WATS 6840 – Ecohydraulics
Module 4: Traditional Habitat Suitability Models
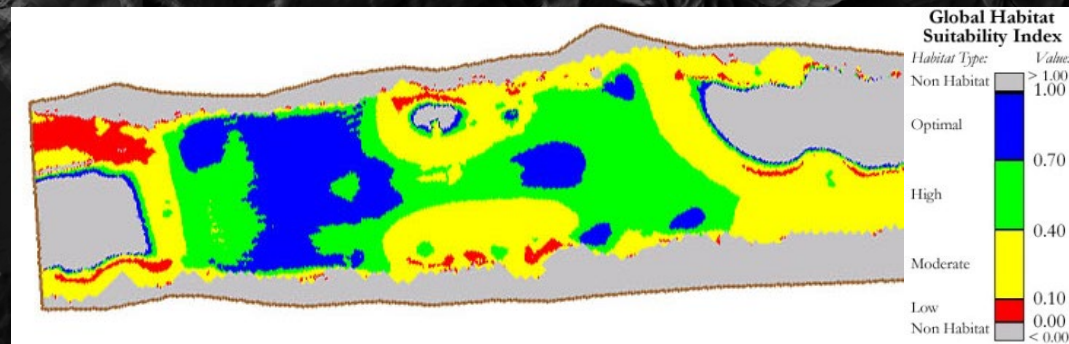
Global Habitat Suitability Index

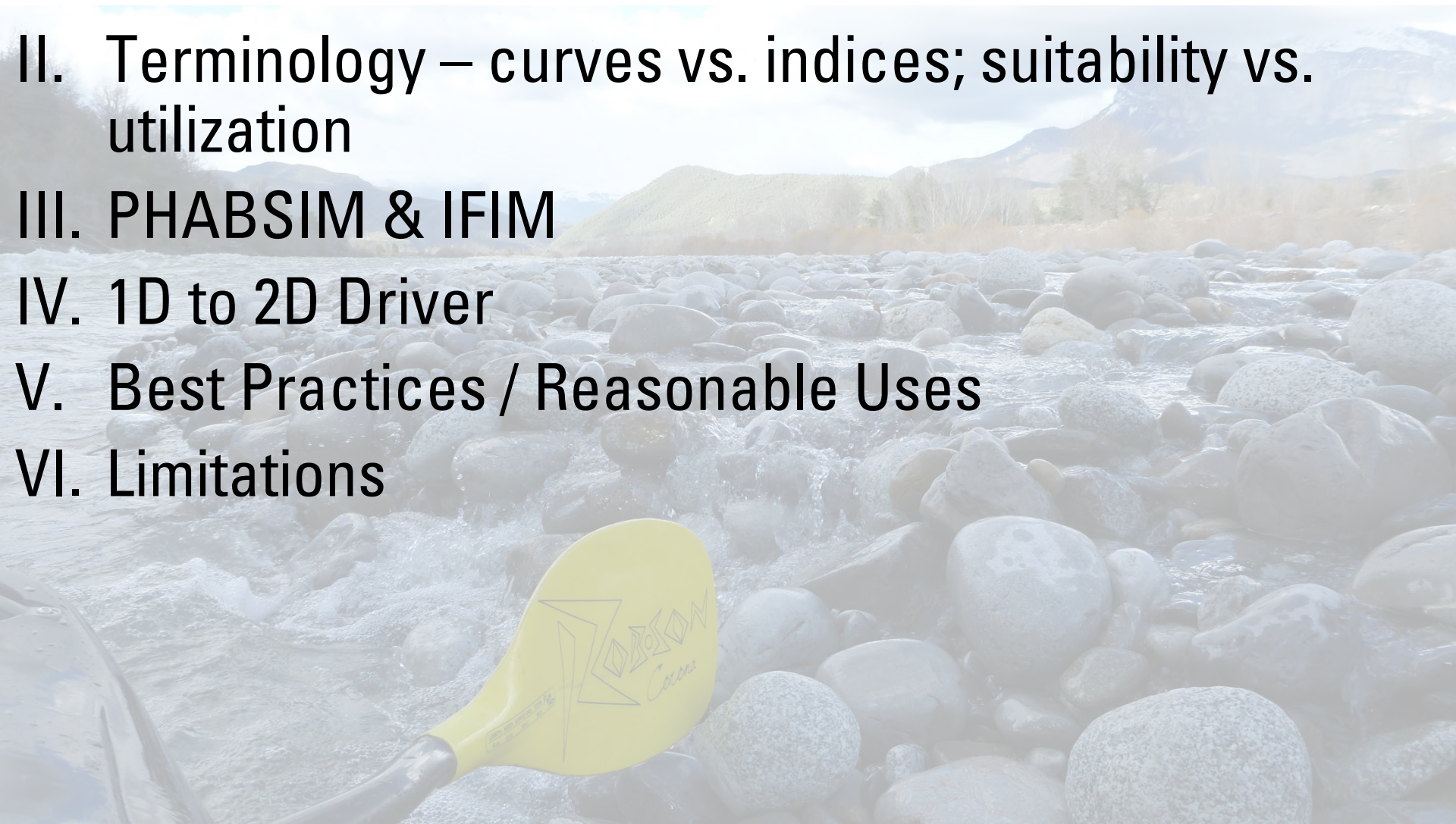| Habitat Type:	Value:
Non Habitat	> 1.00
	1.00
Optimal	
	0.70
High	
	0.40
Moderate	
	0.10
Low	0.00
Non Habitat	< 0.00

UtahState University
DEPARTMENT OF WATERSHED SCIENCES

Joe Wheaton & Nick Bouwes

Traditional Habitat Suitability Models

Main Focus of Ecohydraulic Models → FISH

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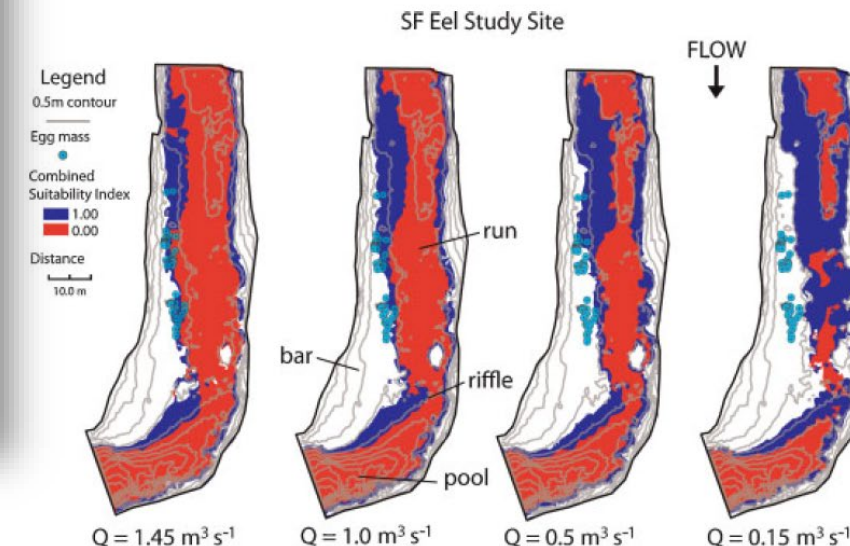

Figure 8. Suitable habitat at the SF Eel study site as modeled flows decrease from (a) $1.45 \, m^3 \, s^{-1}$ (2006 egglaying discharge) to (b) $1.0 \, m^3 \, s^{-1}$, (c) $0.5 \, m^3 \, s^{-1}$, and (d) $0.15 \, m^3 \, s^{-1}$ (low summer flow). Upstream is at the top of each inset figure; Background 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

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…
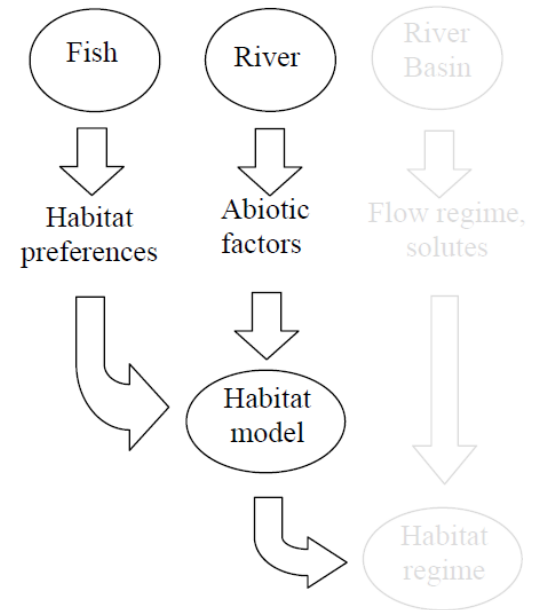
The paradigm of habitat modelling (After Leclerc, 2002)

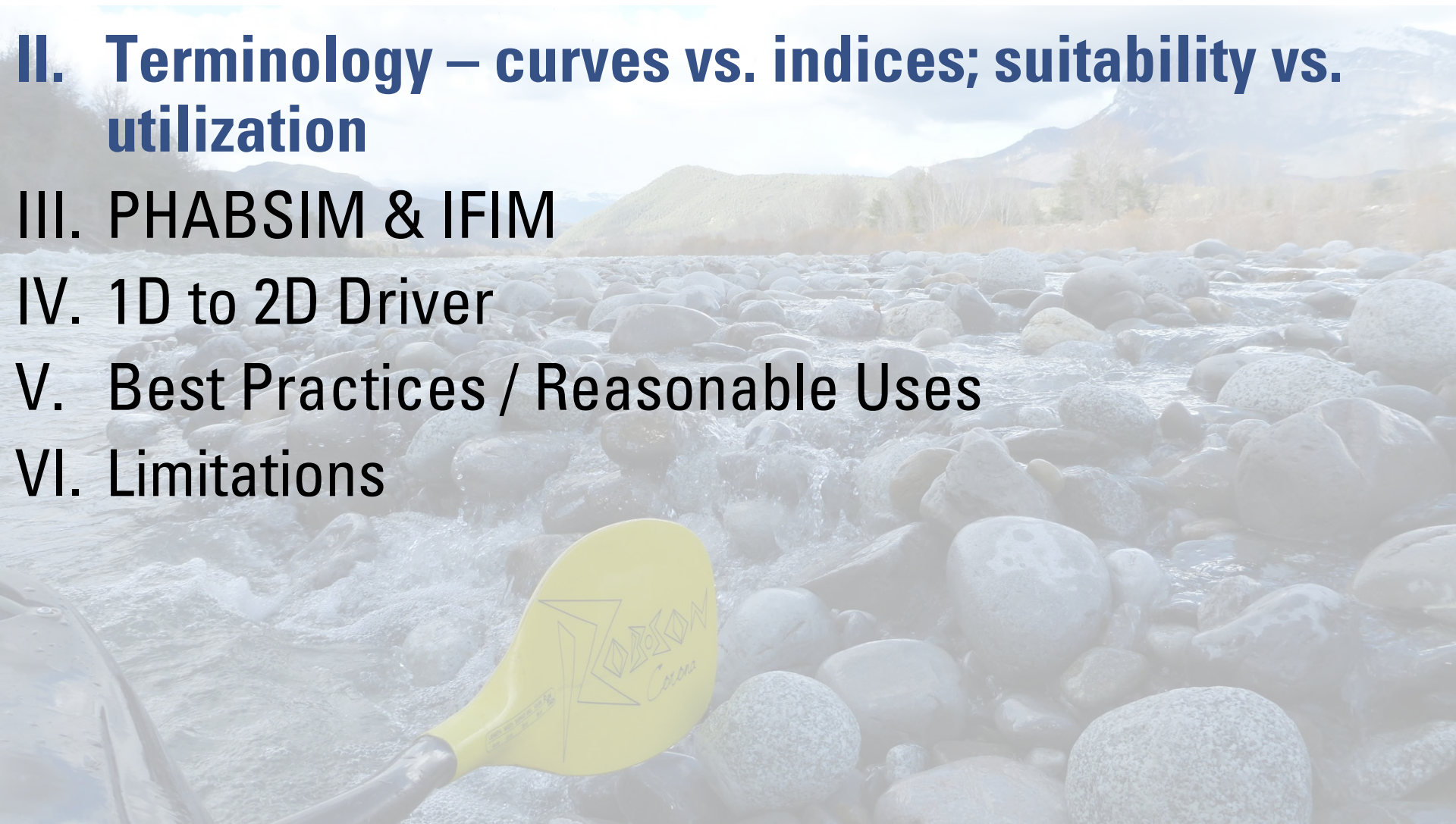From LeClerc 2005

Traditional Habitat Suitability Models

Informal Quiz

1. What are these acronyms for?
    1. HPC
    2. HSC
    3. HSI
    4. HUC
2. Do HPC $\approx$ HSC $\approx$ HSI $\approx$ HUC ?

Some Common But Confusing Terms

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

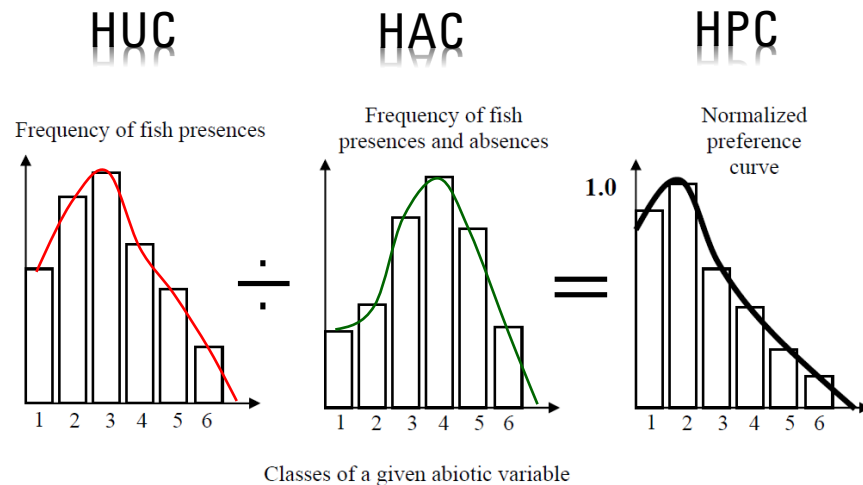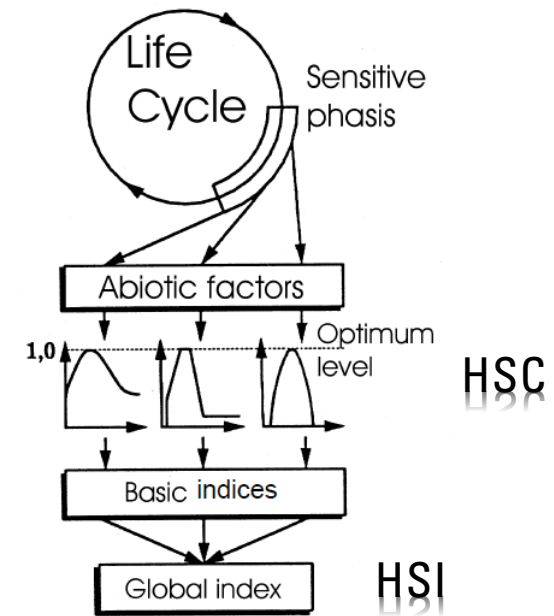Figure 3 : The general methodology for establishing fish preference curves

Building a classical fish *preferendum* model

From LeClerc 2005 (Chapter)

- 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

So about that HSC…
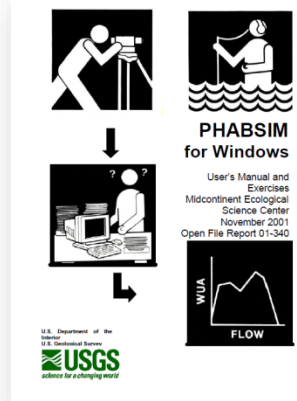
- Habitat suitability curve classification…
- Once I got one… can I use it everywhere?

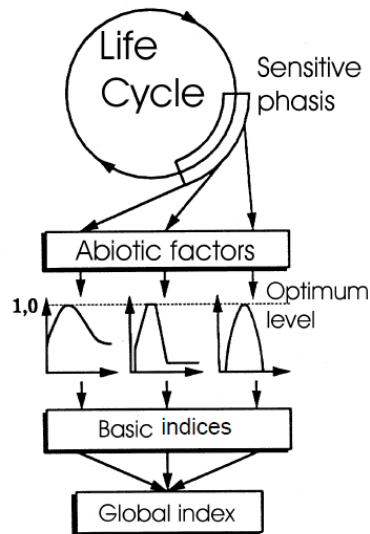Building a classical fish *preferendum* model

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.

https://pubs.er.usgs.gov/publication/ofr2001340

From the Literature…

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

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

To view the information contained within the Blue Books in Adobe Acrobat Reader (.pdf) format, click on the corresponding .pdf icon.
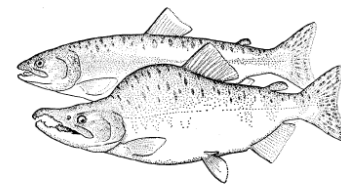
HSI BLUE BOOK TITLES FWS/OBS Report #

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/emrishelp3/list_of_habitat_suitability_index_hsi_models_pac.htm

HSC

Variable		Suitability graphs
V_4	Percent fines (< 0.3 cm). Measure at the same time and sites as V_3.	
V_5	Average water column velocities for spawning and embryo incubation. Measure at the same time and sites as V_3.	
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 } Adult

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} } Embryo

Max. temp. (migration) — V_{11} } 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
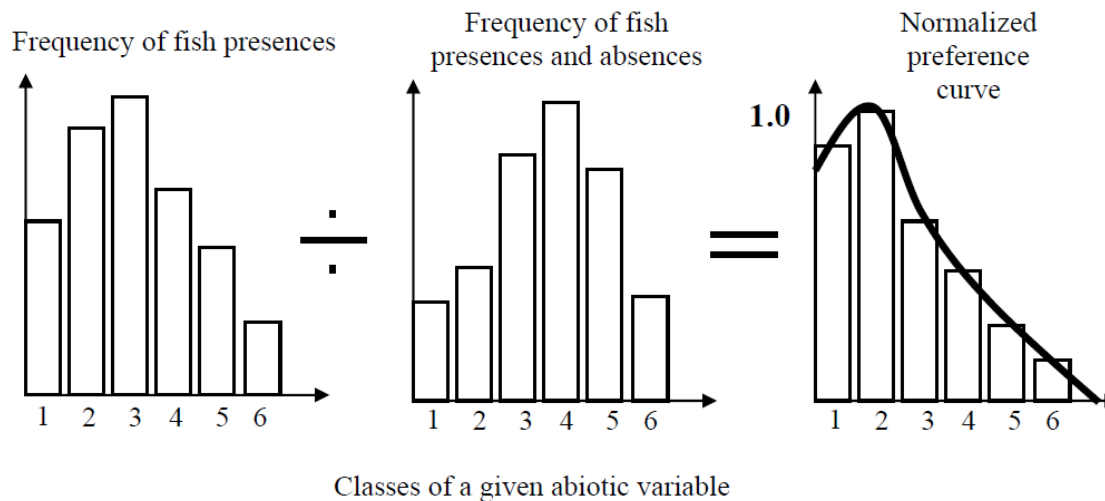
Figure 3 : The general methodology for establishing fish preference curves
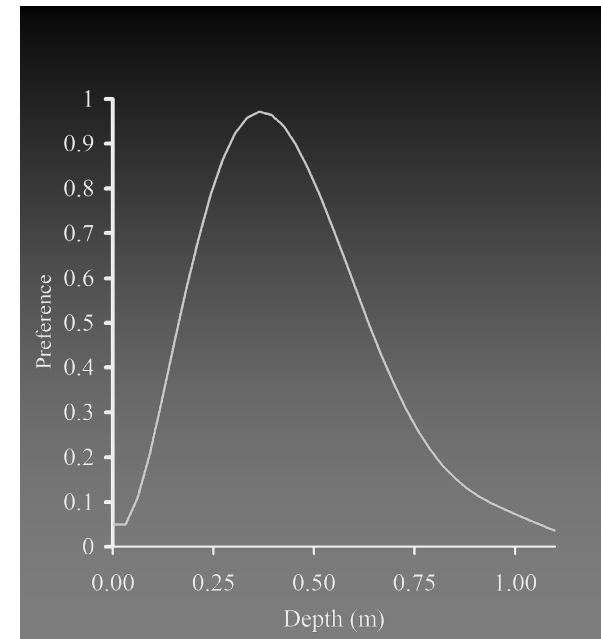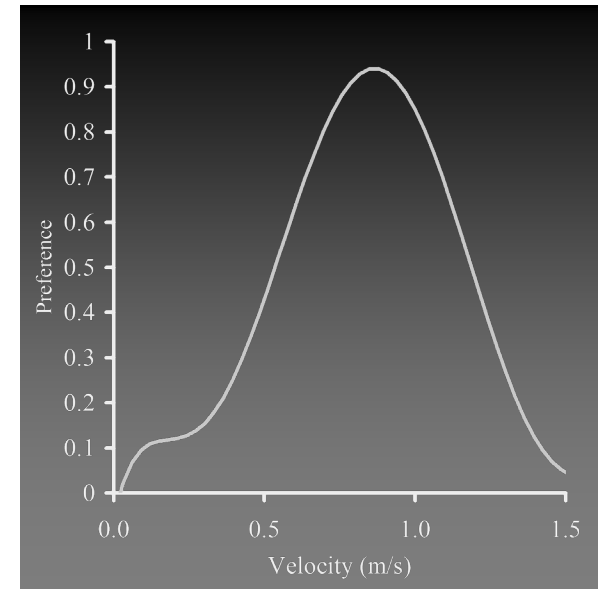
Why do I care about availability?

- 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…

Habitat preference curve

$y = 0.0261x^6 - 0.3605x^5 + 1.8821x^4 - 4.4422x^3 + 4.1376x^2 - 0.3702x + 0.0497$
$R^2 = 0.9924$
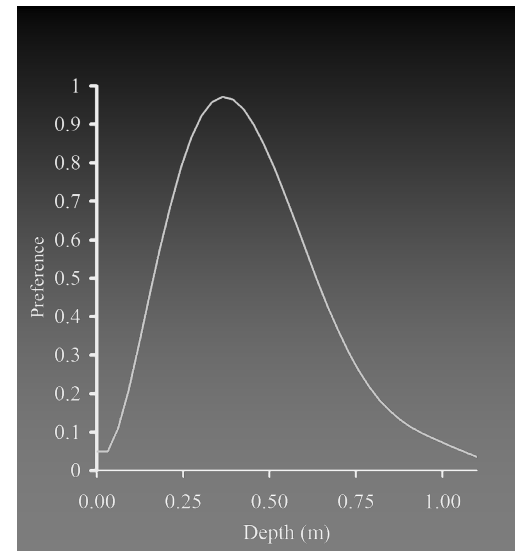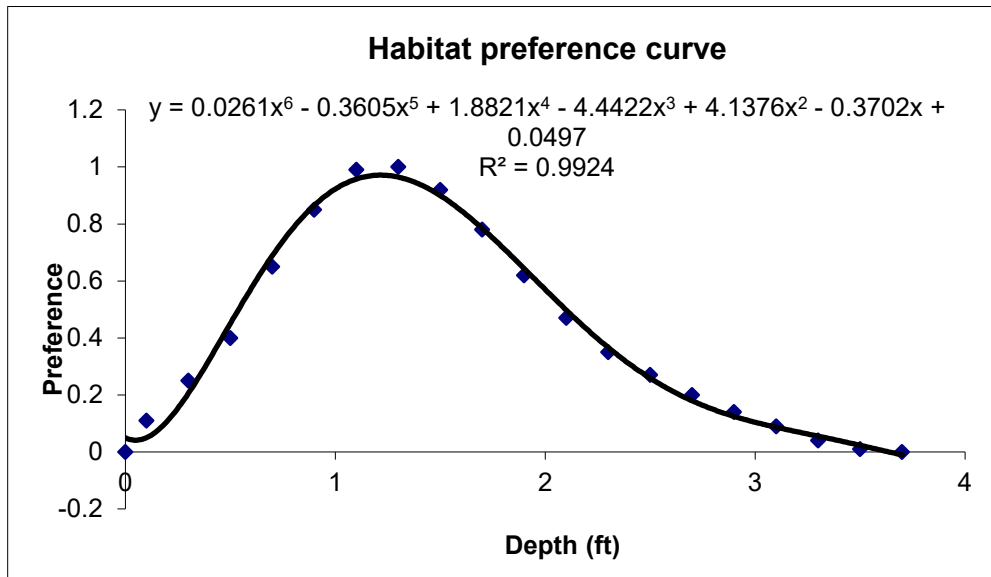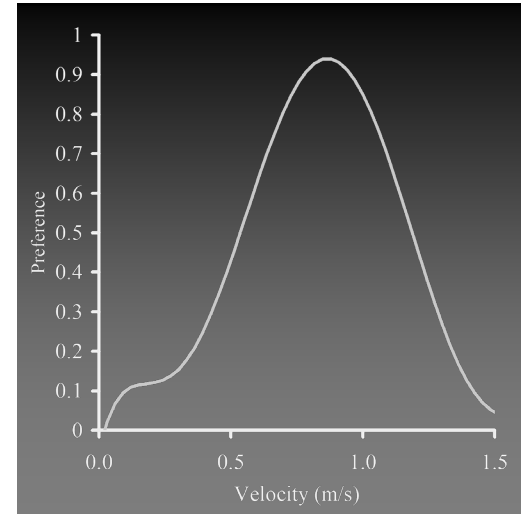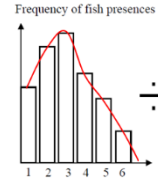
How do I go from HSCs to HSI?

This is the abiotic input

This is the empirical biotic input

This is the ecohydraulic 'model'

HSC

HSI

Morphology/Hydraulics

Water depth

Flow velocity

Substrate

Preference Functions

adult

adult

adult

Habitat Suitability

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

$$SI_{ges} = \min\left(SI_i, SI_{i+1}, ..., SI_I\right)$$ ← Minimum

Habitat suitability Index (HSI)

low	0.00
	0.10
	0.20
	0.30
middle	0.40
	0.50
	0.60
	0.70
high	0.80
	0.90

$$SI_{ges} = \sum_{i=1}^{I} SI_i \Big/ I$$ ← Arithmetic Mean

$$SI_{ges} = \left(\prod_{i=1}^{I} SI_i\right)^{1/I}$$ ← Geometric Mean
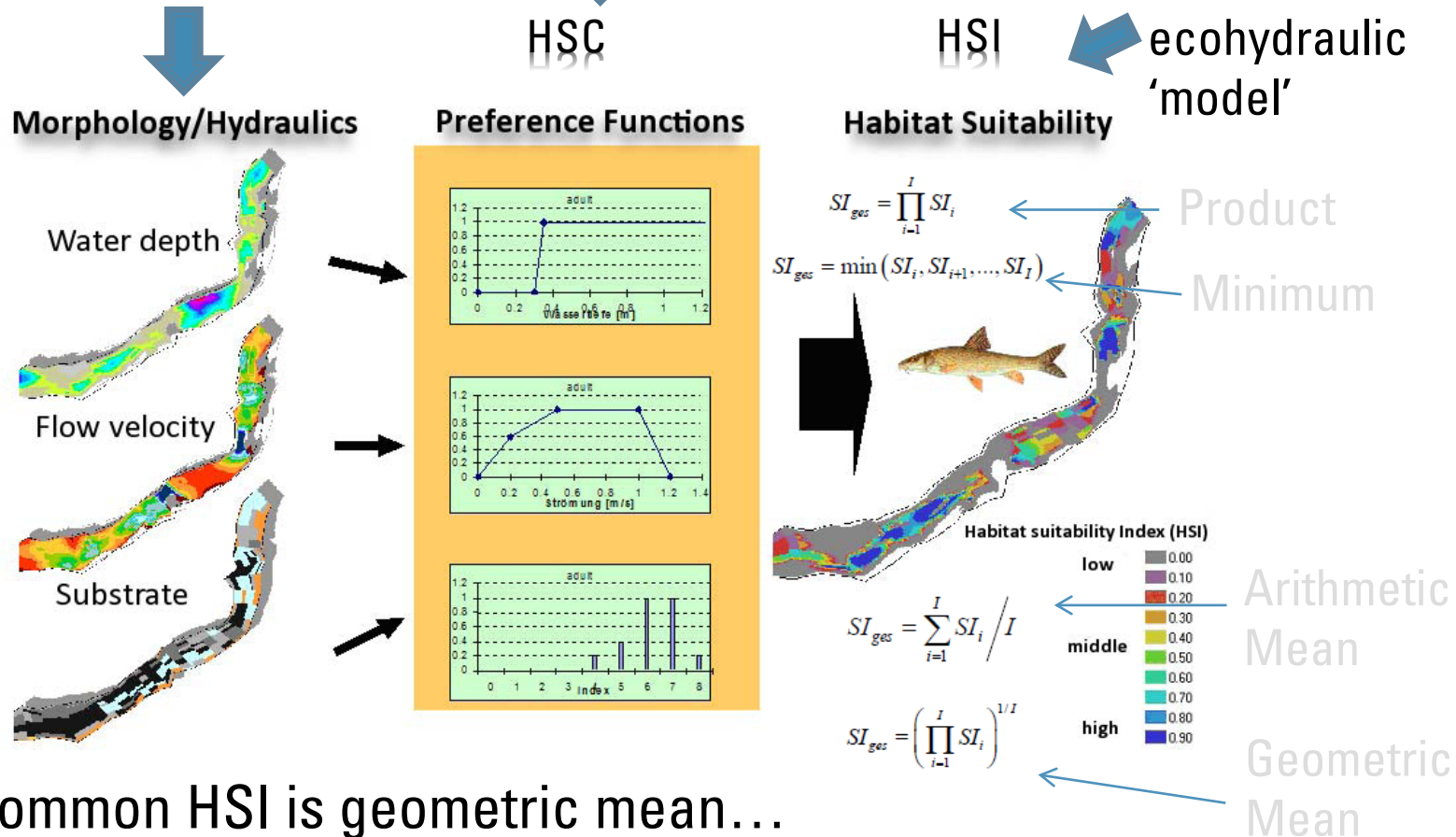
- Most common HSI is geometric mean…
- You can also weight individual HSCs

http://www.casimir-software.de/data/CASiMiR_Fish_Handb_EN_2010_10.pdf

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…

Morphology/Hydraulics

Water depth

Flow velocity

Substrate

Preference Functions

Habitat Suitability

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

$$SI_{ges} = \min\left(SI_i, SI_{i+1}, ..., SI_I\right)$$

Habitat suitability Index (HSI)

low

middle

high

0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90

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

$$SI_{ges} = \left(\prod_{i=1}^{I} SI_i\right)^{1/I}$$
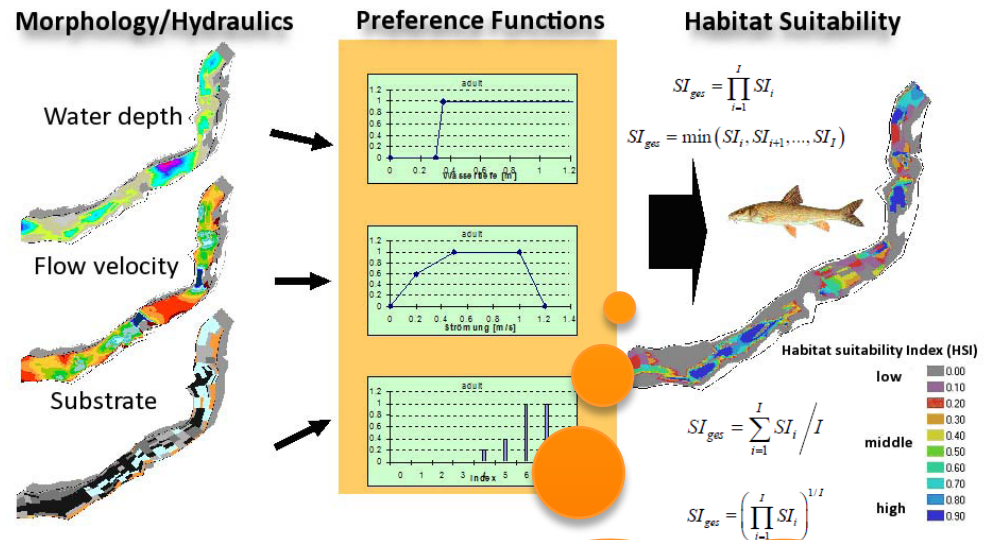
Do I need to have a 'model' of morphology/hydraulics to use HSI?

Traditional Habitat Suitability Models

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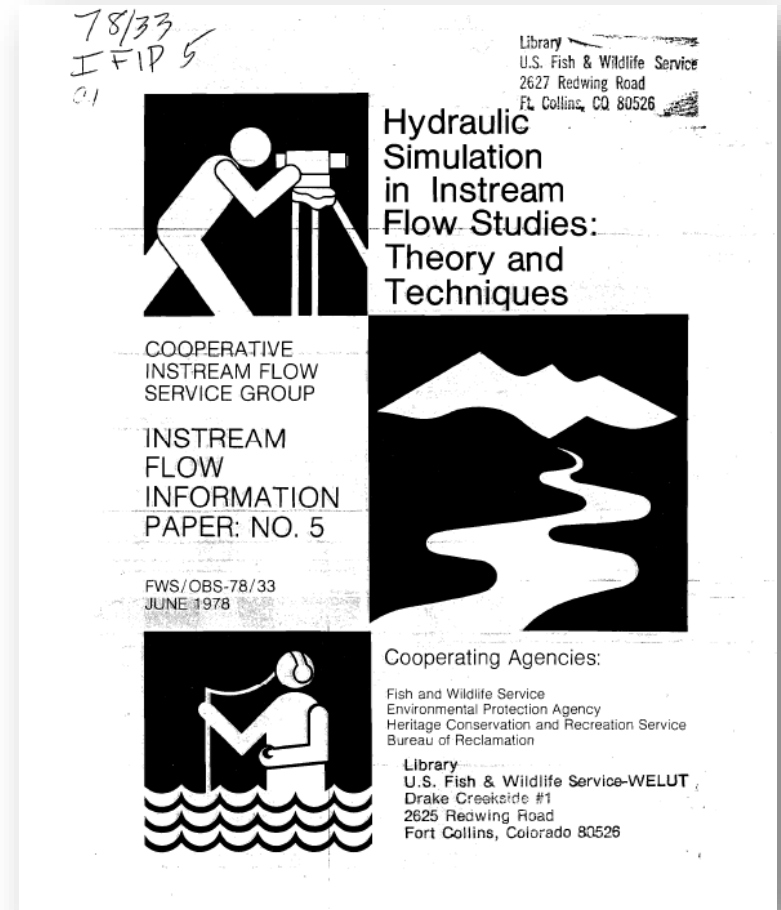
Bovee KD and Milhous R. 1978. *Hydraulic simulation in instream flow studies: theory and techniques. Instream Flow Information Paper 5.* FWS/OBS-78/33, U. S. Fish and Wildlife Service, Fort Colins, CO, 156 pp. Available at:

PHABSIM for ~~DOS~~ → WINDOWS!

• Driven by a 1D Hydraulic Model

Corresponding habitat value representing a composite of depth velocity and channel index for each cell

$$d_i = \frac{d_1 + d_2}{2} \qquad v_i = \frac{v_1 + v_2}{2}$$
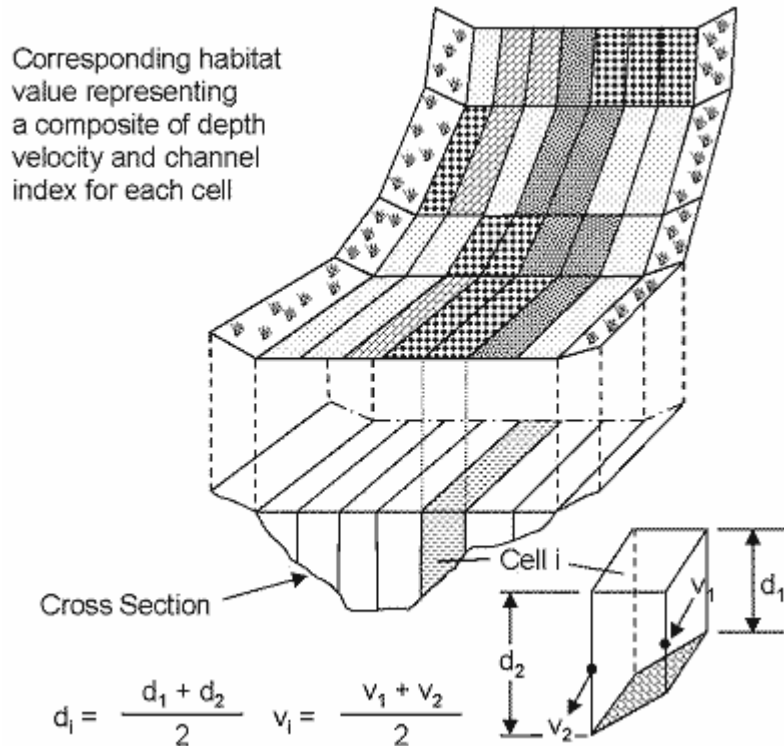
PHABSIM for Windows

User's Manual and Exercises
Midcontinent Ecological Science Center
November 2001
Open File Report 01-340

WUA / FLOW

U.S. Department of the Interior
U.S. Geological Survey

USGS
science for a changing world

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

Which hydraulic model?

- So these are models for what type of flow type?

First click File

Then click New Project

Introduction

Flow in an open channel is a three-dimensional process. It includes response to change in the channel shape, secondary currents, and it varies continuously across and along the axis of the stream. Models of varying complexity capture the overall streamflow process to different degrees. In PHABSIM, the Water Surface Profile model (WSP) uses the step-backwater method to obtain a one-dimensional representation of flow. The STGQ and MANSQ models use empirical means to obtain similar transect-based representations of flow. The hydraulic models in PHABSIM operate with assumptions of a fixed bed profile and a sloped water surface that is level across each cross section. There are many empirical relations used to simplify flow representations so they can be represented on transects, rather than continuously. Thus, flow representations within PHABSIM are discretized as cells located across transects. The influence of the assumptions and one-dimensional form of PHABSIM models will become more apparent as the reader progresses through this chapter.

Hydraulic modeling within PHABSIM characterizes the physical attributes within the stream (i.e., depth, velocity, and channel index) over a desired range of discharges. This characterization could be accomplished by direct empirical measurements taken at small increments of discharge covering the range of discharges of interest for a habitat study. However, time, safety and funding constraints typically prevent this empirical approach. Fortunately, it is possib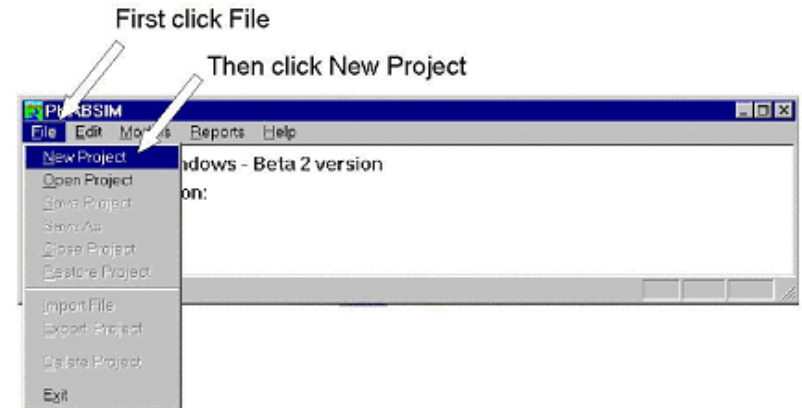le to sample the stream's hydraulic properties at a few target discharges and then rely on these data to calibrate one or more hydraulic model(s) and use the model(s) to predict the stream hydraulic attributes over the full range of discharges of interest in the study. The success or failure of this effort is dependent on the quantity and quality of the field data, the complexity of the physical nature of the stream, and ultimately the ability of the hydraulic models to reflect the physical processes in the stream.

The material in this chapter represents concepts and application strategies of elements contained in the hydraulic simulation portion of the information flow within the PHABSIM system as indicated by the area labeled hydraulic simulation in Figure 1-2. The chapter concludes with a section on evaluating hydraulic model results.

http://www.fort.usgs.gov/products/Publications/15000/chapter2.html

PHABSIM HSI called C_i

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

Composite suitability for cell i = HSCv * HSCd * HSCci
= 0.9 * 0.55 * 0.7
= 0.3465

Cell i

d_i

v_i

channel index i

HSC

1
0.9

0

v_i velocity

1

0.55

0

d_i depth

1

0.7

0

channel index
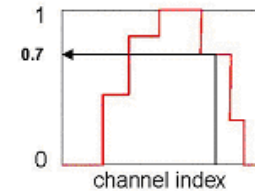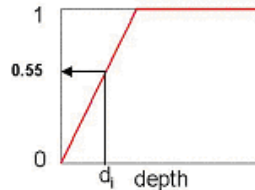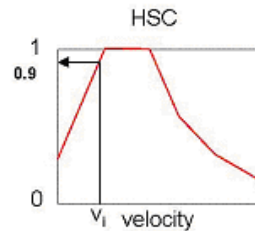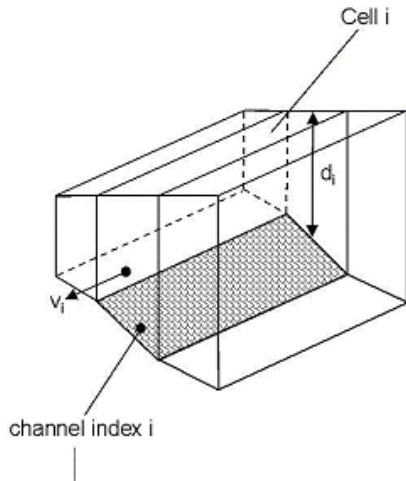
The most common method is a multiplicative aggregation given by:

$$C_i = V_i * D_i * S_i \qquad (4\text{-}2)$$

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:

$$C_i = \sqrt[3]{V_i * D_i * S_I} \qquad (4\text{-}3)$$

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:

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

Weighted Useable Area

HABTAE Flow/Habitat Relations
RAINBOW TROUT

FRY   JUVENILE   ADULT   Spawning
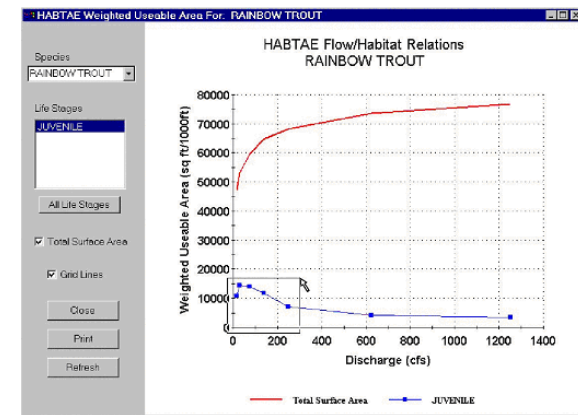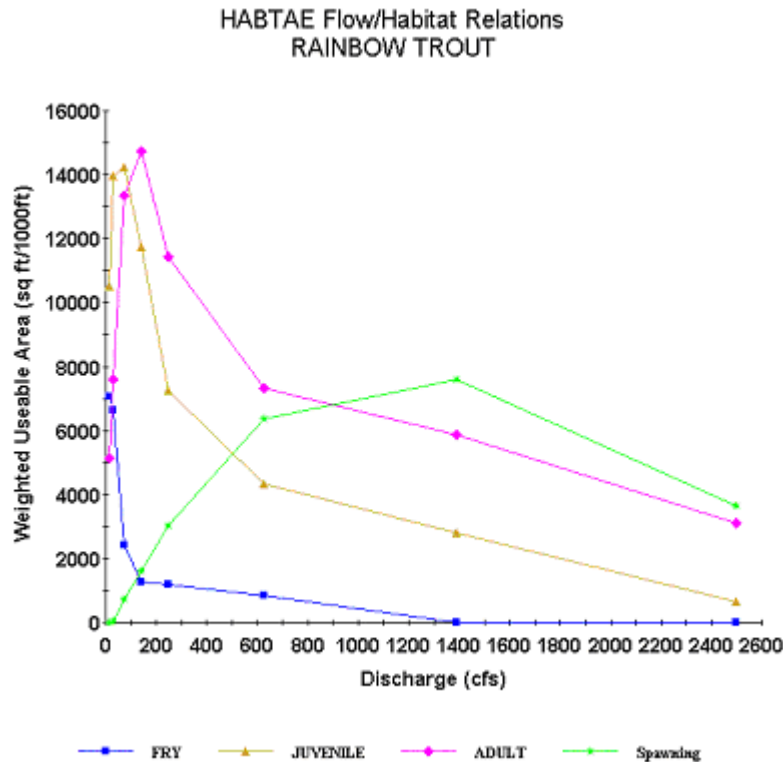
- A C_i is just at one flow…

$$WUA = \sum_{i=1}^{n} A_i * C_i$$

where: WUA = total Weighted Usable Area in stream at specified discharge

C$_i$ = composite suitability for cell i

A$_i$ = vertical view area of cell i (bed area or volume)

IFIM

- Instream Flow Incremental Methodology

Overview of Incremental Methodology
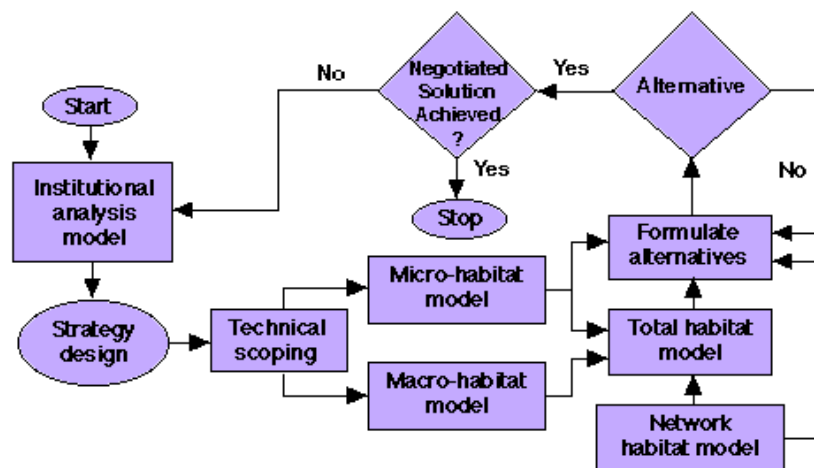
Figure 1. Overview of Incremental Methodology

Overview of Instream Flow Incremental Methodology:

1. Start of the IFIM process
2. Legal and Institutional Analysis Model (LIAM)
3. Strategy Design
4. Technical Scoping
5. Micro and Macro-habitat Models
6. Formulate Alternatives Using Total Habitat Model, Network Habitat Model
7. If Alternative is not feasible, step back to (6) and re-Formulate Alternatives.
8. Negotiate issue resolution with stakeholders. If negotiation concludes further analys

http://www.fort.usgs.gov/Products/Software/ifim/5phases.asp
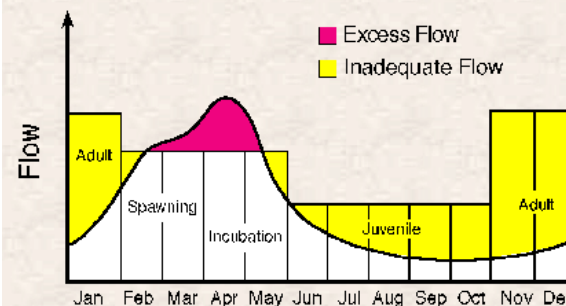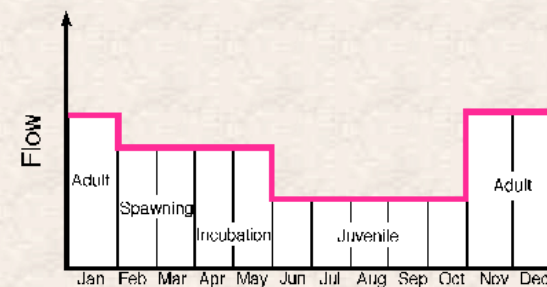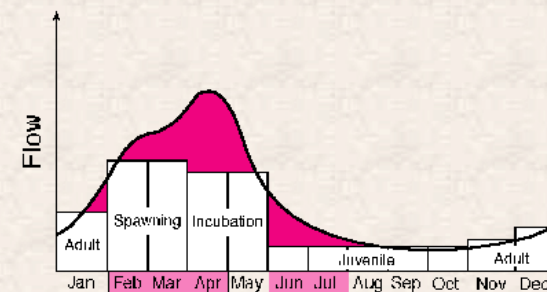
Traditional Habitat Suitability Models

How many transects needed?

- To be accurate, what transect spacing should we have?

Fig. 1. – Frequency histogram of number of transects per kilometer from 552 PHABSIM studies.

From Payne et al. (2004): DOI: 10.151/hydro:2004003

Corresponding habitat value representing a composite of depth velocity and channel index for each cell

Cross Section

Cell i

$d_i = \dfrac{d_1 + d_2}{2}$ $v_i = \dfrac{v_1 + v_2}{2}$

Mid 90's… people started saying

Two-Dimensional Hydrodynamic Modeling: A Neglected Tool in the Instream Flow Incremental Methodology

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Abstract.—The instream flow incremental methodology (IFIM) needs to be improved to more reliably predict the effects of altering fish habitat. Two-dimensional (2-D) hydrodynamic modeling with moving boundaries by the finite element approach overcomes many limitations related to classical physical habitat simulation modeling (mostly 1-D). Some of its most important properties are: the spatial resolution of the model can be adapted to the scale of individual fish habitats and to the spatial variability of field data; the areas frequently uncovered because of flow regime are correctly taken into account through the drying–wetting capability; and the flow resistance variables are more accurate in 2-D because they can be specified as functions of the local substrate conditions or lateral shear stresses. This approach is illustrated by a study of the habitat of juvenile Atlantic salmon Salmo salar of the Moisie River (Quebec) where a water diversion has been planned. The results of simulations carried out at two sites (a braided reach and a deep, narrow channel) over a wide range of discharges are presented. Average model error was about 10% for velocity and 2% for discharges. A finite element integration procedure allowed habitat suitability indexes (HSI) to be combined with the results of the hydrodynamic model. In this manner, detailed maps of the spatial distribution of the HSI as well as a "weighted usable area" were obtained for each discharge simulated. Atlantic salmon habitat did not appear to be very sensitive to projected flow alterations. The improved accuracy and resolution in predicting the effects of altering physical habitat variables by 2-D models would permit a better understanding of the shortcomings related to biological aspects of IFIM applications.

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Using two-dimensional hydrodynamic models at scales of ecological importance

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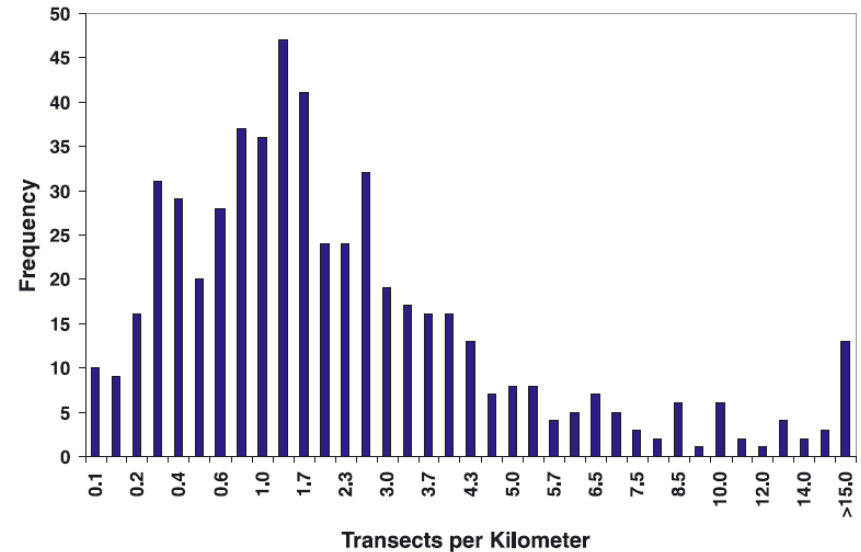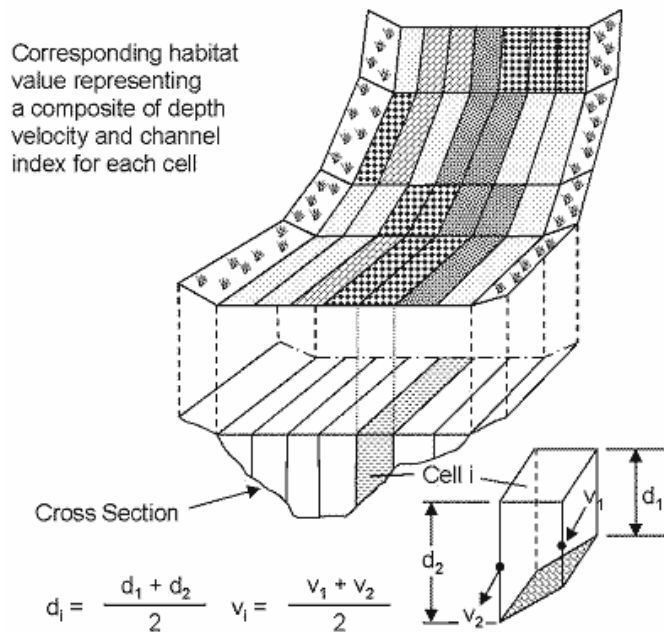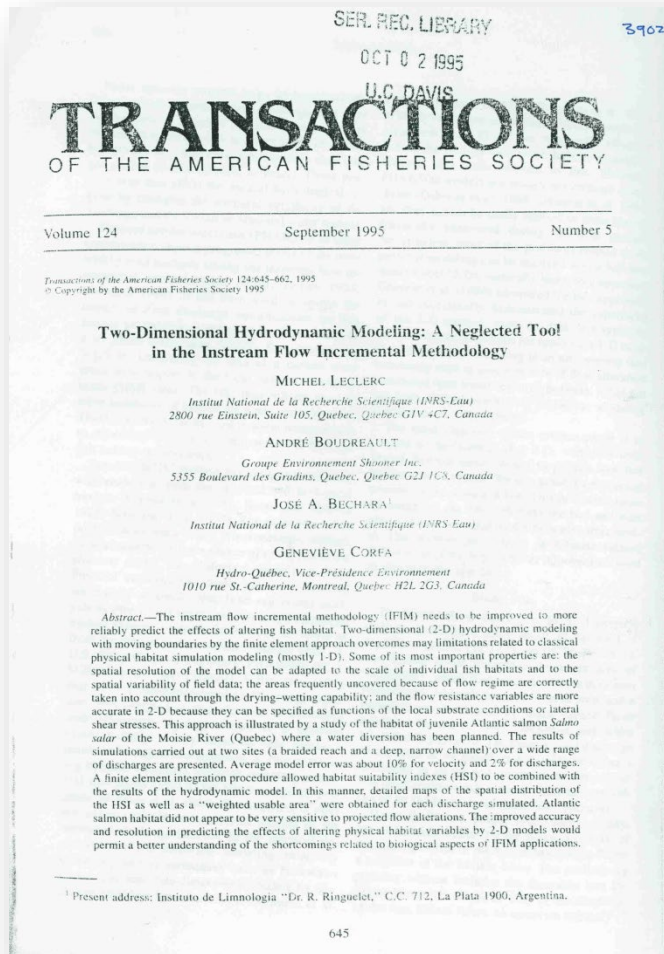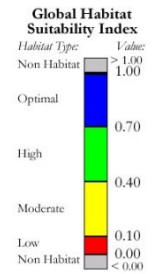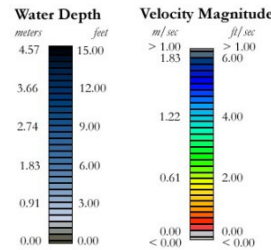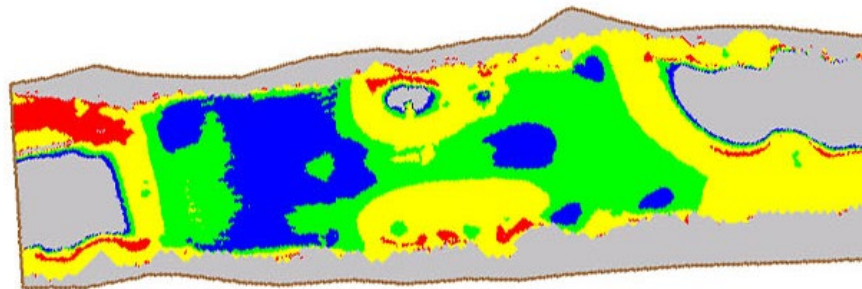
Abstract

Modeling of flow features that are important in assessing stream habitat conditions has been a long-standing interest of stream biologists. Recently, they have begun examining the usefulness of two-dimensional (2-D) hydrodynamic models in attaining this objective. Current modeling practices consider relatively long channel sections with their bathymetry represented in terms of large, macro-scale, topographic features. Meso-scale topographic features, such as boulders, root-wads and other obstructions are typically not considered in the modeling process. Instead, the overall effects of these flow obstructions are captured through increased values in the channel roughness parameters. Such an approach to 2-D modeling allows one to accurately predict average depth and velocity values; however, it is not capable of providing any information about the flow patterns in the vicinity of these obstructions. Biologists though have known that such meso-scale features and the complex velocity patterns generated by their presence, play an important role in the ecology of streams, and thus cannot be ignored. It is therefore evident that there is a need to develop better tools, capable of modeling flow characteristics at scales of ecological importance. The purpose of this study is to expand the utility of 2-D hydraulic models to capture these flow features that are critical for characterizing stream habitat conditions.

There exists a paucity of research addressing what types of topographic features should be included in 2-D model studies and to what extent a boulder or series of exposed boulders can influence predicted flow conditions and traditional useable habitat computations. Moreover, little research has been performed to evaluate the impact mesh refinement has on model results in natural streams. Numerical simulations, based on a natural river channel containing several large boulders, indicate that explicitly modeling local obstructions/boulders can significantly impact predicted flow parameters. The presence of these obstructions create velocity gradients, velocity shelters, transverse flows and other ecologically important flow features that are not reproduced when their geometry is not incorporated into the hydraulic model. Sensitivity analyses show that reducing element sizes in the vicinity of obstructions and banks is crucial in modeling the spatial flow patterns created by meso-scale topographic features. This information, combined with similar data obtained in future studies, can provide guidelines for the placement of fishrocks and other structures often used in stream restoration projects as well as determining what types of meso-scale topographic features might need to be incorporated into habitat suitability studies. Such information may also ultimately allow new spatial habitat metrics to be developed. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Numerical analysis; Bathymetry; Rivers and streams; Aquatic environment; Fish habitat; Spatial variations; Boulders

1. Introduction

Flow through natural channels is typically quite complex. The flow interacts with sediment and the

- 1D is not realistic

Fig. 9. The effect obstruction size and placement has on local habitat conditions. The plots represent enlarged views of habitat conditions near the obstructions. Velocity conditions without any obstruction present are shown in (a). (b) Reflects the influence of a 1.83 × 1.83 m² obstruction placed near the bank. (c) Depicts the flow conditions produced by a single 2.26 × 2.11 m² boulder placed further out in the stream.
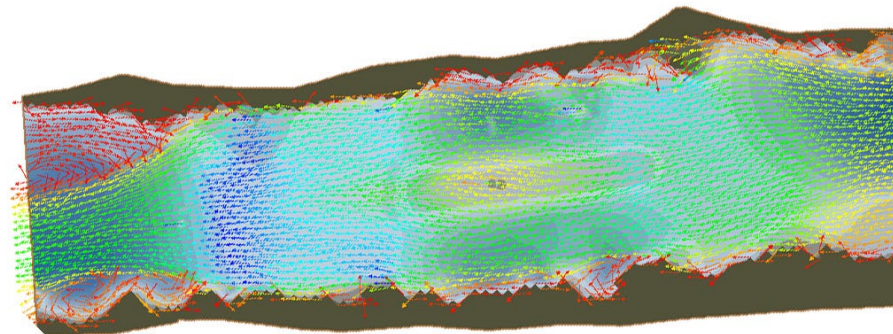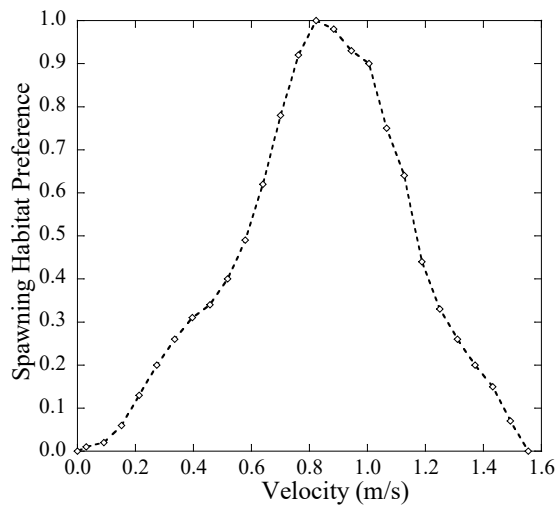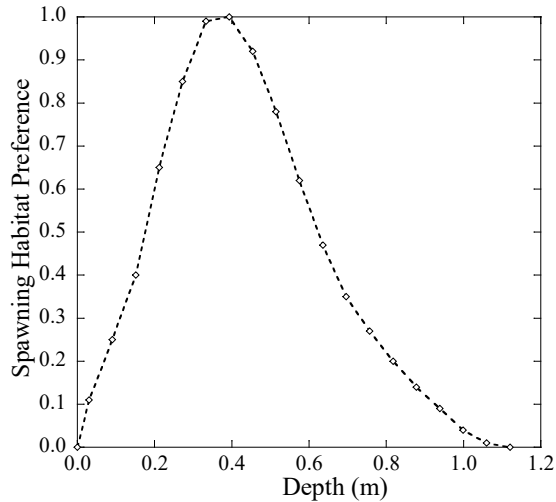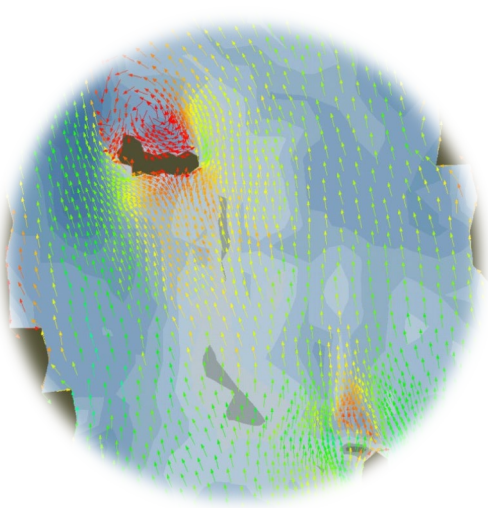
Ecohydraulic Models Driven by 2D CFD

- What if we use same ecohydraulic model, but drive it by a multidimensional hydraulic simulation?
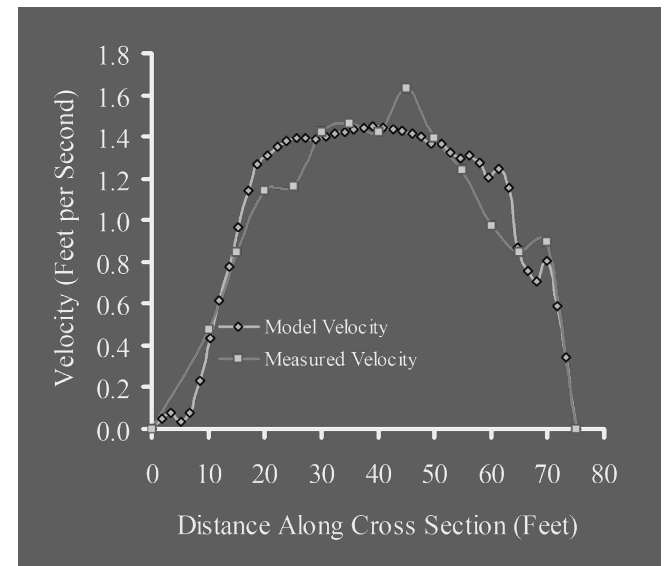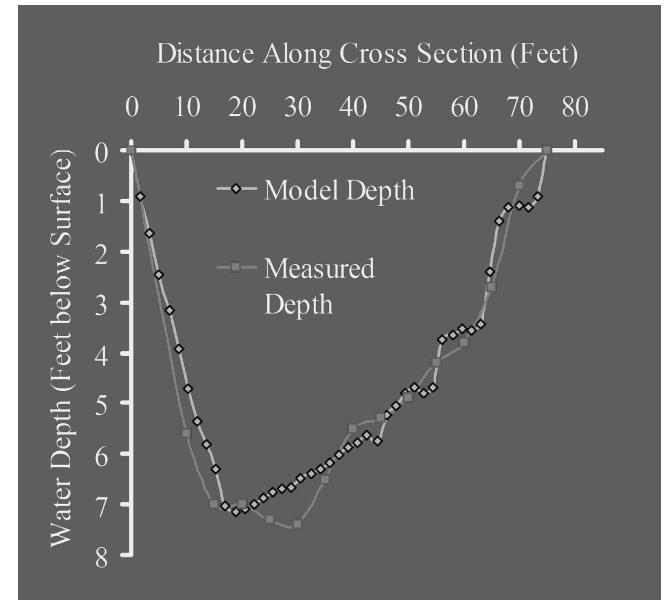
Crowder & Diplas (2000) Argument
2D Models are Appropriate for Capturing Ecologically Significant Patterns

But they should be validated
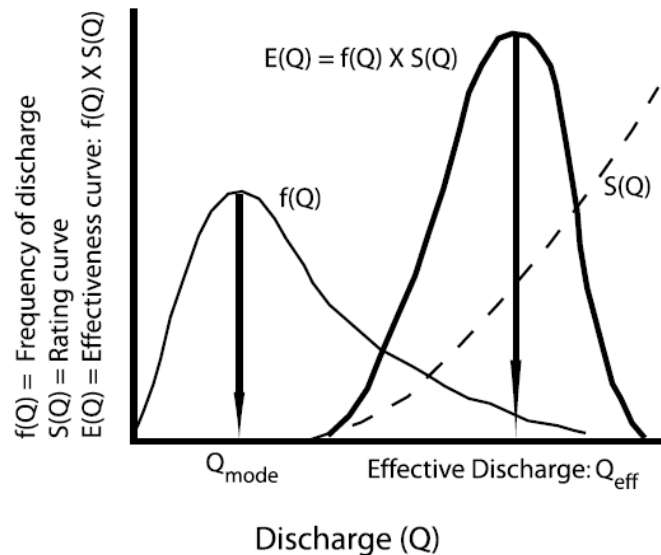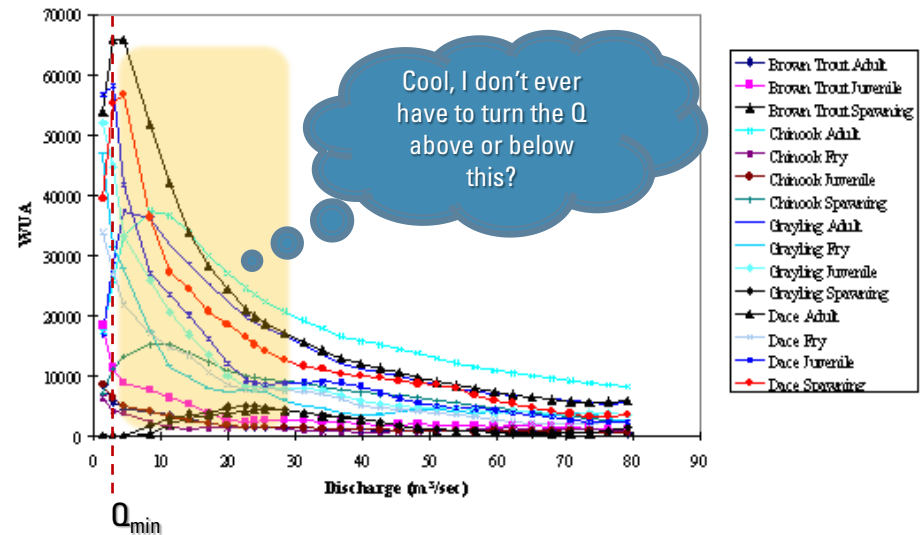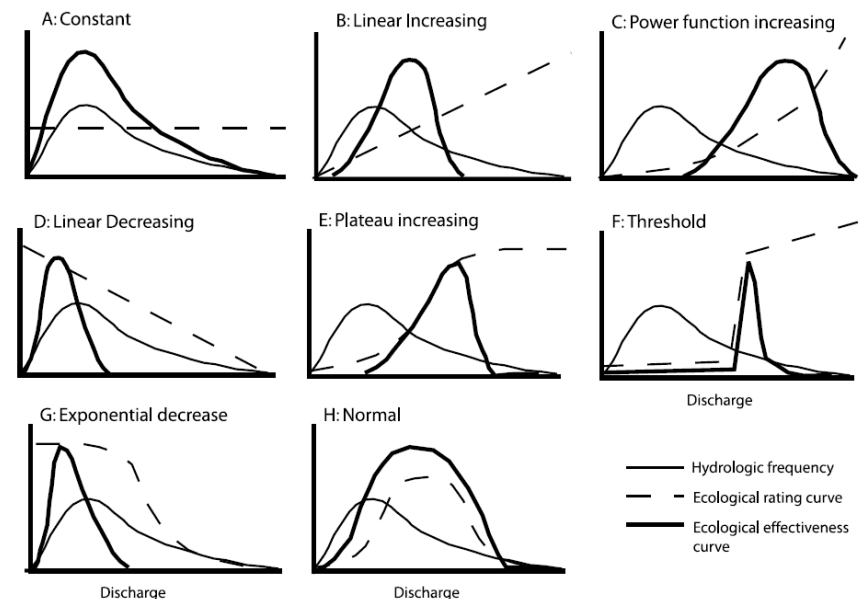and/or verified?

How do you do that?

Traditional Habitat Suitability Models

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?

Cool, I don't ever have to turn the Q above or below this?

Q_{min}

Figure 1. Components of effective discharge (Q_{eff}). Adapted from *Wolman and Miller* [1960].
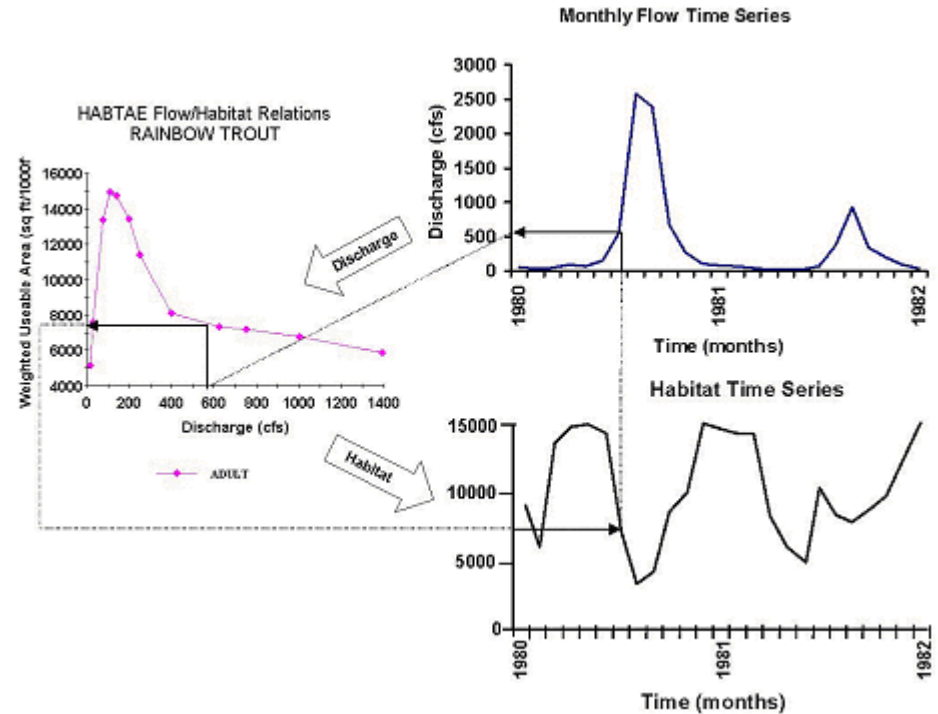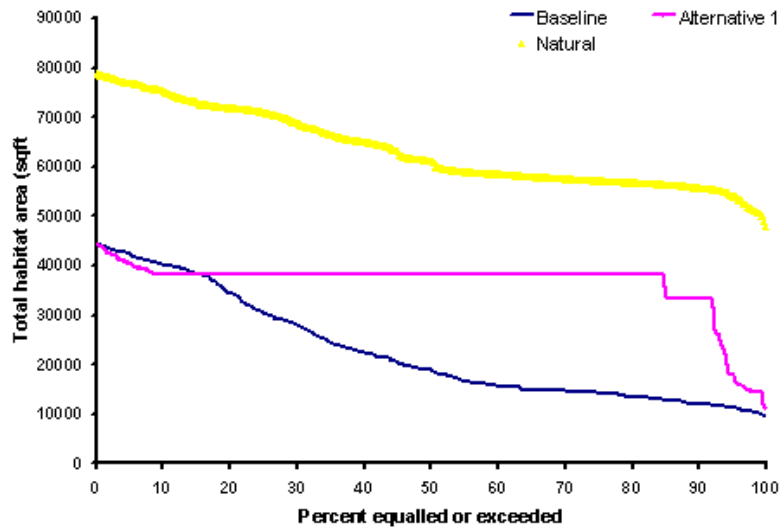
Figure 13. Hypothetical response curves for a variety of ecological variables. For potential ecological variables, see Table 2 and discussion in text.
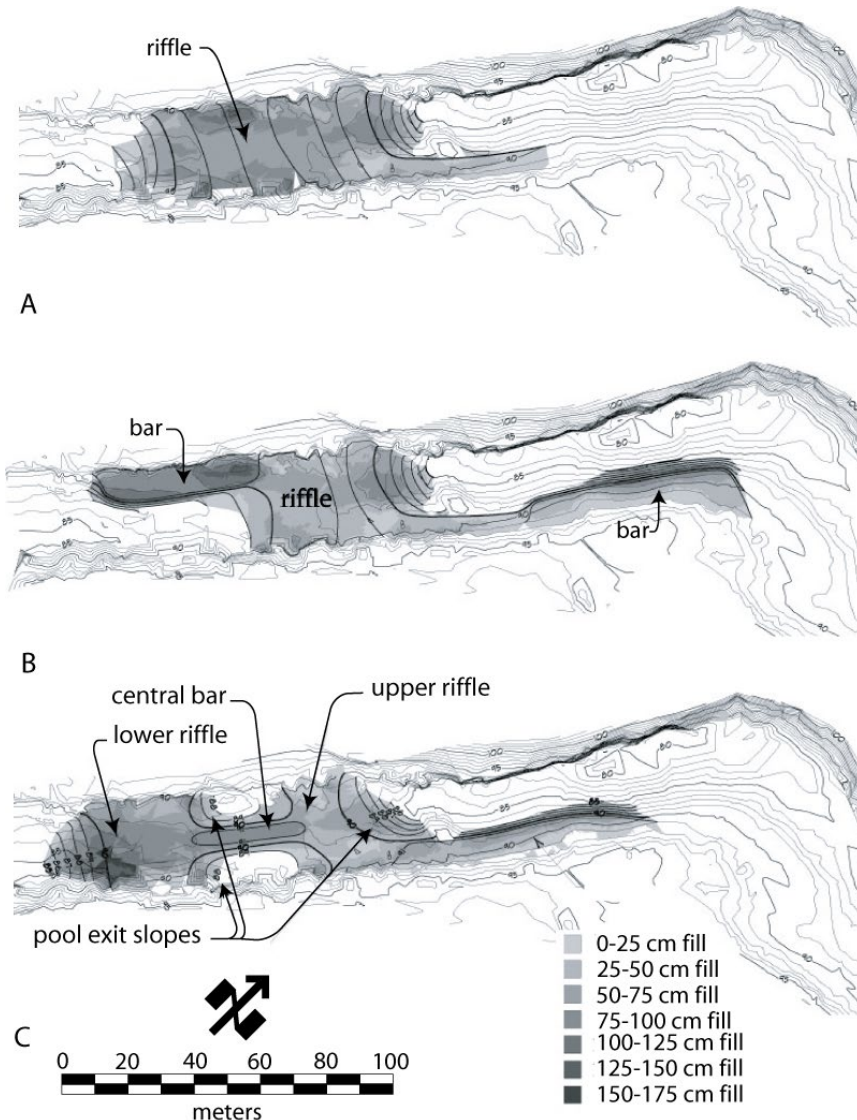
Habitat Time Series

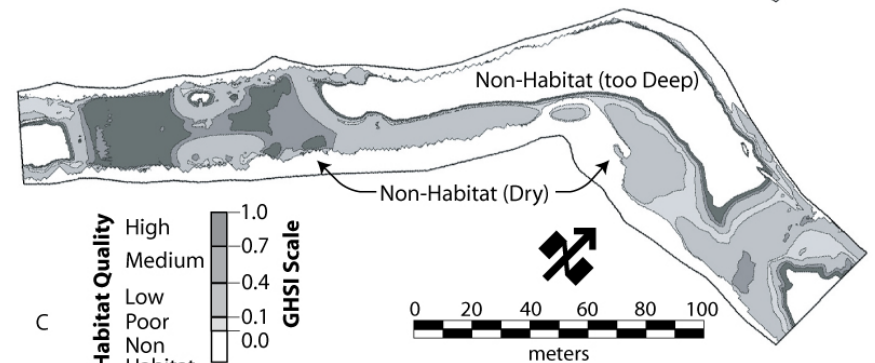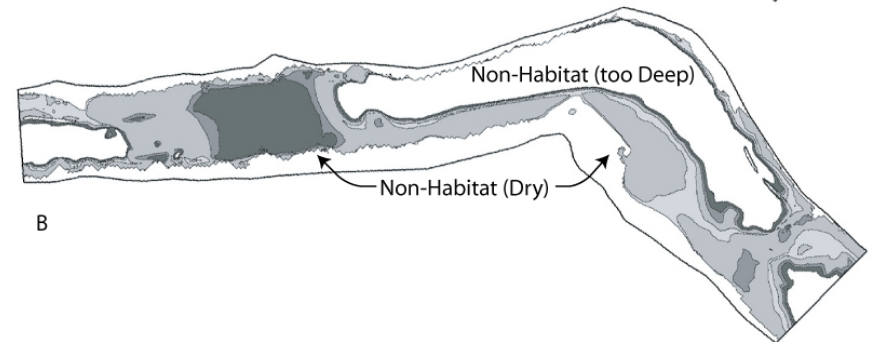- If you've got actual hydrograph, you can run a habitat time series (i.e. hydrodynamics)

HABTAE Flow/Habitat Relations
RAINBOW TROUT

Monthly Flow Time Series

Habitat Time Series

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

Same Place… Different Configurations

riffle

A

bar

riffle

bar

B

central bar   upper riffle
lower riffle

pool exit slopes

C

| 0 | 20 | 40 | 60 | 80 | 100 |

meters

0-25 cm fill
25-50 cm fill
50-75 cm fill
75-100 cm fill
100-125 cm fill
125-150 cm fill
150-175 cm fill

From Wheaton, Pasternack and Merz (2004)

- Use range of different design scenarios to test design hypotheses under a range of conditions
  - Physically different designs
  - Different scenarios of forcing conditions
- Project 'outcome' IS NOT likely to be static
- Design for dynamic outcome relative to magnitude of dynamics (i.e. variability) of system

Different Designs – Different Hypotheses

Broad Flat Riffle

Alternate Bar

central bar
lower riffle
upper riffle
pool exit slopes

Complex Central Bar

riffle

bar

bar

A

B

C

Non-Habitat (too Deep)
Non-Habitat (Dry)

0-25 cm fill
25-50 cm fill
50-75 cm fill
75-100 cm fill
100-125 cm fill
125-150 cm fill
150-175 cm fill

Habitat Quality
High
Medium
Low
Poor
Non Habitat

GHSI Scale
1.0
0.7
0.4
0.1
0.0

meters
0 20 40 60 80 100
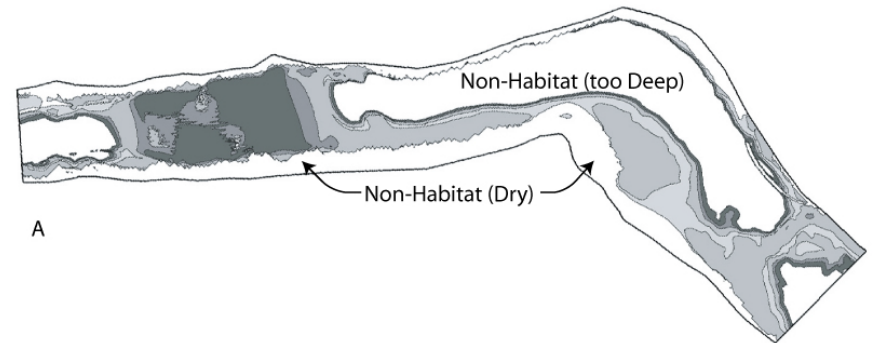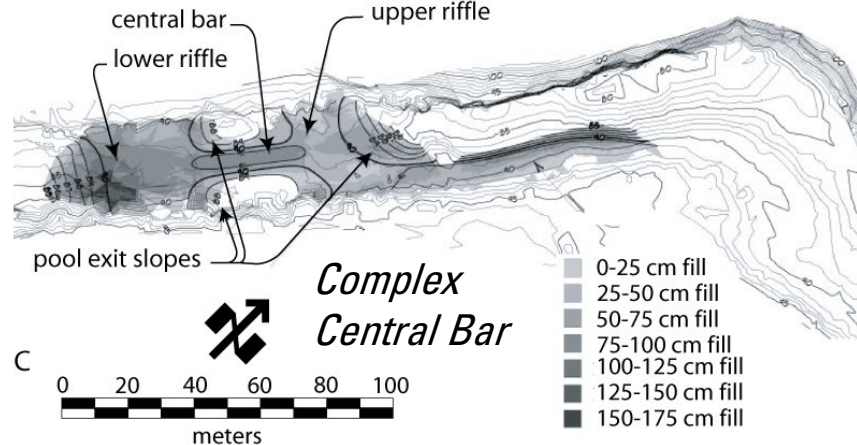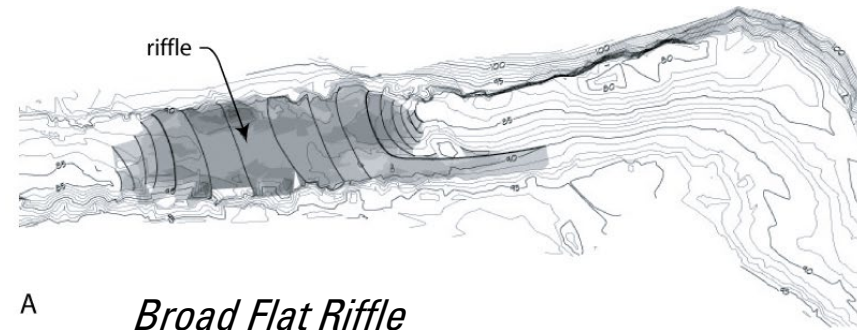
Model Outcome – Is It Right?

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?

→ Y ⟶ **TYPE I** ***Can only*** replicate reality

Y or N

OR

TYPE II Replicates reality ***incorrectly***

OR

TYPE III ***Correctly does not*** replicate reality (but it might approximate it)
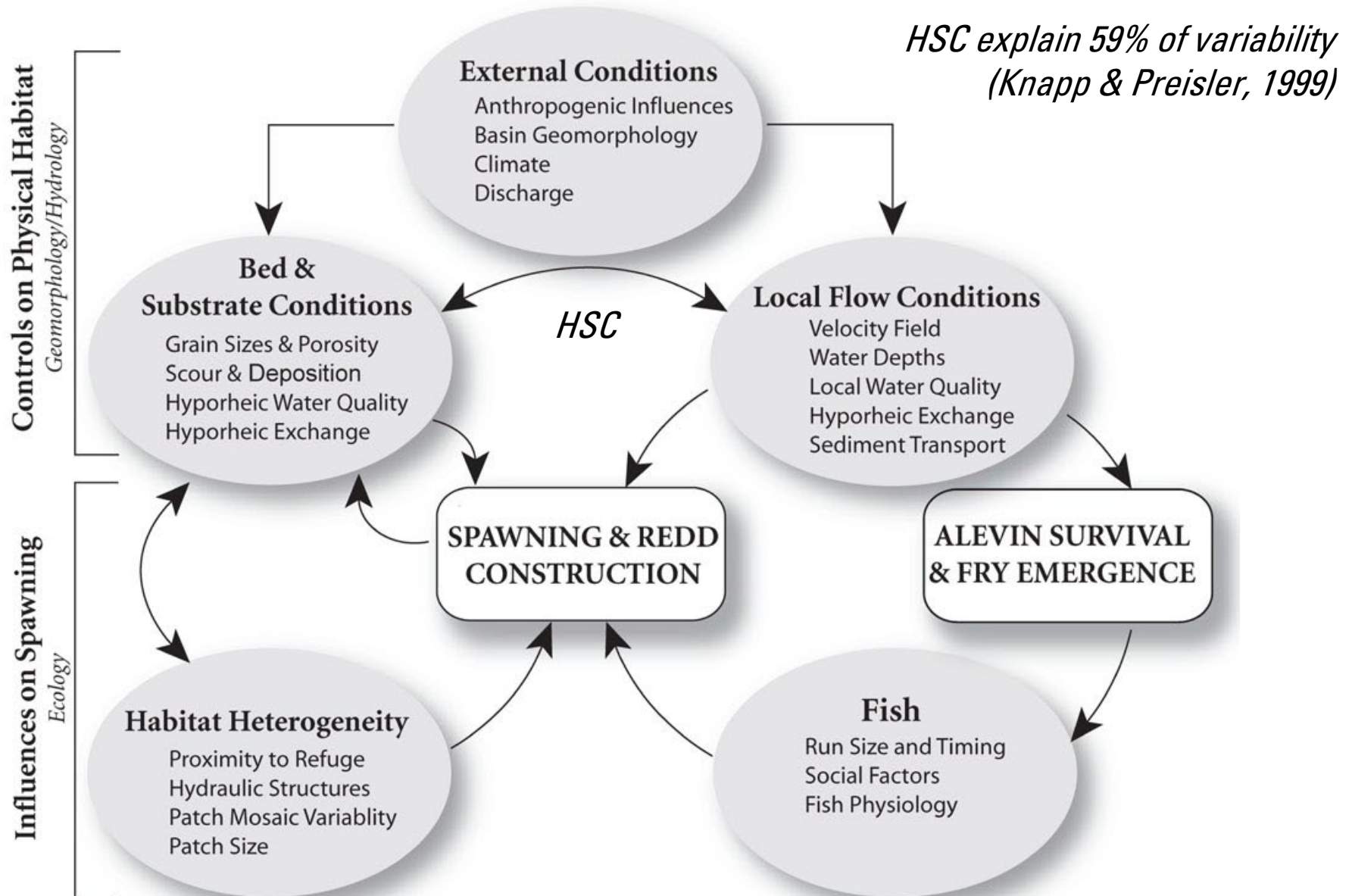
OR **TYPE IV** ***Incorrectly does not*** replicate reality.

Model Might Perform Poorly…

HSC explain 59% of variability
(Knapp & Preisler, 1999)

Controls on Physical Habitat — *Geomorphology/Hydrology*

Influences on Spawning — *Ecology*

External Conditions
Anthropogenic Influences
Basin Geomorphology
Climate
Discharge

Bed & Substrate Conditions
Grain Sizes & Porosity
Scour & Deposition
Hyporheic Water Quality
Hyporheic Exchange

Local Flow Conditions
Velocity Field
Water Depths
Local Water Quality
Hyporheic Exchange
Sediment Transport

HSC

SPAWNING & REDD CONSTRUCTION

ALEVIN SURVIVAL & FRY EMERGENCE

Habitat Heterogeneity
Proximity to Refuge
Hydraulic Structures
Patch Mosaic Variablity
Patch Size

Fish
Run Size and Timing
Social Factors
Fish Physiology

# 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?
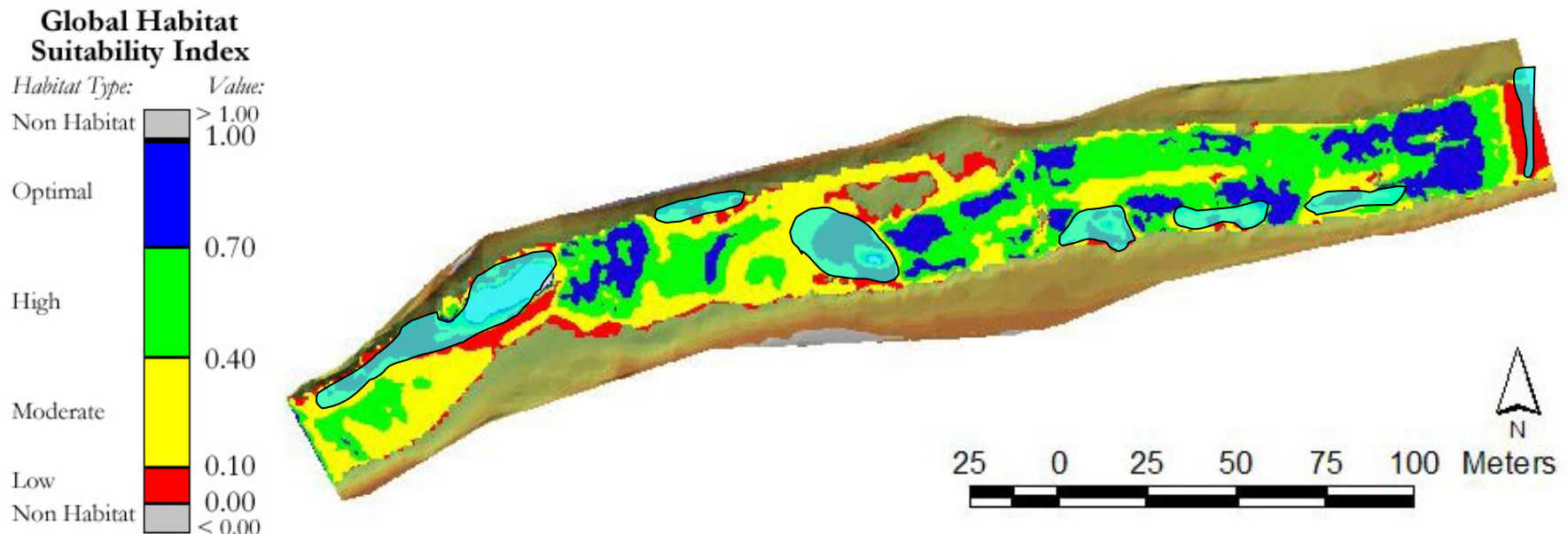
Habitat Utilization Evidence

- 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)*
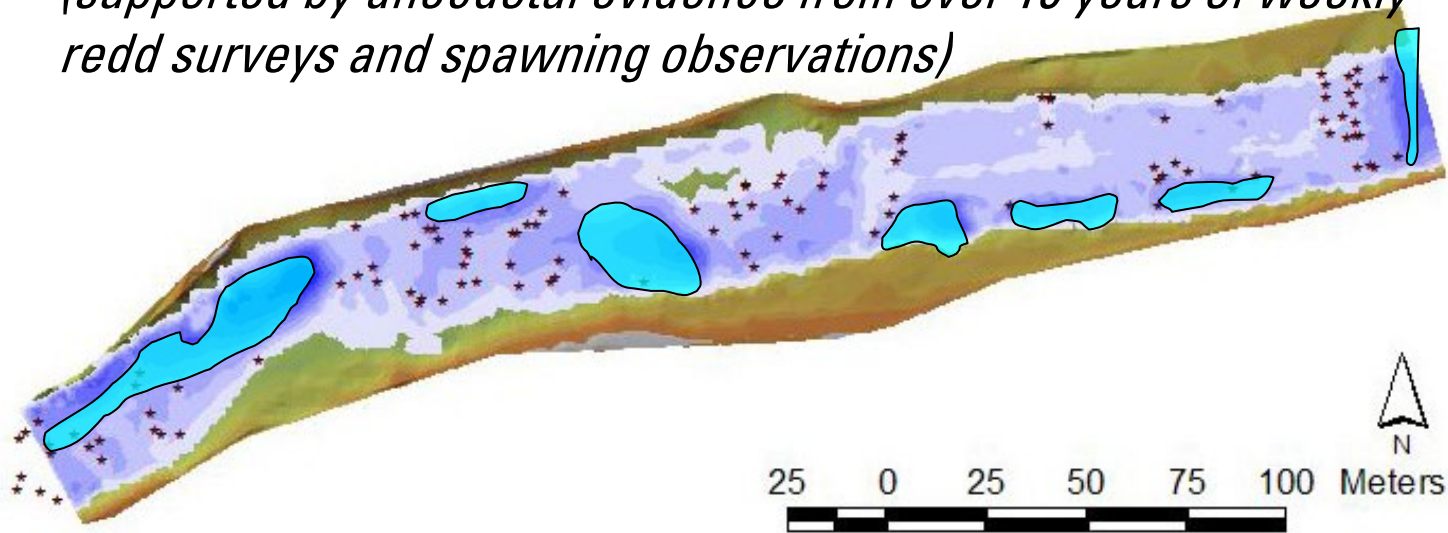
Availability MATTERS

1. How many distinct units (counts) and what size are they (area)?

    - Too small? → Not usable, or too patchy.
    - Too big? → Homogenous

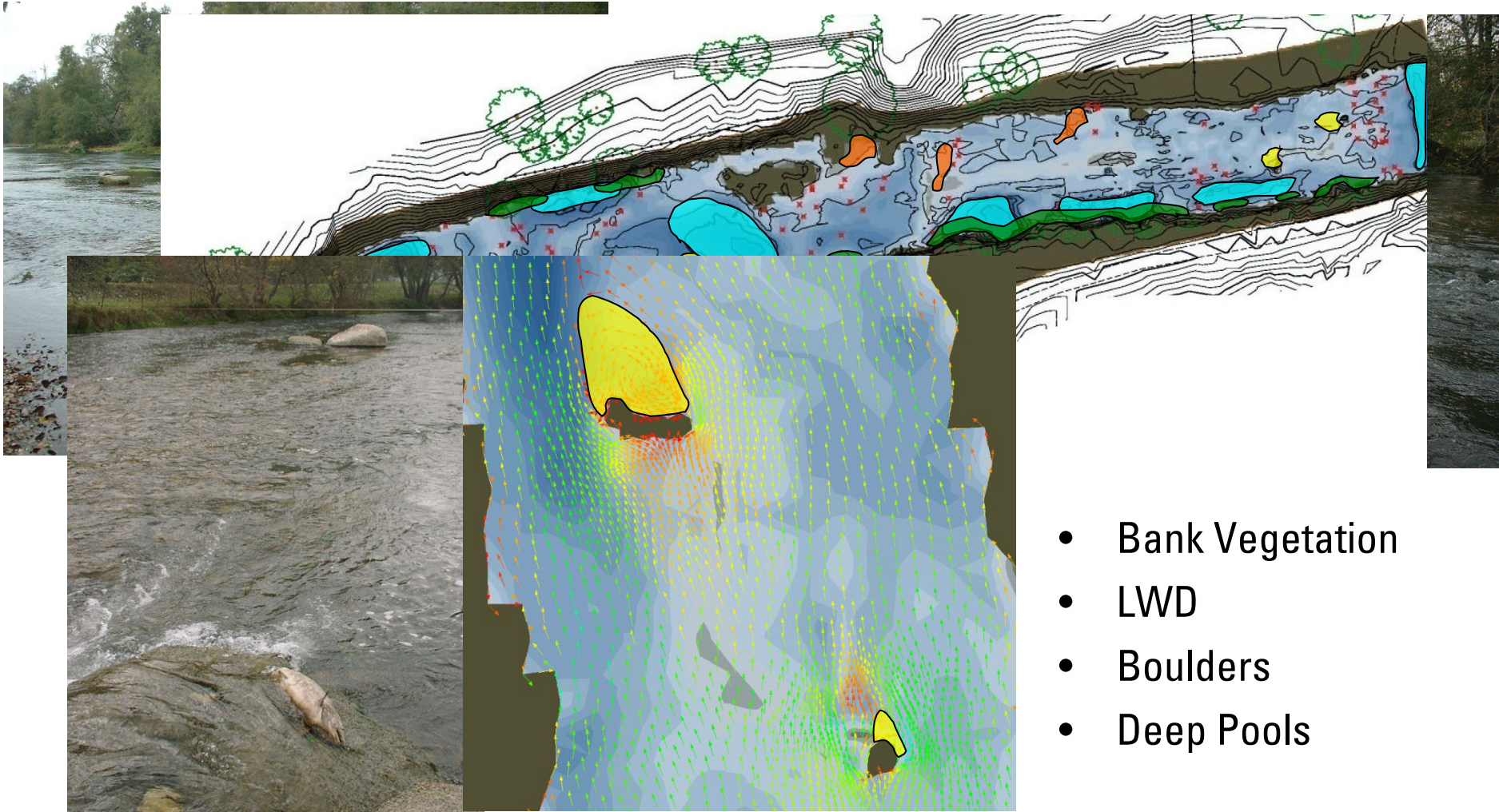2. Are distinct units in close (1-10 m) proximity to "good" spawning habitat?

Global Habitat Suitability Index

Habitat Type:	Value:
Non Habitat	> 1.00 / 1.00
Optimal	
	0.70
High	
	0.40
Moderate	
	0.10
Low	0.00
Non Habitat	< 0.00

25 0 25 50 75 100 Meters

Defining Habitat Heterogeneity Elements

Data Feature: Data Source: Attributed to:

- Bank Vegetation
- LWD
- Boulders
- Deep Pools

Traditional Habitat Suitability Models

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….