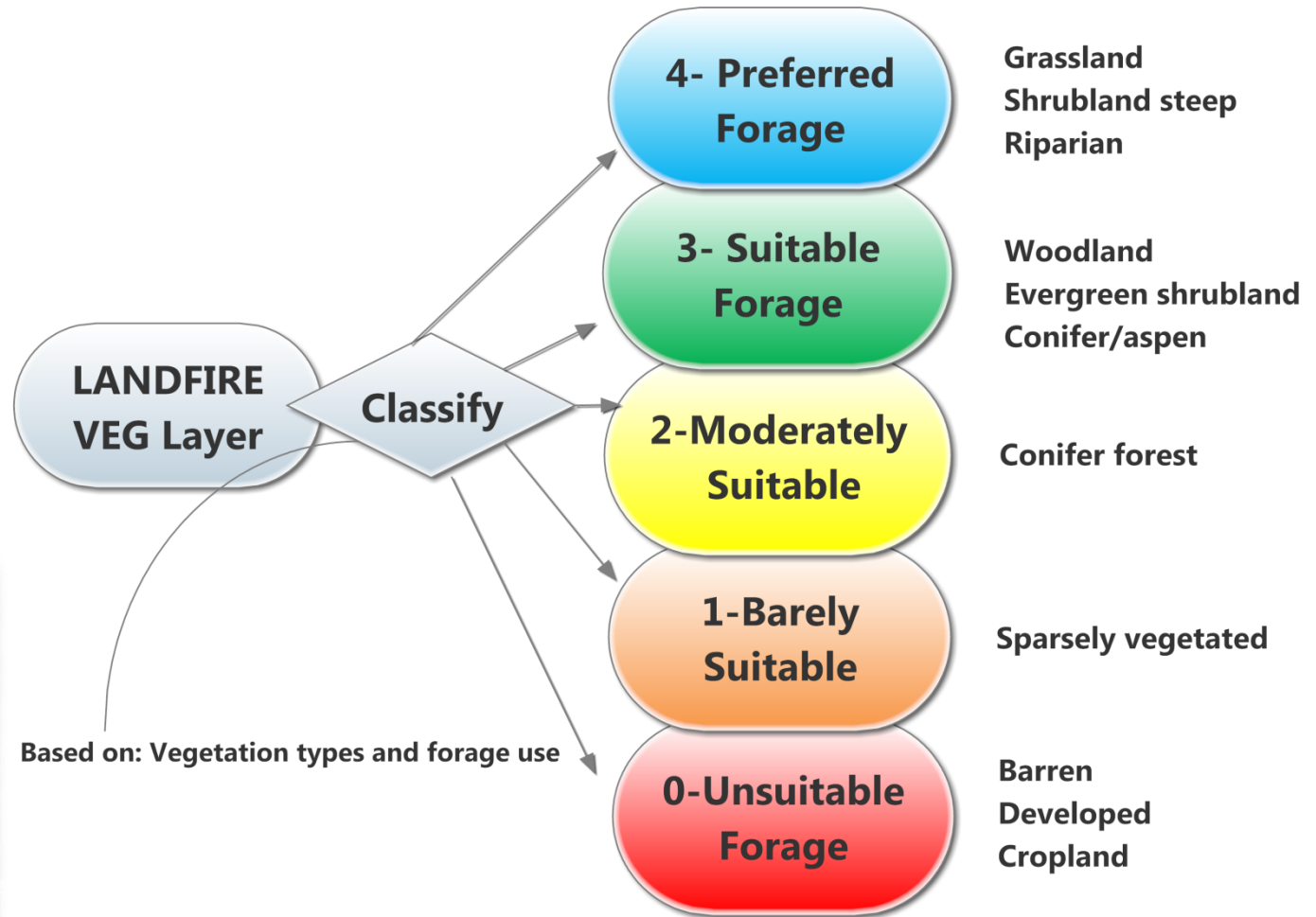
LANDFIRE Existing Land Cover:SAF_SRM

- LF 20: Developed
- LF 31: Barren
- LF 33: Sparsely Vegetated
- LF 54: Introduced Upland Vegetation - Herbaceous
- LF 58: Introduced Woody Wetlands and Riparian Vegetation
- LF 80: Agriculture
- SAF 206: Engelmann Spruce-Subalpine Fir
- SAF 209: Bristlecone Pine
- SAF 210: Interior Douglas-Fir
- SAF 211: White Fir
- SAF 217: Aspen
- SAF 218: Lodgepole Pine
- SAF 219: Limber Pine
- SAF 235: Cottonwood-Willow
- SAF 237: Interior Ponderosa Pine
- SAF 241: Western Live Oak
- SRM 203: Riparian Woodland
- SRM 212: Blackbush
- SRM 314: Big Sagebrush-Bluebunch Wheatgrass
- SRM 402: Mountain Big Sagebrush
- SRM 403: Wyoming Big Sagebrush
- SRM 405: Black Sagebrush
- SRM 409: Tall Forb
- SRM 410: Alpine Rangeland
- SRM 412: Juniper-Pinyon Woodland
- SRM 413: Gambel oak
- SRM 414: Salt Desert Shrub
- SRM 415: Curlleaf Mountain-Mahogany
- SRM 418: Bigtooth Maple
- SRM 421: Chokecherry-Serviceberry-Rose
- SRM 422: Riparian
- SRM 501: Saltbush-Greasewood
- SRM 502: Grama-Galetta
- SRM 503: Arizona Chaparral
- SRM 504: Juniper-Pinyon Pine Woodland



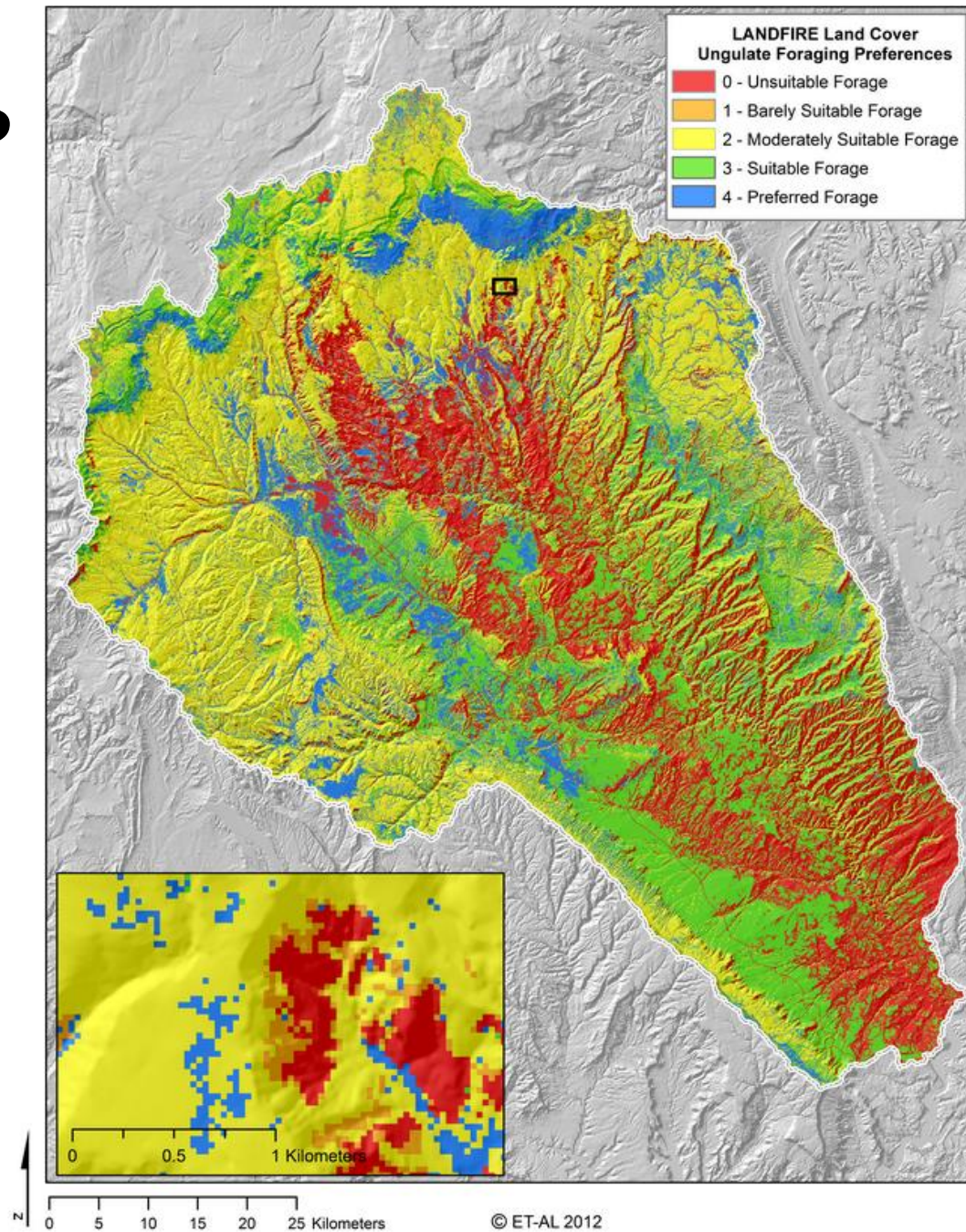
CLASSIFY VEGETATION PREFERENCE

- Based on?



IS THIS A HABITAT MODEL?

- Uses that classification...



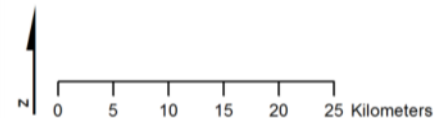
IS THIS A HABITAT MODEL?

Probability of Ungulate Utilization



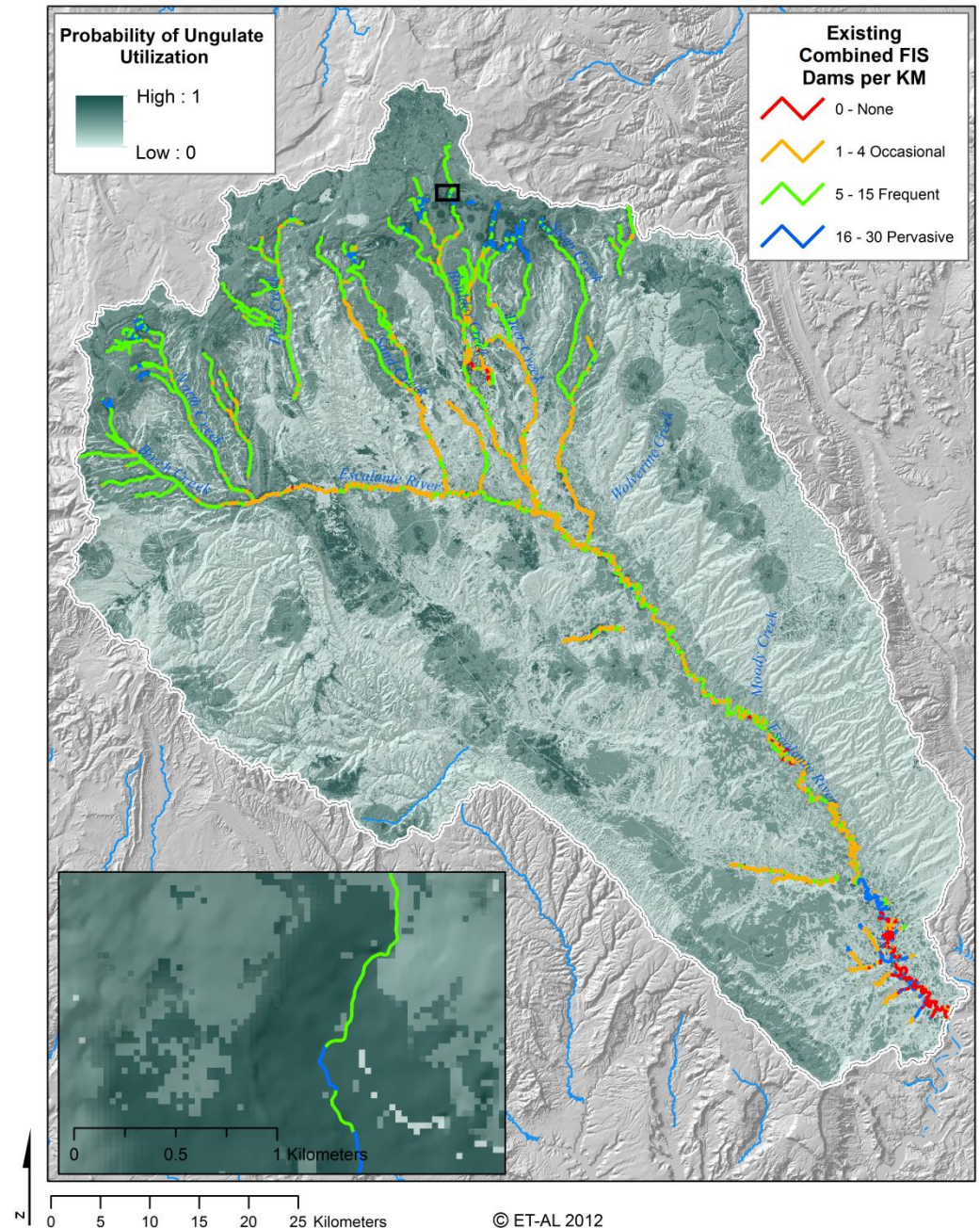
What goes in?

- Slope
- Distance from Water
- Vegetation



A VECTOR MODEL & A RASTER MODEL

- How do I run a vector model (e.g. network) vs. a raster model?
- How do I combine results of multiple outputs?

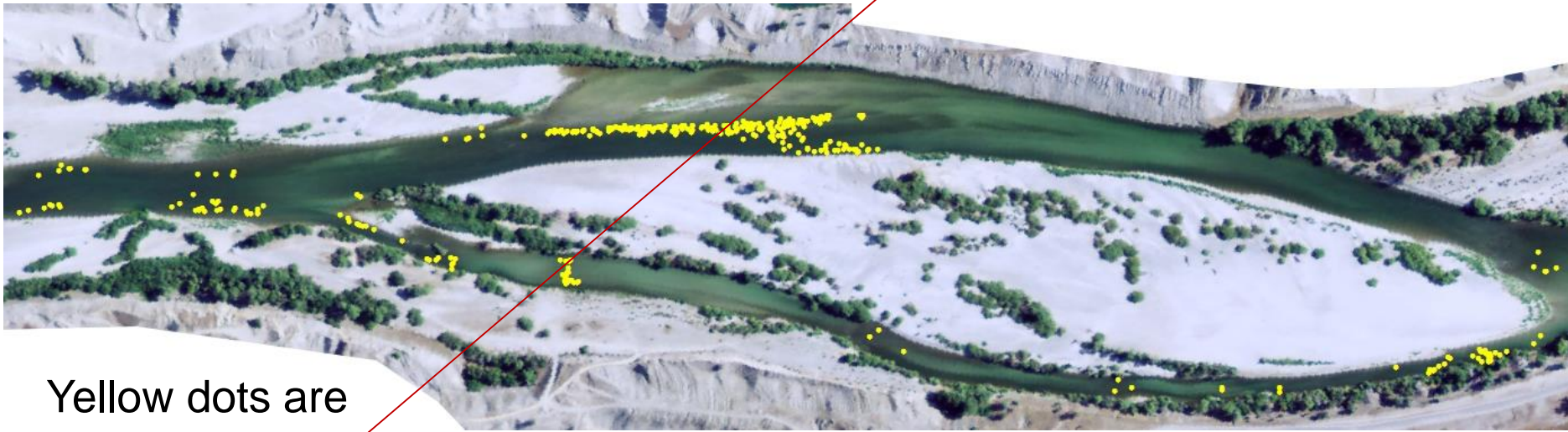


STEPS TO CHARACTERIZE PHYSICAL HABITAT

1. Make biological observations
2. Determine/quantify habitat suitability needs
 1. Empirically?
 2. Theoretically?
 3. Mechanistically?
 4. Heuristically?
3. Map habitat using model results
4. Bioverify results
5. Analyze habitat statistics and spatial structure

BIOLOGICAL OBSERVATIONS

- Sampling or census approach?
- Measure geographic locations of utilization
- Measure physical attributes at locations



Yellow dots are
observations

TODAY'S PLAN



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I. Fish Example

III. Lab – Habitat Occupancy Model

I. Ungulates (Cows)...

MAIN FOCUS OF ECOHYDRAULIC MODELS

- Most ecohydraulic models focus on fish
- Some attempt to look at macroinvertebrates (e.g. Jorde et al.)
- Some look at frog habitat (e.g. Yarnell et al. 2010: DOI 10.1002/rra.1447)

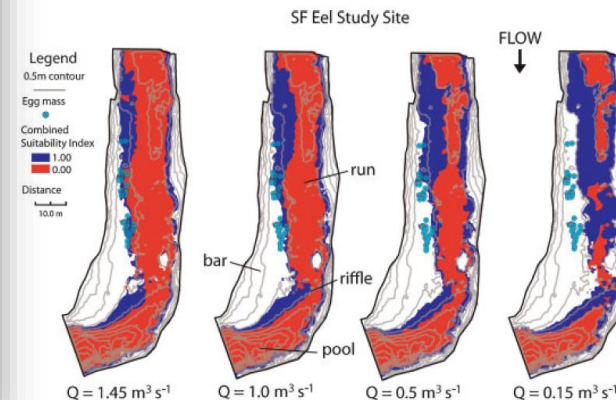
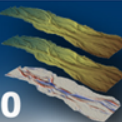


Figure 8. Suitable habitat at the SF Eel study site as modeled flows decrease from (a) $1.45 \text{ m}^3 \text{ s}^{-1}$ (2006 egg-laying discharge) to (b) $1.0 \text{ m}^3 \text{ s}^{-1}$, (c) $0.5 \text{ m}^3 \text{ s}^{-1}$, and (d) $0.15 \text{ m}^3 \text{ s}^{-1}$ (low summer flow). Upstream is at the top of each inset figure. Background shows 0.5 m bed elevation contours; Overlaid colours depict the extent of flow and habitat suitability [suitable in blue (dark grey) and unsuitable in red (light grey)]; Encircled dots indicate egg locations. This figure is available in colour online at wileyonlinelibrary.com

PRIMARY TYPES OF ECOHYDRAULIC MODELS

- Main Types
 - Habitat suitability models
 - Bioenergetics
 - Agent Based Models
- Others:
 - Population dynamics
 - Stock recruitment
 - Nutrient dynamics
 - Individual-based ecological modeling



TODAY'S PLAN



I. Introduction to Habitat Models

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I. Fish example

II. Fuzzy-Logic Based Models

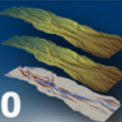
I. Beaver Example

III. Bioenergetics Based Models

I. Fish Example

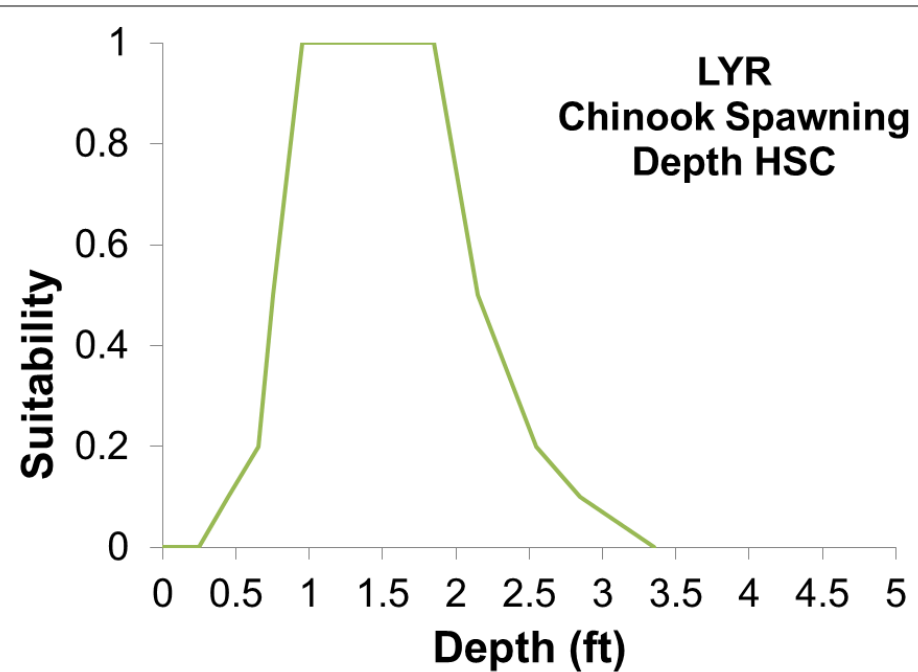
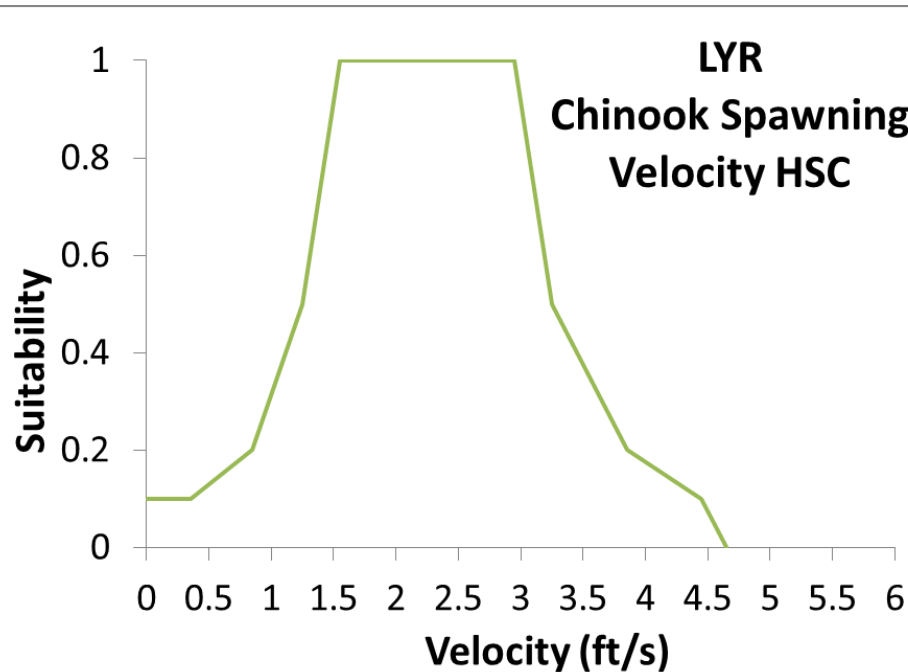
III. Lab – Habitat Occupancy Model

I. Ungulates (Cows)...



HABITAT SUITABILITY CURVE (HSC)

- Graphical representation of suitability of physical condition
- Simple HSC: scale statistical distribution to 0-1 range
- Fundamentally, this is an empirical relationship

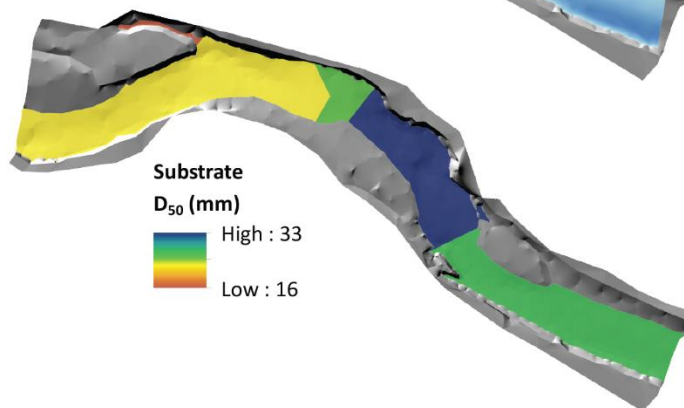
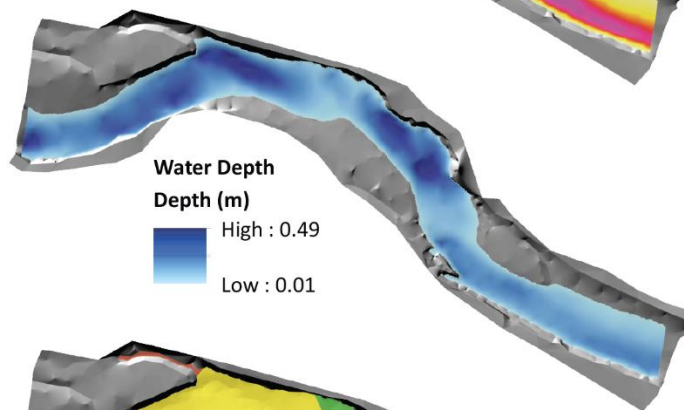
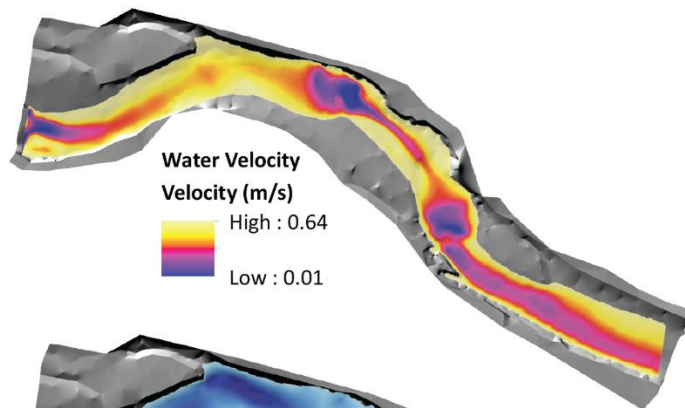


HABITAT SUITABILITY INDEX

Entiat River, Entiat Basin, WA

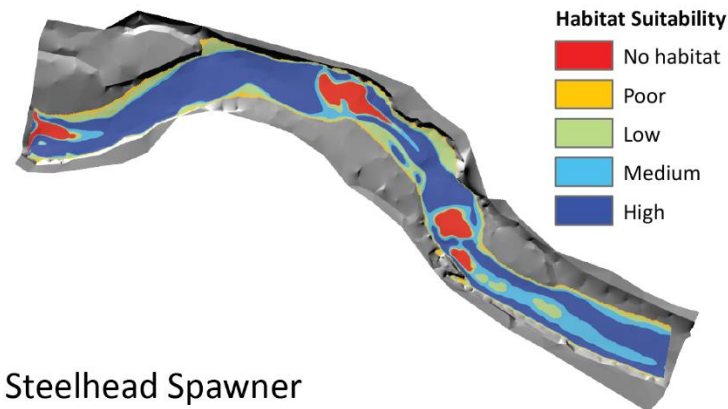
ENT00001-2A9, Visit 1054, 2012

HSI Model Inputs

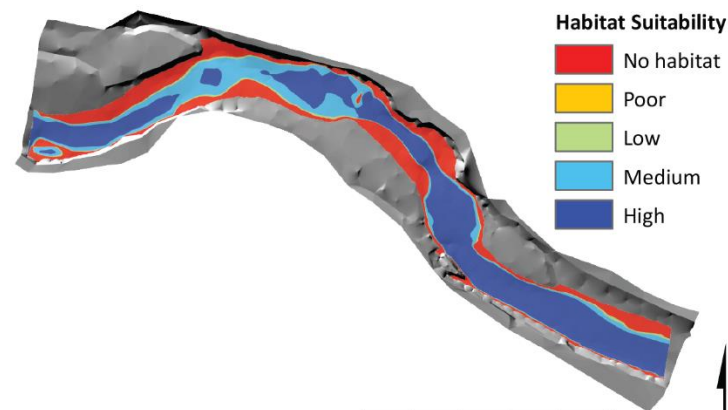


HSI Model Outputs

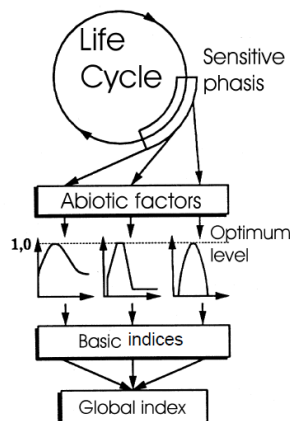
Steelhead Juvenile Habitat Suitability



Steelhead Spawner Habitat Suitability

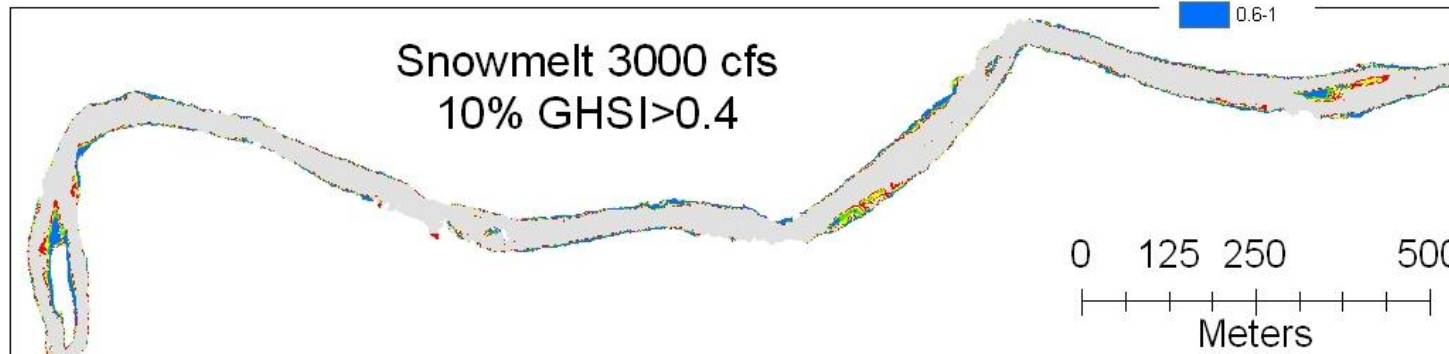
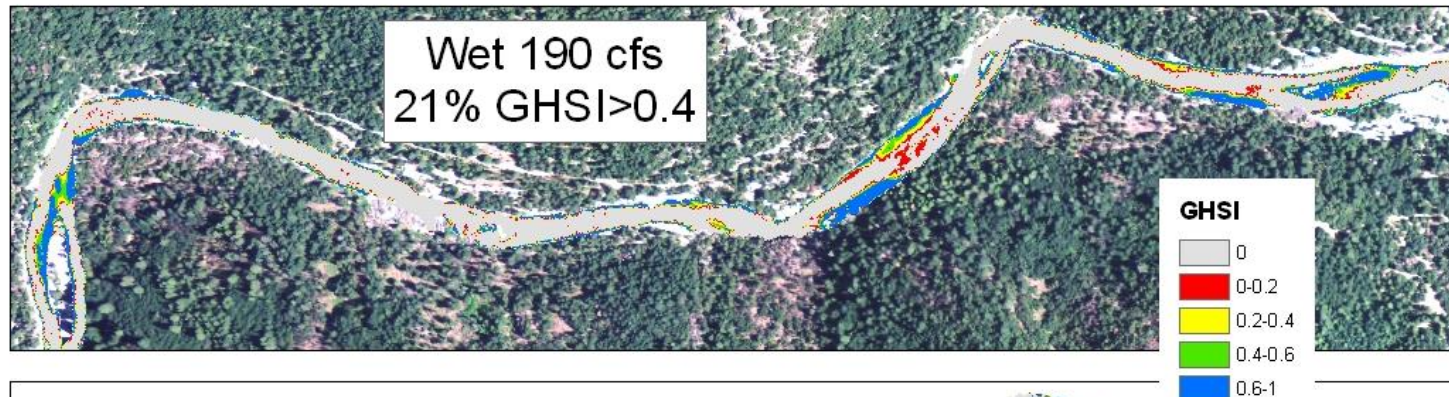
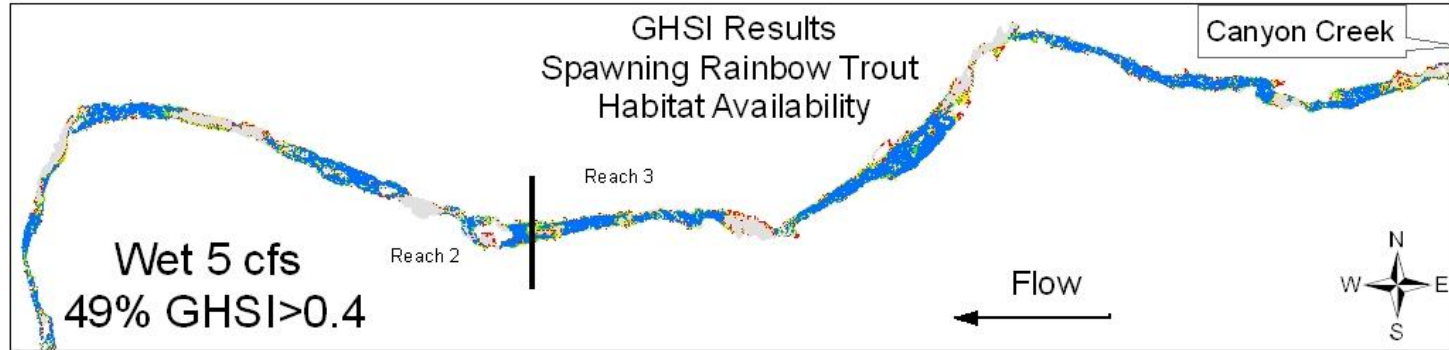


0 20 40 60 80 100 Meters

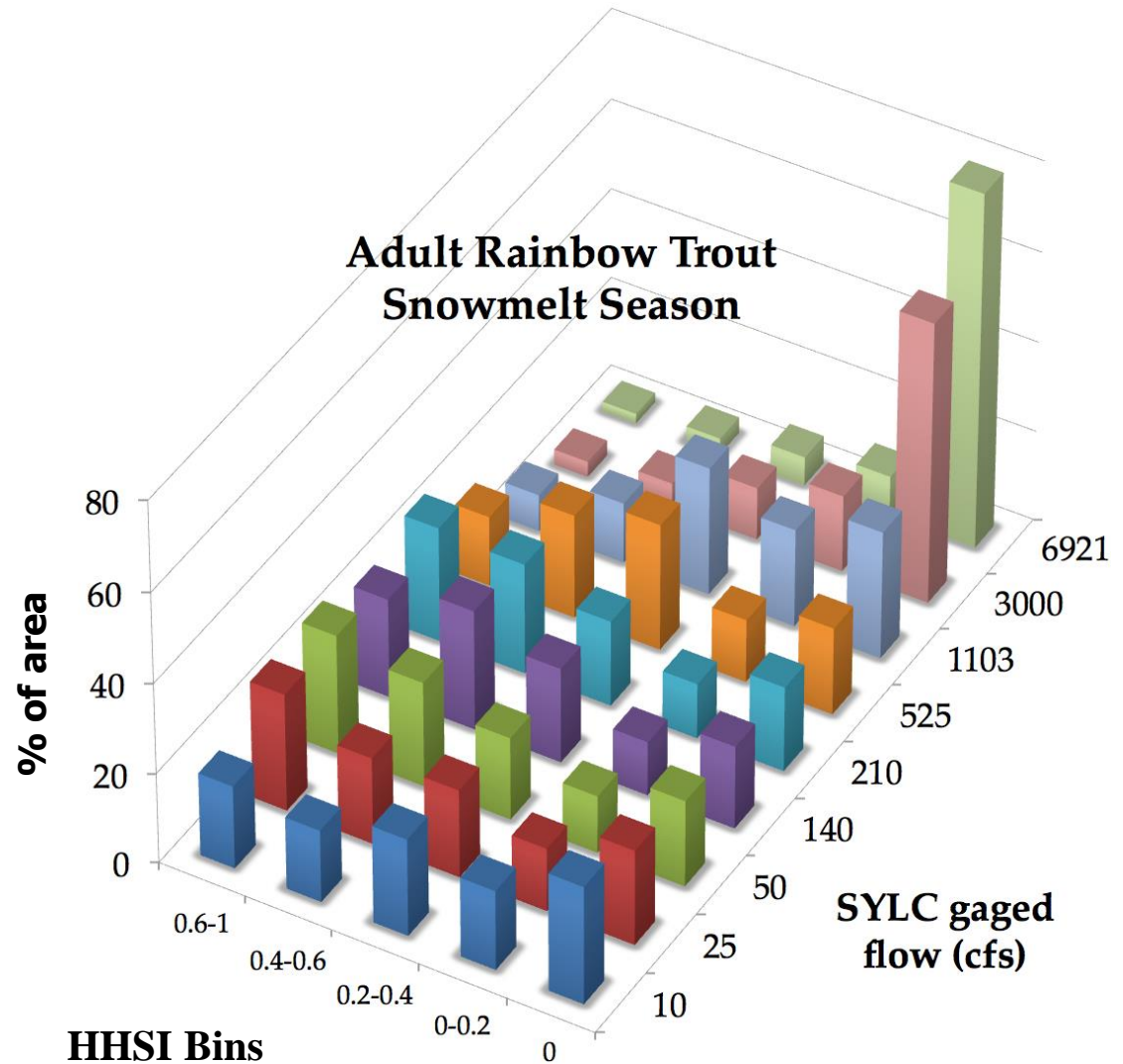


Building a classical fish *preferendum* model

EXAMPLE HHSI MAPS FOR DIFFERENT FLOWS

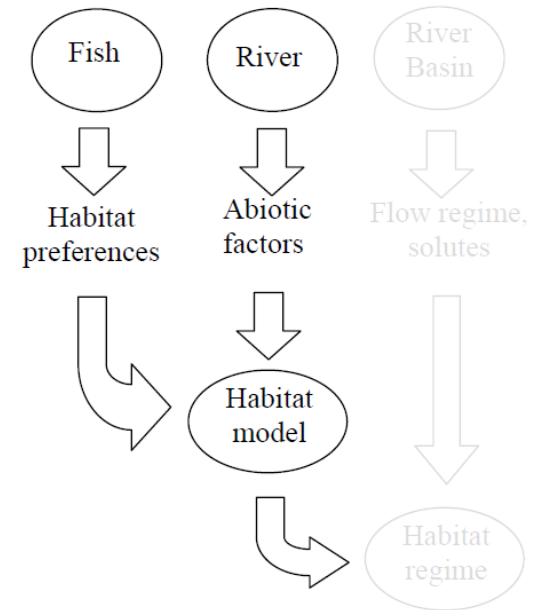


HABITAT QUALITY BINS BY DISCHARGE



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...



The paradigm of habitat modelling (After Leclerc, 2002)

From LeClerc 2005 (Chapter)

SOME COMMON BUT CONFUSING TERMS

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

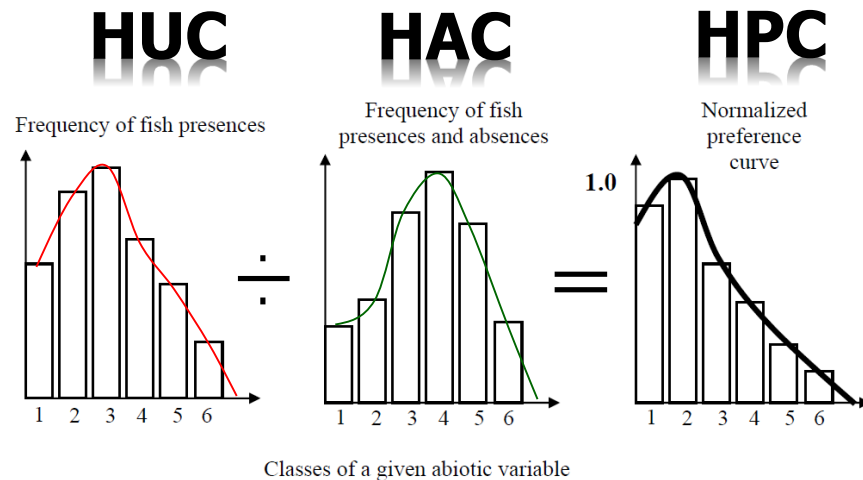
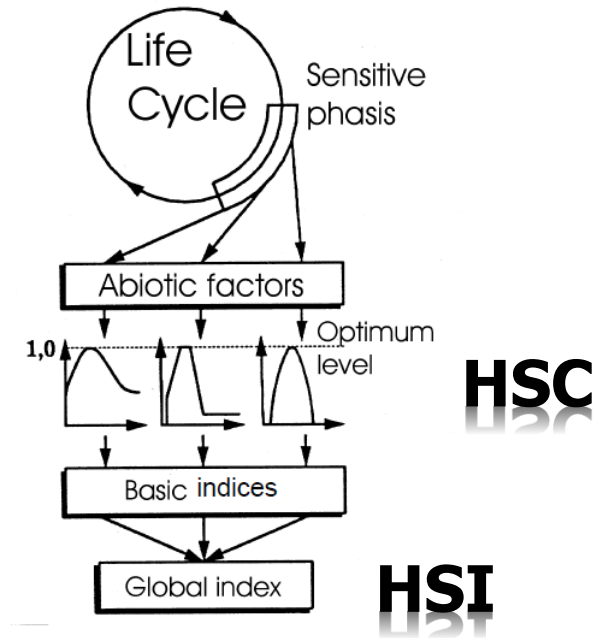


Figure 3 : The general methodology for establishing fish preference curves

- 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

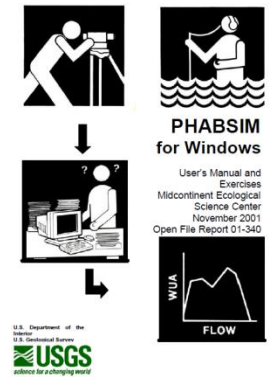


Building a classical fish *preferendum* model

From LeClerc 2005 (Chapter)

SO ABOUT THAT HSC...

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

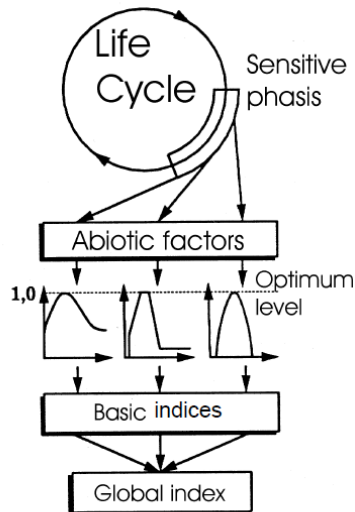


In general, suitability curves have been classified according to the following categories (Bovee et al., 1998, pp. 73–78):

- 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.



Building a classical fish *preferendum* model

FROM THE LITERATURE...

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

List of Habitat Suitability Index (HSI) models

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

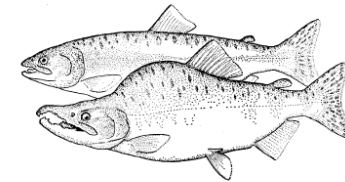
American Oyster (Gulf of Mexico) [.Pdf](#) 82/10.57
 Brown Shrimp (N Gulf of Mexico) [.Pdf](#) 82/10.54
 Hard Clam [.Pdf](#) 82/10.77
 Littleneck Clam [.Pdf](#) 82/10.59
 Pink Shrimp [.Pdf](#) 82/10.76
 Red King Crab [.Pdf](#) 82/10.153
 White Shrimp (N Gulf of Mexico) [.Pdf](#) 82/10.54

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

http://el.erdc.usace.army.mil/emrrp/emris/emrshelp3/list_of_habitat_suitability_index_hsi_models_pac.htm

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



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

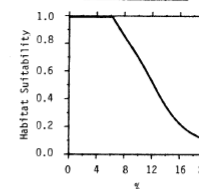
HSC

Suitability graphs

Variable

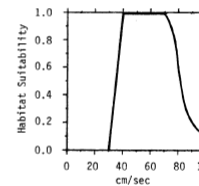
V_1

Percent fines (< 0.3 cm). Measure at the same time and sites as V_3 .



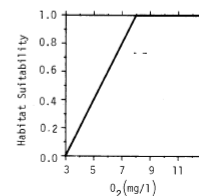
V_3

Average water column velocities for spawning and embryo incubation. Measure at the same time and sites as V_1 .



V_6

Minimal dissolved O_2 level during the egg incubation and preemergent yolk sac fry period. Measure at time of highest temperatures during the incubation period.



Habitat variables and suitability graphs

Model Component

Annual max-min pH — V_1
 Ave. max-min temp. (migrat./spawn) — V_2
 Ave. substrate size — V_3
 Percent fines — V_4
 Ave. water velocity — V_5
 Min. dissolved O_2 — V_6
 Ave. max-min temp. (embryo) — V_7
 Max. salinity — V_8
 Avg. base flow (spawn/incubation) — V_9
 Peak flow (incubation) — V_{10}
 Max. temp. (migration) — V_{11}

Adult

Embryo

Fry

HSI

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

FROM THE FIELD... (CAT II or III)

- 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

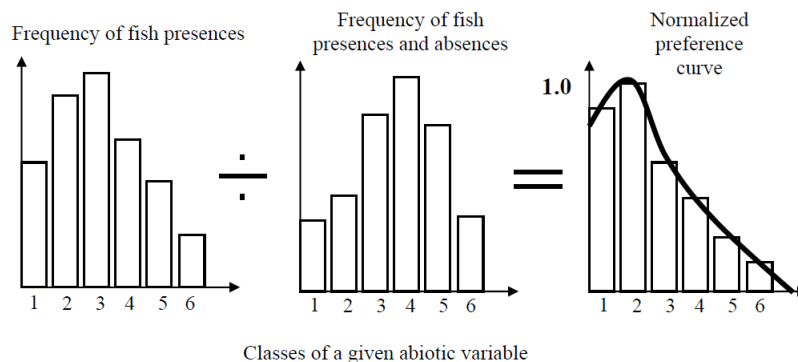
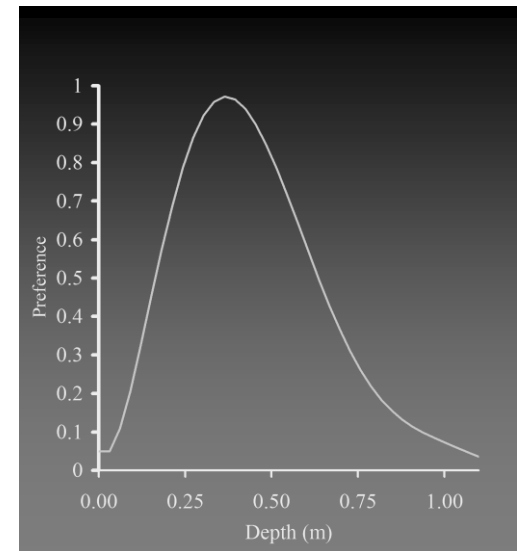
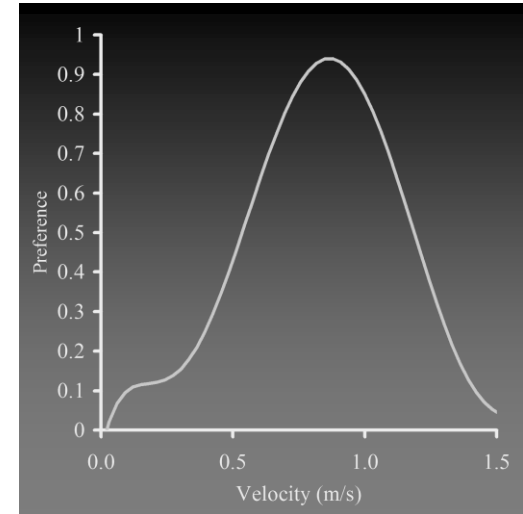
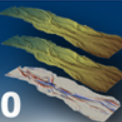


Figure 3 : The general methodology for establishing fish preference curves



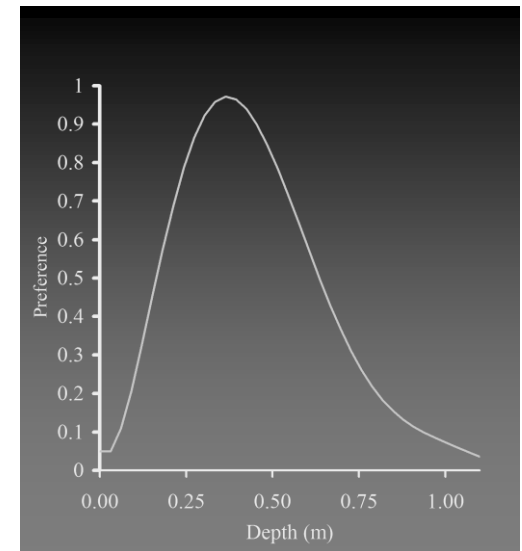
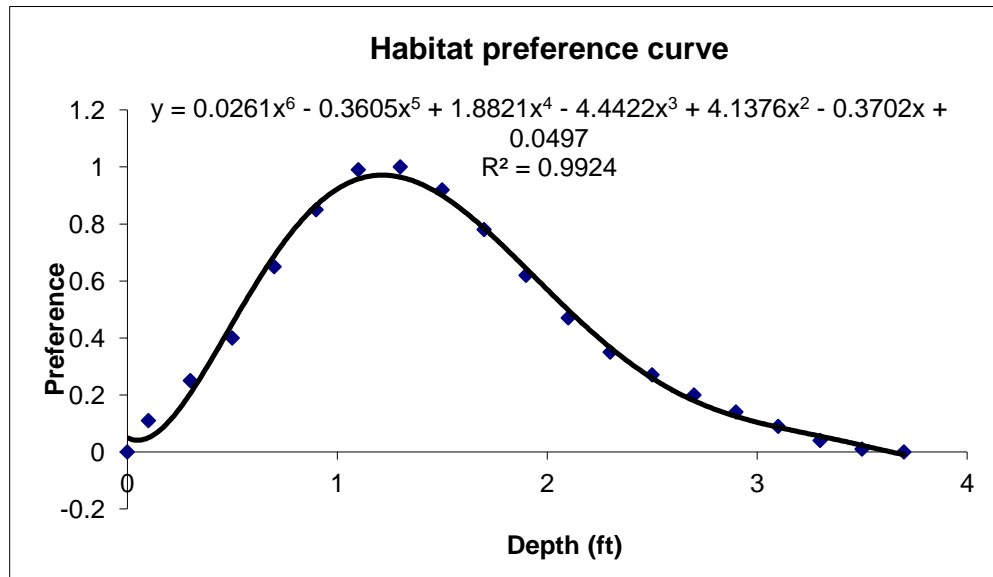
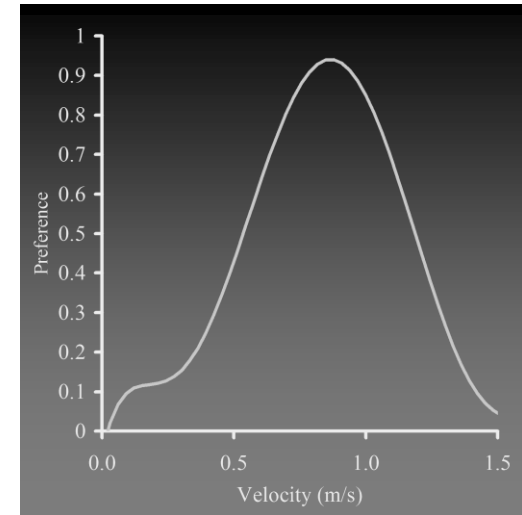
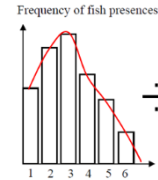
WHY DO I CARE ABOUT AVAILABILITY?

- If I just want a HSC, surely I could just use a HUC?
- Except... if I have a whole bunch of one type of habitat, it might artificially appear preferable



HOW DO I GO FROM HISTOGRAM TO CURVE?

- Convert histogram values to points...
- Normalize count to 0 to 1 scale
- Then fit some horrible higher order polynomial curve...



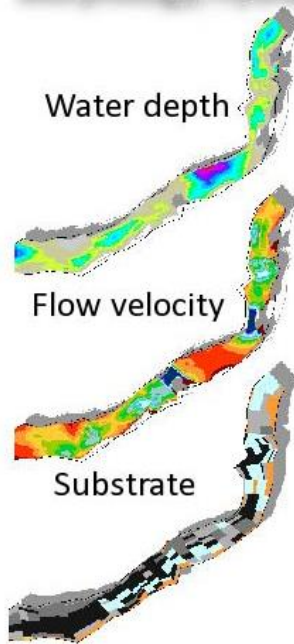
HOW DO I GO FROM HSCs TO HSI?

This is the abiotic input

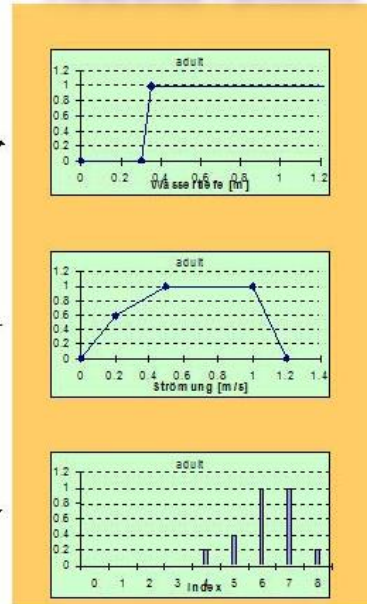
This is the empirical biotic input

This is the ecohydraulic 'model'

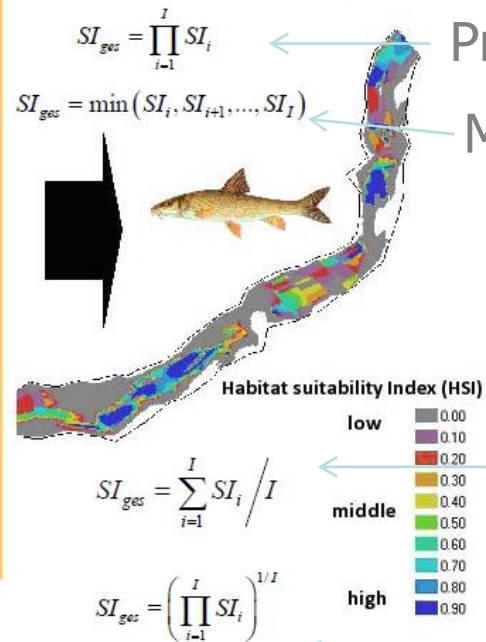
Morphology/Hydraulics



HSC
Preference Functions



HSI
Habitat Suitability



$$SI_{ges} = \prod_{i=1}^I SI_i$$

Product

$$SI_{ges} = \min(SI_1, SI_{i+1}, \dots, SI_I)$$

Minimum

$$SI_{ges} = \sum_{i=1}^I SI_i / I$$

Arithmetic Mean

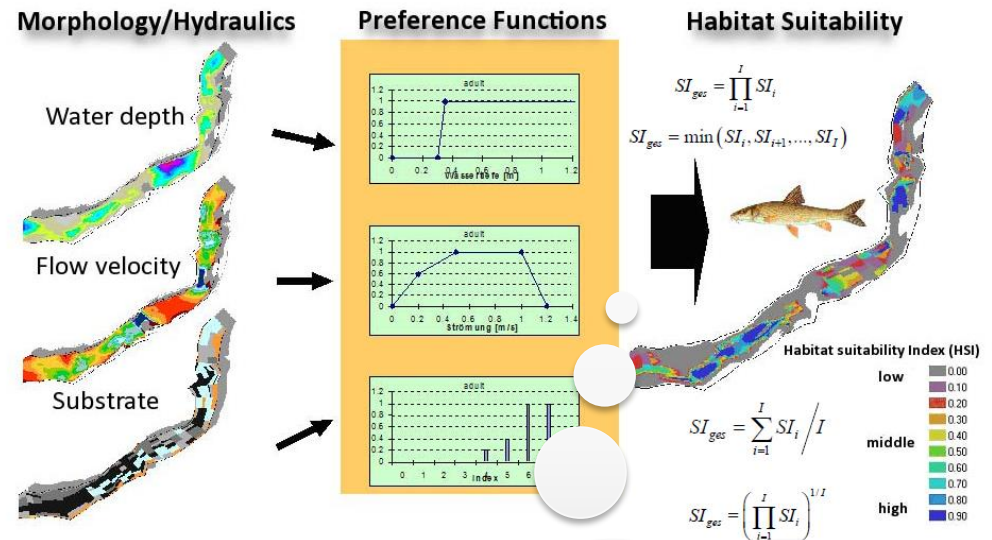
$$SI_{ges} = \left(\prod_{i=1}^I SI_i \right)^{1/I}$$

Geometric Mean

- Most common HSI is geometric mean...
- You can also weight individual HSCs

PLUG & CHUG... HSI IS DETERMINISTIC

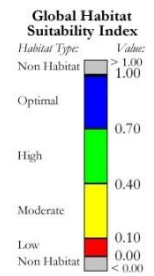
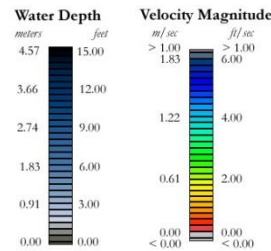
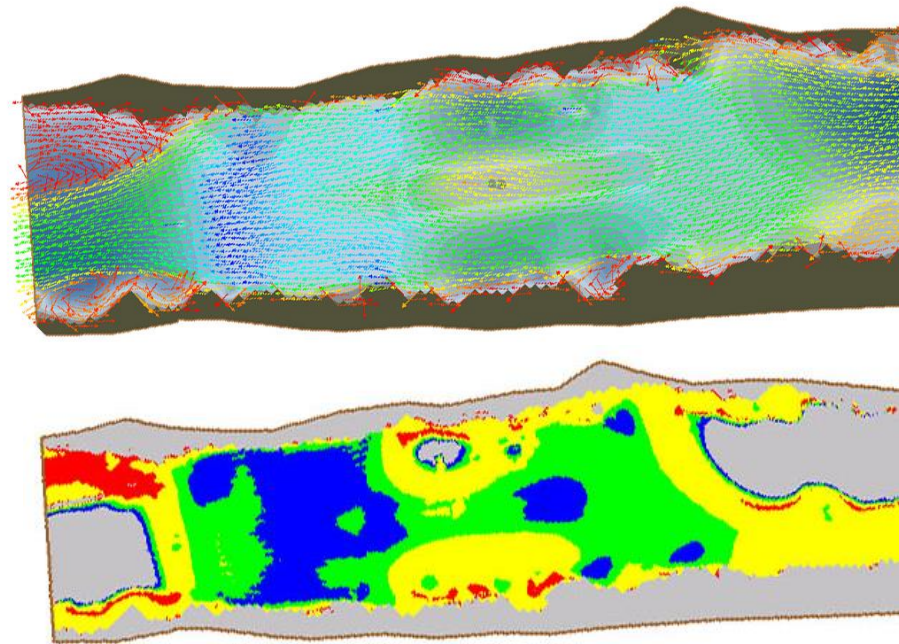
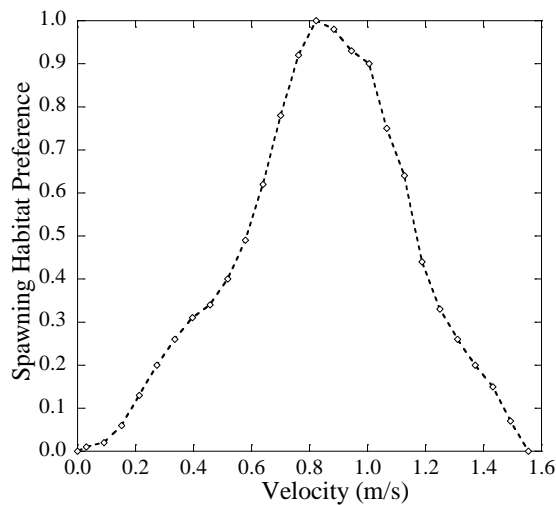
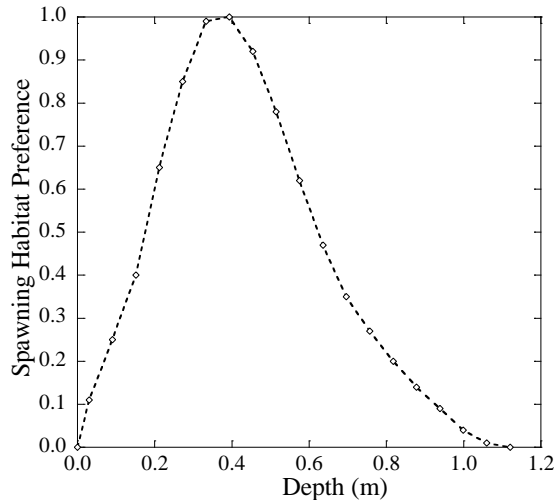
- You use the same HSI for every cell or node
- Each node will have different abiotic input
- Thus you get a spatially variable output...



Do I need to have a
'model' of
morphology/hydraulics
to use HSI?

ECOHYDRAULIC MODELS DRIVEN BY 2D CFD

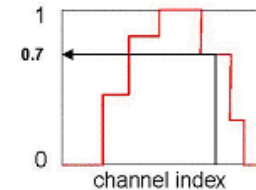
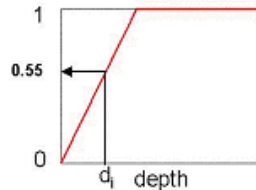
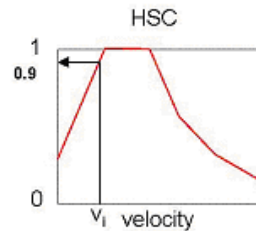
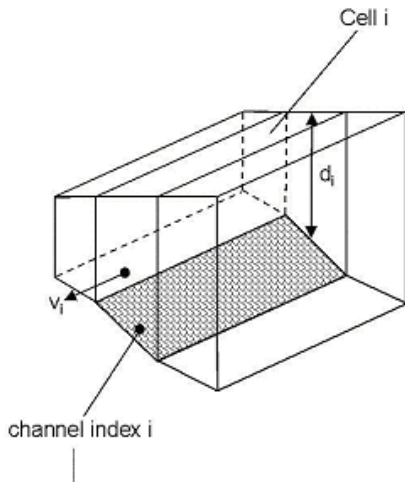
- What if we use same ecohydraulic model, but drive it by a multidimensional hydraulic simulation?



PHABSIM HSI CALLED C_i

- Composite Suitability for Cell I
- What does this calculation represent?

Composite suitability for cell i = $HSC_v * HSC_d * HSC_{ci}$
 $= 0.9 * 0.55 * 0.7$
 $= 0.3465$



The most common method is a multiplicative aggregation given by:

$$C_i = V_i * D_i * S_i \quad (4-2)$$

where: C_i = composite suitability of cell I
 V_i = suitability associated with velocity in cell I
 D_i = suitability associated with depth in cell I
 S_i = suitability associated with channel index in cell I

Second, the geometric mean can be used. This implies a compensation effect between the component suitability values. If two of three individual composite suitabilities are within the optimum range and the third is very low, the third individual composite suitability has a reduced effect on the computation of the composite suitability. The geometric mean is calculated as:

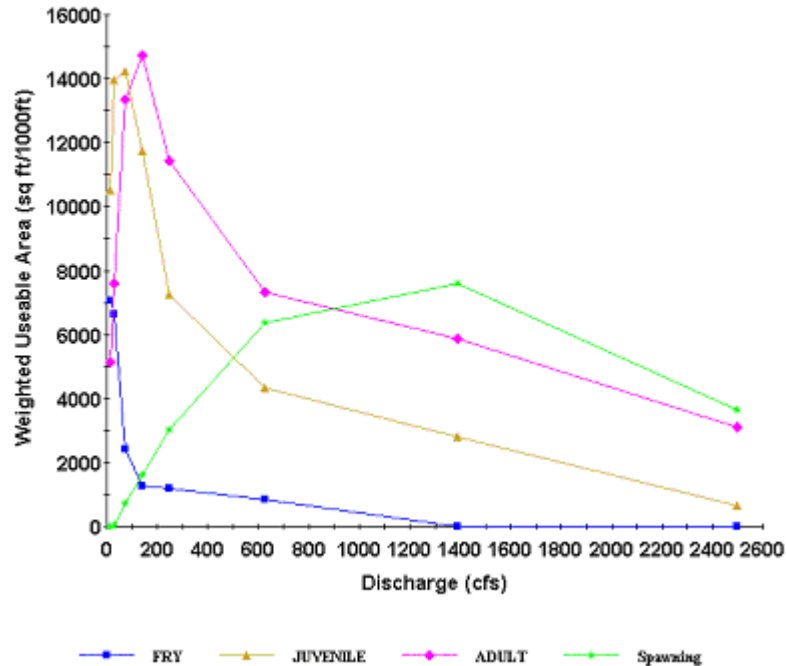
$$C_i = \sqrt[3]{V_i * D_i * S_i} \quad (4-3)$$

Third, the most locally limiting individual suitability factor can be selected by setting the composite suitability for the cell based on the minimum of the individual cell factors according to:

$$C_i = \text{Min}(V_i, D_i, S_i) \quad (4-4)$$

WEIGHTED USEABLE AREA

HABTAE Flow/Habitat Relations
RAINBOW TROUT



What metrics can we derive from composite HSI?

- Weighted Usable Area (WUA)

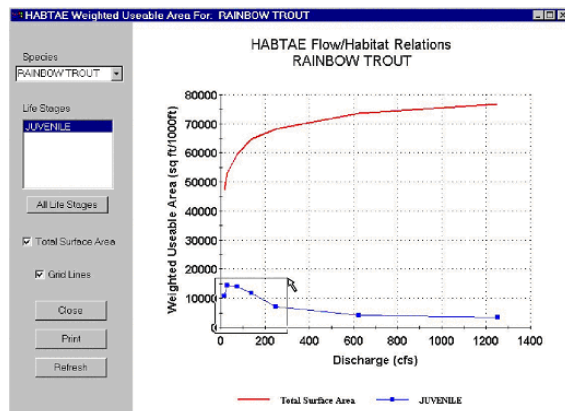
$$WUA = \sum_{i=1}^n HSI_i * Area_i$$

- Weighted Usable Area :
Wetted Area

- Normalized, easier to compare among sites, basins

- Capacity Estimates

- Juveniles:
 - WUA / Juvenile territory size
- Redd capacity:
 - WUA / Redd area



WUA FOR A RANGE OF SPECIES & LS

- You can look at this and if you're a flow manager what would you do?
- Is this right?

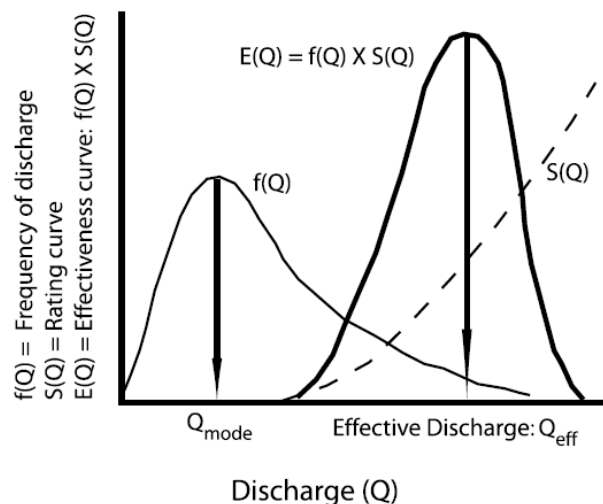


Figure 1. Components of effective discharge (Q_{eff}). Adapted from Wolman and Miller [1960].

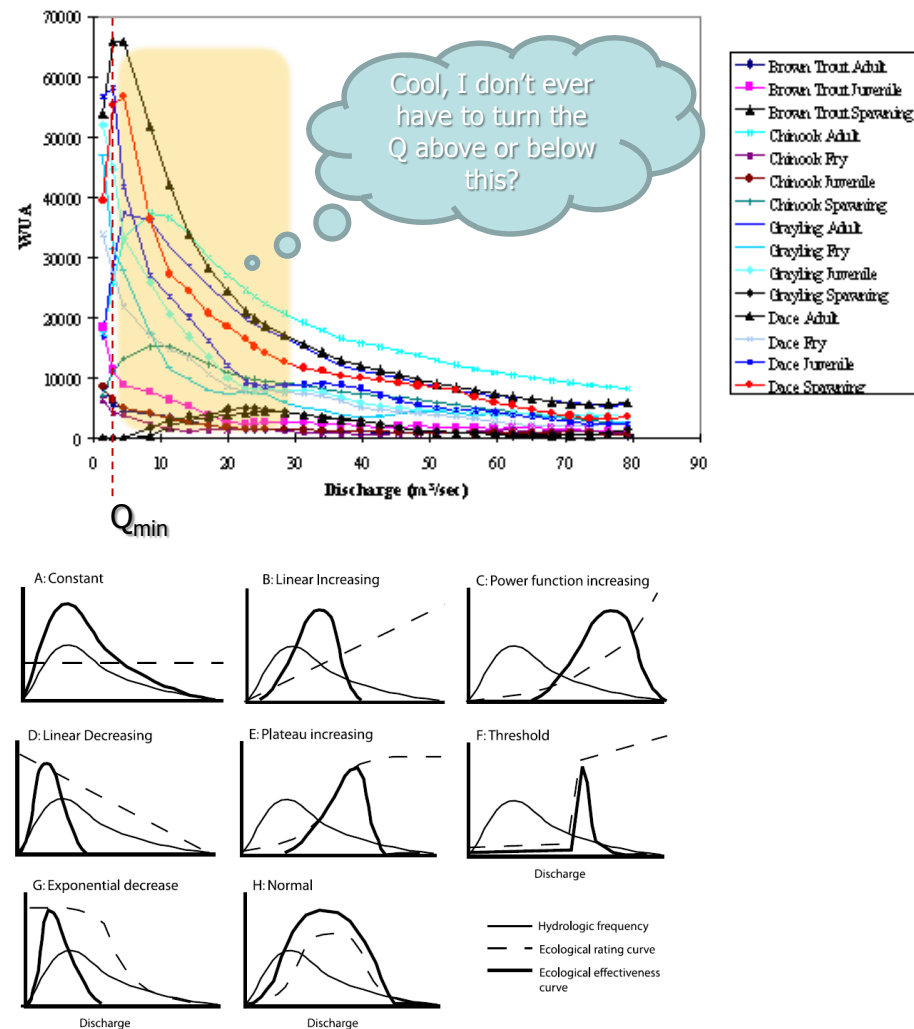
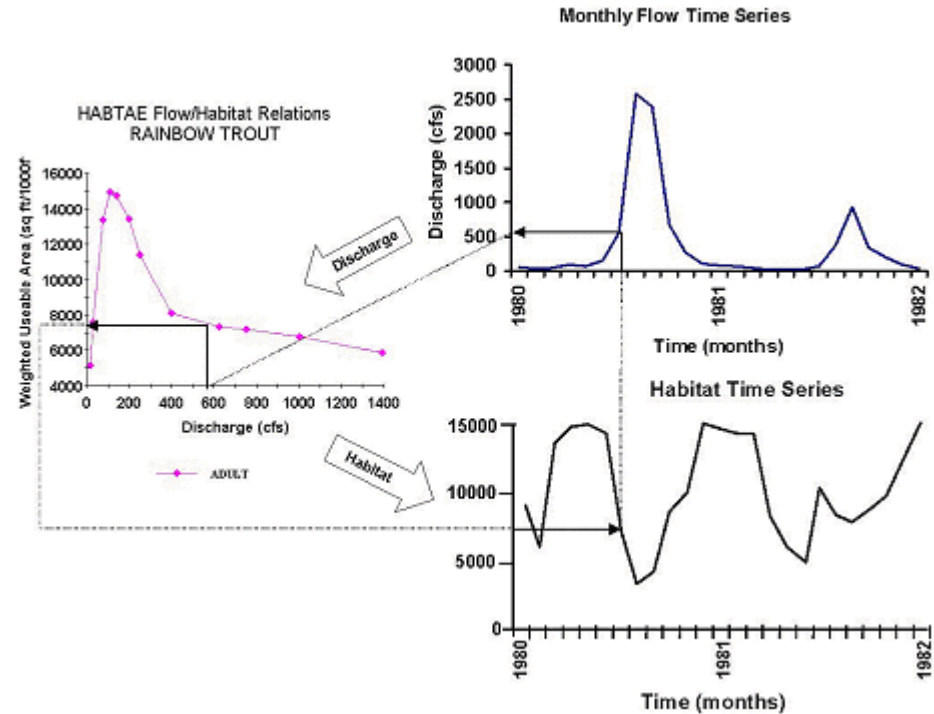
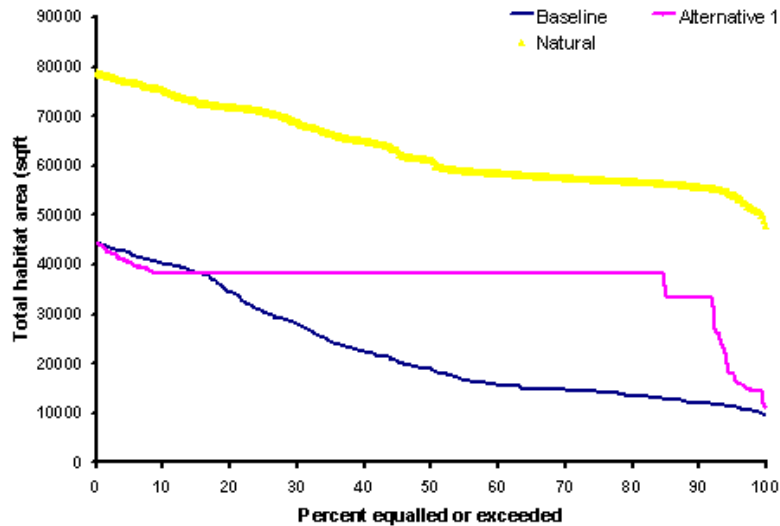


Figure 13. Hypothetical response curves for a variety of ecological variables. For potential ecological variables, see Table 2 and discussion in text.

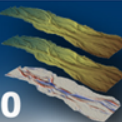
HABITAT TIME SERIES

- If you've got actual hydrograph, you can run a habitat time series



- With a habitat time series, you can derive a habitat duration curve..

BIOVERIFICATION... VALIDATION



MODEL OUTCOME – IS IT RIGHT?

MODEL STATE MATRIX → OUTCOMES

ID	Discretisation	Process laws	Parameterisation
1	Y	Y	Y
2	N	N	N
3	Y	Y	N
4	Y	N	N
5	Y	N	Y
6	N	Y	N
7	N	Y	Y
8	N	N	Y

Replicates
Reality?

TYPE I

→ Y → Can only replicate reality

OR

TYPE II

Replicates reality
incorrectly

OR

TYPE III

Correctly does not
replicate reality
(but it might approximate it)

OR

TYPE IV

Incorrectly does not replicate reality.

BIOVERIFICATION CONCEPT

- “Bioverification” is a **test of the combined predictions** that results from coupling 2D model results with HSCs.
- A **bioverified model** yields *reasonable predictions of habitat availability*, which may then be used in spatial and statistical analyses, such as assessment of habitat areas as a function of discharge.
- Bioverification is achieved with a test of the Electivity Index.

ELECTIVITY INDEX (EI) DEFINITION

Utilization-to-Available Ratio by habitat quality class

$$\%U_i = 100 \times \frac{\# \cdot reds_i}{total \cdot \# \cdot reds}$$

$$\%A_i = 100 \times \frac{bedarea_i}{total \cdot area}$$

$$EI = \frac{\%U_i}{\%A_i}$$

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

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!



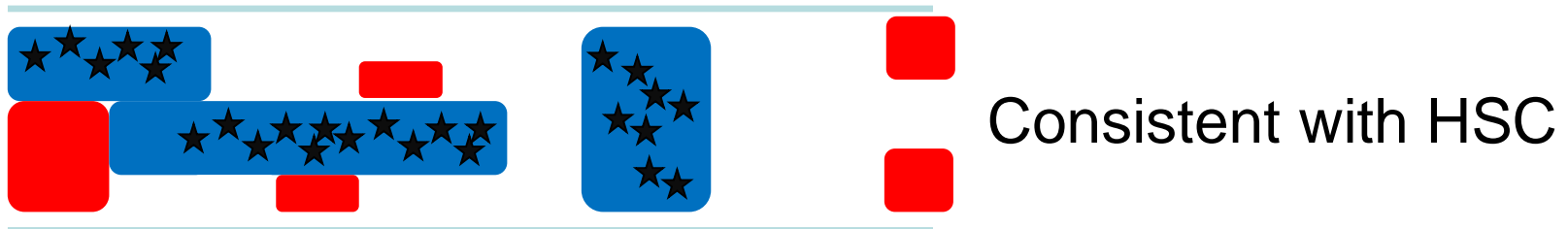
Trivial Prediction!



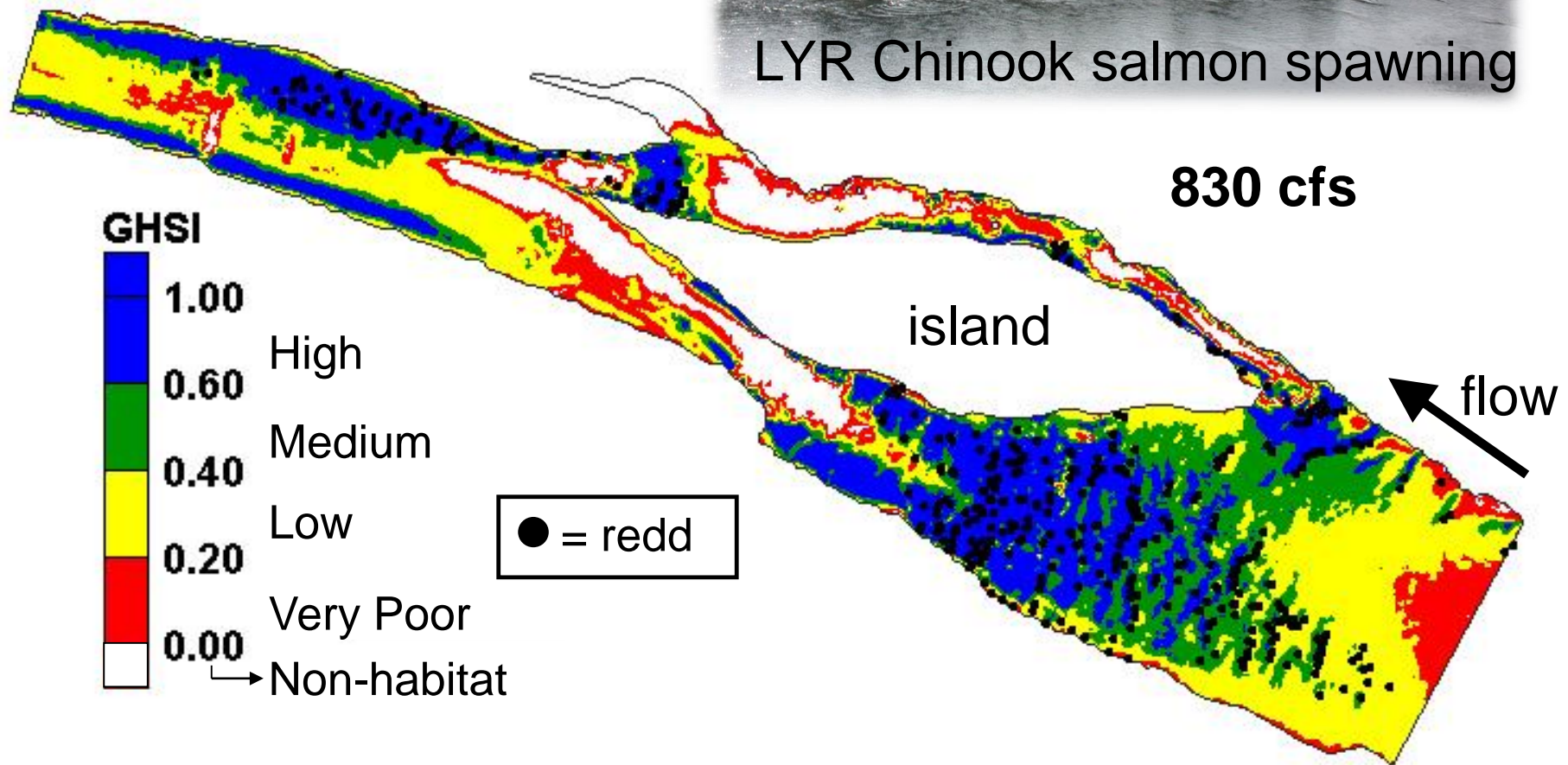
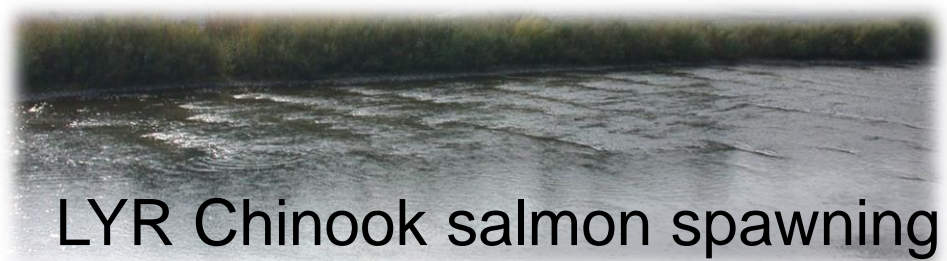
Risky Prediction!

BIOVERIFICATION PERFORMANCE INDICATOR 2

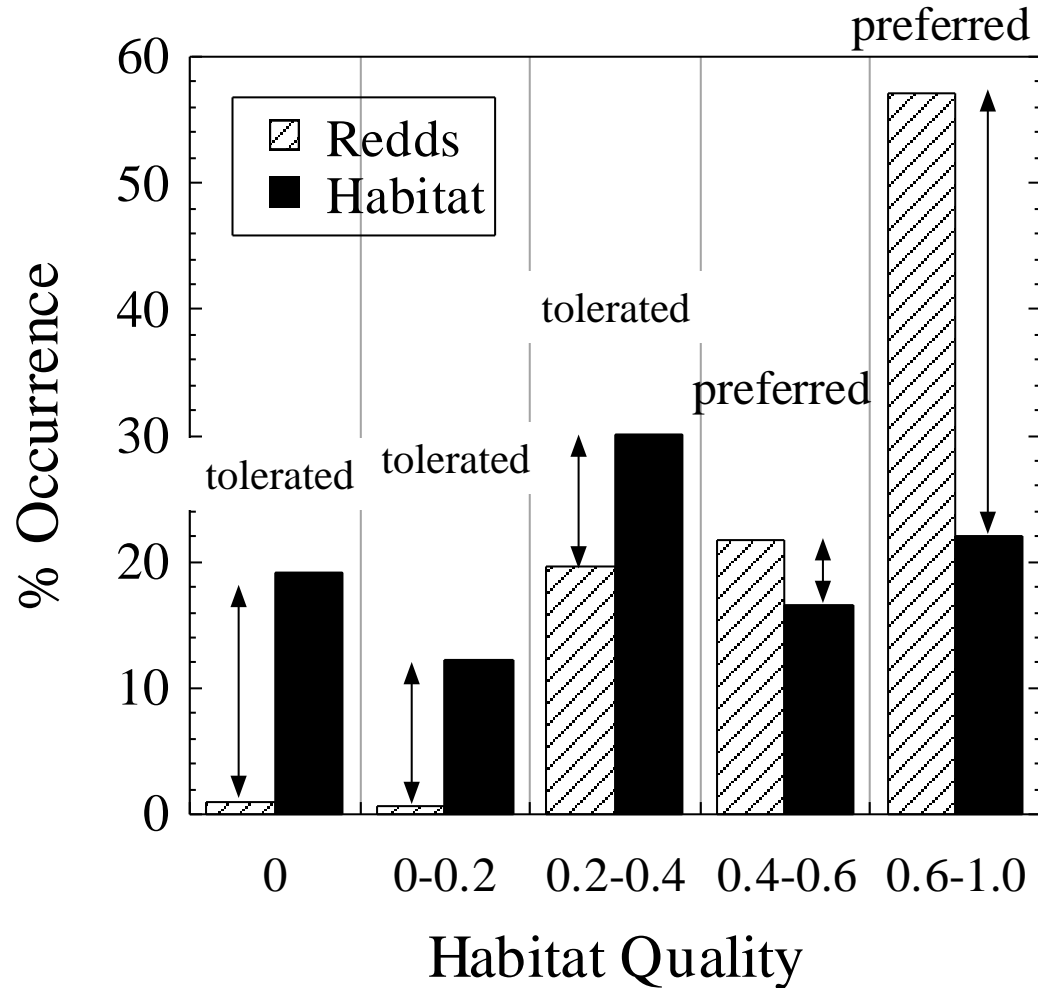
- Habitat classes with $EI > 1$ must be those with high habitat index values and habitat classes with $EI < 1$ must be those with low habitat index values.



EXAMPLE OF BIOVERIFICATION

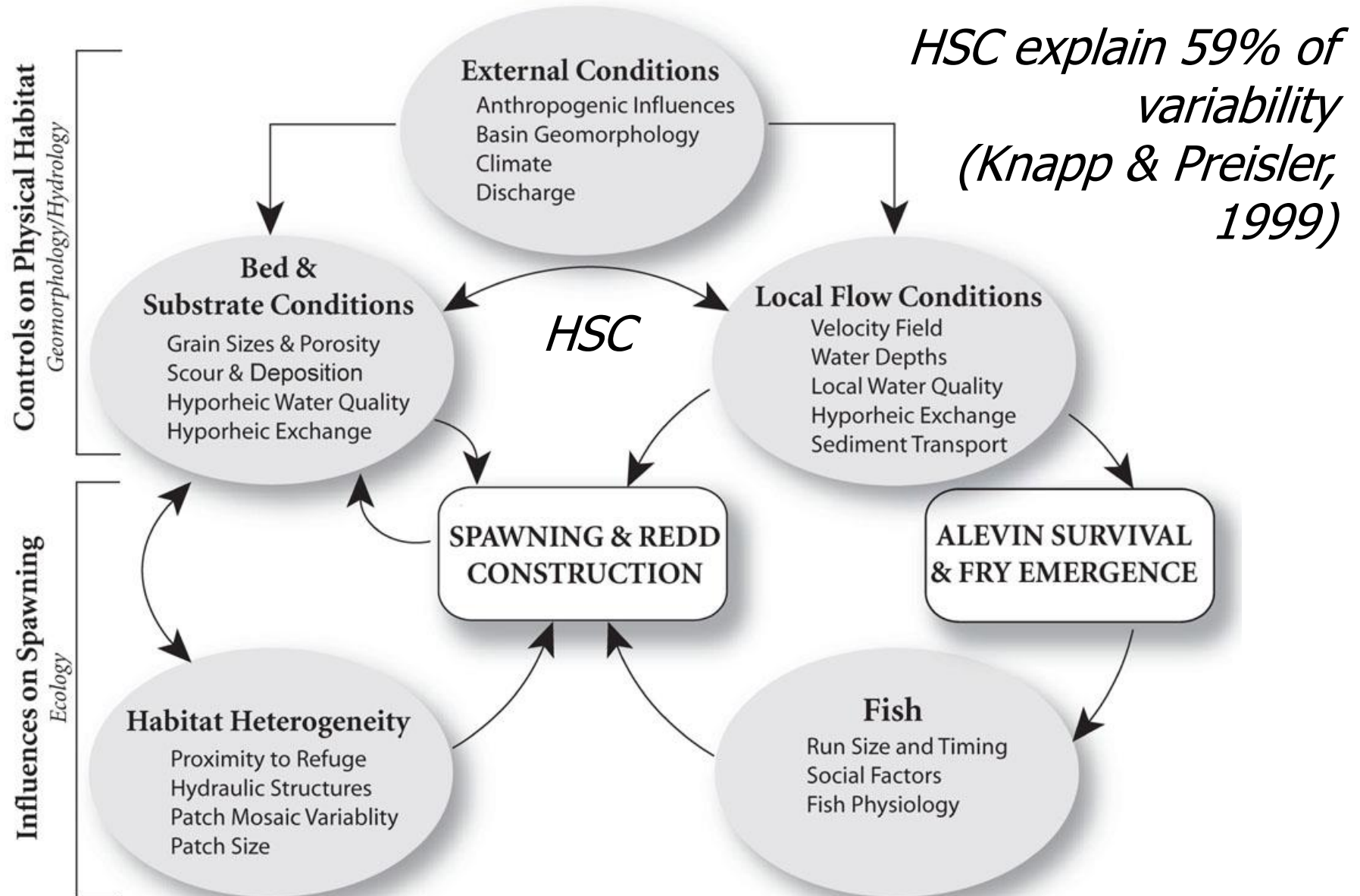


BIOVERIFICATION TESTS



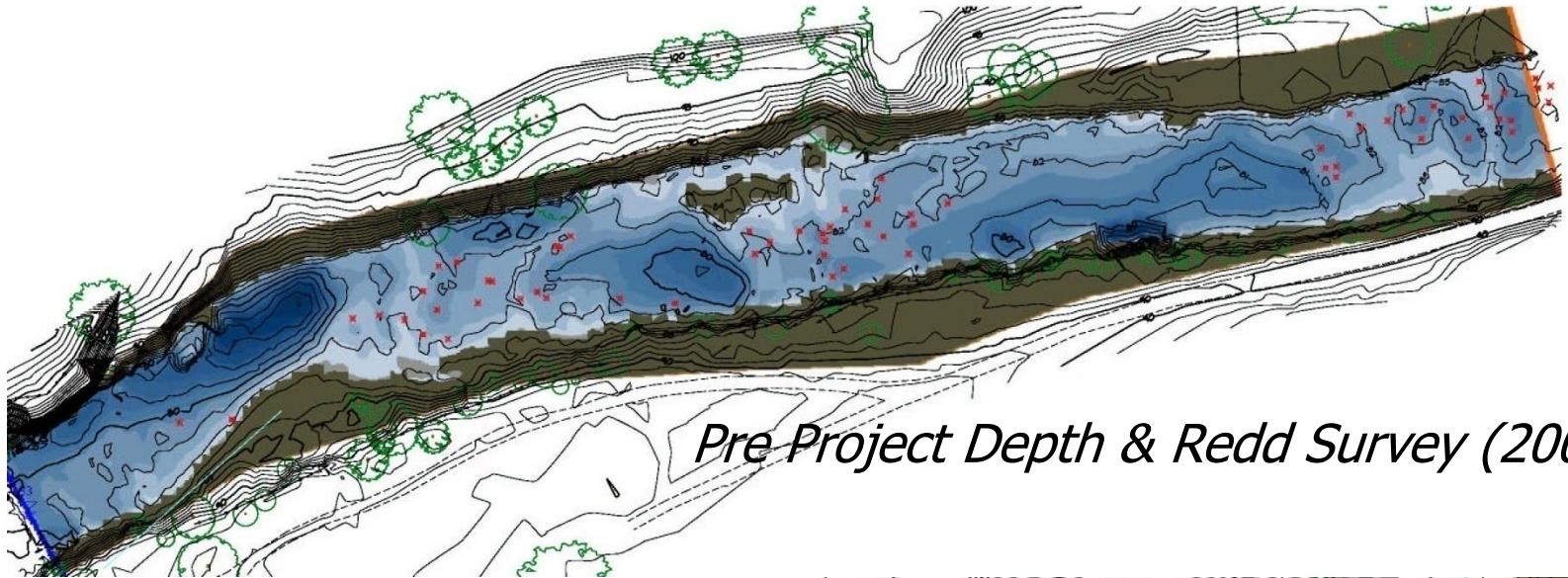
- 2 bins with $EI > 1$
- 3 bins with $EI < 1$
- Lowest bins have lowest EIs
- Highest bins have highest EIs

MODEL MIGHT PERFORM POORLY...

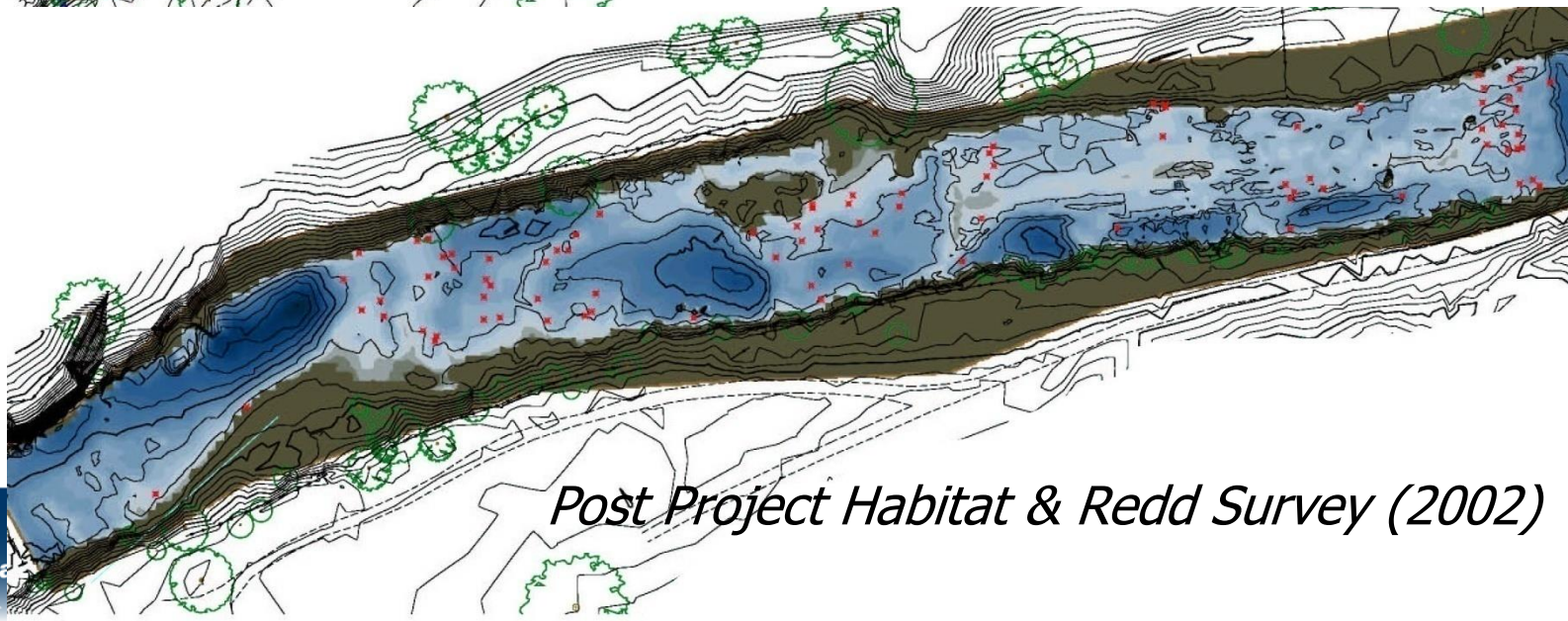


PRE VS. POST PROJECT ASSESSMENT

Hydrodynamic Model Results



Pre Project Depth & Redd Survey (2001)

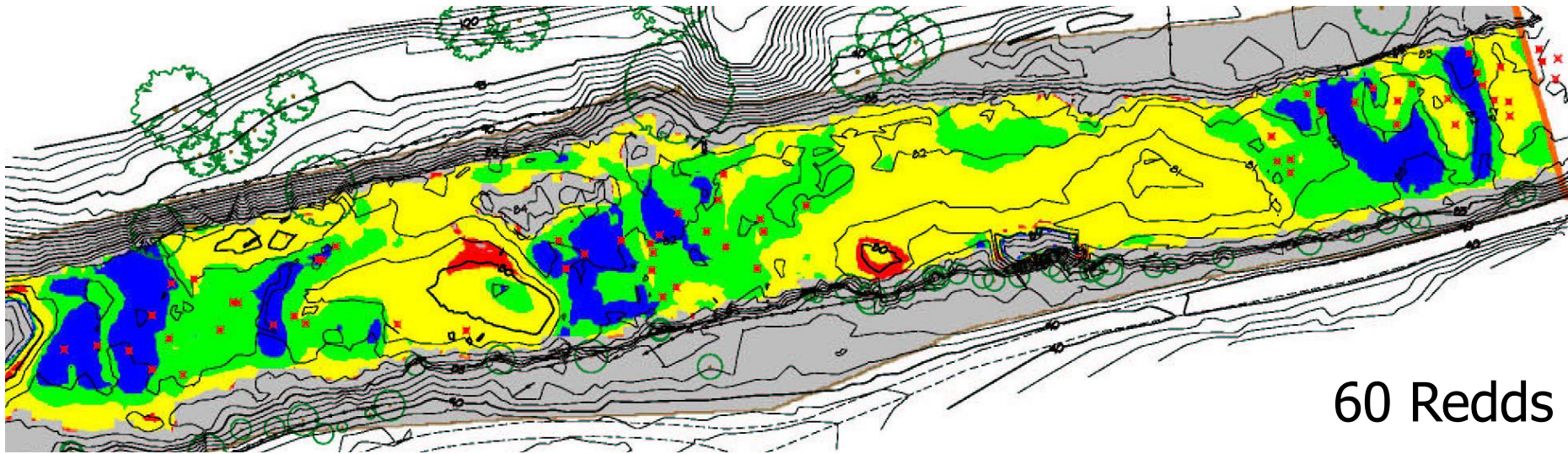


Post Project Habitat & Redd Survey (2002)

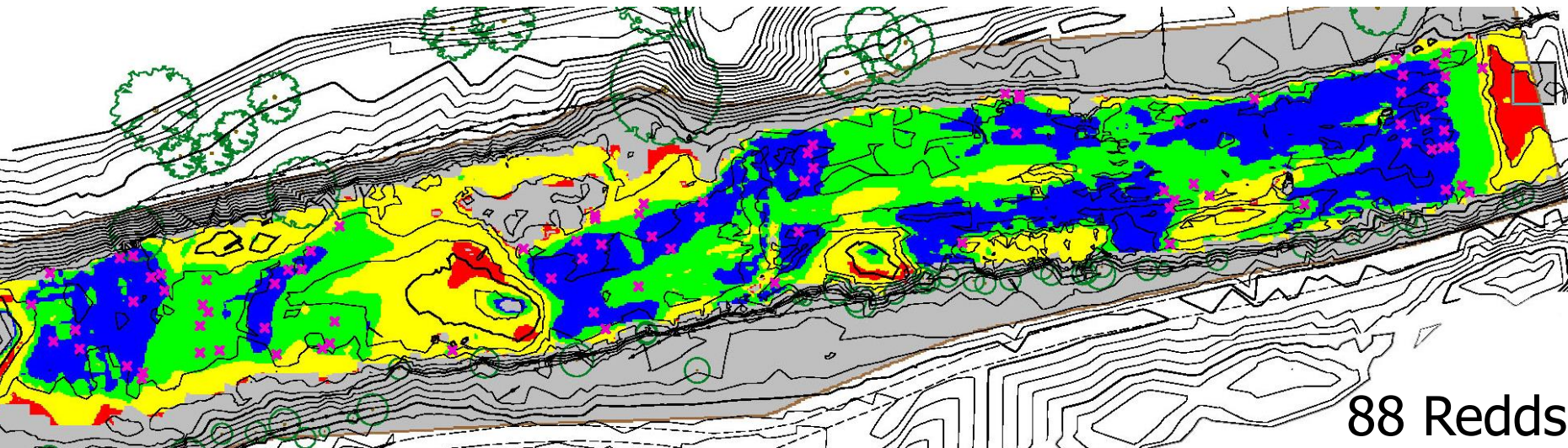
LONG TERM MONITORING

2001 & 2002 Redd Surveys

Back to [Critical Questions](#)



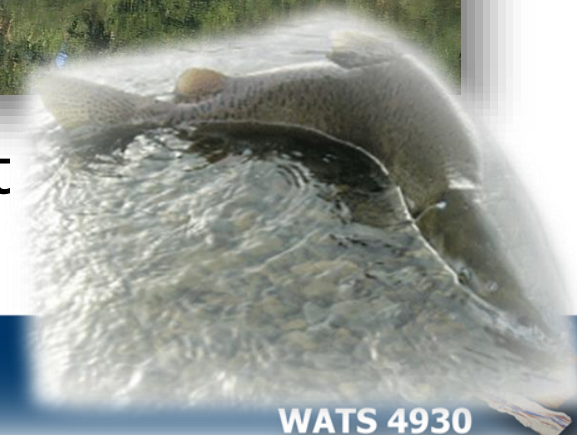
60 Redds



88 Redds

IS HETEROGENEITY IMPORTANT TO A SPAWNING FEMALE SALMON?

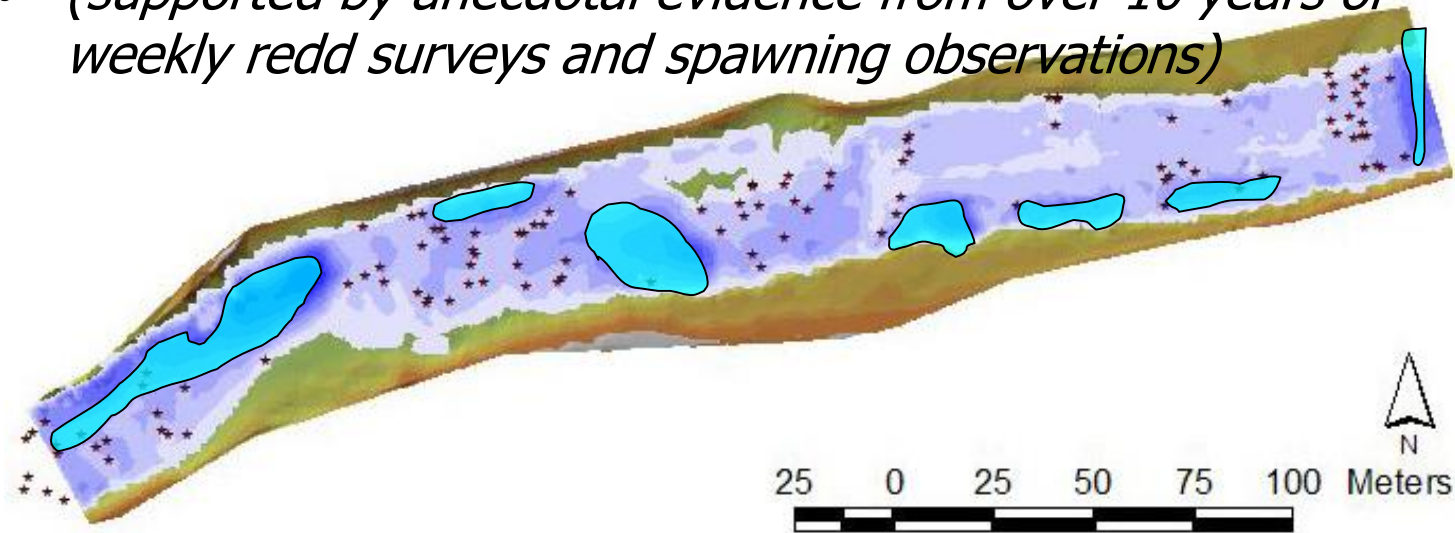
Habitat Heterogeneity is usually assumed to support species diversity (assumed to be good).



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

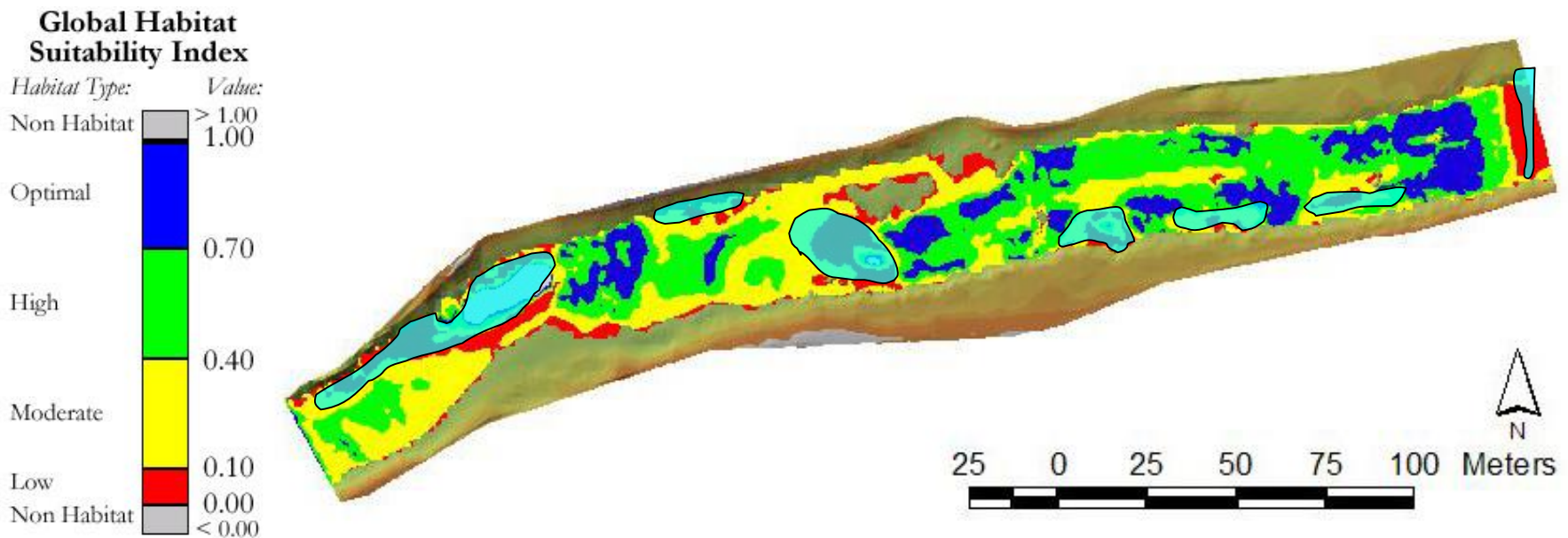
HABITAT UTILIZATION EVIDENCE

- How many spawners actually utilize these features? (i.e. are individual redds in close proximity to distinct units?)
- Assume individual redds in *close* proximity equals utilization
- *(supported by anecdotal evidence from over 10 years of weekly redd surveys and spawning observations)*



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?

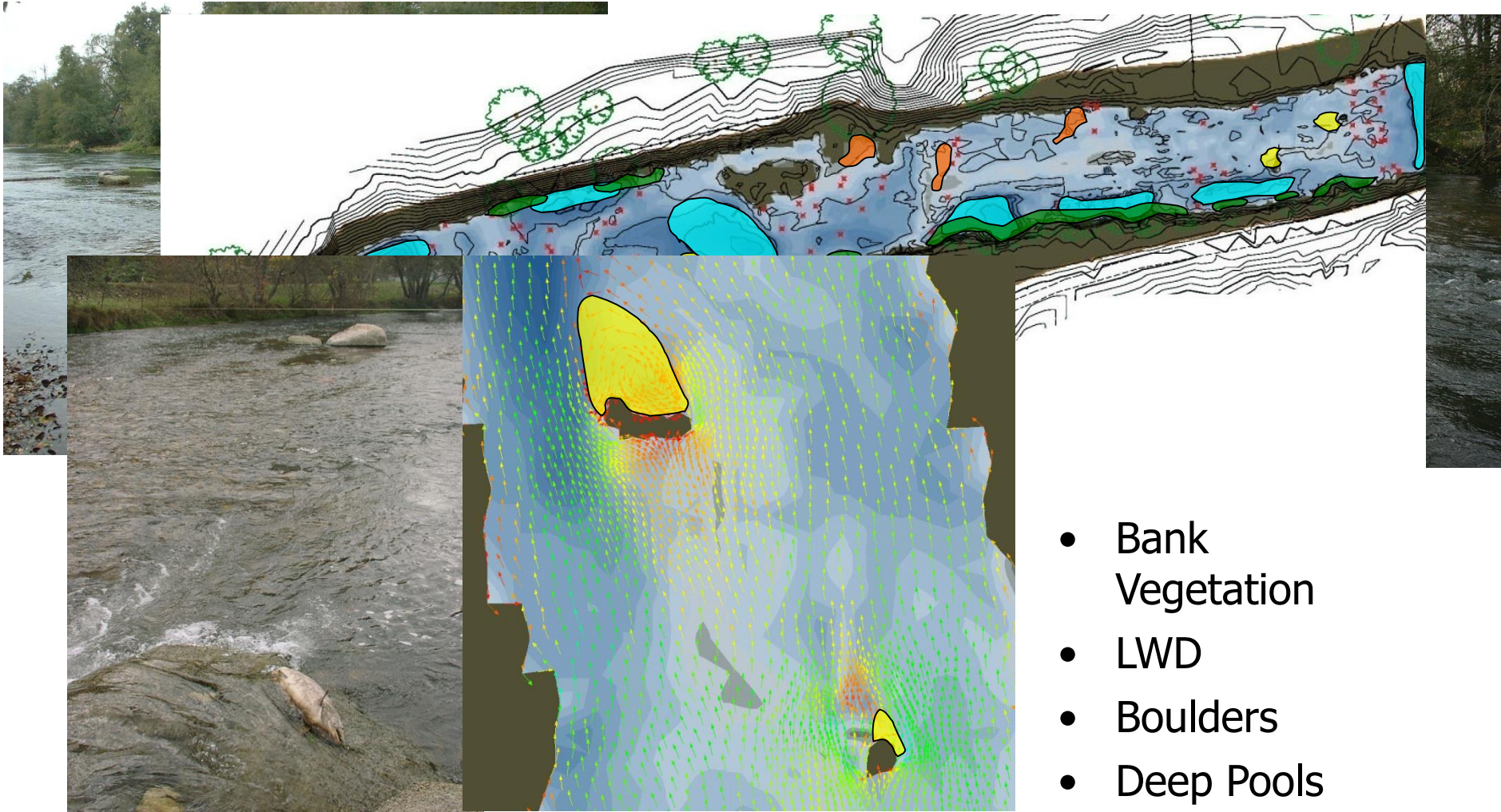


DEFINING HABITAT HETEROGENEITY ELEMENTS

Data Feature:

Data Source:

Attributed to:



- Bank Vegetation
- LWD
- Boulders
- Deep Pools

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 than velocity, depth substrate)
- Lots of field data needed (i.e. HSC from HUC & HAC)
- HSC are site specific....

FRAMEWORK FOR MODELING HSI

The screenshot displays the Habitat Model Software interface. The main window shows a project tree on the left with folders like 'Habitat Suitability Modeling', 'Model Definitions', 'Model Configuration', 'Simulations', and 'Inputs'. The 'Inputs' folder is expanded, showing variables like 'MeanVelocity', 'WaterDepth', 'D50_RM112', and 'Temperature'. Overlaid on this are two dialog boxes. The 'Import Project Input' dialog is in the background, and the 'Configure HSI Simulation' dialog is in the foreground. The 'Configure HSI Simulation' dialog has fields for 'Output Folder', 'Name', 'Model', and 'Inputs'. The 'Inputs' section contains a table with two rows of input variables. The 'Outputs' section has a checkbox for 'Keep individual outputs' and an 'Output Name' field. The 'Ok' and 'Cancel' buttons are at the bottom right.

Habitat Model Software

File Definition Configuration Help

Habitat Suitability Modeling

Model Definitions

Model Configuration

Simulations

Chinook J

Chinook S

Inputs

MeanVel

WaterDep

D50_RM1

Temperature

Import Project Input

Name: MeanVelocity

Input variable: De

Units: me

Data Source

Original path: C:\

Project path: Inp

Field

Help

Configure HSI Simulation

Output Folder: Simulations\ChinookJuvenileRM112\ChinookJuvenileRM112

Name: Chinook Juvenile - RM 112

Model: Maret et al 2006 Upper Salmon - vel, depth - Chinook Juvenile

Inputs

Name	Type	Weight	Project Input
Mean column velocity for Chinook juveniles	Inflection	0.5	MeanVelocity
Water depth for Chinook juveniles	Inflection	0.5	MeanVelocity

Outputs

☐ Keep individual outputs

Output Name: Simulations\ChinookJuvenileRM112\ChinookJuvenileRM112.tif

Help Ok Cancel

NETWORK EXTRAPOLATION

IN CHaMP, HSI RUN AT 100's of SITES

Big Springs, Lemhi Basin, ID

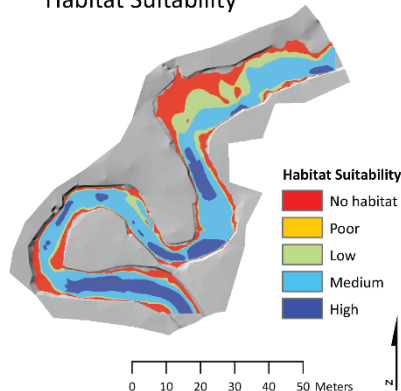
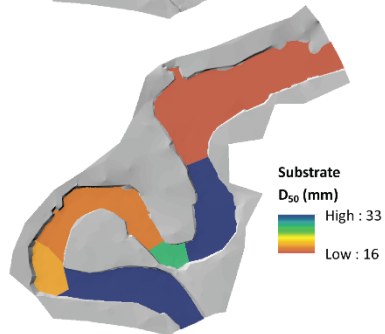
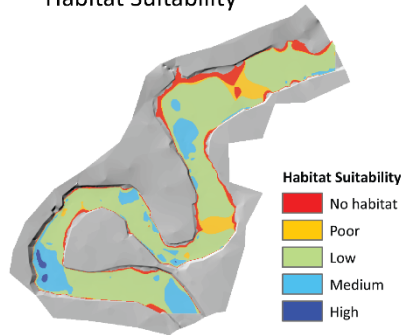
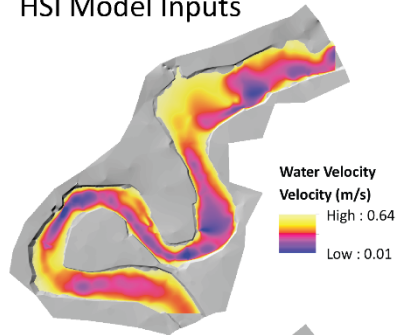
LEM00001-BigOSprings6, Visit 551, 2012

HSI Model Inputs

HSI Model Outputs

Chinook Juvenile Habitat Suitability

Chinook Spawner Habitat Suitability



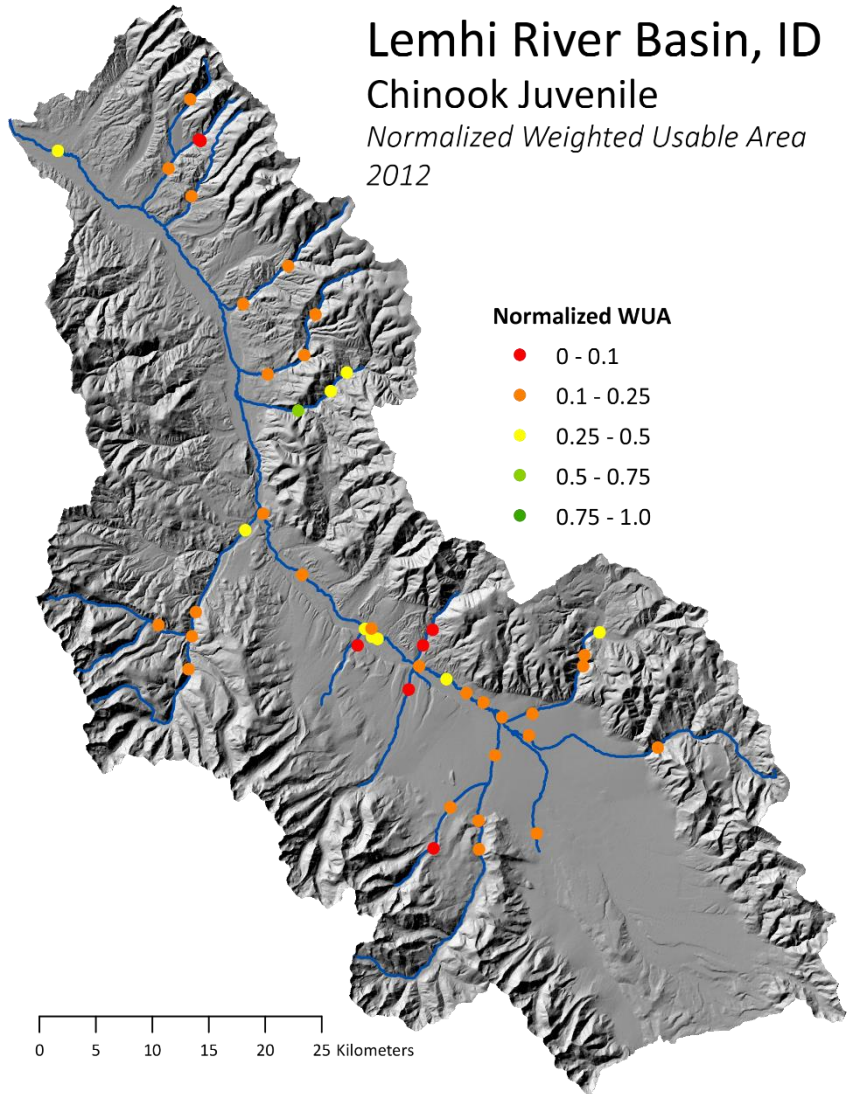
Lemhi River Basin, ID

Chinook Juvenile

Normalized Weighted Usable Area
2012

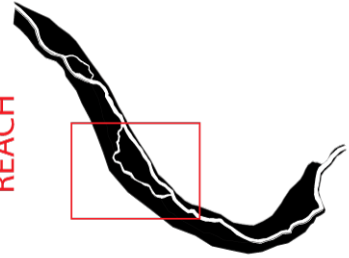
Normalized WUA

- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1.0

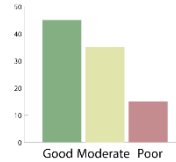
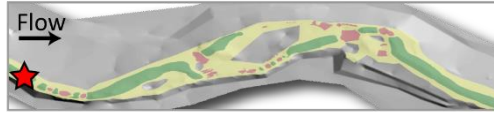


HOW TO GO FROM DOTS TO NETWORK?

REACH



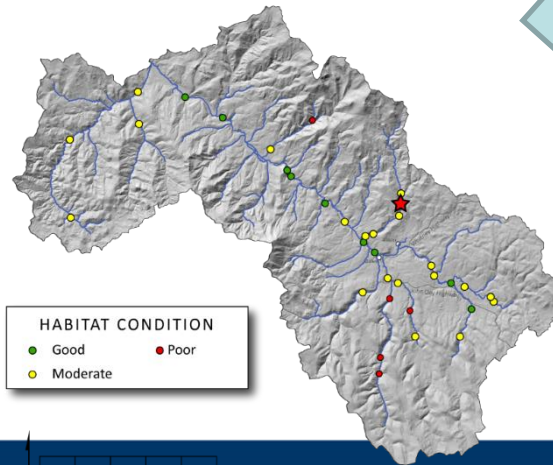
① SITE LEVEL



② SITE SUMMARY: ●

③ SITES ON NETWORK

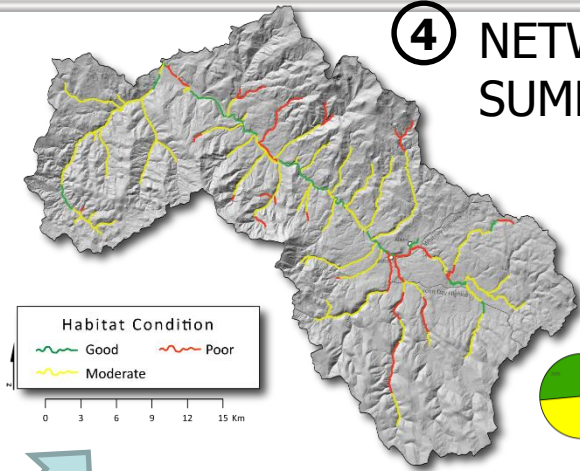
NETWORK



⑤ WATERSHED / POPULATION



④ NETWORK SUMMARY



BASIN

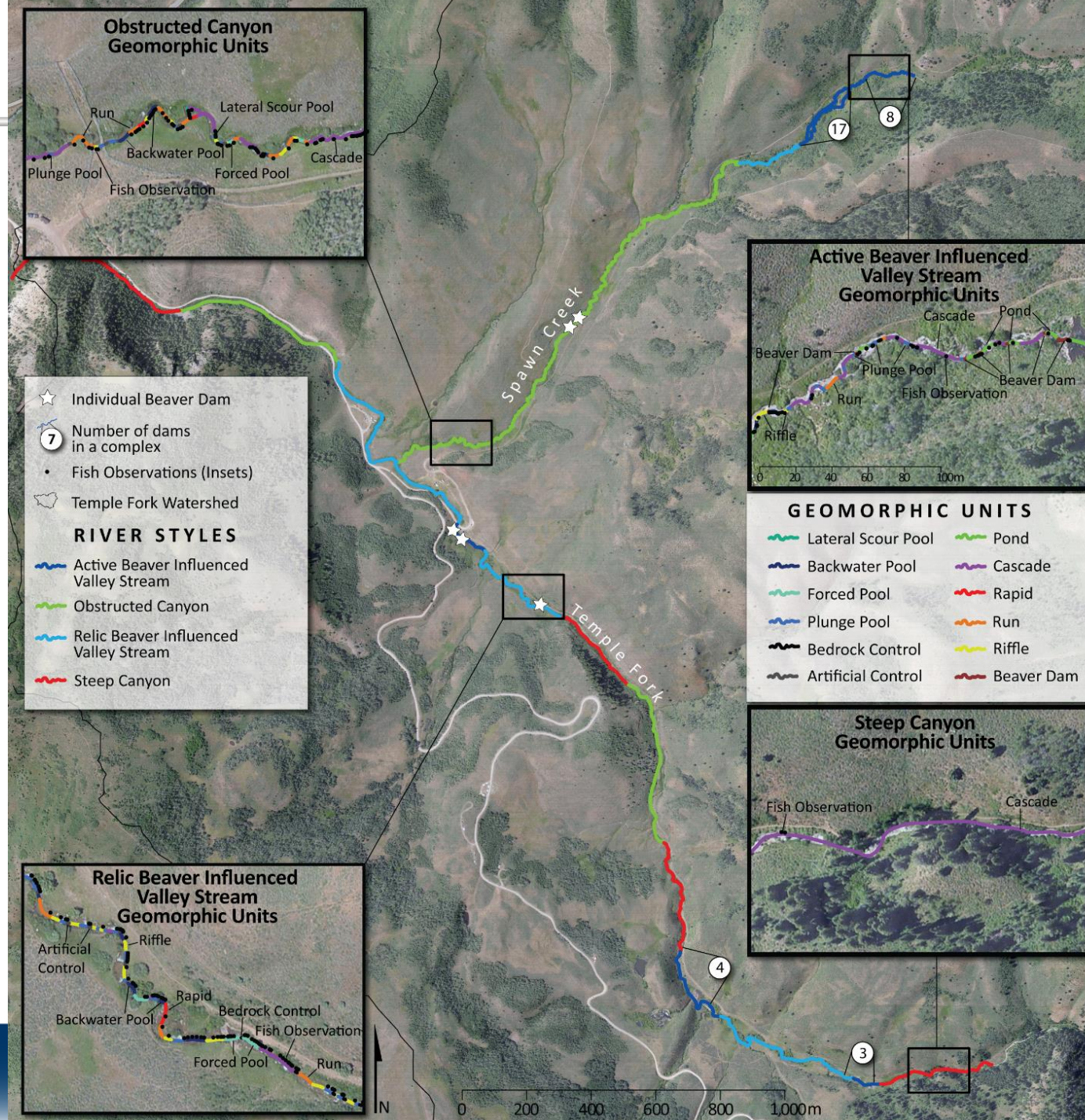


⑥ BASIN



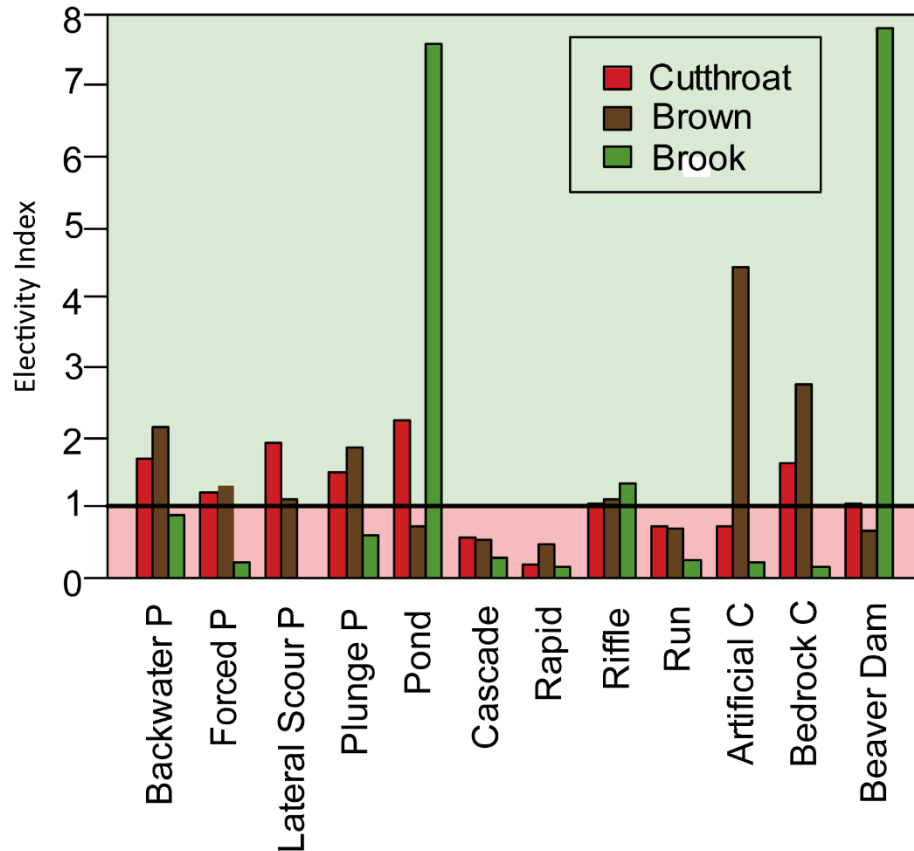
FOR CONCEPTUAL PURPOSES ONLY
WATS 4930

REACH TYPES MATTER

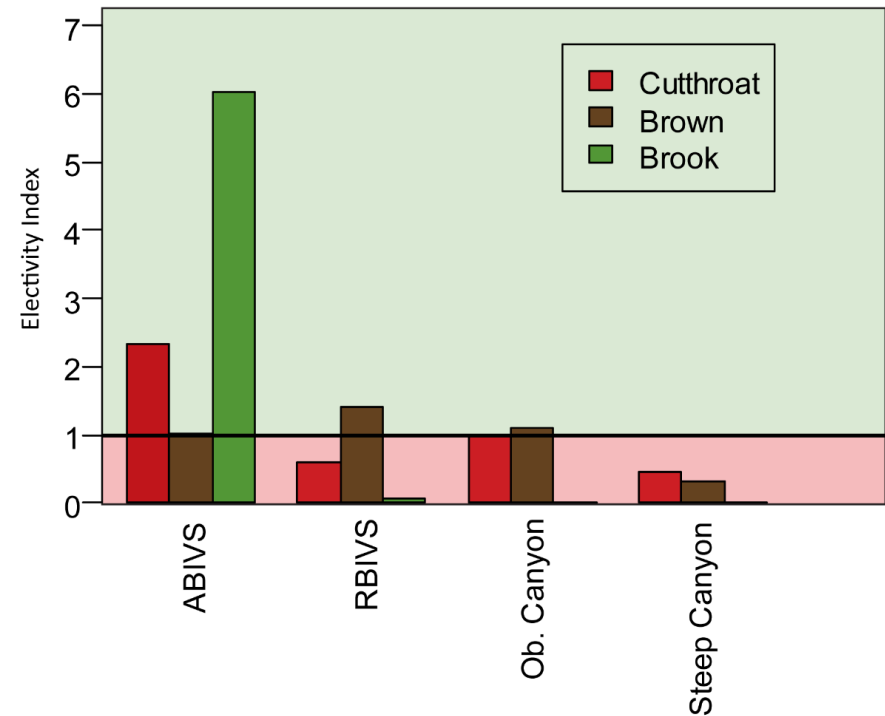


FISH ELECTIVITY INDICES @ DIFF SCALES

GU & SE SCALE



REACH SCALE



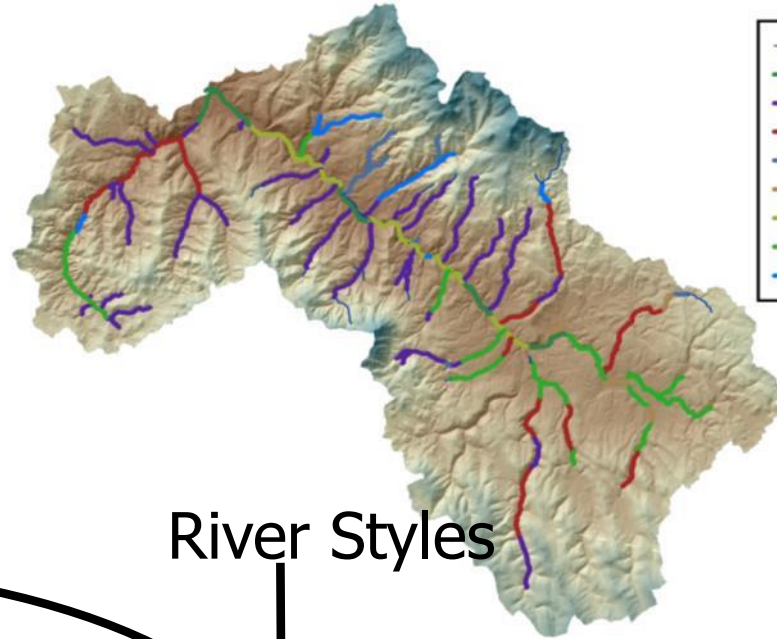
Carrying Capacity
Temperature Productivity

NREI

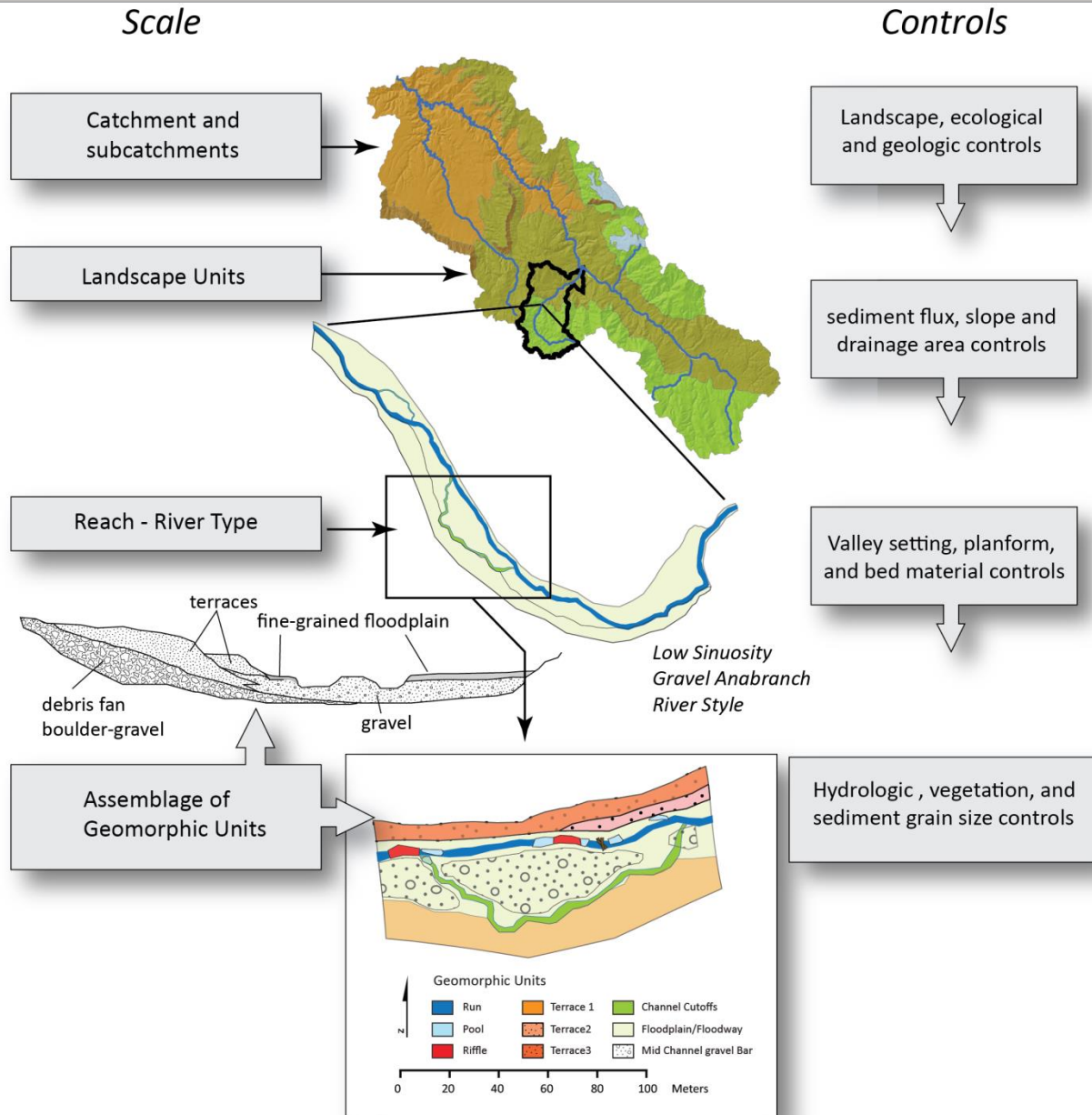
Site

River Styles

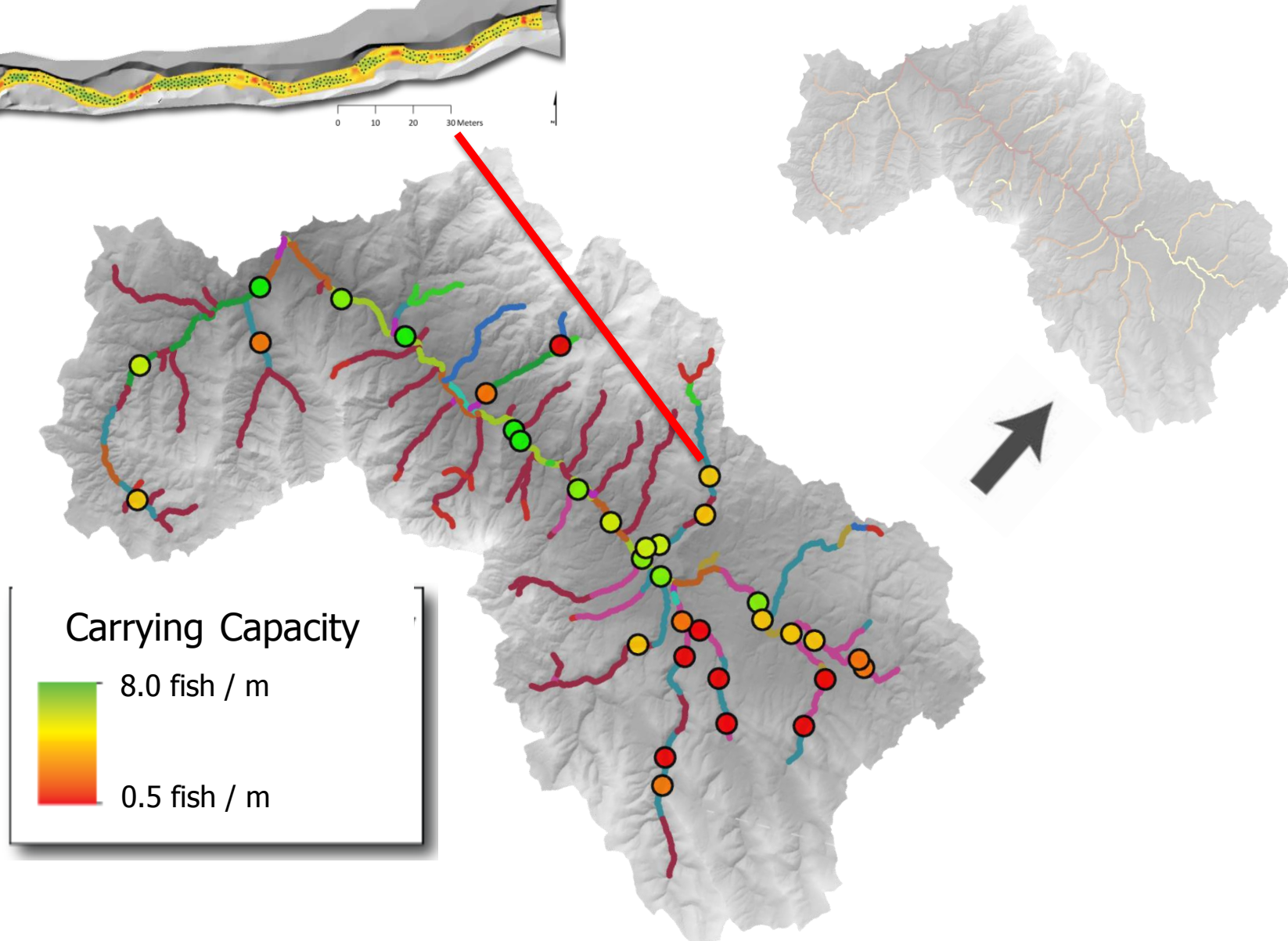
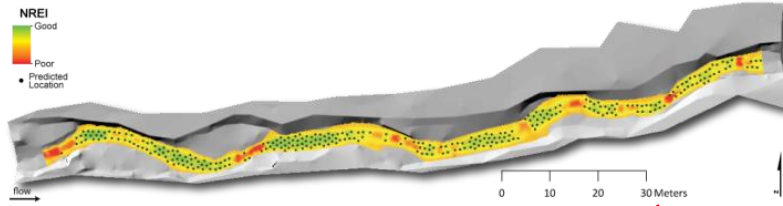
Watershed



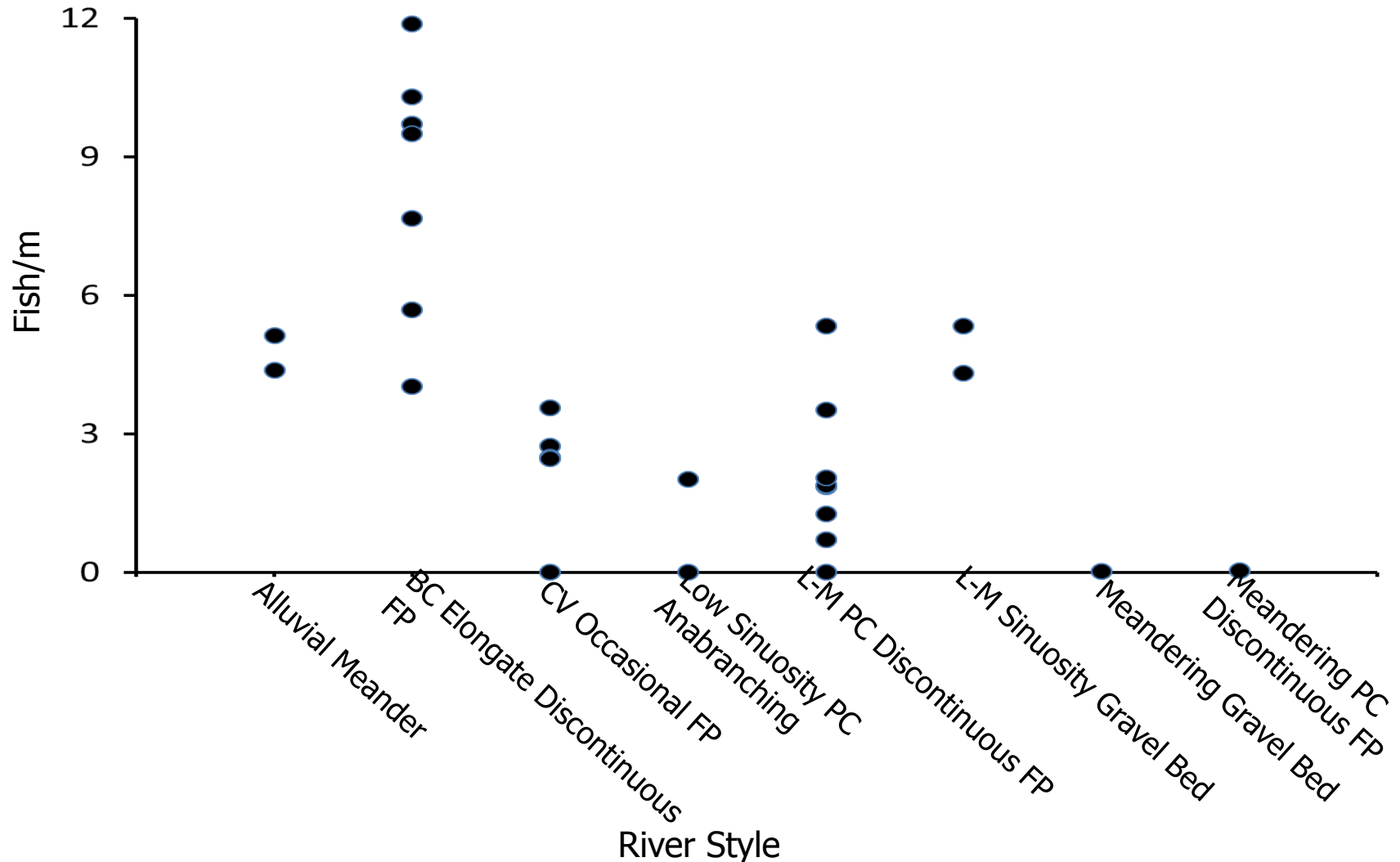
RIVER STYLES TO HELP EXTRAPOLATE



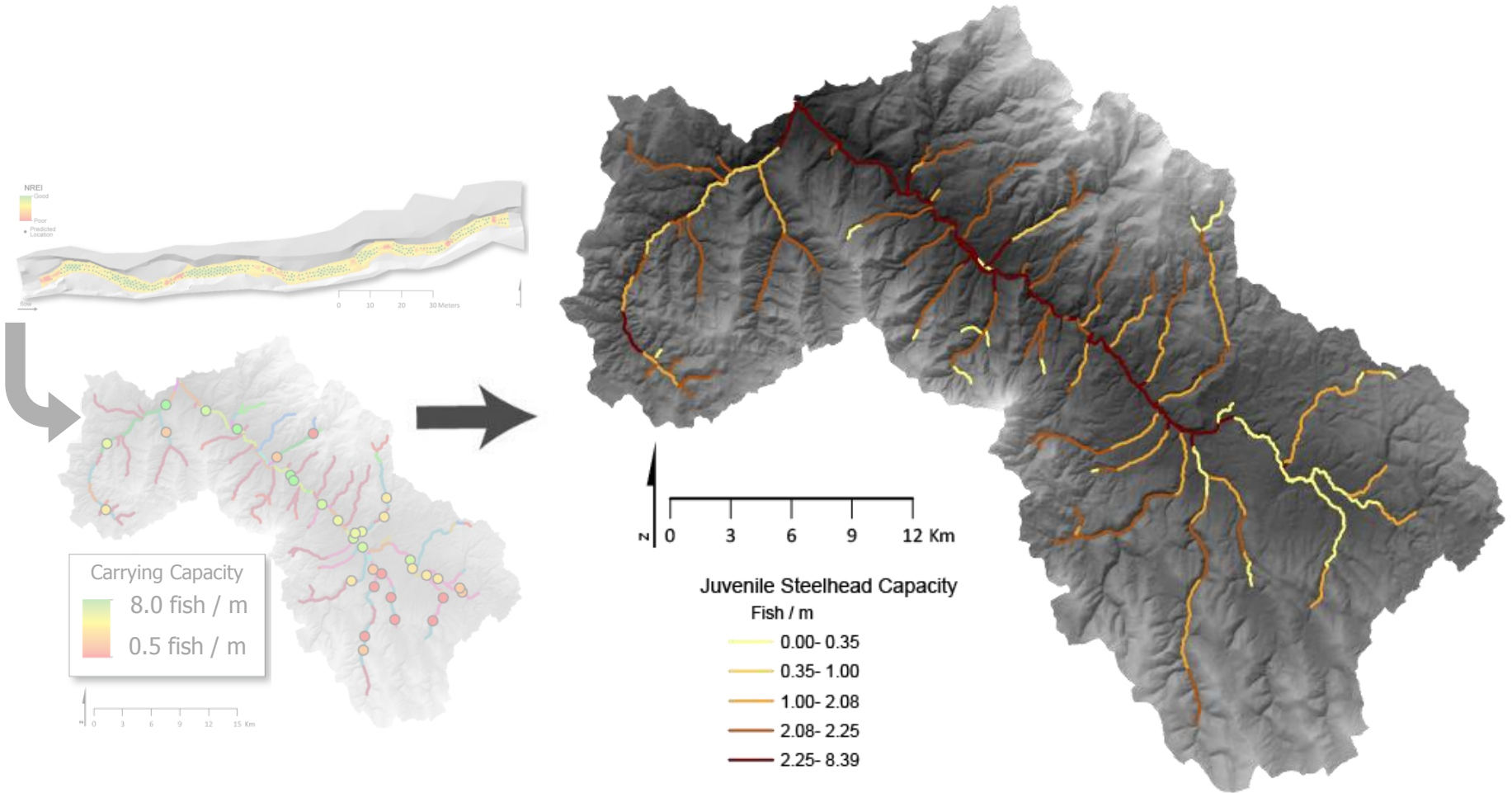
NETWORK MODEL: CARRYING CAPACITY



HSI JUVENILE CAPACITY ESTIMATES

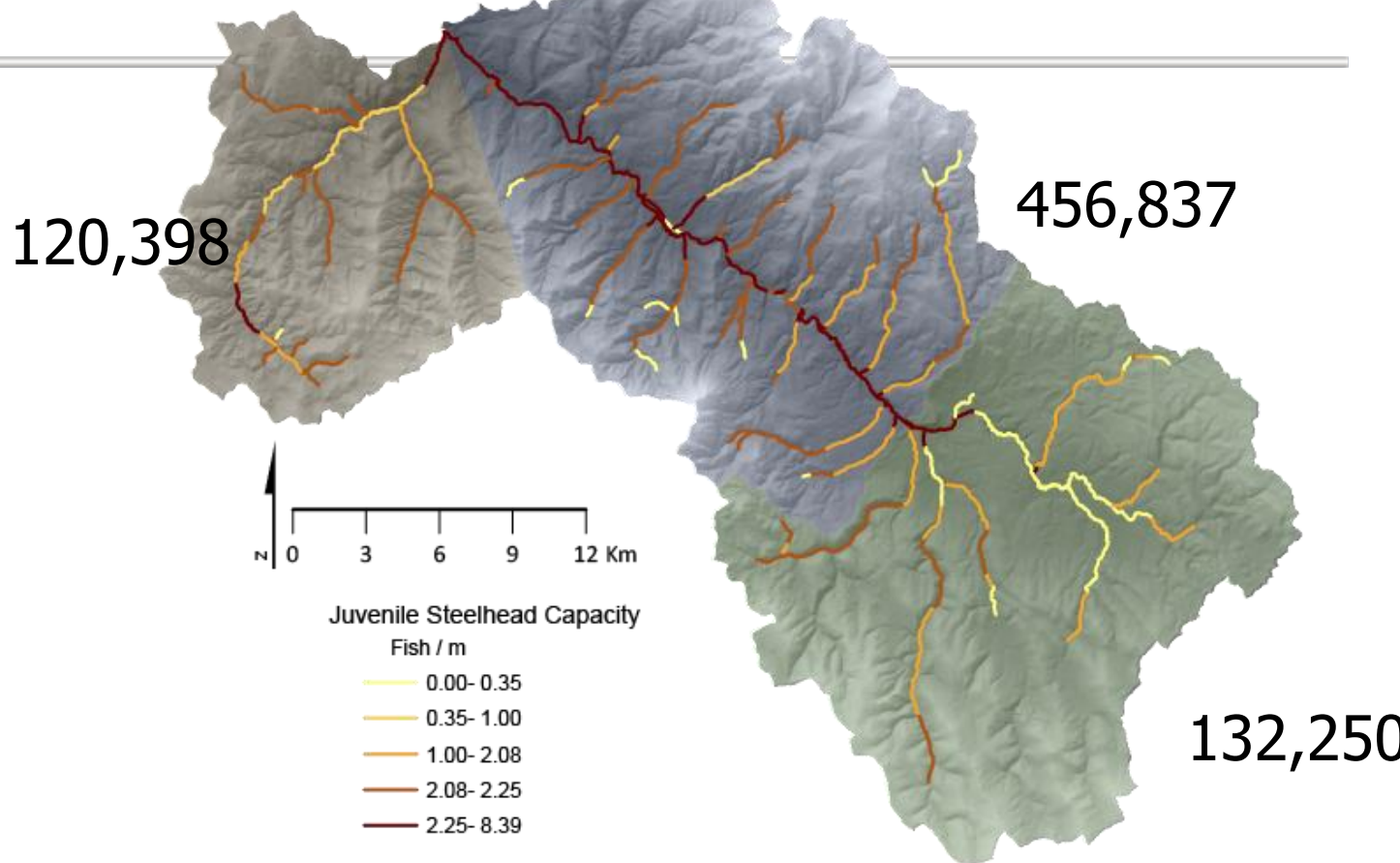


NETWORK MODEL: CARRYING CAPACITY



JUVENILE STEELHEAD CAPACITY

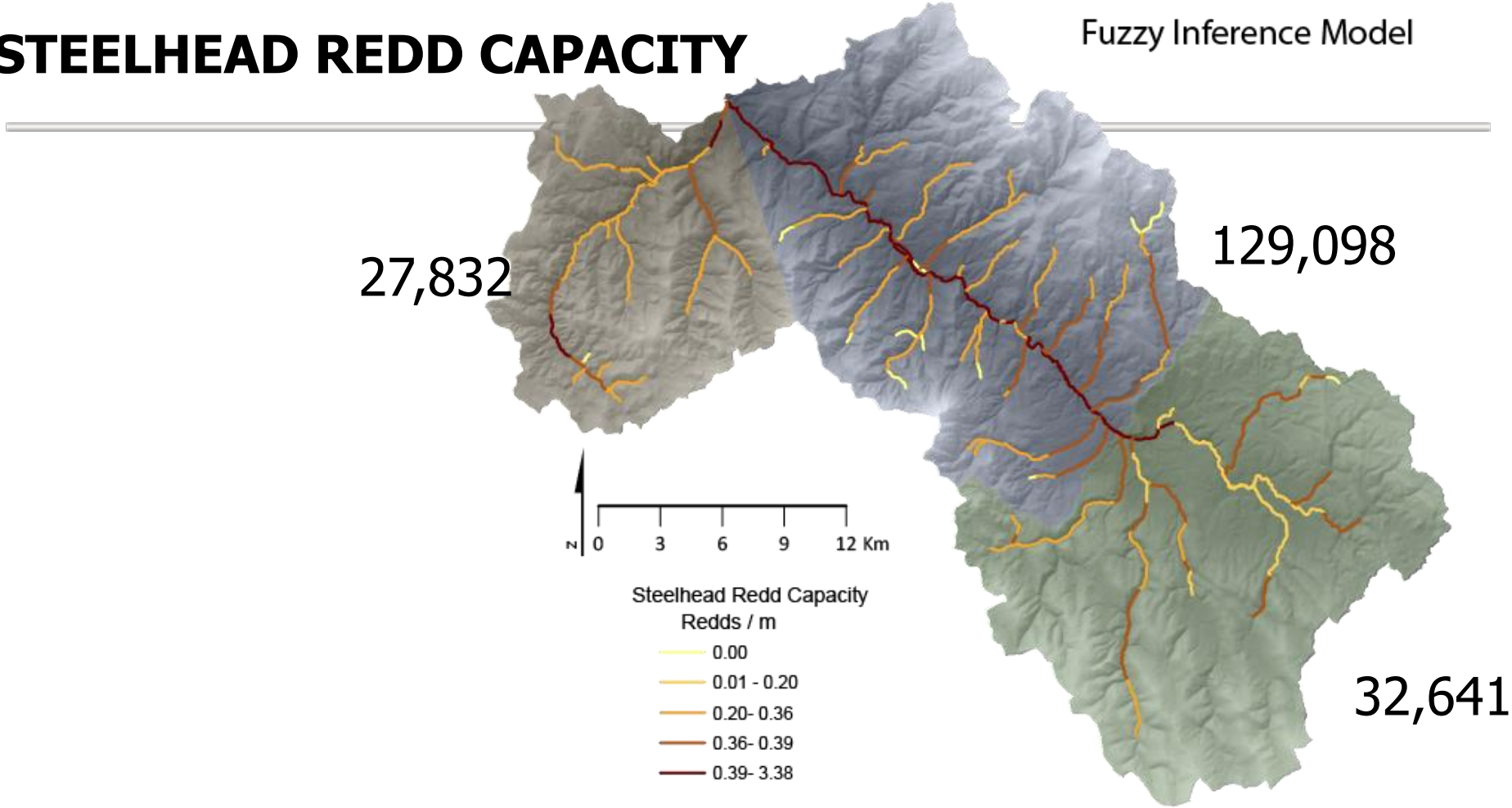
NREI Model



Management unit	River Km	NREI density	FIS density	HSI density
Camp Cr.	52.3	2.30 fish/m	2.27 fish/m	3.02 fish/m
Lower Mainstem	138.2	3.31 fish/m	3.26 fish/m	3.81 fish/m
Upper MFJD	80.1	1.65 fish/m	1.59 fish/m	2.76 fish/m
Watershed capacity		709,486 steelhead	698,960 steelhead	905,219 steelhead

STEELHEAD REDD CAPACITY

Fuzzy Inference Model



Management unit	River Km	FIS density	HSI density
Camp Cr.	52.3	0.53 redds/m	0.36 redds/m
Lower Mainstem	138.2	0.93 redds/m	0.67 redds/m
Upper MFJD	80.1	0.41 redds/m	0.24 redds/m

Watershed capacity 189,570 steelhead redds 130,550 steelhead redds

TODAY'S PLAN



I. Introduction to Habitat Models

II. Habitat Models

I. HSI – Suitability Based Models

I. Fish example

II. Fuzzy-Logic Based Models

I. Beaver Example

III. Bioenergetics Based Models

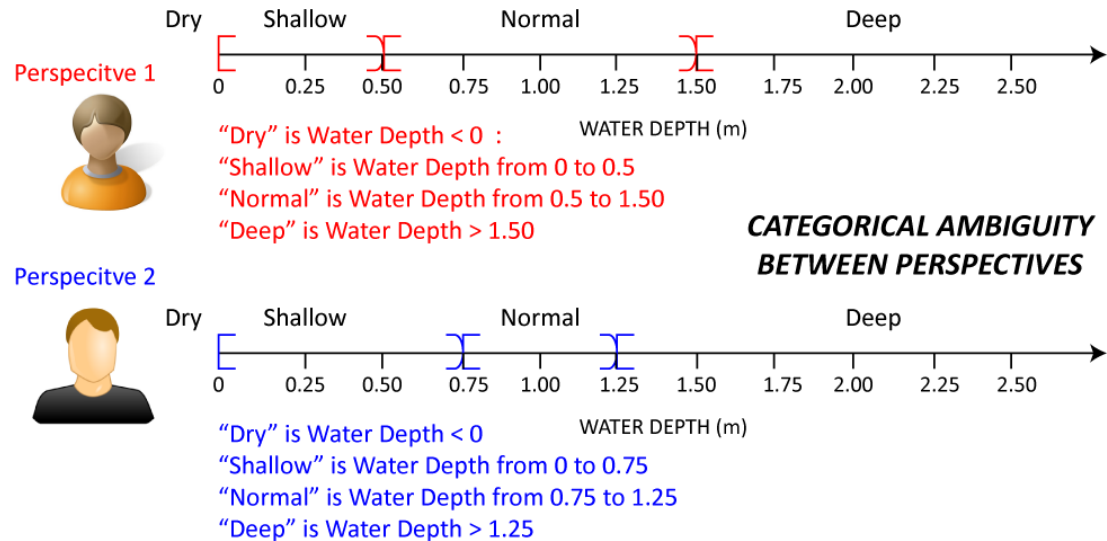
I. Fish Example

III. Lab – Habitat Occupancy Model

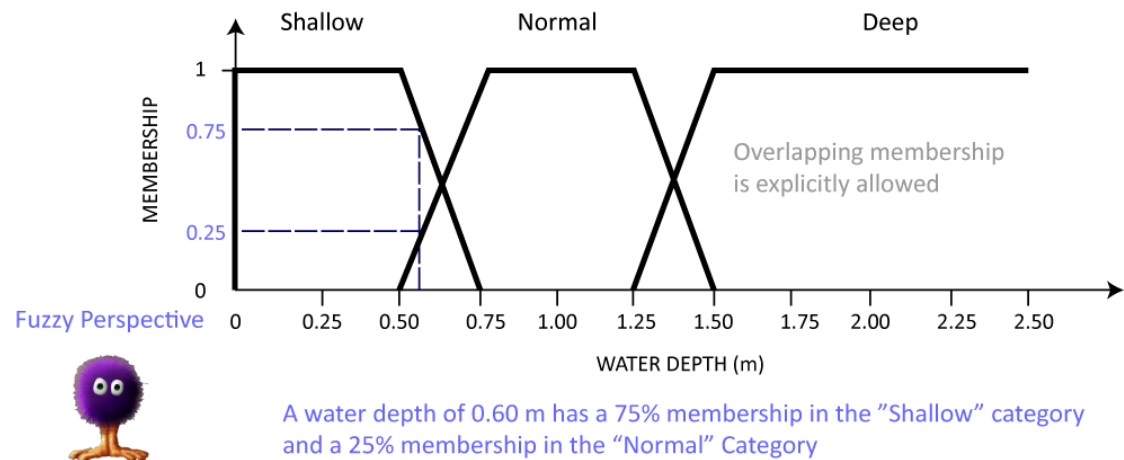
I. Ungulates (Cows)...

CRISP VS. FUZZY SETS

CRISP CATEGORIZATION OF CONTINUOUS VARIABLE

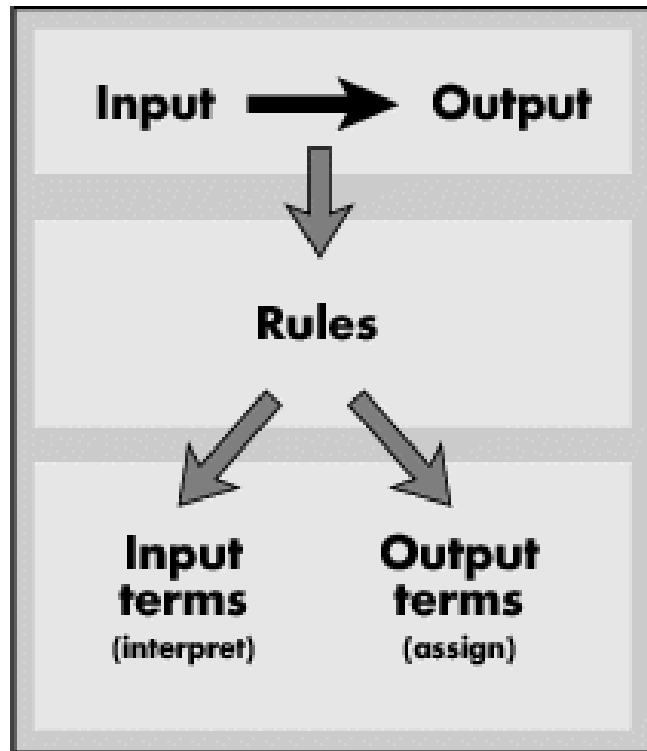


FUZZY MEMBERSHIP IN CATEGORIES BASED ON AMBIGUITY/ UNCERTAINTY

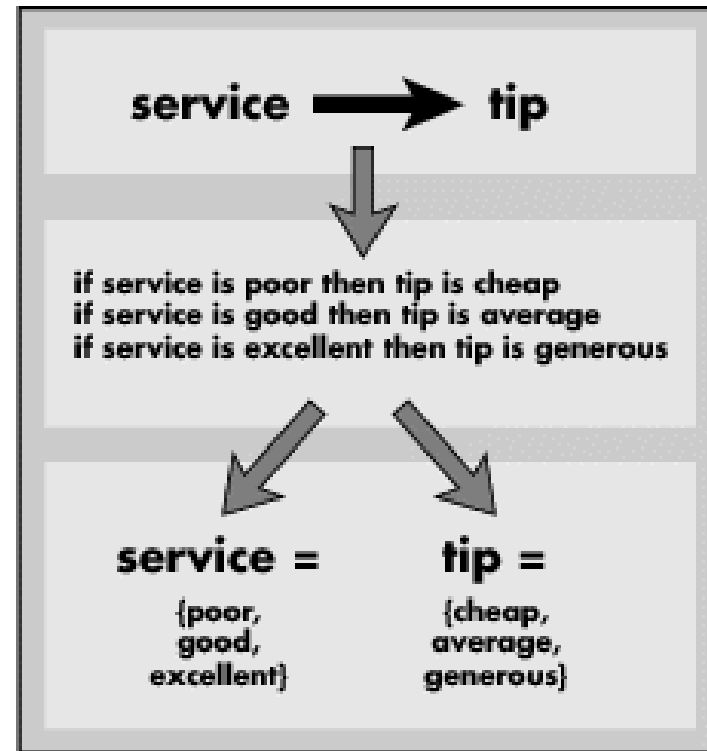


AN INFERENCE SYSTEM – RULE BASED

The General Case...



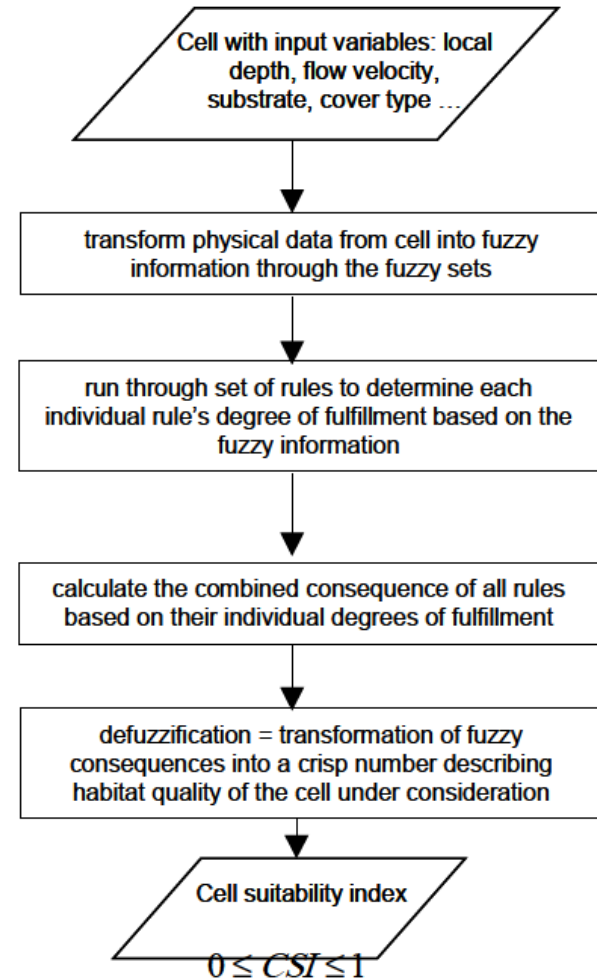
A Specific Example...



STEPS IN A FUZZY INFERENCE SYSTEM

1. Define output categories and membership functions
2. Decide inputs
 1. Define categories and membership functions for each input
3. Build rule table (weight rules if desired)
4. Apply each relevant rule
5. Method for combining rules to
6. Method for defuzzifying output (back to crisp value)

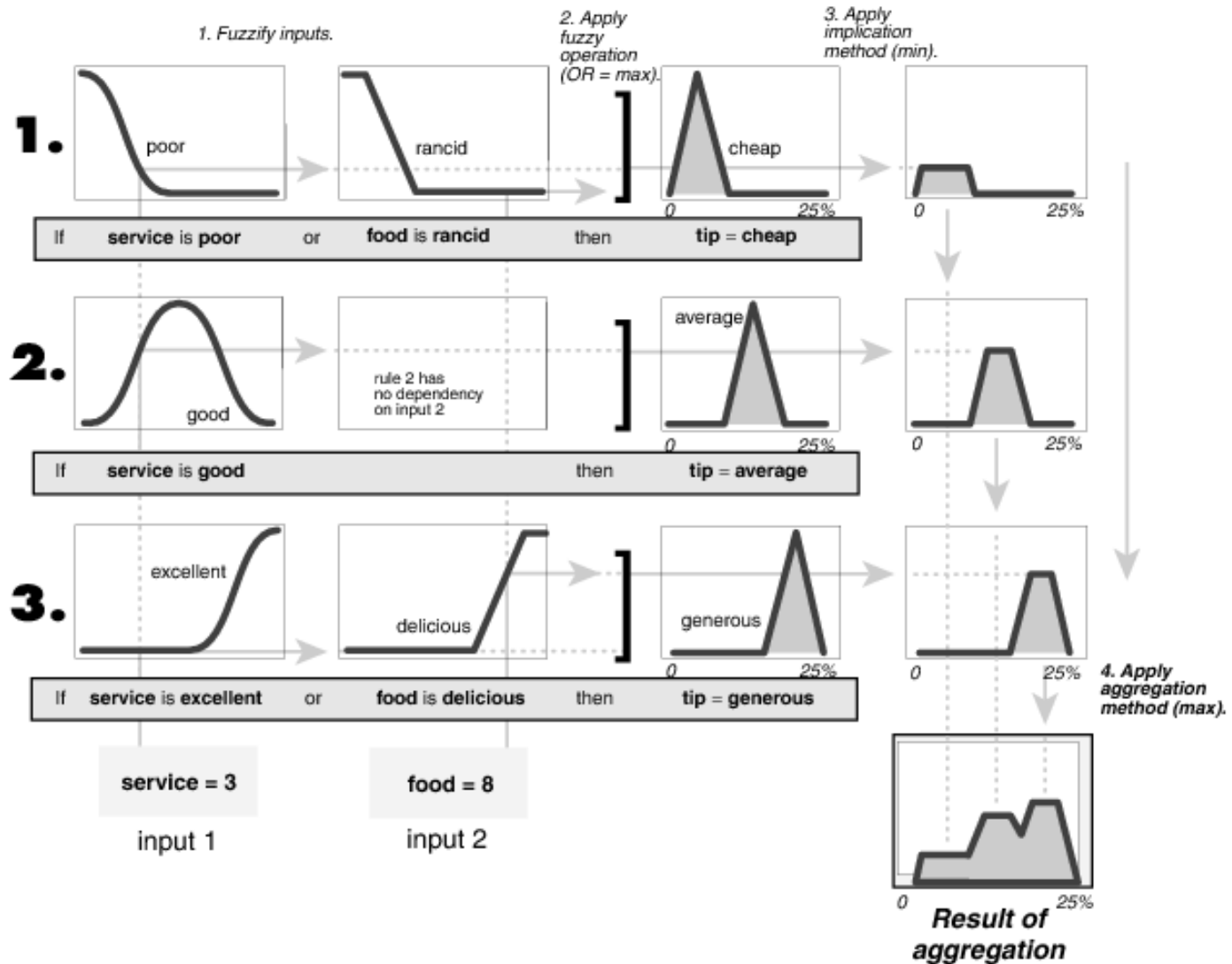
Schneider M and Jorde K. 2003. Fuzzy-Rule Based Models for the Evaluation of Fish Habitat Quality and Instream Flow Assessment, Proc. International IFIM Users Workshop: Fort Collins, CO, 22 pp.



AGGREGATE ALL OUTPUTS

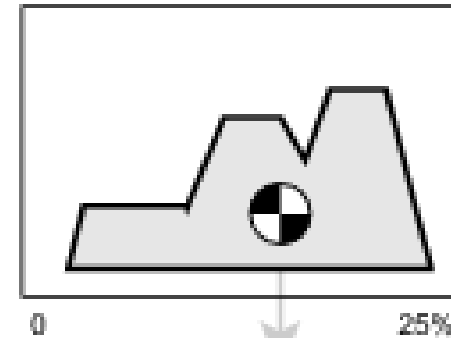
Three built-in methods are supported:

- max (maximum)
- probor (probabilistic OR)
- sum (simply the sum of each rule's output set)



DE-FUZZIFY OUTPUTS

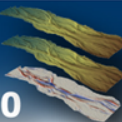
- Five built-in methods supported:
 - Centroid
 - bisector
 - middle of maximum
 - largest of maximum
 - smallest of maximum
- Centroid - most popular defuzzification method - returns the center of area under the curve.



5. Defuzzify the aggregate output (centroid).

tip = 16.7%

Result of
defuzzification



CASiMiR

- There is an English version...

CASiMiR



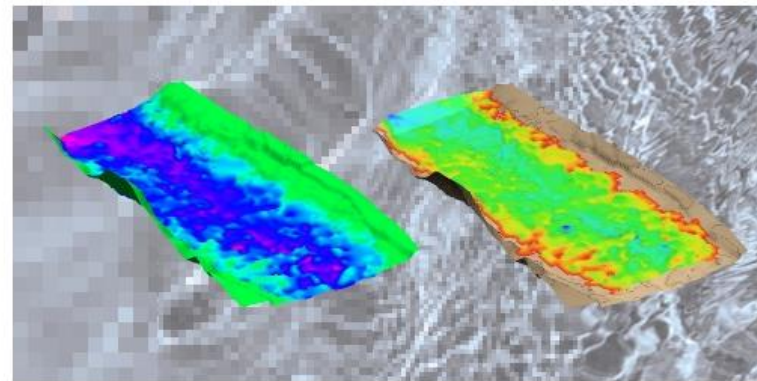
Universität Stuttgart
Institut für Wasserbau



Schneider & Jorde
Ecological Engineering GmbH

Computer Aided Simulation Model for Instream Flow Requirements 

Home	Workshops	Anwendungen	Download	Publikationen	Kontakt
------	-----------	-------------	----------	---------------	---------



Über CASiMiR

Informieren Sie sich über diese einzigartige Fuzzy-Logik Software. [Hier](#) finden Sie alle Infos zu den Funktionen und Anwendungen der Software.

Software downloaden

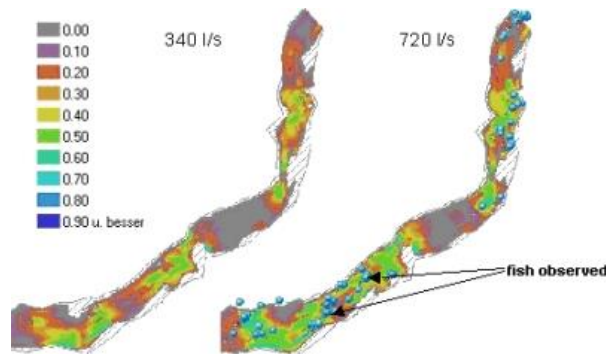
[Hier](#) finden Sie die neuesten Versionen des CASiMiR Programmes.

Willkommen

Auf der Homepage zu CASiMiR - dem Simulationssystem zur Untersuchung von Gewässerhabitaten. Wir freuen uns, dass Sie sich für unsere CASiMiR Software interessieren. Diese Internetseite stellt Ihnen einige [Anwendungsmöglichkeiten](#) für die Software vor. Im [Downloadbereich](#) stellen wir Ihnen einzelne Module von CASiMiR zur freien Nutzung zur Verfügung. Mit Hilfe einzelner Fallbeispiele können Sie selbst erste Modellierungen durchführen. Wenn Sie weitere Fragen haben und Informationen möchten, wenden Sie sich an [Kontakt](#). Außer Informationen zum Modell haben wir auch eine Liste von [Publikationen](#) mit Bezug zu CASiMiR bereit gestellt.

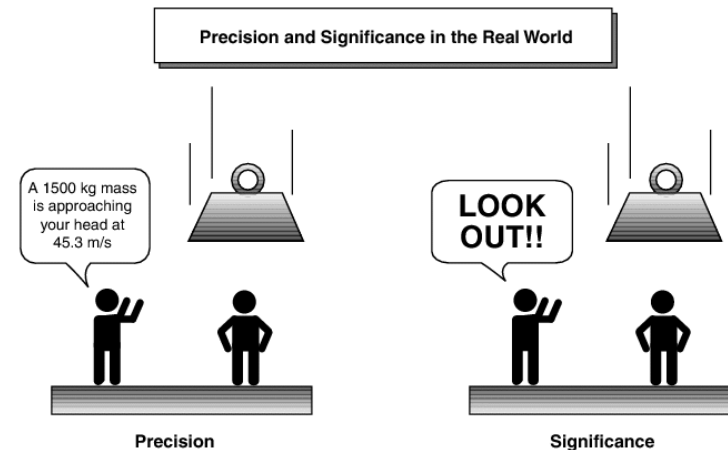
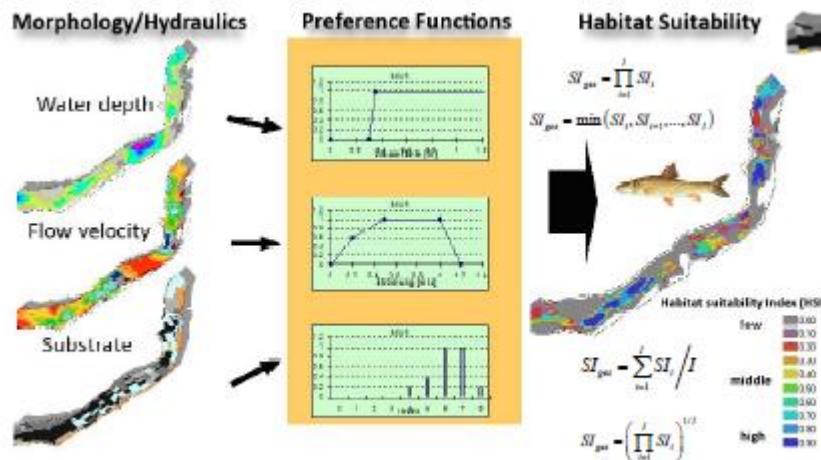
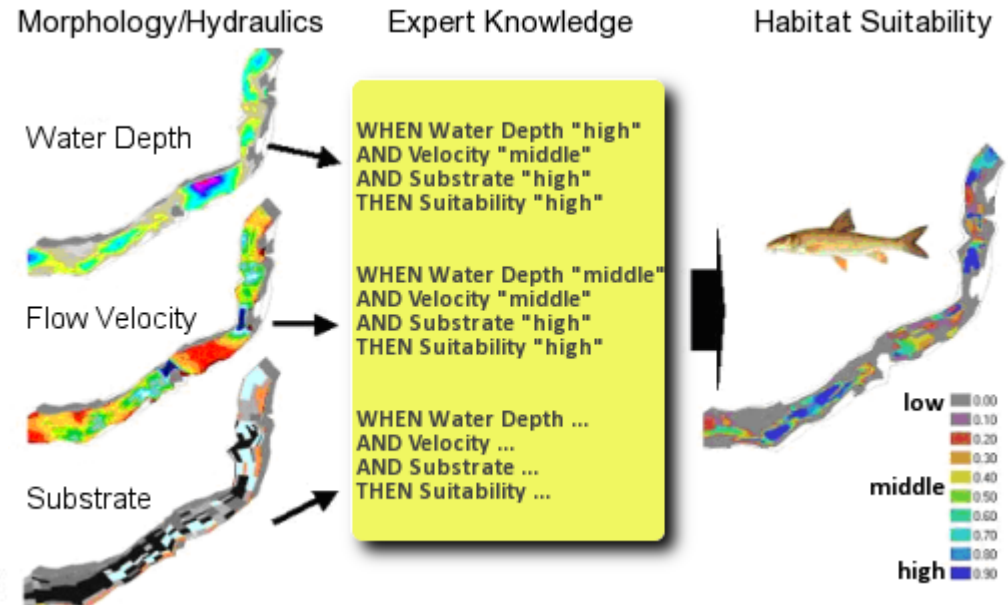
Kontakt aufnehmen

Wir freuen uns von Ihnen Rückmeldungen zu bekommen. Für Fragen können Sie uns per [Email](#) erreichen an der [Universität Stuttgart](#) oder bei der [sje GmbH](#)



FUZZY VS. HSI

- In contrast to HIS based approach, here we use expert knowledge...

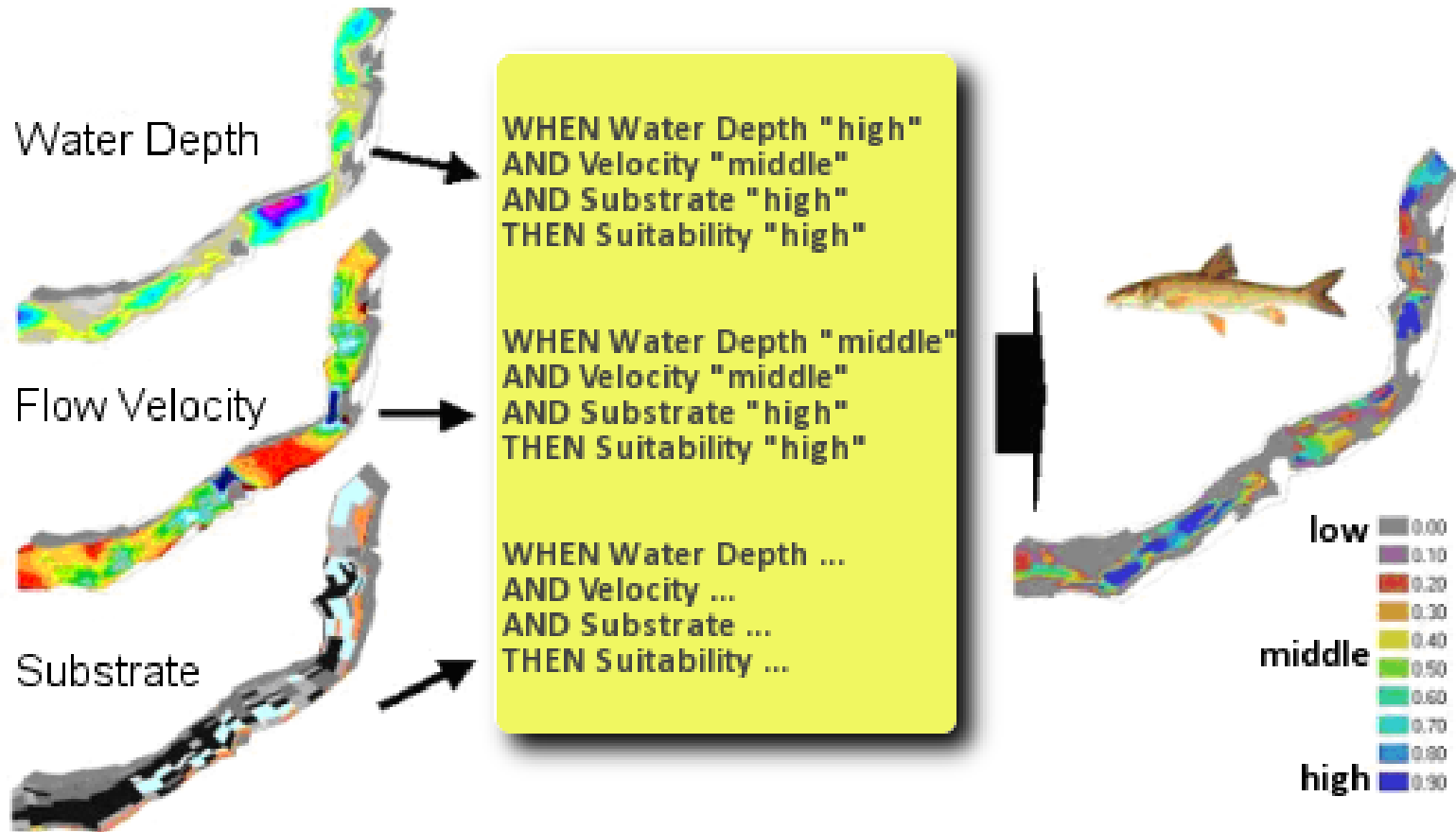


FIS SYSTEM

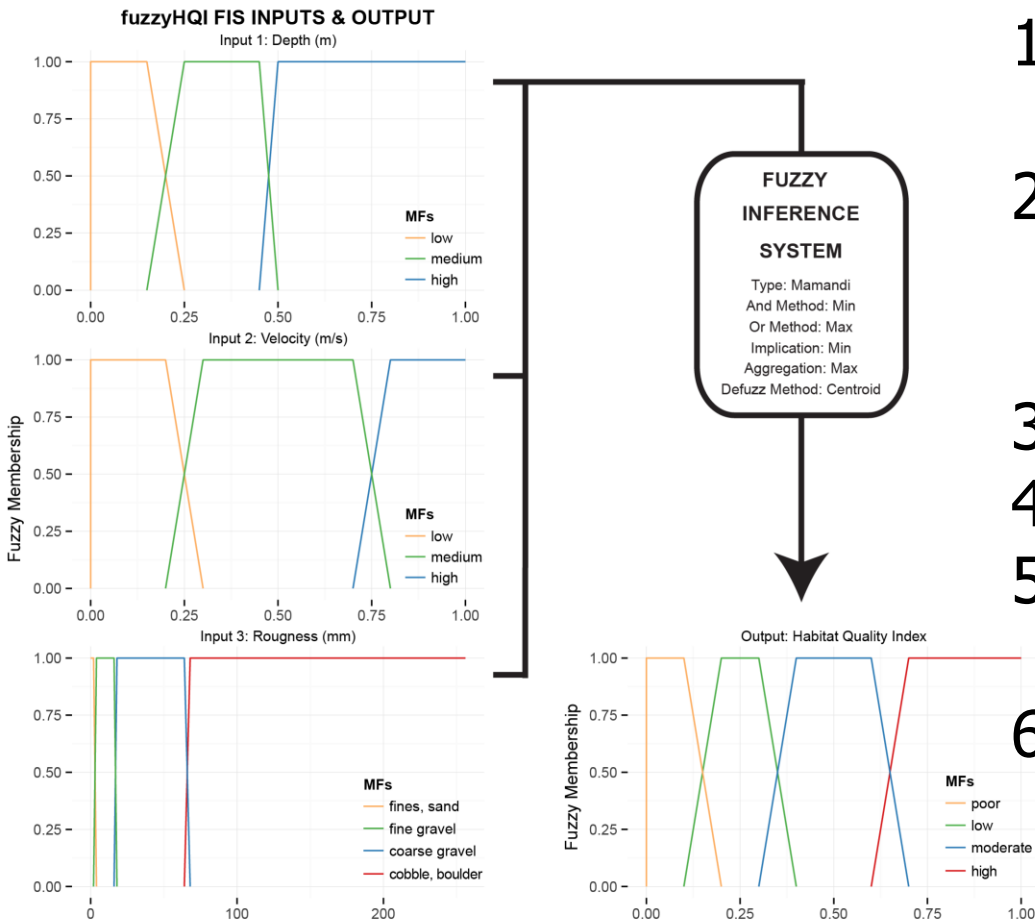
Morphology/Hydraulics

Expert Knowledge

Habitat Suitability



FUZZY APPROACH TO FISH MODELING



Steps in building Fuzzy Model:

1. Define output categories and membership functions.
2. Decide inputs. Define categories and membership functions for each input.
3. Build rule table.
4. Apply each relevant rule.
5. Choose method for combining rules.
6. Choose method for defuzzifying output (back to crisp value)

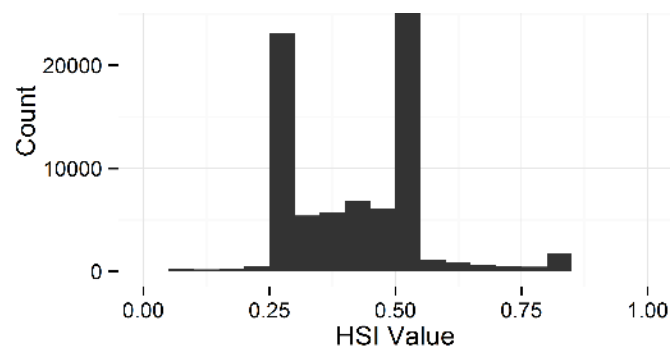
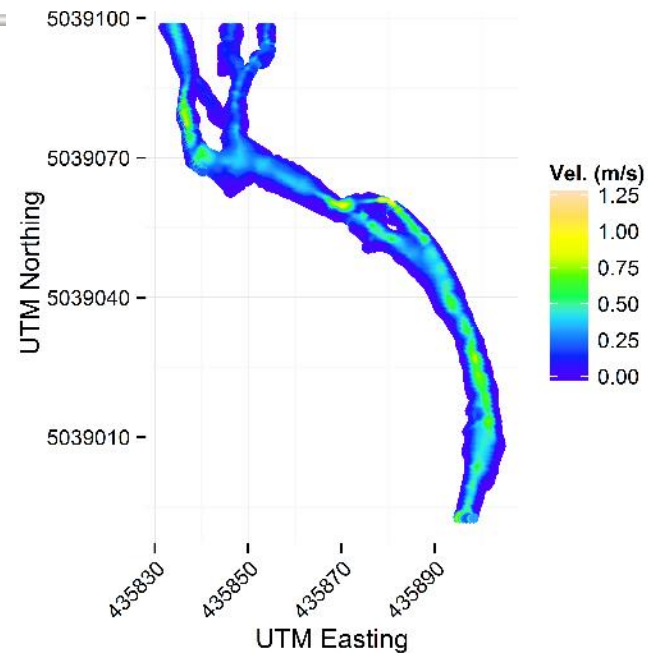
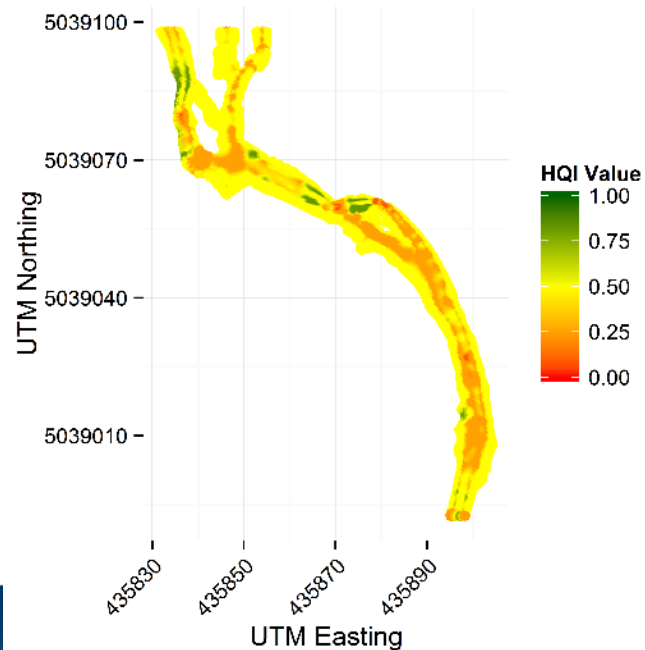
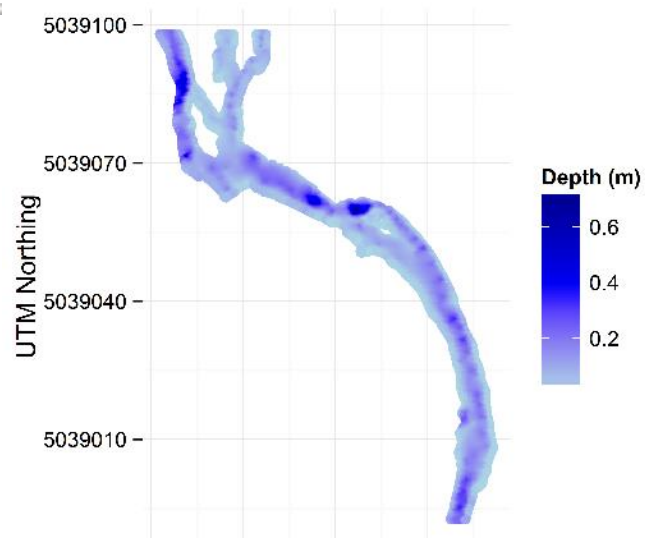
Fuzzy HSI

Example Output:

CBW05583-142490 2013 Steelhead Juvenile fisHQI Results

Q = 0.236 cms.; Model = Fuzzy v. 01

WUA = 340.8 sq.m.; WUA:Wetted Area = 0.41



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



ADVANTAGES OF FUZZY...

- 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 than traditional HSI

TODAY'S PLAN



I. Introduction to Habitat Models

II. Habitat Models

I. HSI – Suitability Based Models

I. Fish example

II. Fuzzy-Logic Based Models

I. Beaver Example

III. Bioenergetics Based Models

I. Fish Example

III. Lab – Habitat Occupancy Model

I. Ungulates (Cows)...

BRAT – BEAVER RESTORATION ASSESSMENT TOOL



BEAVER RESTORATION ASSESSMENT TOOL



BRAT

 Search this site

BRAT Resources

BRAT

Vision

▼ Documentation

Manual Implementation of
Capacity Models

Workshops

Escalante Pilot Project

Beaver Restoration Information

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Welcome to the BRAT website. The **Beaver Restoration Assessment Tool** will be a decision support and planning tool intended to help researchers and resource managers assess the potential for beaver as a stream conservation and restoration agent over large regions and watersheds.

The BRAT models can be run with widely available existing data sets, and used to identify opportunities, potential conflicts and constraints through a mix of assessment of existing resources and scenario-based assessment of potential futures. The primary backbone to BRAT are some spatial models that predict the capacity of riverscapes to support dam-building activity by beaver. These models have been tested in a pilot project in Utah and are ready for broader implementation. The rest of the decision support tool is under development (read [Vision here](#)).



The
WALTON FAMILY
FOUNDATION



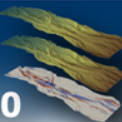
ECOFLIGHT



- Wally MacFarlane
- Martha Jensen
- Jordan Gilbert
- Jordan Burningham

<http://brat.joewheaton.org>

WATS 4930

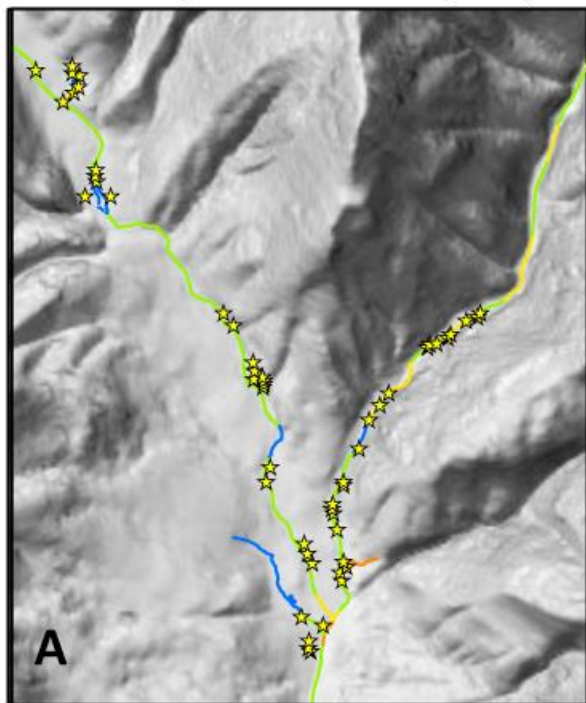


BRAT OUTPUTS IN A NUTSHELL



- Existing & Historic Capacities → Potential Conflict → Management

Existing Beaver Dam Capacity



Potential for Human Beaver Conflict



Ecosystem Management



★ Actual Beaver Dams

Maximum Dam Density (dams/km)

0 - None 0 - 1 Rare 1 - 4 Occasional
5 - 15 Frequent 16 - 40 Pervasive

Probability of Conflict

0 - 10% 50 - 75%
10 - 25% > 75%
25 - 50%

Beaver Management Zones

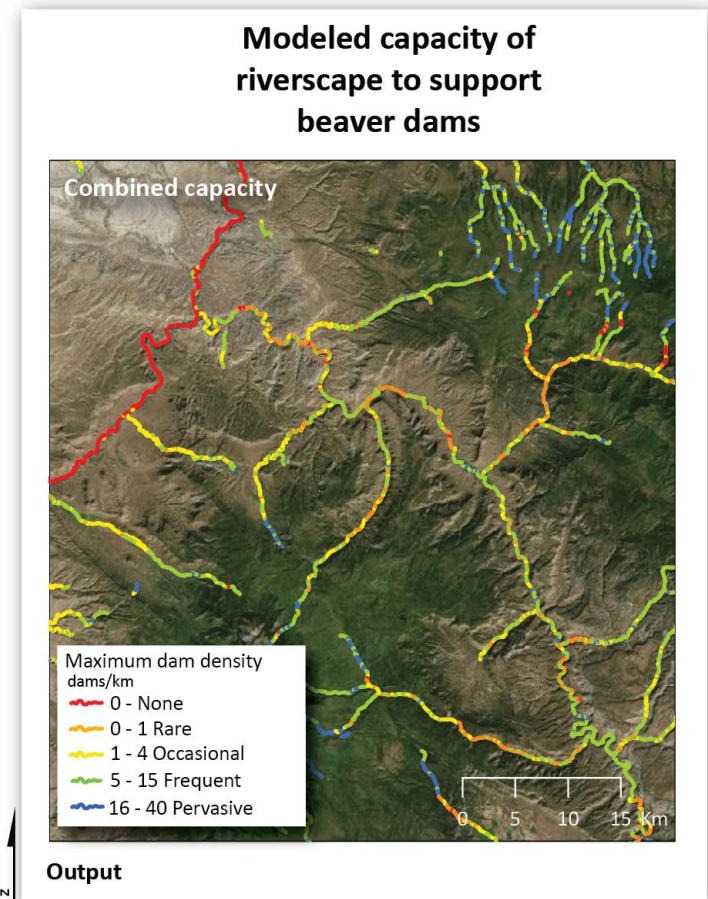
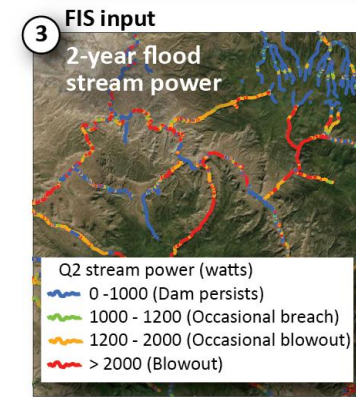
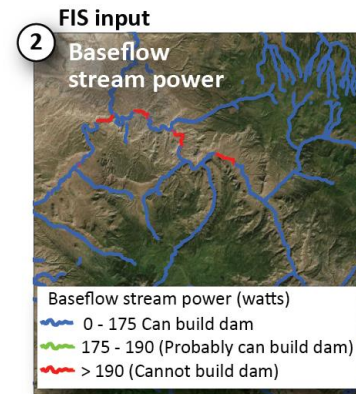
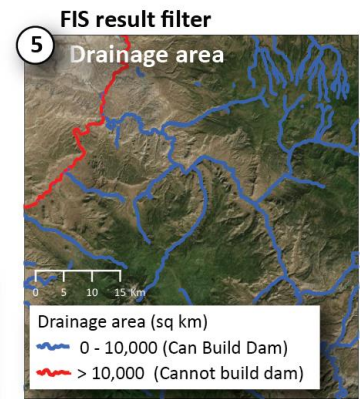
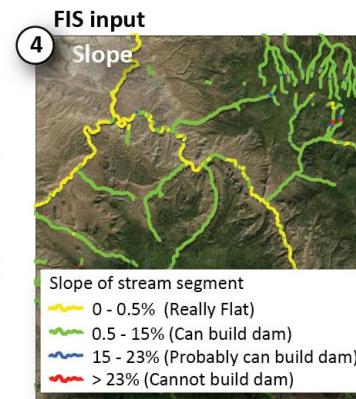
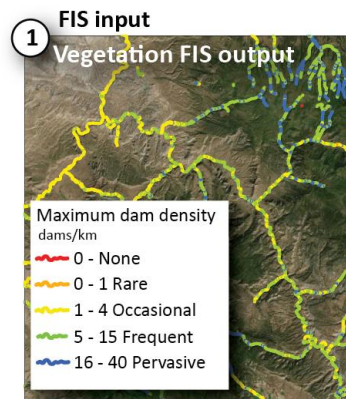
Unsuitable: Naturally Limited Long-Term Restoration Zone
Unsuitable: Anthropogenically Limited Living with Beaver (Low Source)
Quick Return Restoration Zone Living with Beaver (High Source)
Low Hanging Fruit



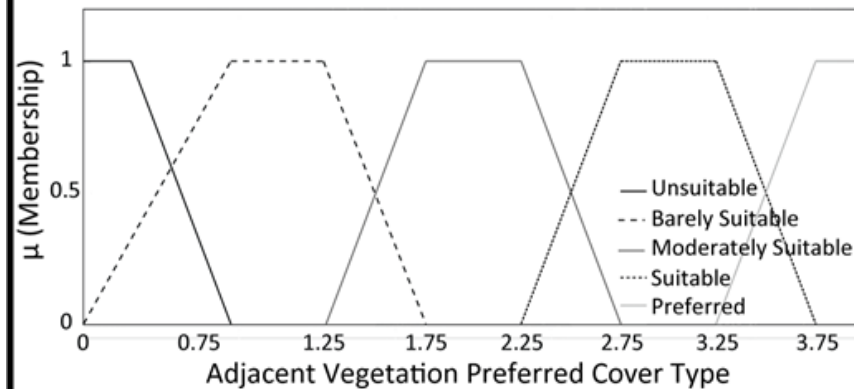
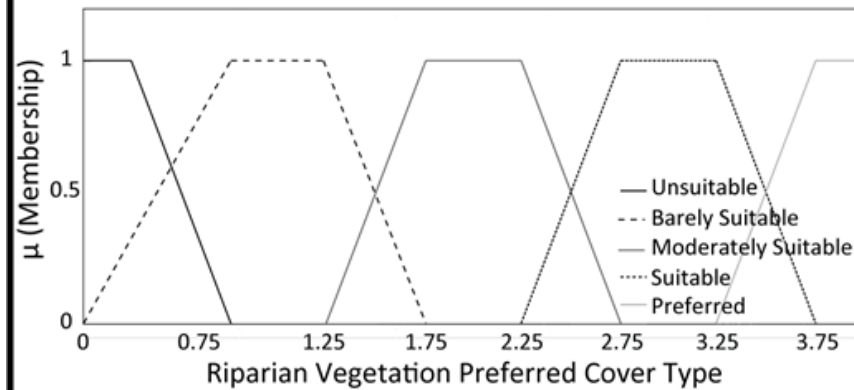
0 0.5 1 1.5 2 Kilometers

BRAT – THE INPUTS...

- Can all be run from freely available, nationally available datasets
- Could be run for entire US or logic applied locally
- Makes a prediction at 250 m long reaches



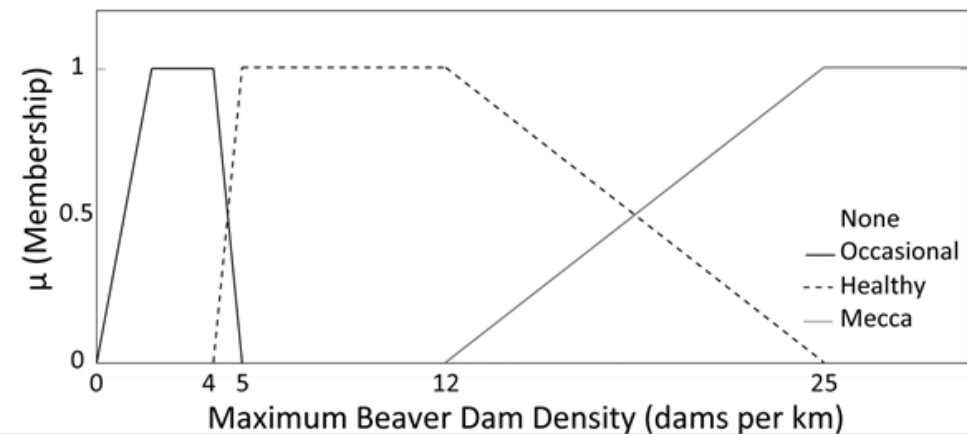
INPUTS



FUZZY INFERENCE SYSTEM

Type: Mamandi
 And Method: Min
 Or Method: Max
 Implication: Min
 Aggregation: Max
 Defuzz Method: Centroid

OUTPUT



PERENNIAL STREAM & VEGETATION FIS

MEMBERSHIP FUNCTIONS (*.FIS)

- Simple ascii text file
- Computing w/ words

```
input_veg.asc  GrazingProb_3input.fis  VegCapacityBeaver_2input.fis
1  [System]
2  Name='VegCapacityBeaver'
3  Type='mamdani'
4  Version=2.0
5  NumInputs=2
6  NumOutputs=1
7  NumRules=25
8  AndMethod='min'
9  OrMethod='max'
10 ImpMethod='min'
11 AggMethod='max'
12 DefuzzMethod='centroid'
13
14 [Input1]
15 Name='RiparianVegPrefCover'
```

```
14 [Input1]
15 Name='RiparianVegPrefCover'
16 Range=[0 4]
17 NumMFs=5
18 MF1='UnsuitableMaterial':'trimf',[0 0 1]
19 MF2='BarelySuitableMaterial':'trimf',[0 1 2]
20 MF3='ModeratelySuitableMaterial':'trimf',[1 2 3]
21 MF4='SuitableMaterial' : 'trimf' , [2 3 4]
22 MF5='PreferredMaterial' : 'trimf' , [3 4 4]
23
24 [Input2]
25 Name='AdjacentVegPrefCover'
26 Range=[0 4]
27 NumMFs=5
28 MF1='UnsuitableMaterial':'trimf',[0 0 1]
29 MF2='BarelySuitableMaterial':'trimf',[0 1 2]
30 MF3='ModeratelySuitableMaterial':'trimf',[1 2 3]
31 MF4='SuitableMaterial' : 'trimf' , [2 3 4]
32 MF5='PreferredMaterial' : 'trimf' , [3 4 4]
33
34 [Output1]
35 Name='BeaverDamsVegCanSupport'
36 Range=[0 45]
37 NumMFs=4
38 MF1='None':'trimf',[0 0 1]
39 MF2='Occasional':'trapmf',[0 1 4 5]
40 MF3='Moderate':'trapmf',[4 5 12 20]
41 MF4='Mecca':'trapmf',[12 20 45 45]
42
```


THE RULE TABLE...

43	[rules]
44	1 1, 1 (1) : 1
45	2 1, 2 (1) : 1
46	3 1, 2 (1) : 1
47	4 1, 2 (1) : 1
48	5 1, 3 (1) : 1
49	1 2, 2 (1) : 1
50	2 2, 2 (1) : 1
51	3 2, 2 (1) : 1
52	4 2, 3 (1) : 1
53	5 2, 3 (1) : 1
54	1 3, 2 (1) : 1
55	2 3, 2 (1) : 1
56	3 3, 3 (1) : 1
57	4 3, 3 (1) : 1
58	5 3, 3 (1) : 1
59	1 4, 2 (1) : 1
60	2 4, 2 (1) : 1
61	3 4, 3 (1) : 1
62	4 4, 3 (1) : 1
63	5 4, 3 (1) : 1
64	1 5, 2 (1) : 1
65	2 5, 3 (1) : 1
66	3 5, 3 (1) : 1
67	4 5, 4 (1) : 1
68	5 5, 4 (1) : 1

INPUTS					OUTPUT
IF	Suitability of Streamside Vegetation		Suitability of Riparian/Upland Vegetation		Dam Density Capacity
RULES	1	Unsuitable	&	Unsuitable	, then None
	2	Barely Suitable	&	Unsuitable	, then Occasional
	3	Moderately Suitable	&	Unsuitable	, then Occasional
	4	Suitable	&	Unsuitable	, then Occasional
	5	Preferred	&	Unsuitable	, then Frequent
	6	Unsuitable	&	Barely Suitable	, then Occasional
	7	Barely Suitable	&	Barely Suitable	, then Occasional
	8	Moderately Suitable	&	Barely Suitable	, then Occasional
	9	Suitable	&	Barely Suitable	, then Frequent
	10	Preferred	&	Barely Suitable	, then Frequent
	11	Unsuitable	&	Moderately Suitable	, then Occasional
	12	Barely Suitable	&	Moderately Suitable	, then Occasional
	13	Moderately Suitable	&	Moderately Suitable	, then Frequent
	14	Suitable	&	Moderately Suitable	, then Frequent
	15	Preferred	&	Moderately Suitable	, then Frequent
	16	Unsuitable	&	Suitable	, then Occasional
	17	Barely Suitable	&	Suitable	, then Occasional
	18	Moderately Suitable	&	Suitable	, then Frequent
	19	Suitable	&	Suitable	, then Frequent
	20	Preferred	&	Suitable	, then Frequent
	21	Unsuitable	&	Preferred	, then Occasional
	22	Barely Suitable	&	Preferred	, then Frequent
	23	Moderately Suitable	&	Preferred	, then Frequent
	24	Suitable	&	Preferred	, then Pervasive
	25	Preferred	&	Preferred	, then Pervasive

COMBINED

1. Veg FIS
 2. Baseflow (can they build a dam?)
 3. 2 Year Flood (does dam blow out)
- = Resulting Capacity

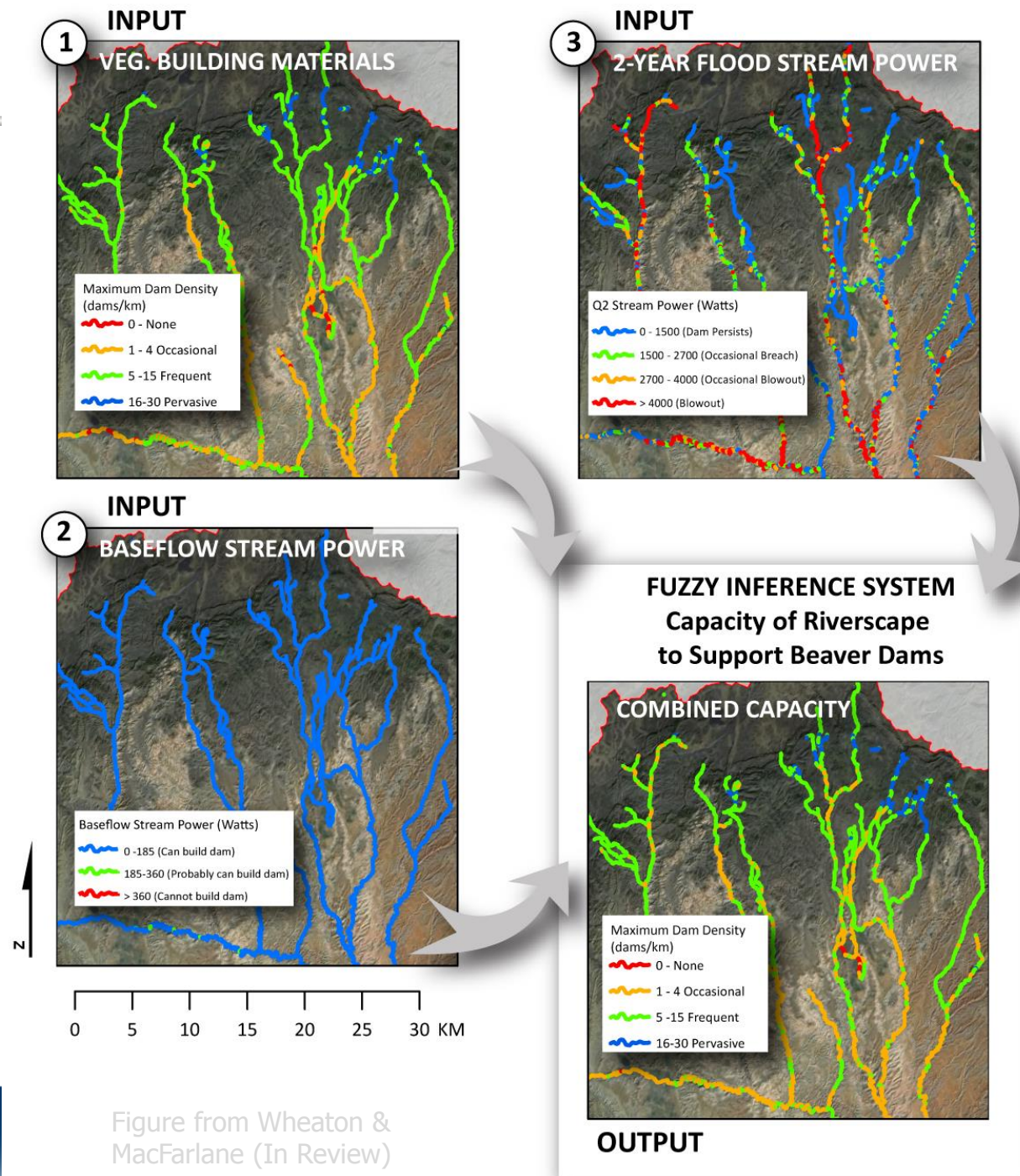
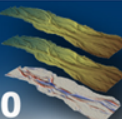
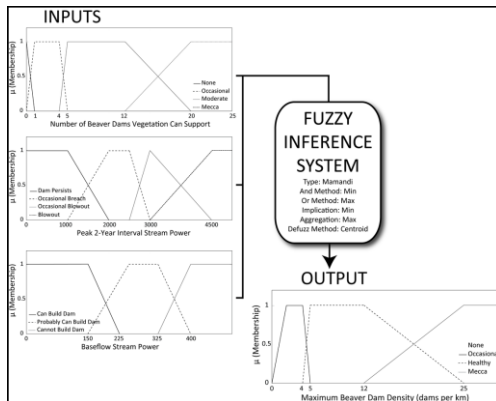


Figure from Wheaton & MacFarlane (In Review)

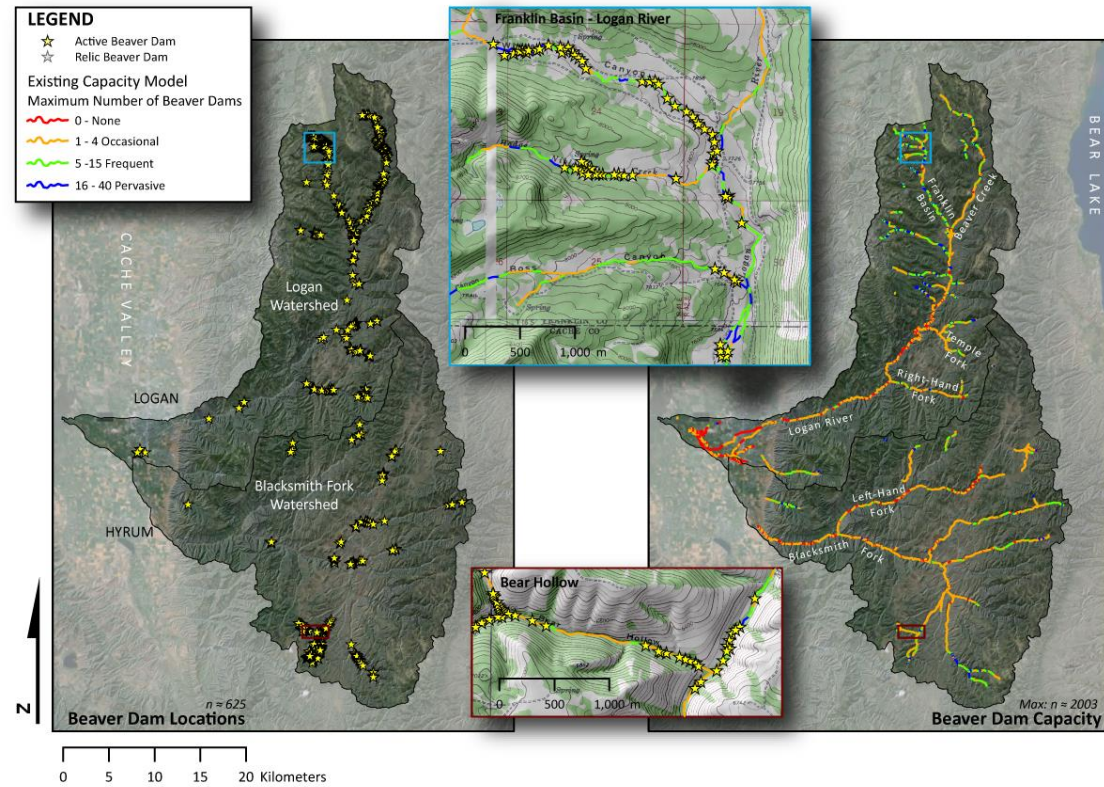
WE USE FUZZY INFERENCE SYSTEMS

- Allow computing with words...
- Explicitly represent uncertainty due to ambiguity

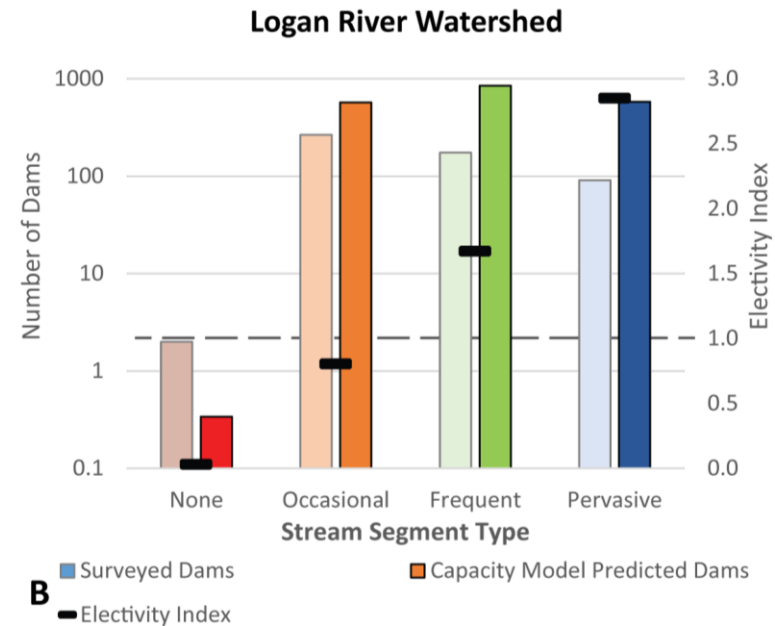
	INPUTS				OUTPUT	
	IF	Vegetative Dam Density Capacity (FIS)	Baseflow Stream Power	2 Year Flood Stream Power		Dam Density Capacity
RULES	1	None	& -	& -	, then	None
	2	-	& Cannot Build Dam	& -	, then	None
	3	Occasional	& Can Build Dam	& Dam Persists	, then	Occasional
	4	Frequent	& Can Build Dam	& Dam Persists	, then	Frequent
	5	Pervasive	& Can Build Dam	& Dam Persists	, then	Pervasive
	6	Occasional	& Can Build Dam	& Occasional Breach	, then	Occasional
	7	Frequent	& Can Build Dam	& Occasional Breach	, then	Frequent
	8	Pervasive	& Can Build Dam	& Occasional Breach	, then	Frequent
	9	Occasional	& Can Build Dam	& Occasional Blowout	, then	Occasional
	10	Frequent	& Can Build Dam	& Occasional Blowout	, then	Occasional
	11	Pervasive	& Can Build Dam	& Occasional Blowout	, then	Frequent
	12	Occasional	& Can Build Dam	& Blowout	, then	Occasional
	13	Frequent	& Can Build Dam	& Blowout	, then	Occasional
	14	Pervasive	& Can Build Dam	& Blowout	, then	Occasional
	15	Occasional	& Can Probably Build Dam	& Occasional Breach	, then	Occasional
	16	Frequent	& Can Probably Build Dam	& Occasional Breach	, then	Frequent
	17	Pervasive	& Can Probably Build Dam	& Occasional Breach	, then	Frequent
	18	Occasional	& Can Probably Build Dam	& Occasional Blowout	, then	Occasional
	19	Frequent	& Can Probably Build Dam	& Occasional Blowout	, then	Occasional
	20	Pervasive	& Can Probably Build Dam	& Occasional Blowout	, then	Frequent
	21	Occasional	& Can Probably Build Dam	& Blowout	, then	Occasional
	22	Frequent	& Can Probably Build Dam	& Blowout	, then	Occasional
	23	Pervasive	& Can Probably Build Dam	& Blowout	, then	Occasional



LOGAN-BLACKSMITH VALIDATION



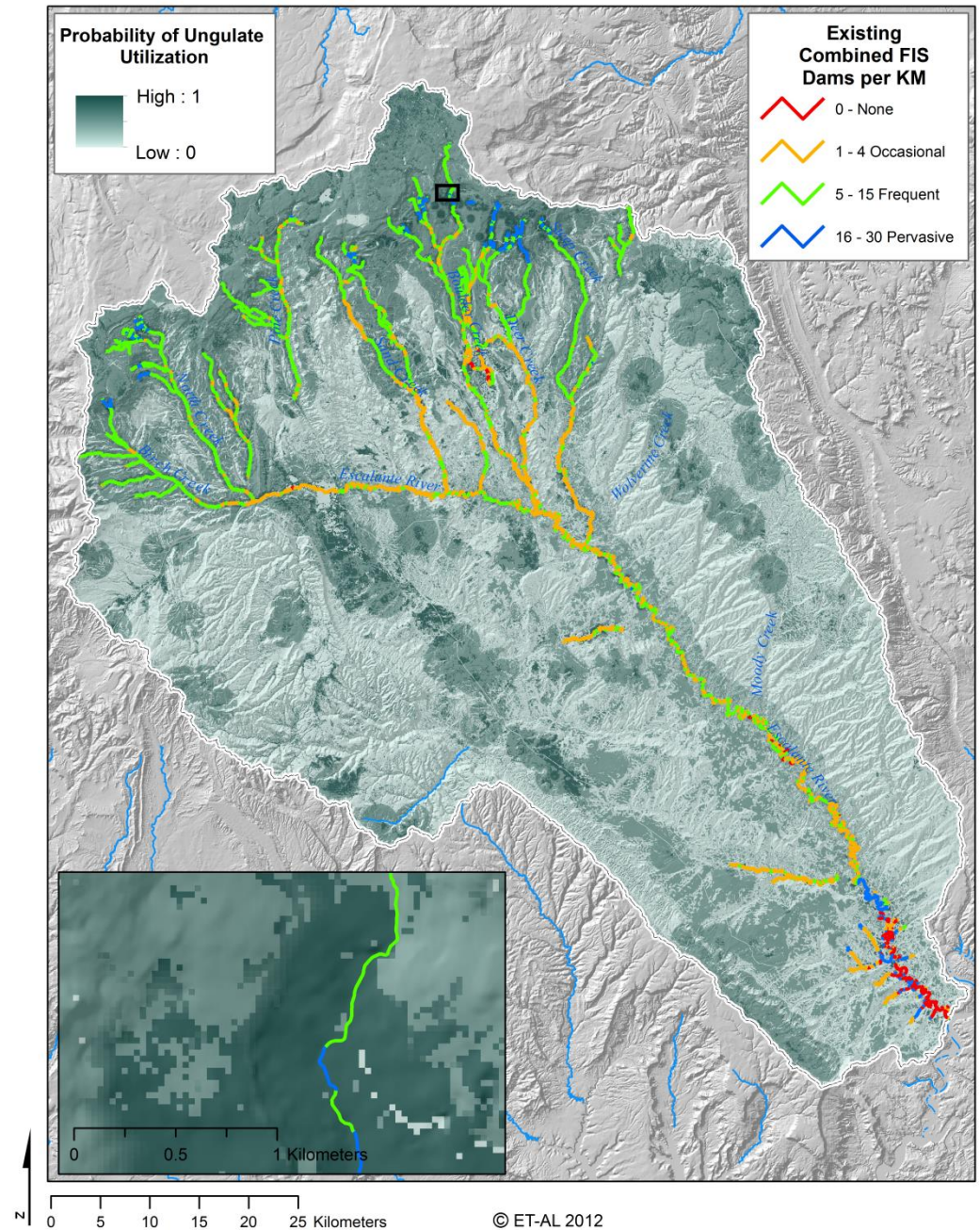
- Actually... 95 more dams....



BRAT Segment Type:	Stream Length (km)	Percentage of Drainage Network	Surveyed Dams	BRAT Estimated Capacity (Number of Dams)	Average Surveyed Dam Density (dams per km)	Average BRAT Predicted Capacity (dams/km)	Percent of Modeled Capacity	Electivity Index
None	43.4	12%	2	0	0.0	0.0	0.0%	0.0
Occasional	215.8	62%	265	573	1.2	2.7	46.2%	0.8
Frequent	68.1	20%	174	850	2.6	12.5	20.5%	1.7
Pervasive	20.9	6%	91	580	4.4	27.7	15.7%	2.8
Total	348.2		532	2003	1.5	5.8	26.6%	

A VECTOR MODEL & A RASTER MODEL

- How do I run a vector model vs. a raster model?
- You will run the Raster model in lab this week (optionally)!



TODAY'S PLAN



I. Introduction to Habitat Models

II. Habitat Models

I. HSI – Suitability Based Models

I. Fish example

II. Fuzzy-Logic Based Models

I. Beaver Example

III. Bioenergetics Based Models

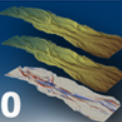
I. Fish Example

III. Lab – Habitat Occupancy Model

I. Ungulates (Cows)...

A BIOENERGETICS APPROACH

- Still need a hydraulic model to characterize the hydraulic habitat...
- Instead of predicting the suitability of an area, predict the cost of swimming there...



BOOKER (2003)

- Used 3D model & MSSS/burst empirical data to consider suitability of habitat at high flows

HYDROLOGICAL PROCESSES
Hydrol. Process. 17, 577–589 (2003)
Published online 21 November 2002 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/hyp.1138

Hydraulic modelling of fish habitat in urban rivers during high flows

D. J. Booker*

Hydro-ecology and Wetlands Section, Centre for Ecology and Hydrology, Maclean Building, Crownmarsh Gifford, Wallingford, Oxon OX10 8BB, UK

Abstract:

In urban rivers, flow regime and channel morphology are the drivers of physical habitat quality for aquatic species. Peak discharges are increased at high flows as a result of impermeable catchments and channel engineering for flood protection schemes. Hazardous conditions and flashy hydrographs mean that measurement of velocities at high flows is a difficult task. This research uses a three-dimensional computational fluid dynamics (3D-CFD) model to simulate hydraulic patterns in two urban river channels. A 3D-CFD code, called SSIM, was used to simulate hydraulic conditions in two engineered river reaches of the River Tame, Birmingham, UK. These two sites represent channels with different levels of engineering. Models were calibrated and tested using field measurements. Results show that modelled water surface levels and velocity profiles are well simulated. Calibrated roughness heights are compared with those derived from field measurement of sediment size. Numerical experiments are used to assess the relationship between grid resolution in the vertical dimension and the form of the modelled velocity profiles. Biologists have used laboratory experiments to determine maximum sustainable swimming speeds (MSSS) of fish, often in order to assess what level of a particular pollutant may be tolerable. In this work, simulations of high-flow hydraulic patterns are used to compare velocity patterns with fish MSSS. Results show that when the water levels rise to fill the first channel of the two-stage channels at the sites, which occurred 16 times in 2000, MSSS are surpassed in the majority of available habitat, suggesting that excessive velocities at high flows are one factor that limits fish habitat. A comparison between the two reaches shows that there is less available habitat in the more modified reach. Conclusions suggest that an approach that integrates water quality issues and physical channel characteristics must be taken in river rehabilitation schemes, as improvements to water quality alone may not be sufficient to improve habitat quality to the desired level. Copyright © 2002 John Wiley & Sons, Ltd.

KEY WORDS computational fluid dynamics; fish swimming speeds; habitat suitability; urban rivers; engineered river channels

INTRODUCTION

River corridors support aquatic ecosystems, provide areas of biodiversity and play important aesthetic and economic roles in urban environments. Many urban rivers in the UK have been influenced by flow regulation, river channel alteration, effluent disposal and pollution. These alterations combine to cause an interaction between flow regime, water quality regime and physical habitat that determines the health of river corridor ecosystems. There is particular impact on urban rivers because their impermeable surfaces cause flashy runoff, concrete straightened channels provide poor physical habitat and contaminated land or effluent disposal create poor water quality. This level of impact is not confined to highly urbanized areas. The River Habitat Survey showed that over 50% of lowland rivers in England and Wales were either obviously, significantly or severely modified (Raven *et al.*, 1998).

There are economic and social benefits of urban regeneration including rivers and river corridors. The NERC URGENT (urban regeneration and environment) programme was designed to carry out the science

* Correspondence to: D. J. Booker, Hydro-ecology and Wetlands Section, Centre for Ecology and Hydrology, Maclean Building, Crownmarsh Gifford, Wallingford, Oxon OX10 8BB, UK. E-mail: dbooker@ceh.ac.uk

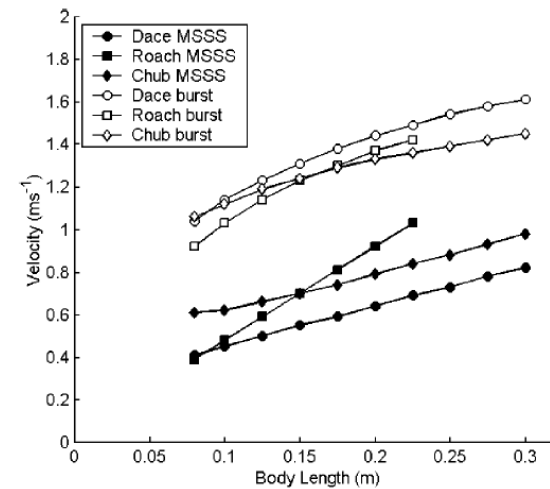


Figure 9. Mean 'maximum sustainable swimming speed' and 'burst swimming speed' for roach, dace and chub at 8 °C (based on data from Clough and Turnpenny, 2001)

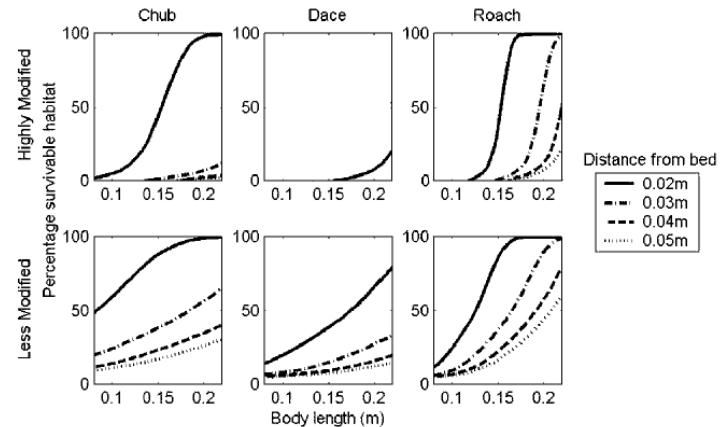


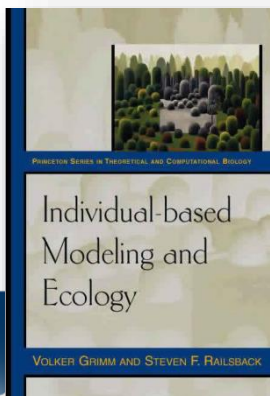
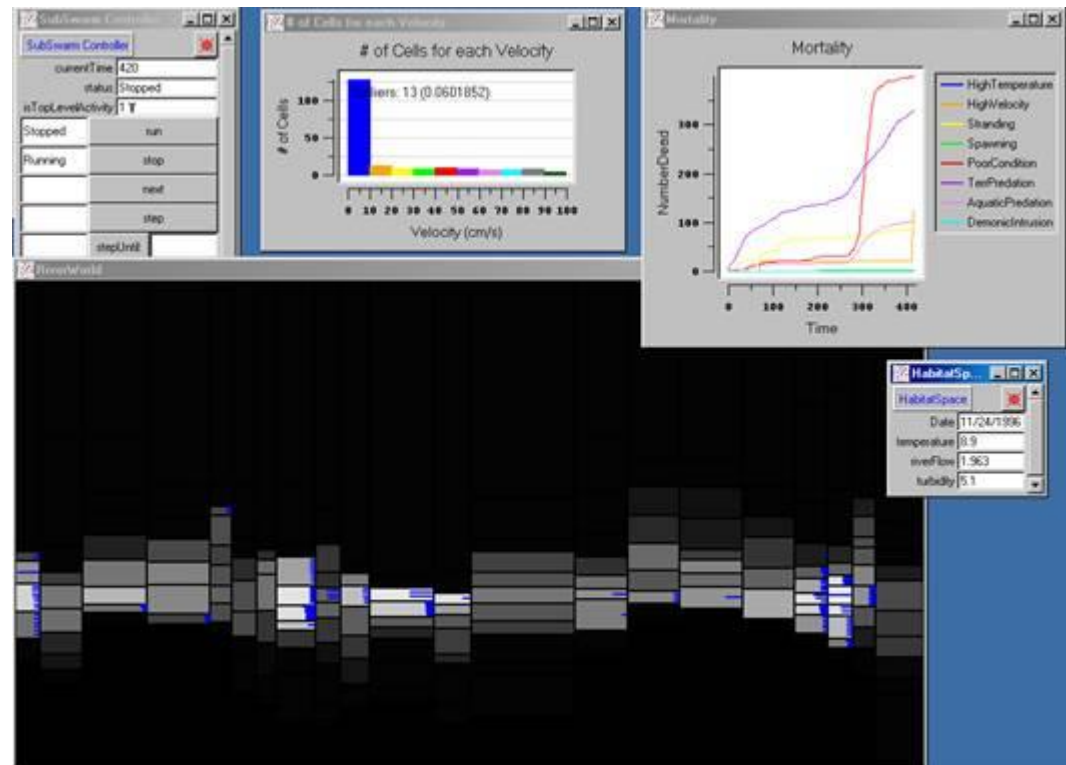
Figure 11. Percentage volume of habitat less than the mean 'maximum sustainable swimming speed' at different distances from the bed in each reach at $18 \text{ m}^3 \text{ s}^{-1}$

inSTREAM

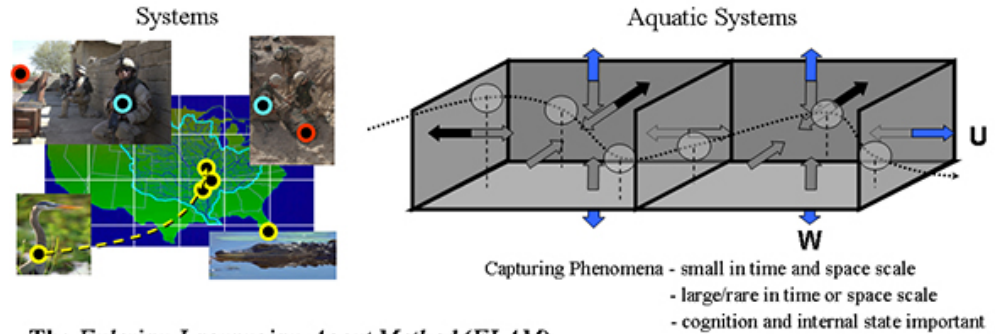
Individual-Based Modeling and Ecology at Humboldt State University



- Fancy rules for spatially and temporally varying hydraulics, temperature, turbidity and food availability
- Crude 1D model



- Fancy 3D CFD hydraulics and sophisticated agent-based model of cognitive response to sensory input



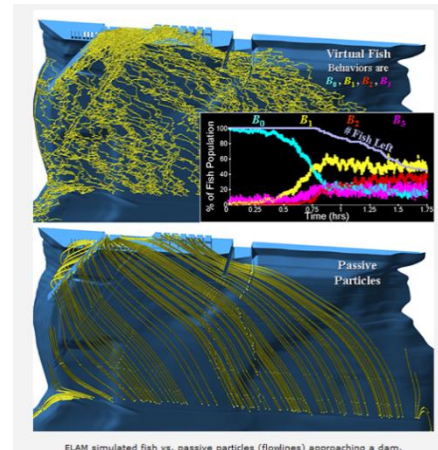
The Eulerian-Lagrangian-Agent Method (ELAM)

- Eulerian framework: governs physical, hydraulic, water quality, terrestrial, avian, and cultural/social domains.
 → mesh composed of nodes.
- Lagrangian framework: governs sensory perception and movement of individuals.
 → continuous directional trajectory composed of discrete locations.
- Agent framework: governs cognitive domain responsible for conversion of sensory input into behavior.
 → mathematics of sensory perception/processing, learning, acclimatization, memory, and internal state.

Ecohydraulics: Fish Passage & Guidance



Engineering design when the decision making of animals dictates success.



BIOENERGETICS MODEL:

$$\text{Consumption} = \text{Growth} + \text{Respiration} + \text{Egestion} + \text{Excretion}$$

Field Measurements

Function of Temperature
Determined from laboratory
studies



- Isolates consumption on growth...

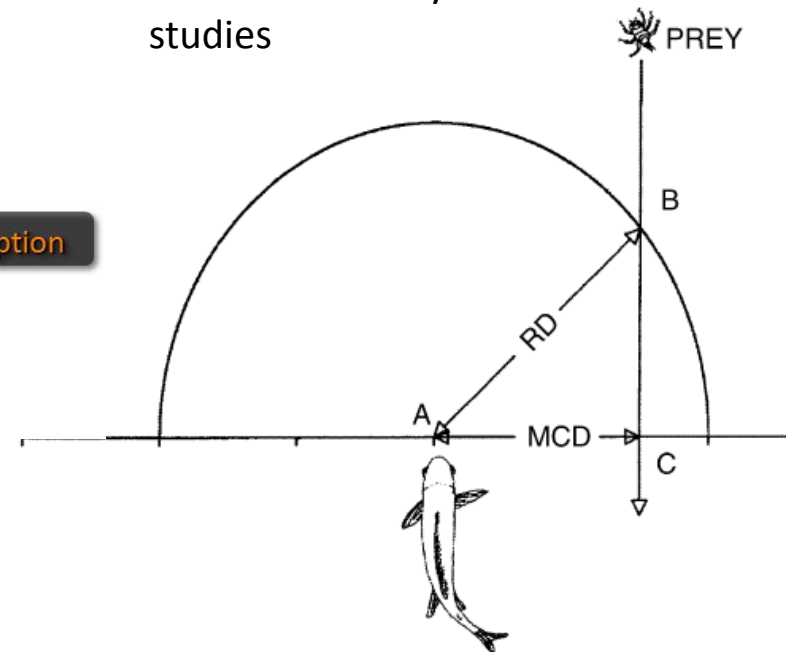
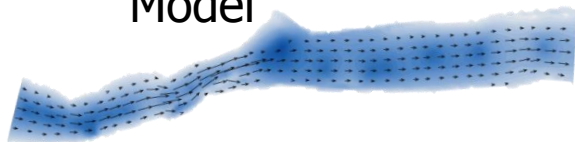


Fig. 3 – Plan view of the foraging model showing the geometry of prey interception. The fish is assumed to

NREI MODELING PROCESS

Inputs

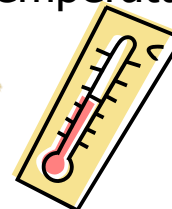
Hydraulic
Model



Drift



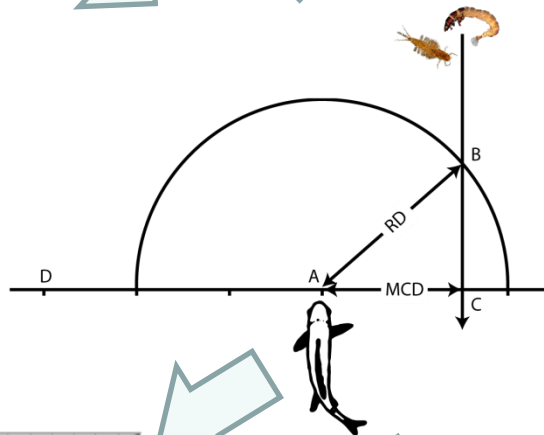
Temperature



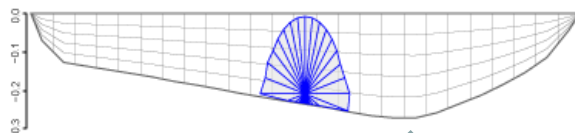
Fish Information



Foraging
and
Swim
Costs
Models



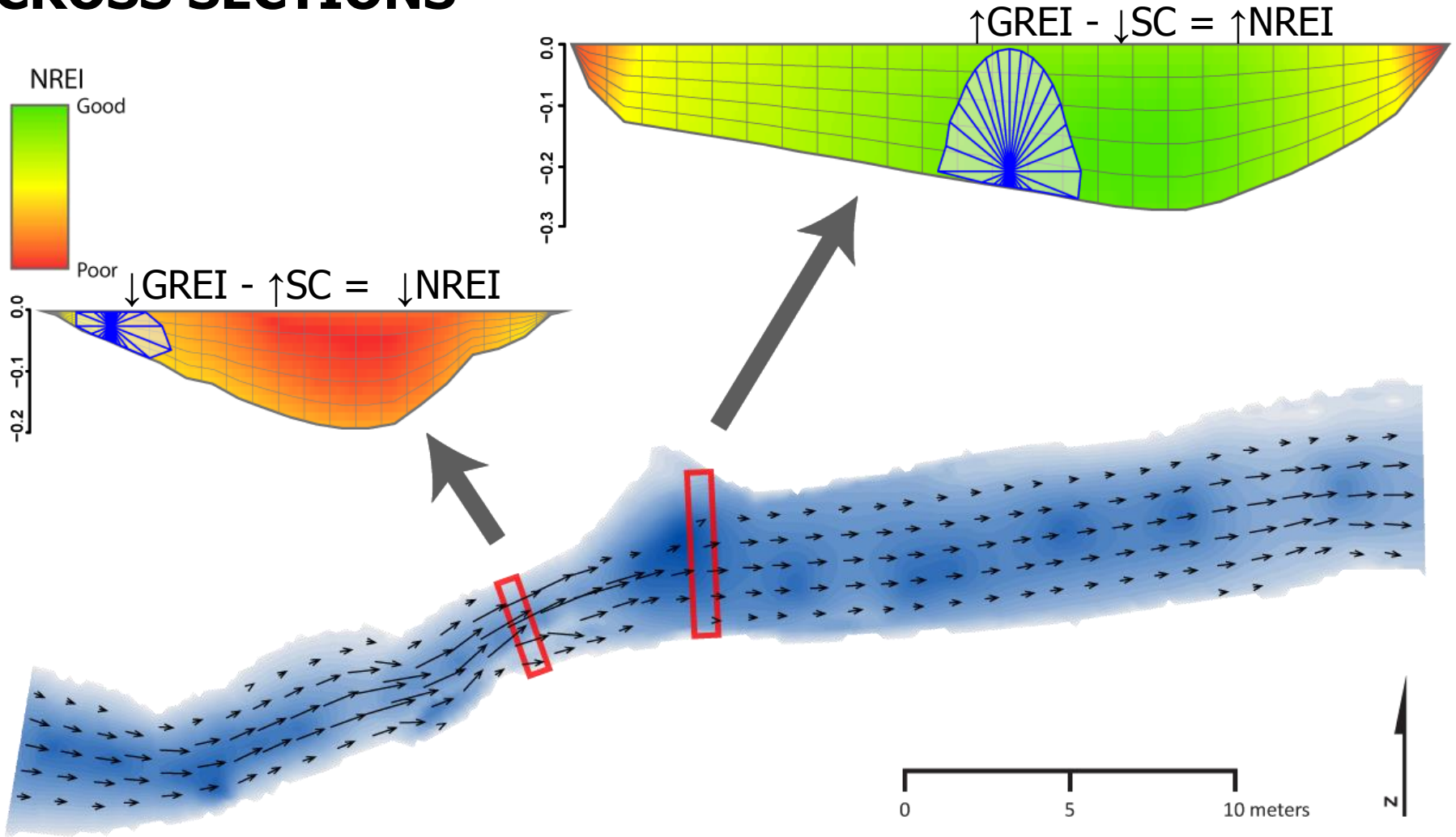
Hughes and Dill
(1990)



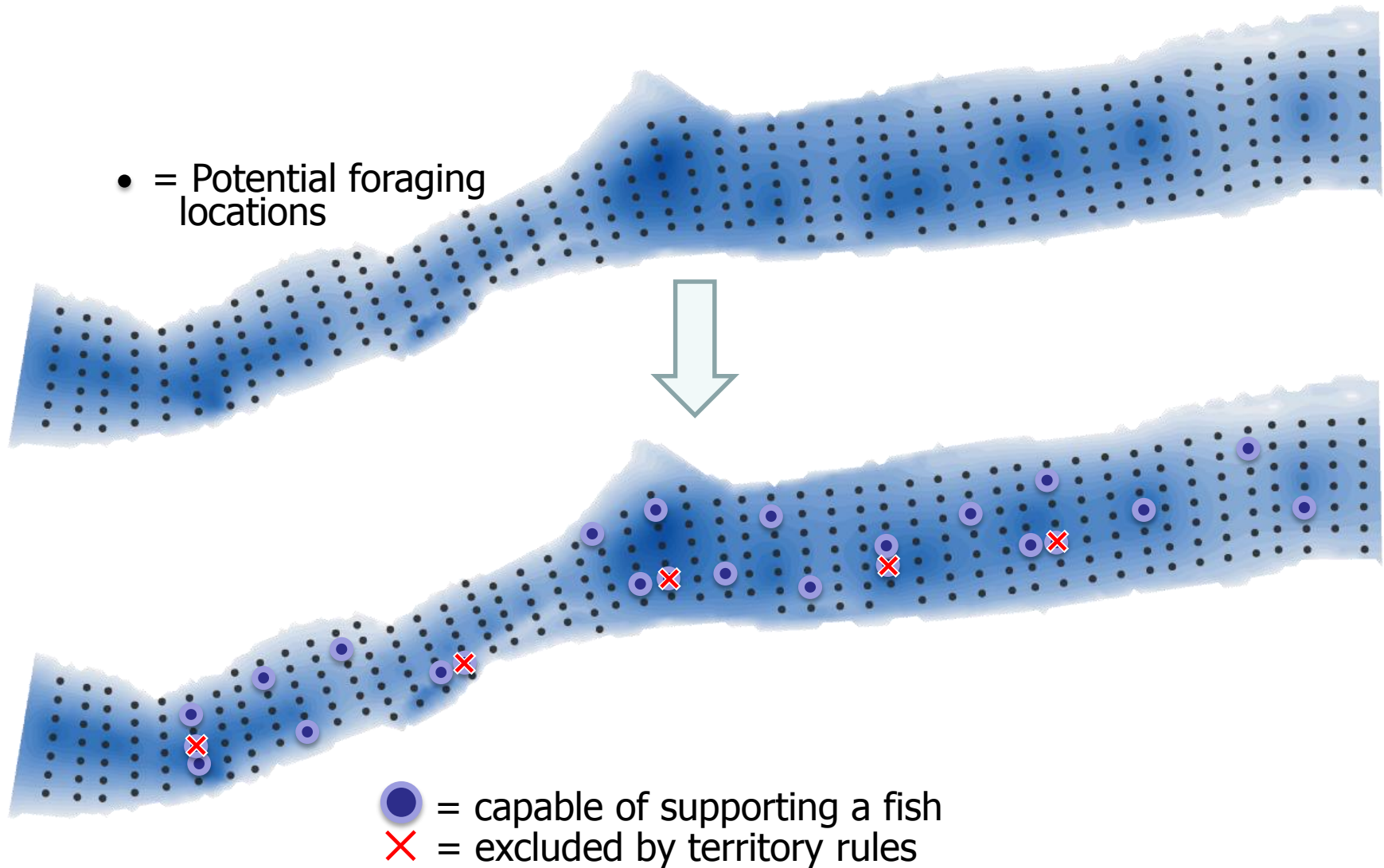
NREI
Calculation

$$\text{GREI} - \text{SC} = \text{NREI}$$

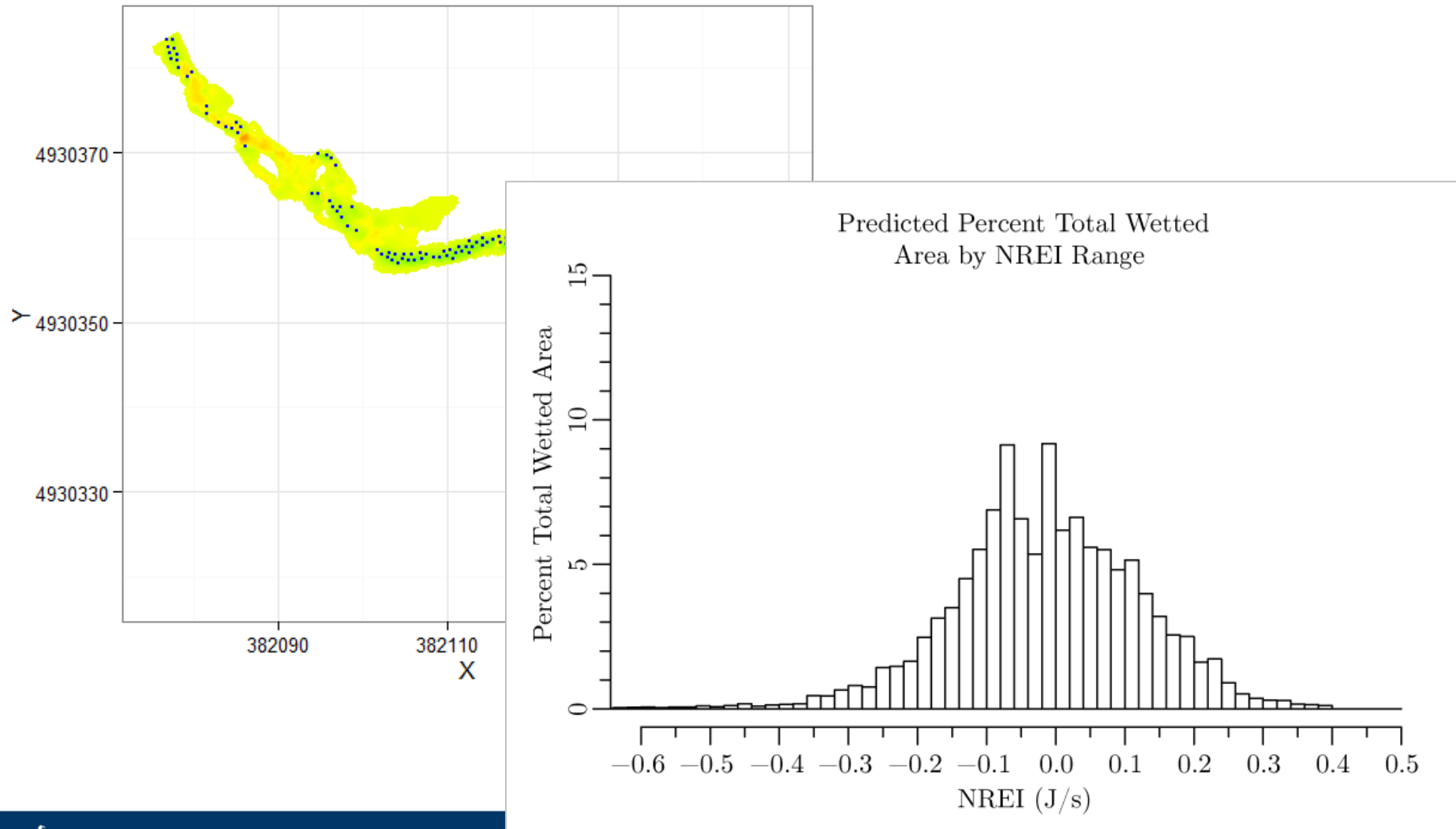
VISUALIZATION: NREI FOR CONTRASTING CROSS SECTIONS



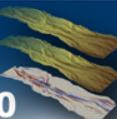
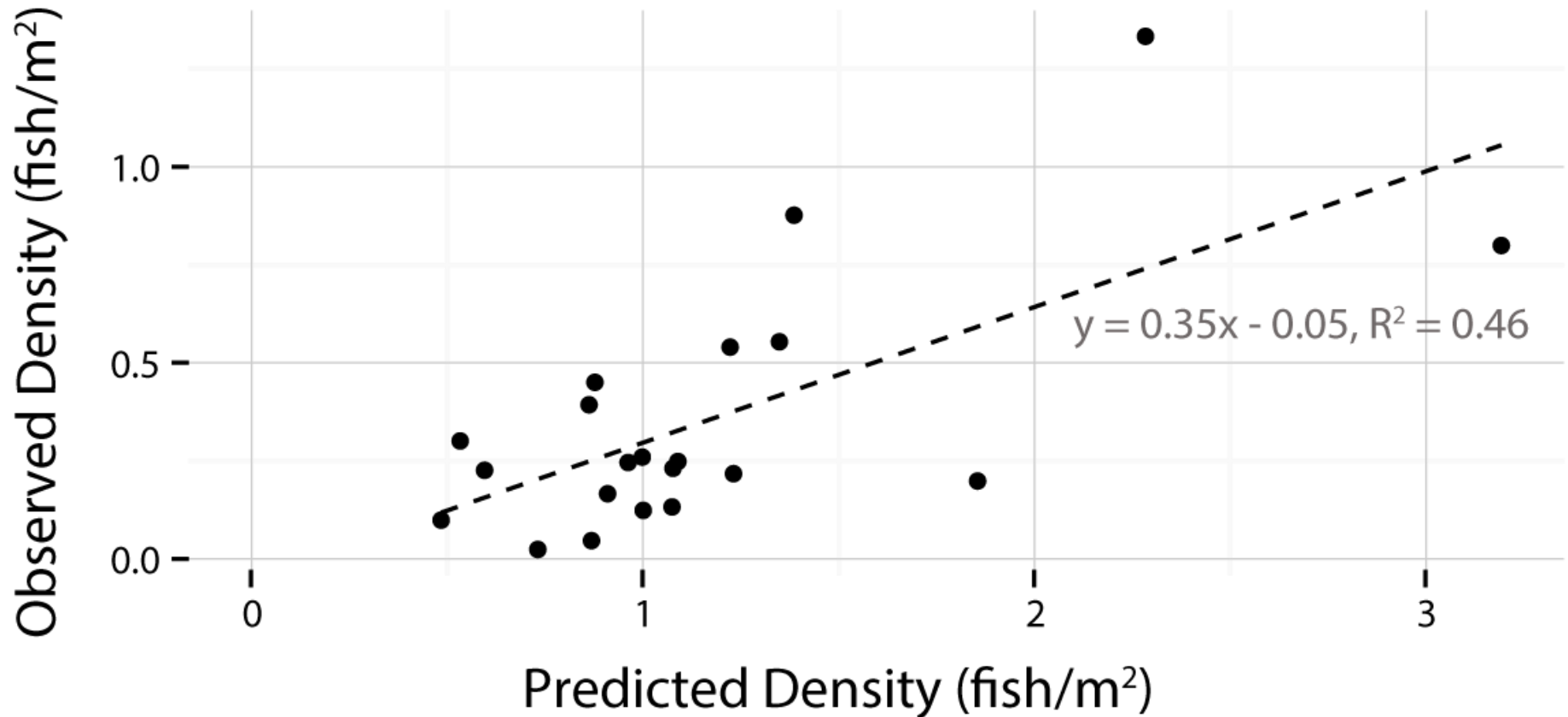
NREI-BASED ESTIMATES OF CARRYING CAPACITY



NREI-BASED SITE MAPS AND DISTRIBUTIONS

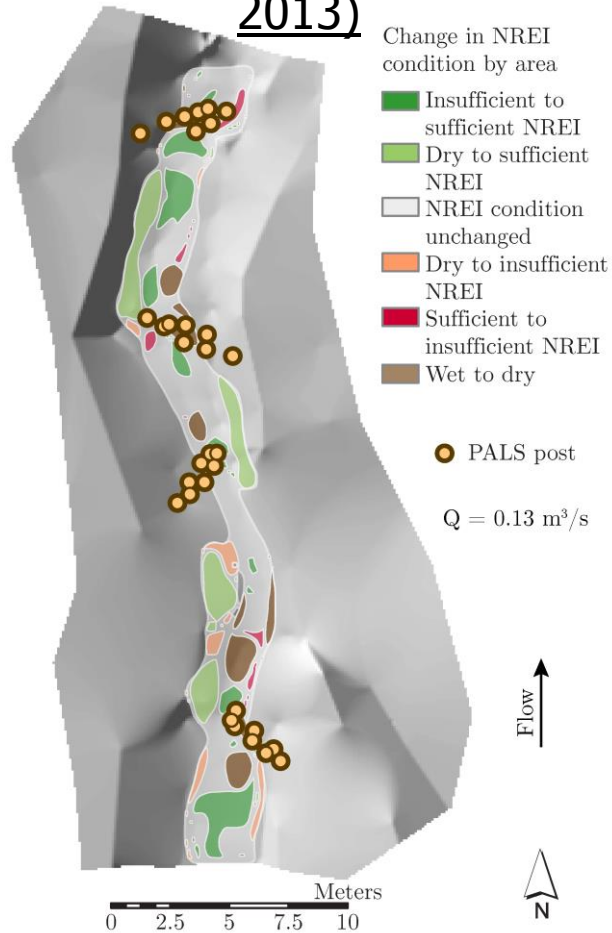


NREI CAPACITY ESTIMATES VALIDATION

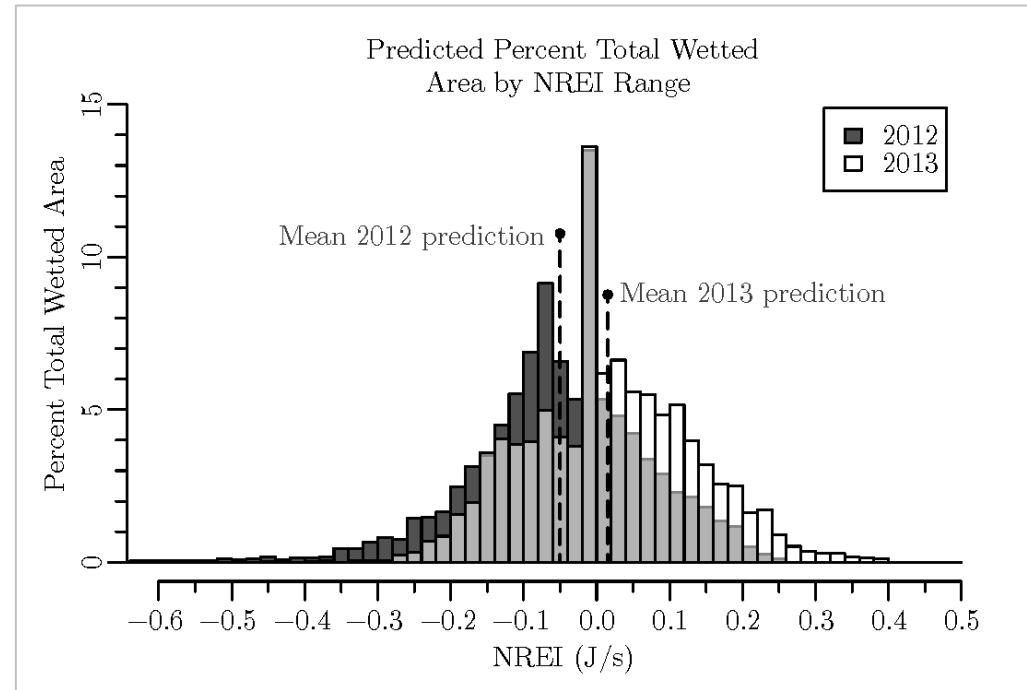


TRACKING SITE VALUES OVER TIME

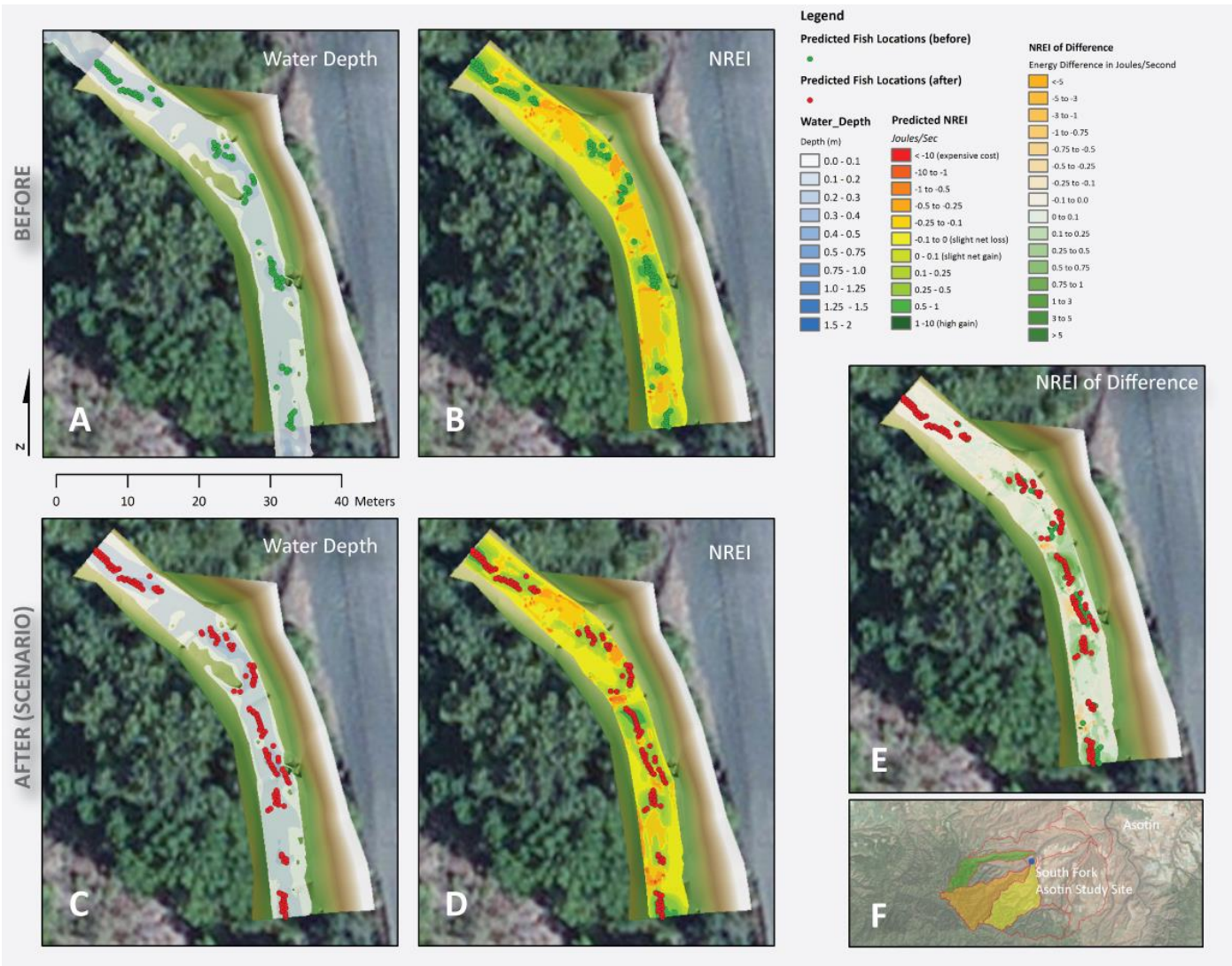
NREI change map (2012 → 2013)



NREI distributions (2012 and 2013)

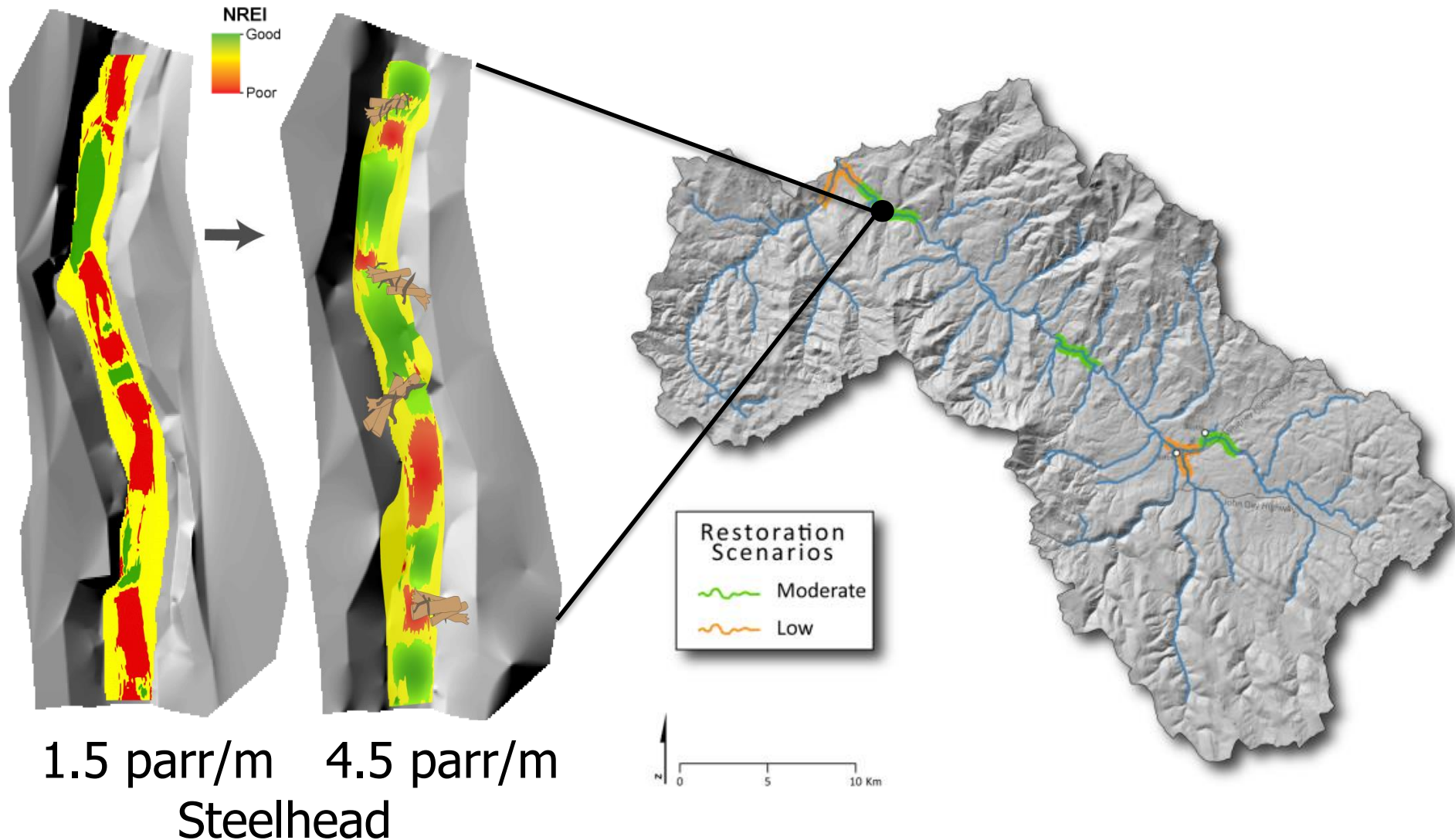


NET RATE OF ENERGY INTAKE – BIOENERGETICS

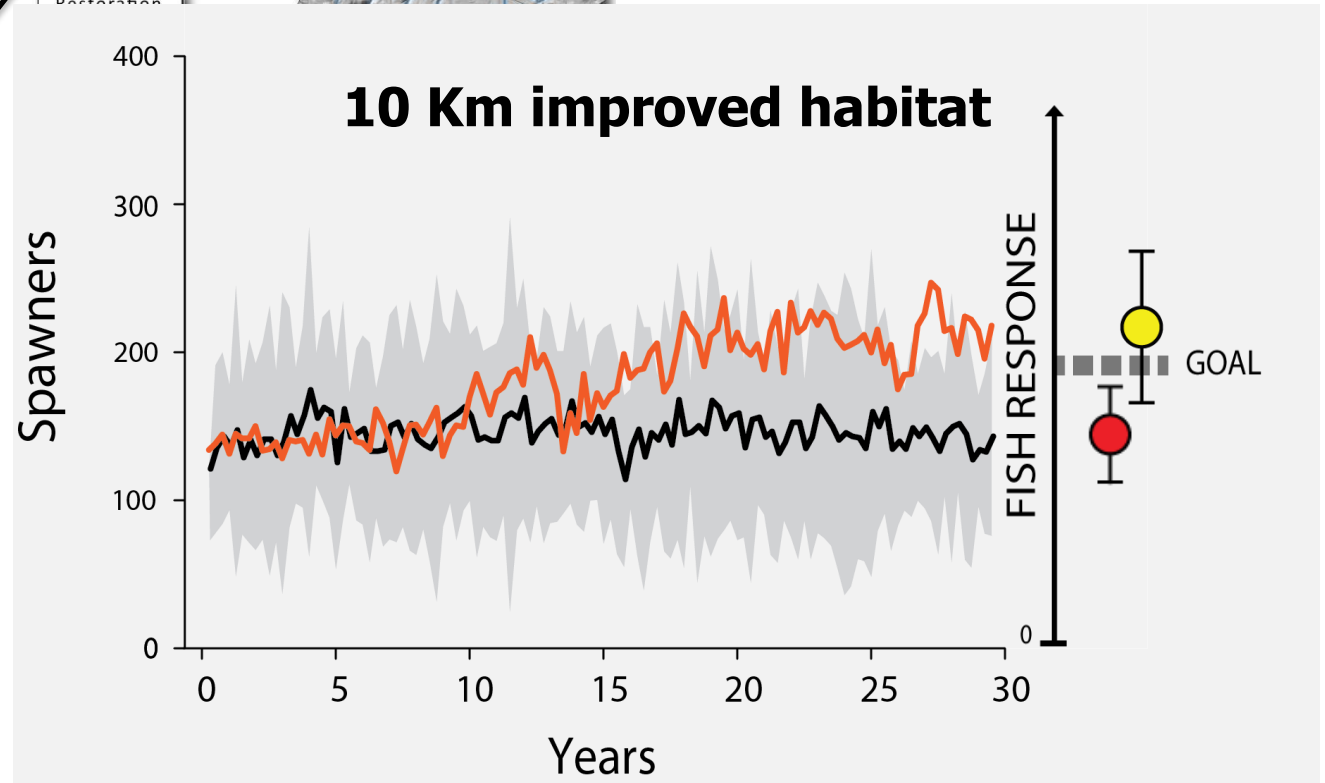
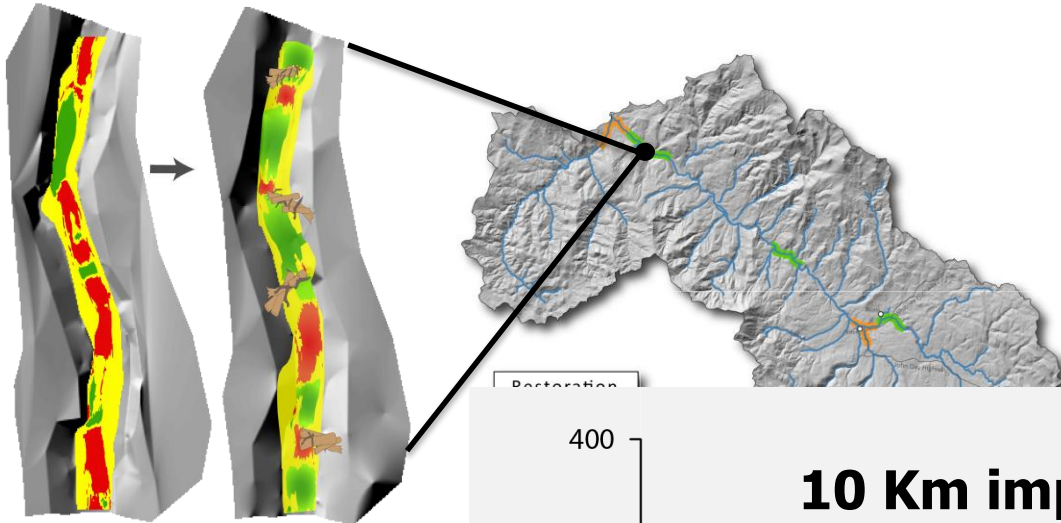


- 2D Hydraulic Model
- Foraging Model (Hayes)
- Drift Model
- Bioenergetics Model
- Combine to look at NREI

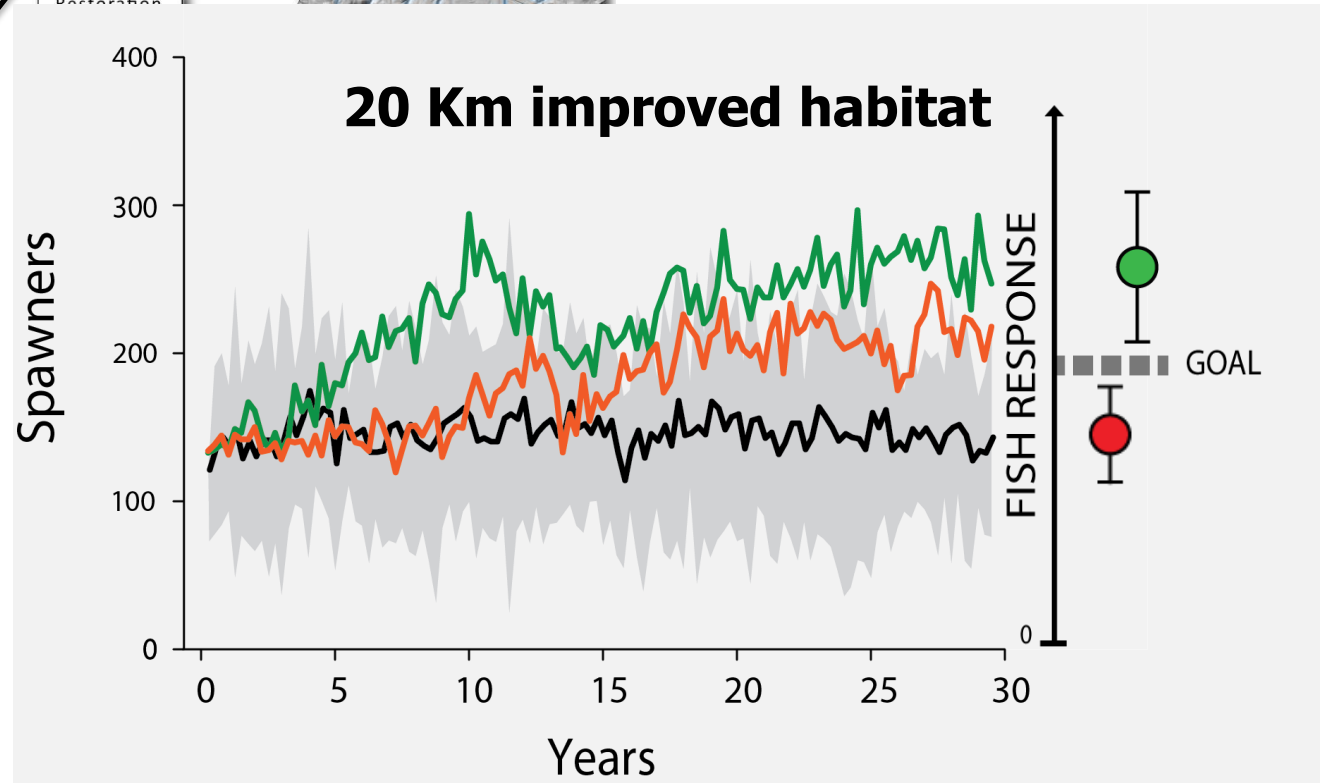
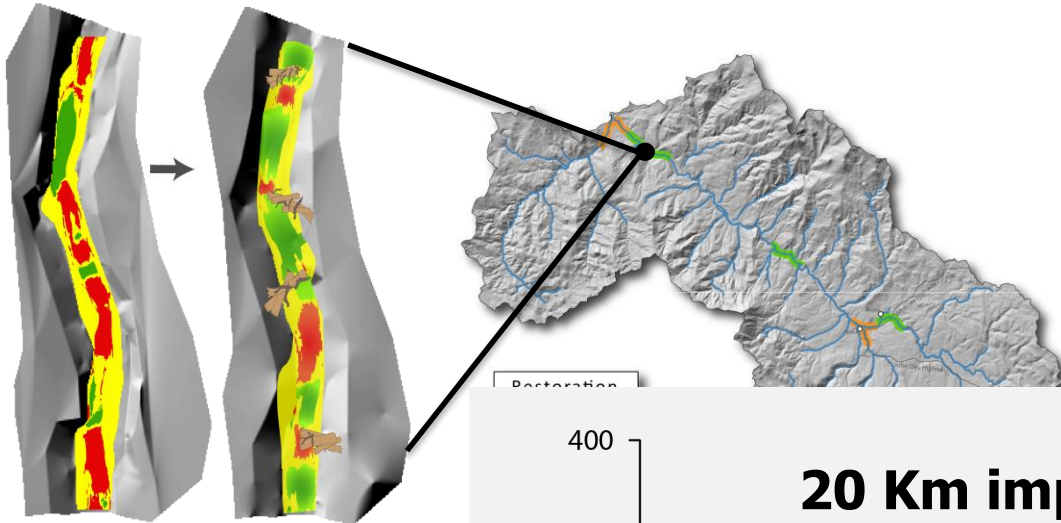
JOHN DAY RIVER: HABITAT MANIPULATION



JOHN DAY RIVER: HABITAT MANIPULATION



JOHN DAY RIVER: HABITAT MANIPULATION



TODAY'S PLAN



I. Introduction to Habitat Models

II. Habitat Models

I. HSI – Suitability Based Models

I. Fish example

II. Fuzzy-Logic Based Models

I. Beaver Example

III. Bioenergetics Based Models

I. Fish Example

III. Lab – Habitat Occupancy Model

I. Ungulates (Cows)...

AN OPTION FOR LAB 9 - MOO

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Help

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Department of Watershed Sciences

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Lab 10 - Habitat Modeling

Contents


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 - 1.1.2 Lab Objectives
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 - 1.3 What to Submit
 - 1.4 Additional Resources
 - 1.4.1 Escalante River Watershed 10 m DEM
 - 1.4.2 Tutorial or Step-by-Step Instructions for Specific Tasks
 - 1.4.3 Web Links:
 - 1.4.4 Follow up Activities:

Introduction to Lab

Background

Habitat models take many different forms. In this lab, we will run a very simple habitat model that predicts the probability of occupancy of ungulates on the landscape. In lecture, we discussed many types of different habitat models, but all the models had in common a number of inputs that help characterize abiotic physical habitat and then some 'model' that scores those inputs and combines them together to give an output.

In this lab we're going to try and figure out where the ungulates (cows) would hang out when left to their own devices. On many federal allotments the



cows are largely left to their own devices. They get dropped off in early summer and picked up in the fall. Active management (e.g. fencing and hiring riders to keep them moving) can significantly change these patterns.

Relevant Links

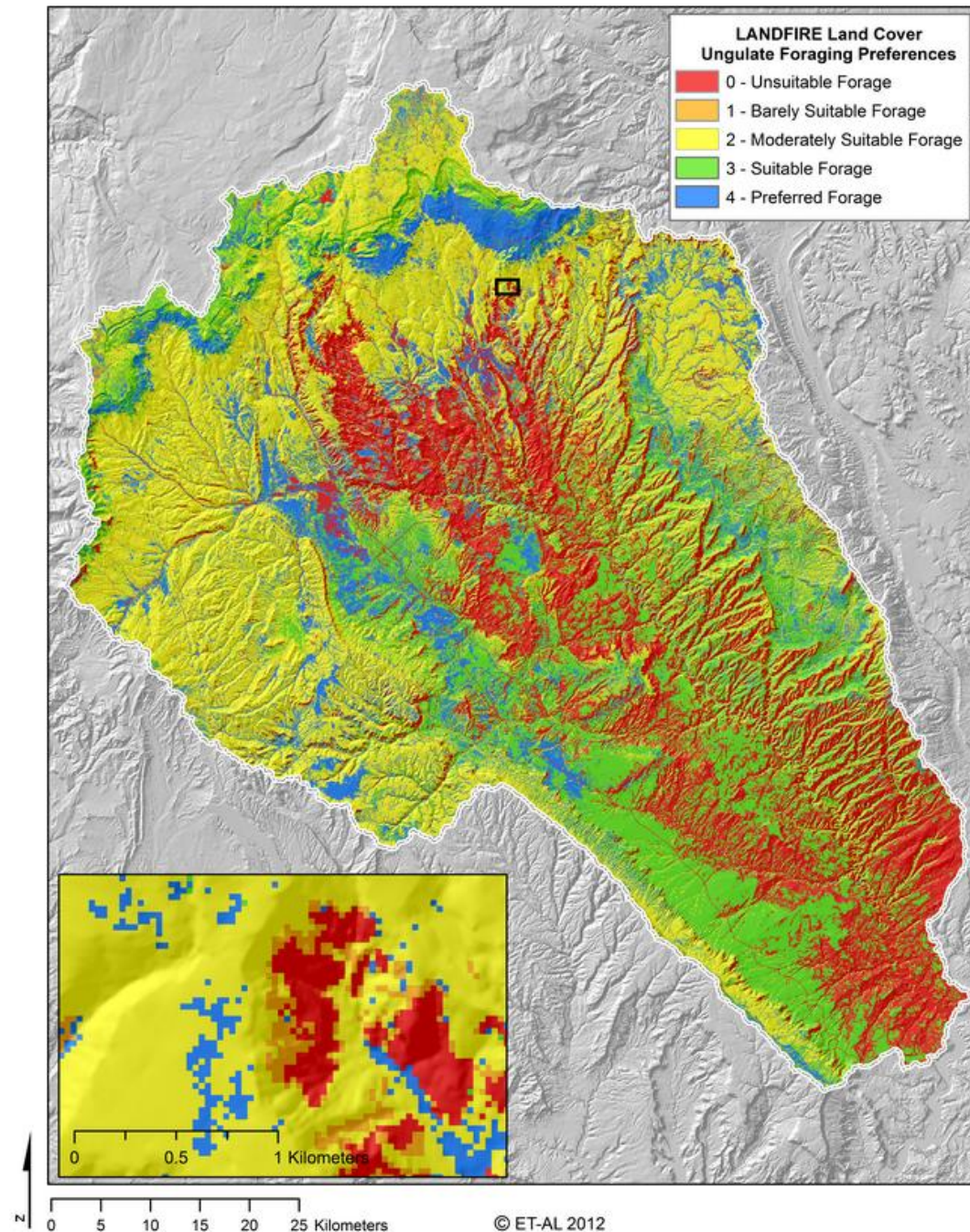
Corresponding Lecture Topic(s)
GIS Topic Link
See all Topics
Lab Due Date
Submitted before start of next week's lab on
Canvas
Relevant Discussion(s):
Name & HyperLink

Data for Lab

Matlab Model & Input Data Files

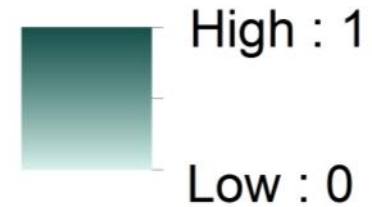
RECALL...

- If you're a cow, what's most important to you?



AN FIS YOU CAN RUN...

Probability of Ungulate Utilization



What goes in?

- Slope
- Distance from Water
- Vegetation

