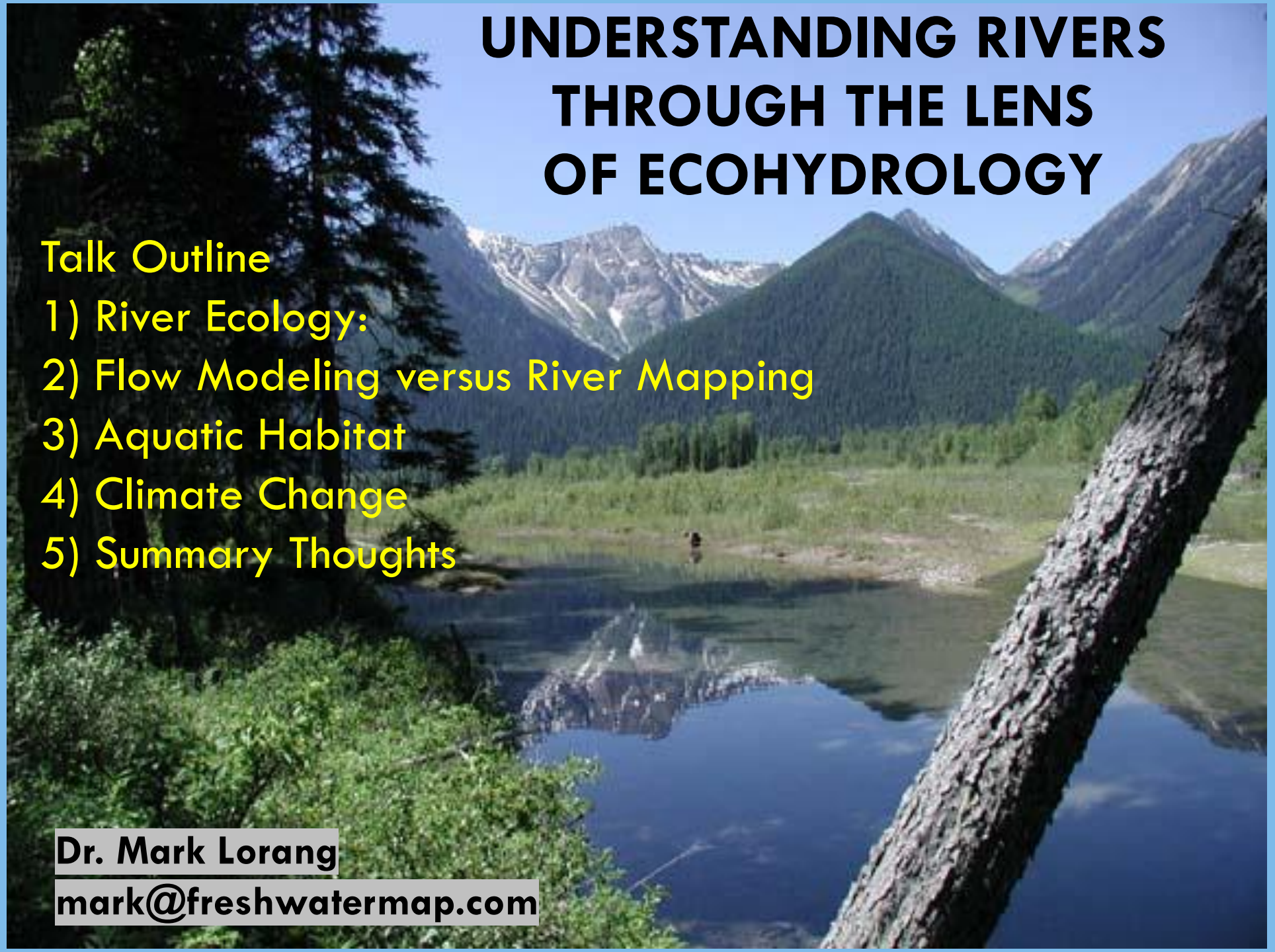
UNDERSTANDING RIVERS THROUGH THE LENS OF ECOHYDROLOGY



Talk Outline

1) River Ecology:
2) Flow Modeling versus River Mapping
3) Aquatic Habitat
4) Climate Change
5) Summary Thoughts

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Key Points Regarding Environment Flow

The essence of ecohydrology is to understand the distribution and abundance of aquatic biota in the context of how and why organisms are dependent on specific biophysical space (habitat) as well as functional processes (e.g. hyporheic - surface water interaction, flooding, channel and bar formation) to complete one stage or another in their life cycles.

Aquatic habitat is the least empirically quantified attribute of rivers and streams.

Quantifying how much aquatic habitat exists in a river, where it is located relative to other important habitats and how it changes as a function of flow regulation in light of climate change is key for assessing environmental flow and finding stakeholder agreement regarding flow regulation.

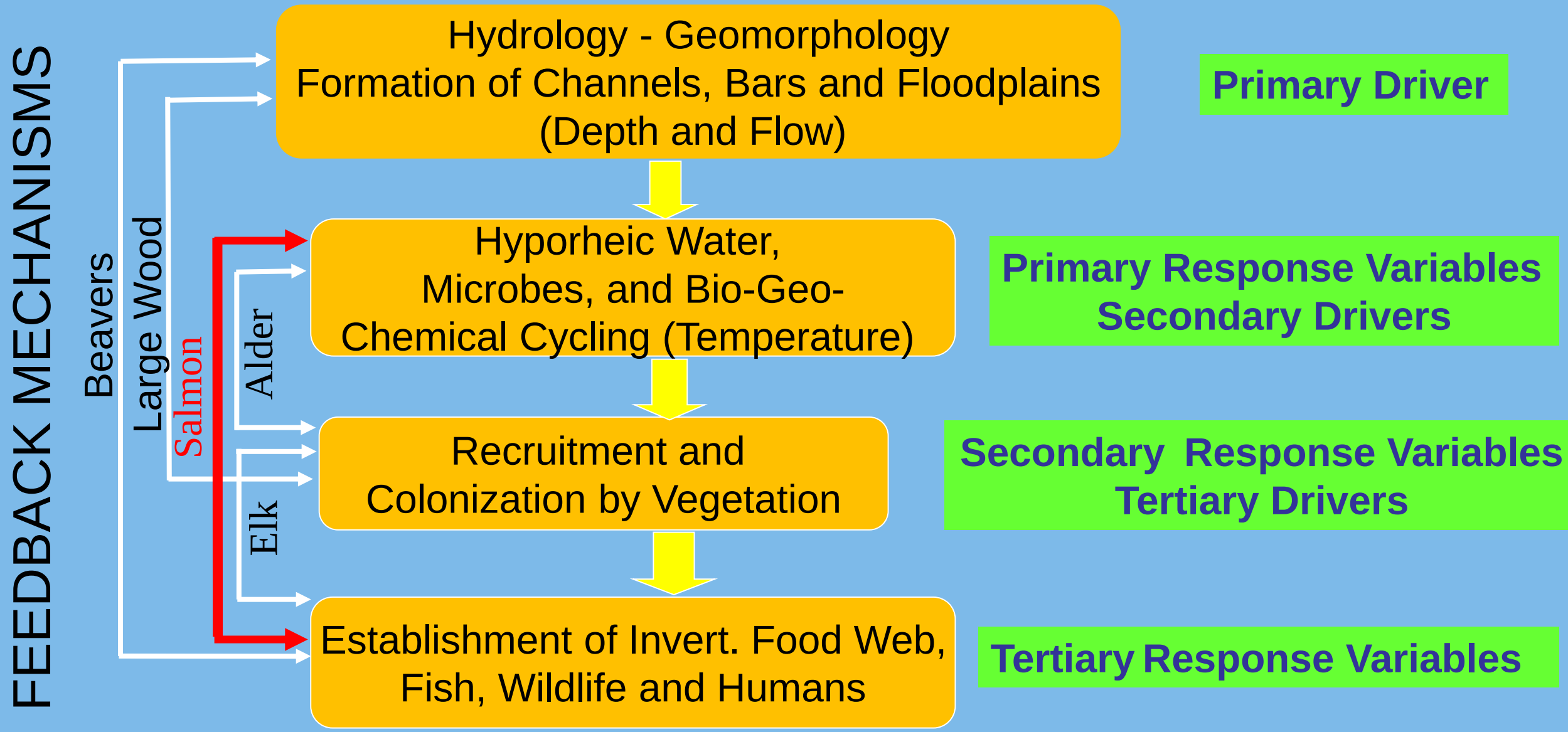
THE GOAL FOR ENVIRONMENTAL FLOW

"BALANCE HUMAN NEEDS FOR FRESHWATER WITH ECOLOGICALLY HEALTHY RIVERS"

Major Components of ENVIRONMENTAL FLOW
Ecosystem Function
Flood Control, Hydropower
Irrigation and Municipal withdrawal,
Shipping, Recreation,
Cultural and other
Societal Needs

Photo: Ric Hauer

Understanding Rivers - Process Organization



"Faced with increases in the demands for water and changes in the patterns of rainfall and evaporation due to climate change, the need to apply ecological theory to management practice has become all the more immediate."

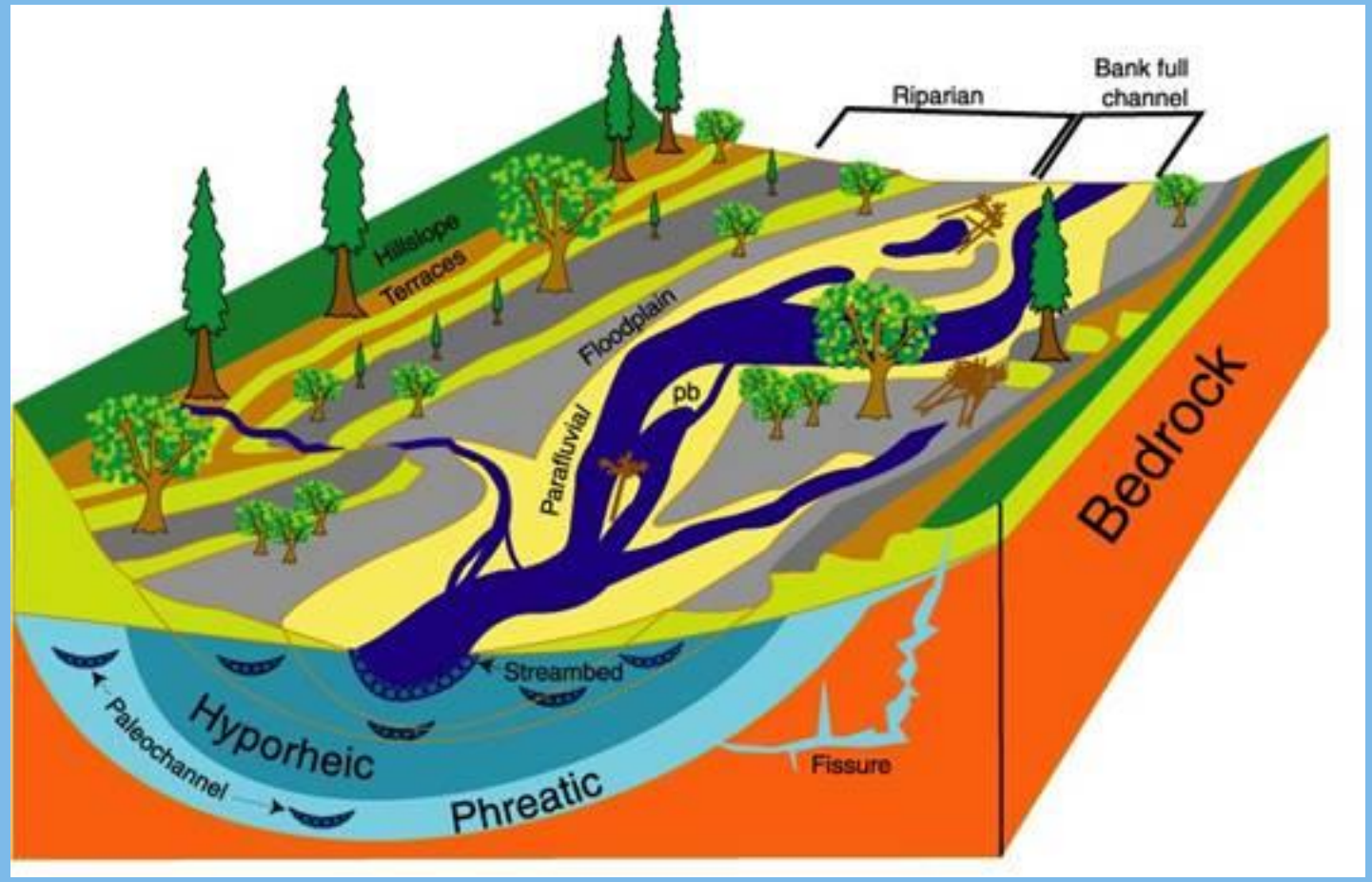
Thompson, R. M. and Lake, P. S. (2010), Reconciling theory and practice: The role of stream ecology. River Res. Applic., 26: 5–14. doi:10.1002/rra.1284

The Shifting Habitat Mosaic Hypothesis:

Primary Drivers: Fluvial Geomorphic Processes and Ground-Surface Water Interaction

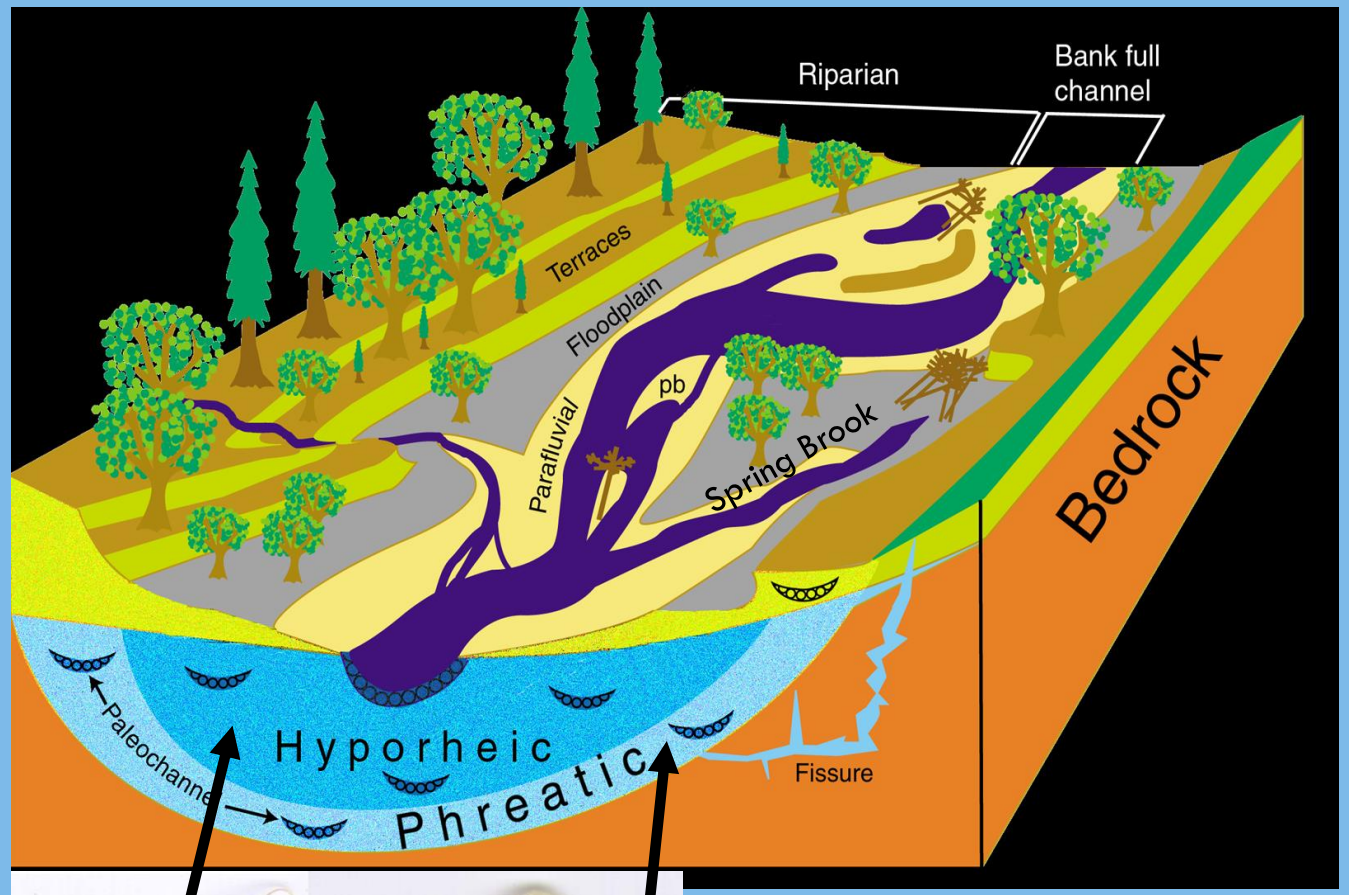
ECOSYSTEM HEALTH IS DEPENDENT ON CONSTANT CHANGE IN HABITAT COMPOSSING THE RIVER CHANNEL, THE FLOOD PLAIN AND THE HYPORHEIC ZONE

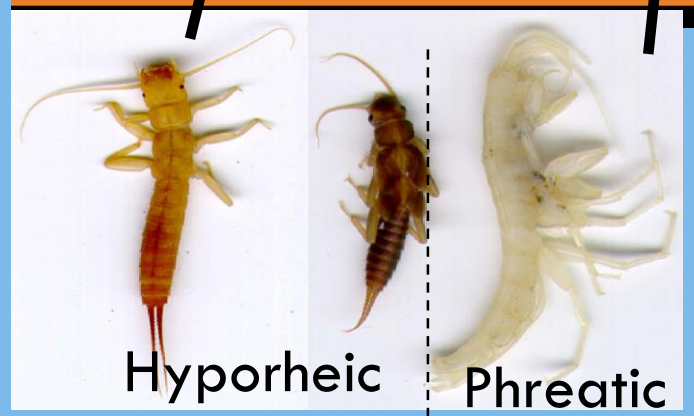
RIVERS MUST FLOOD!



Stanford, J. A., M. S. Lorang, and F. R. Hauer. 2005. **The shifting habitat mosaic of river ecosystems**. Verh. Internat. Verein. Limnol. **29**:123–136.

A 3D view of typical salmon river





Important Points

1) The extent of the hyporheic zone can vary from less than a meter to several kilometers in distance from the surface channels of the river.

2) the majority of bioproduction and nutrient cycling occurs within the hyporheic zone which supports the surface water ecosystem.

3) This mosaic of habitat is what salmon need to survive.

These organisms have life cycles that utilize ground water environments and their presence defines the boundaries of the HYPORHEIC zone, the upper most portion of the unconfined aquifer in direct contact with the surface water.

THREE TYPES OF FLOW DATA

1) A Snapshot of Spatial Flow Structure
   - Satellite and Airborne Imagery

2) Eulerain
   - A Current Meter or Weather Station Fixed in Space Measuring Flow Moving Past

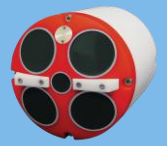
3) Lagrangian*
   - A Weather Balloon or Ocean Drifter Moving with the Flow

* **The Missing Link in River Work**

Reason for Hydro-Acoustic River Mapping

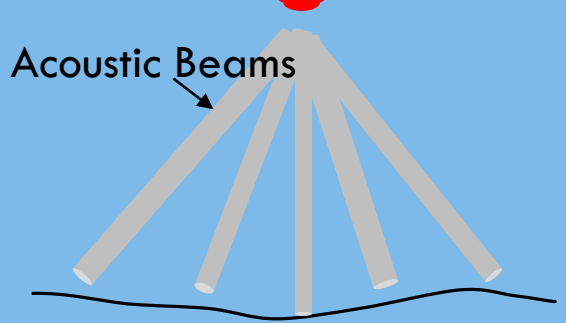
Hydro-Acoustic River Mapping:

GRAB an ADP

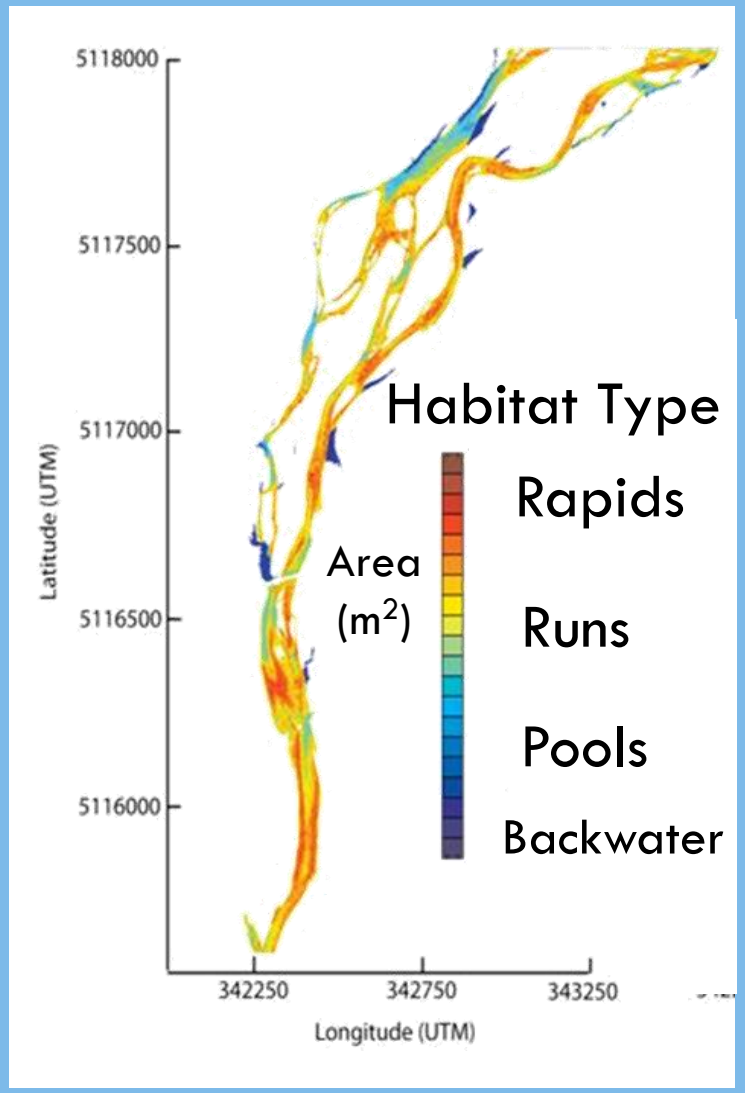


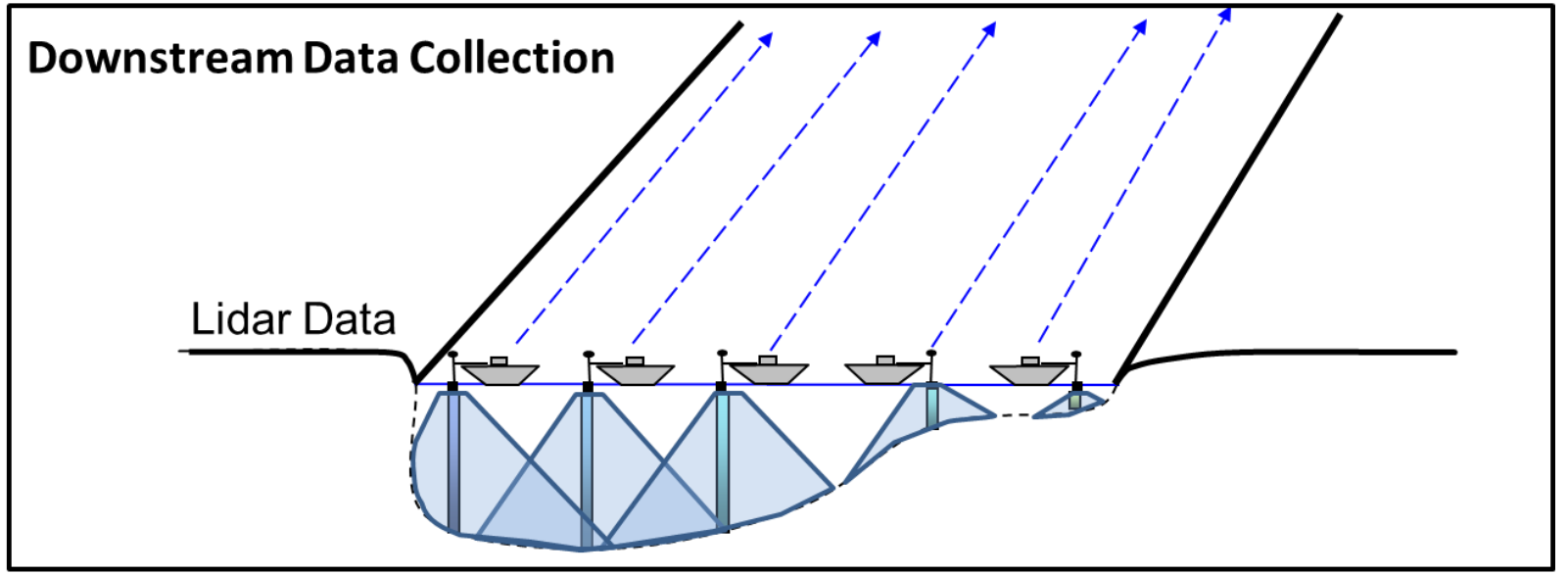
&

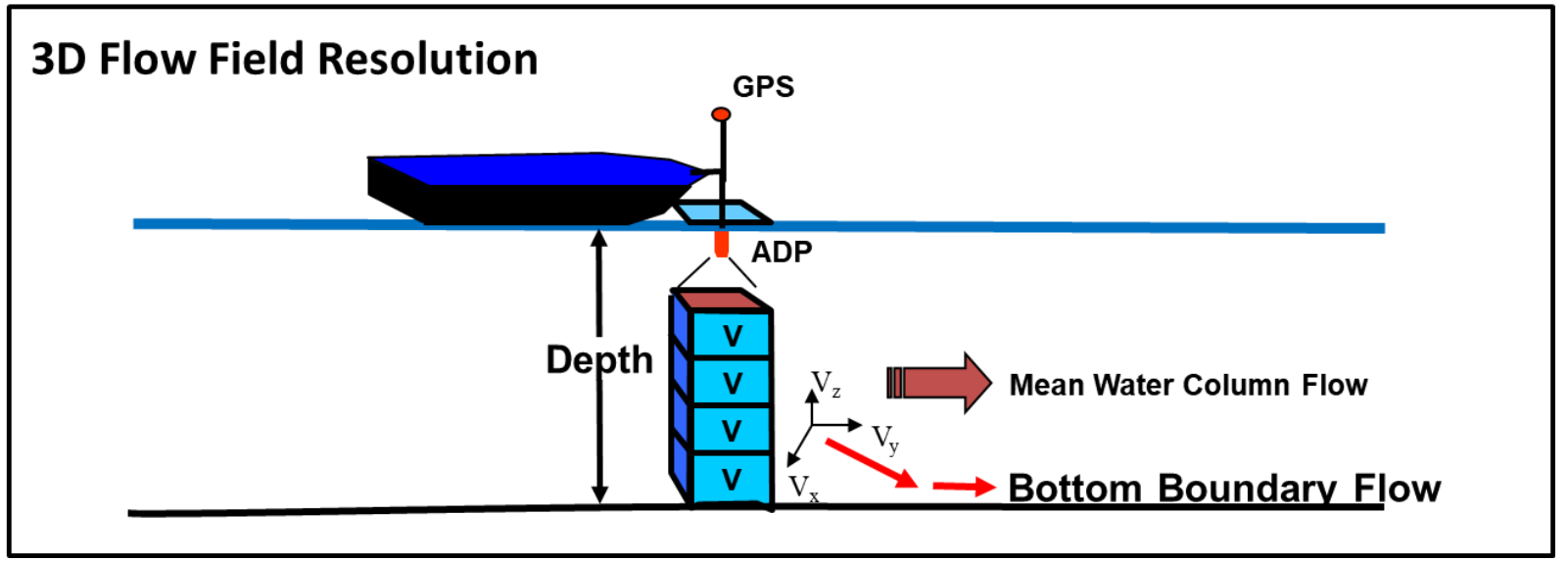
GO WITH THE FLOW



Abundance and Spatial Distribution of Aquatic Habitat




Downstream Data Collection
Lidar Data

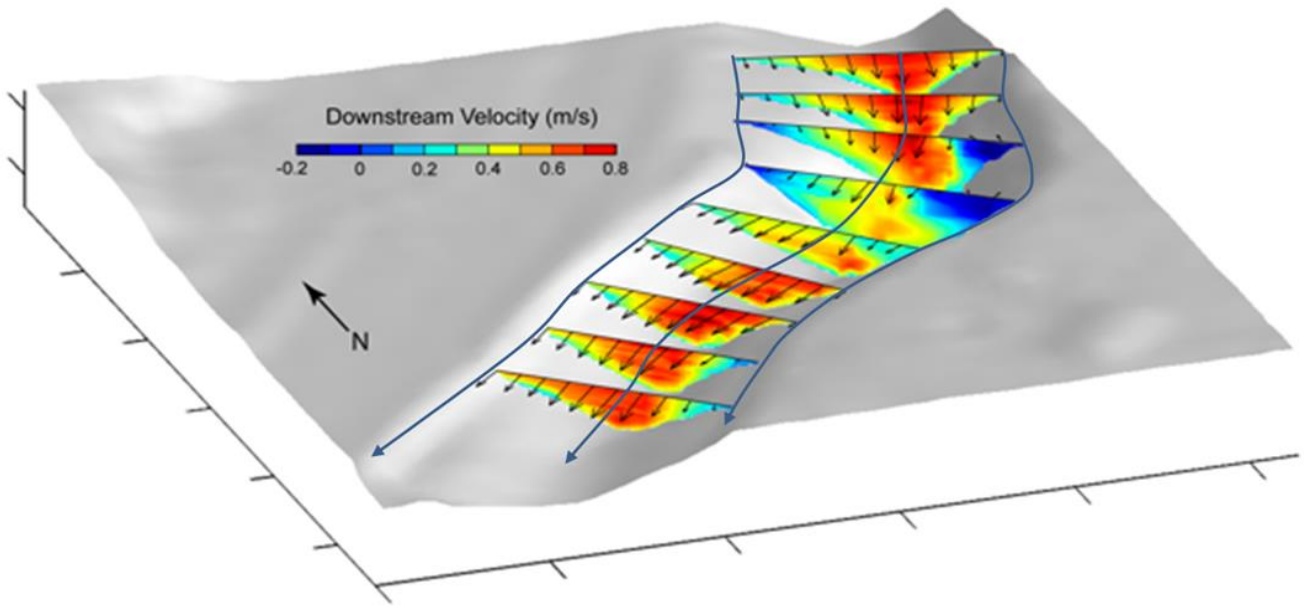

3D Flow Field Resolution
GPS
ADP
Depth
V
V
V
V
V_z
V_y
V_x
Mean Water Column Flow
Bottom Boundary Flow

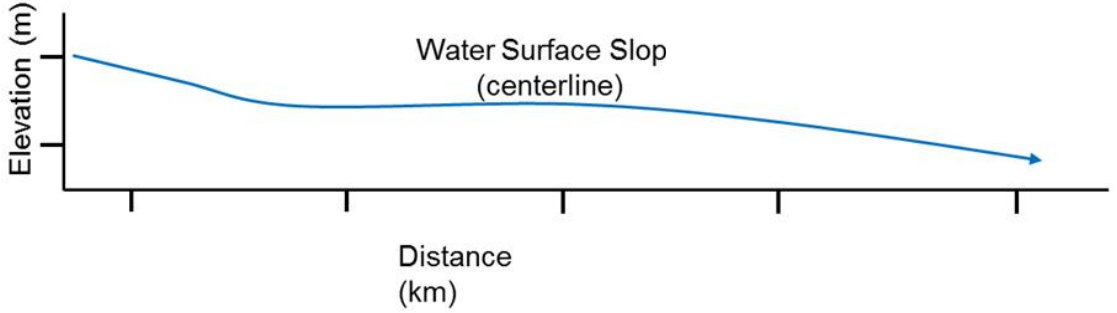
COMPUTATIONAL FLUID DYNAMIC MODELING
VS
HYDRO-ACOUSTIC RIVER MAPPING

MODELING

Measure at Cross-Channel Transects

Model Flow and Depth Between Transects





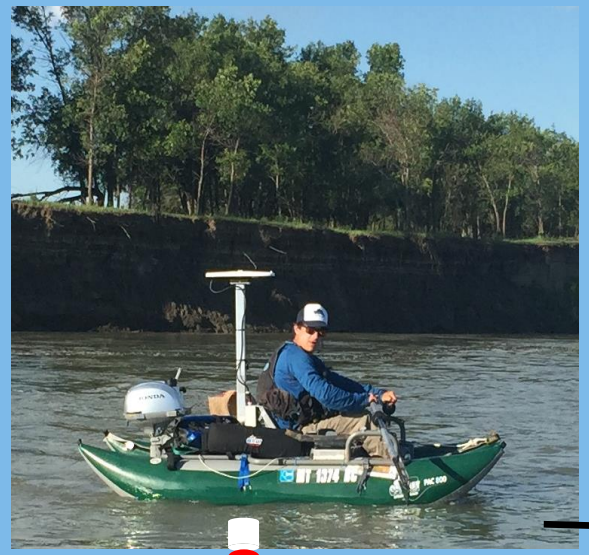
RIVER MAPPING

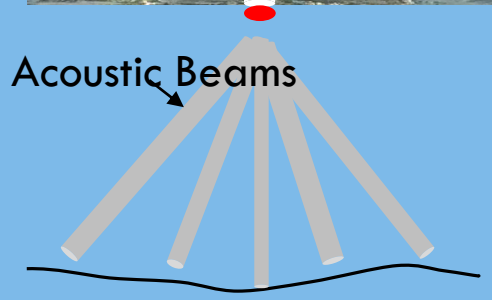
Measure Downstream Transects

Interpolate Flow and Depth Between Transects

Transect Data

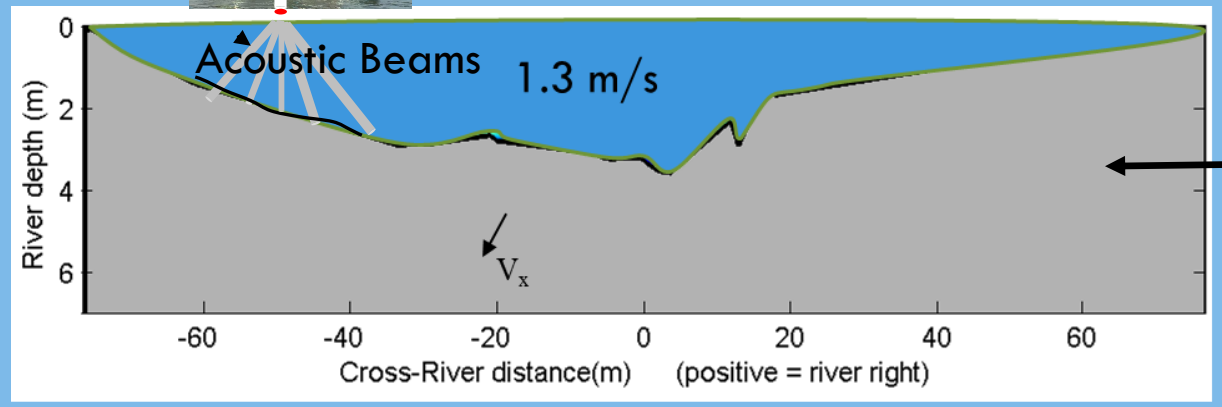
Acoustic Doppler Profiler ADP



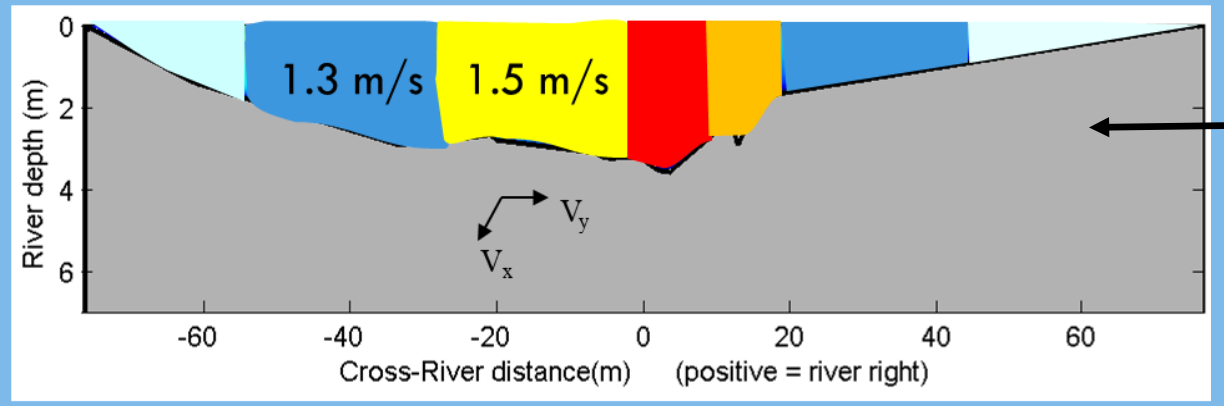


and

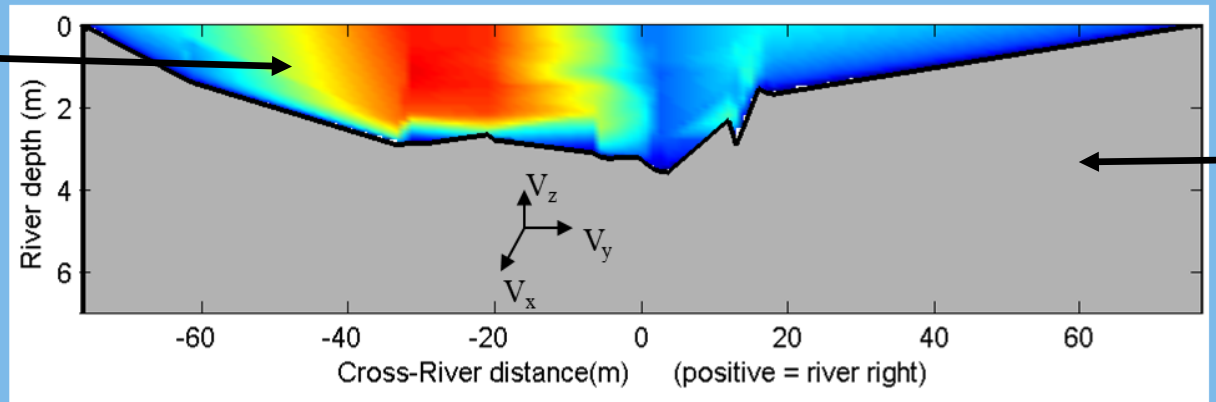
Flow Modeling



HEC-RAS 1D
1 to 10's km



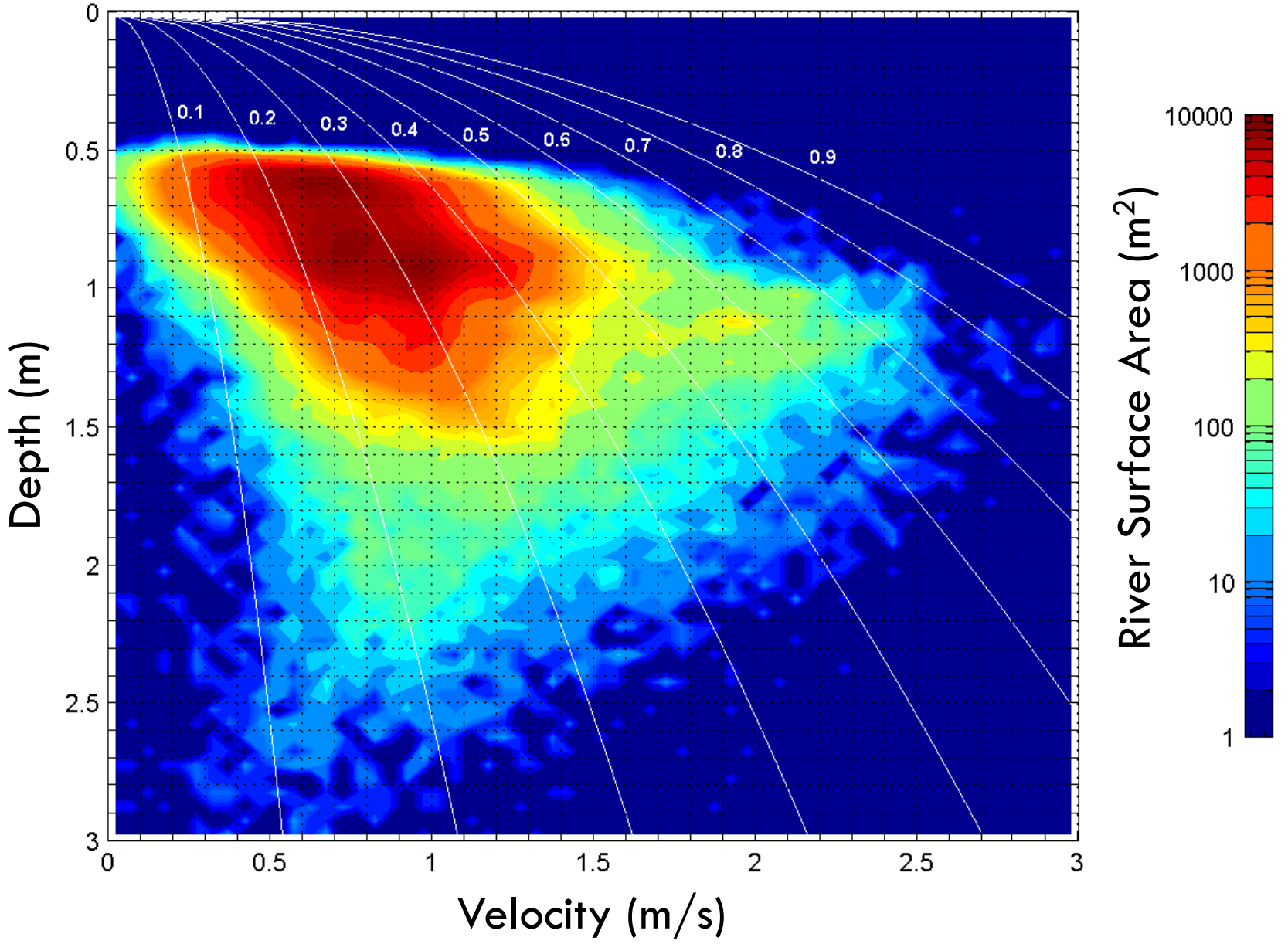
FLOW-2D
10 to 100's km



3D Flow Modeling
1 to 10 km

Assess River Habitat in Terms of Total Abundance

Depth-Velocity-Froude (F_r) Space (white lines)



F_r = Non Dimensional Energetic Indices

$$F_r = \frac{V}{\sqrt{gh}}$$

V = Velocity

h = depth

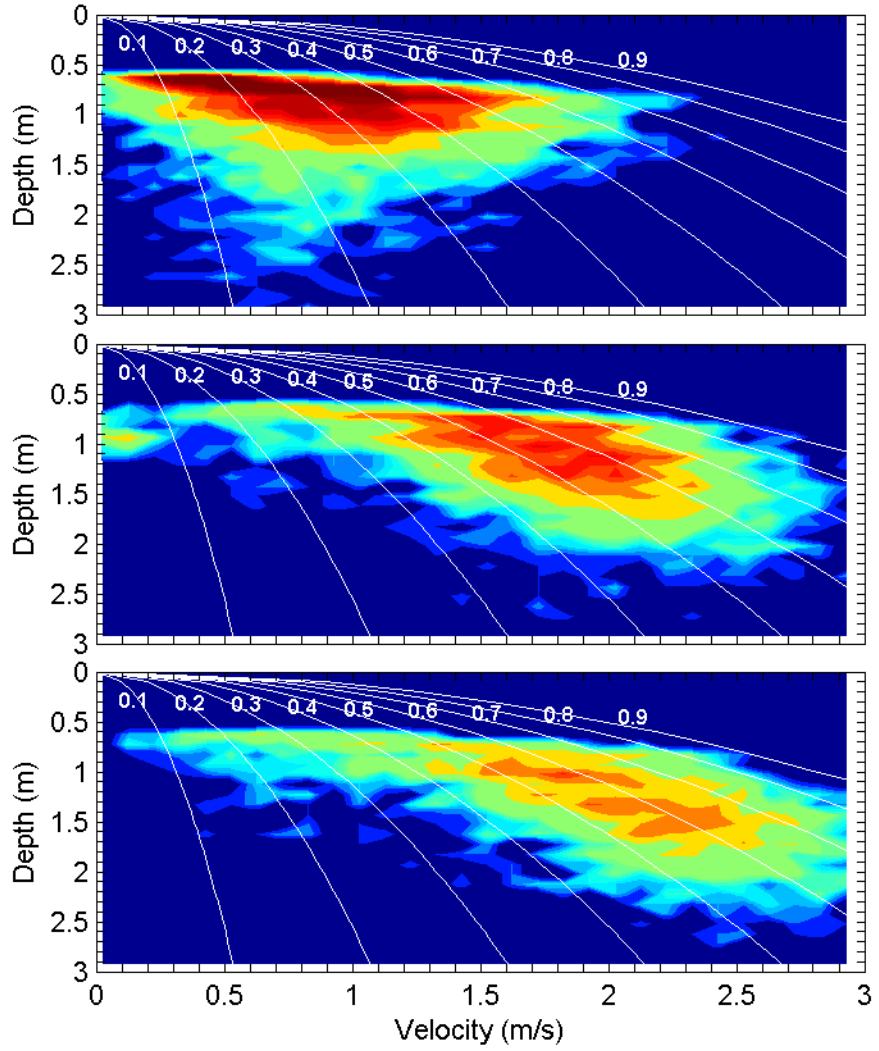
g = gravity constant (9.8 m/s^2)

Pools – Fr = 0.1 to 0.2

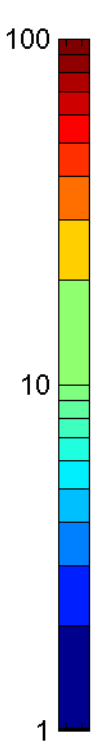
Runs – Fr = 0.3 to 0.7

Riffles and Rapids Fr = 0.7 to 0.9

Assess River Habitat in Terms of Total Abundance VS Discharge



Low Flow



$$F_r \equiv \frac{V}{\sqrt{gh}}$$

V = Velocity
h = depth

River Surface Area (m^2)

Flood Conditions

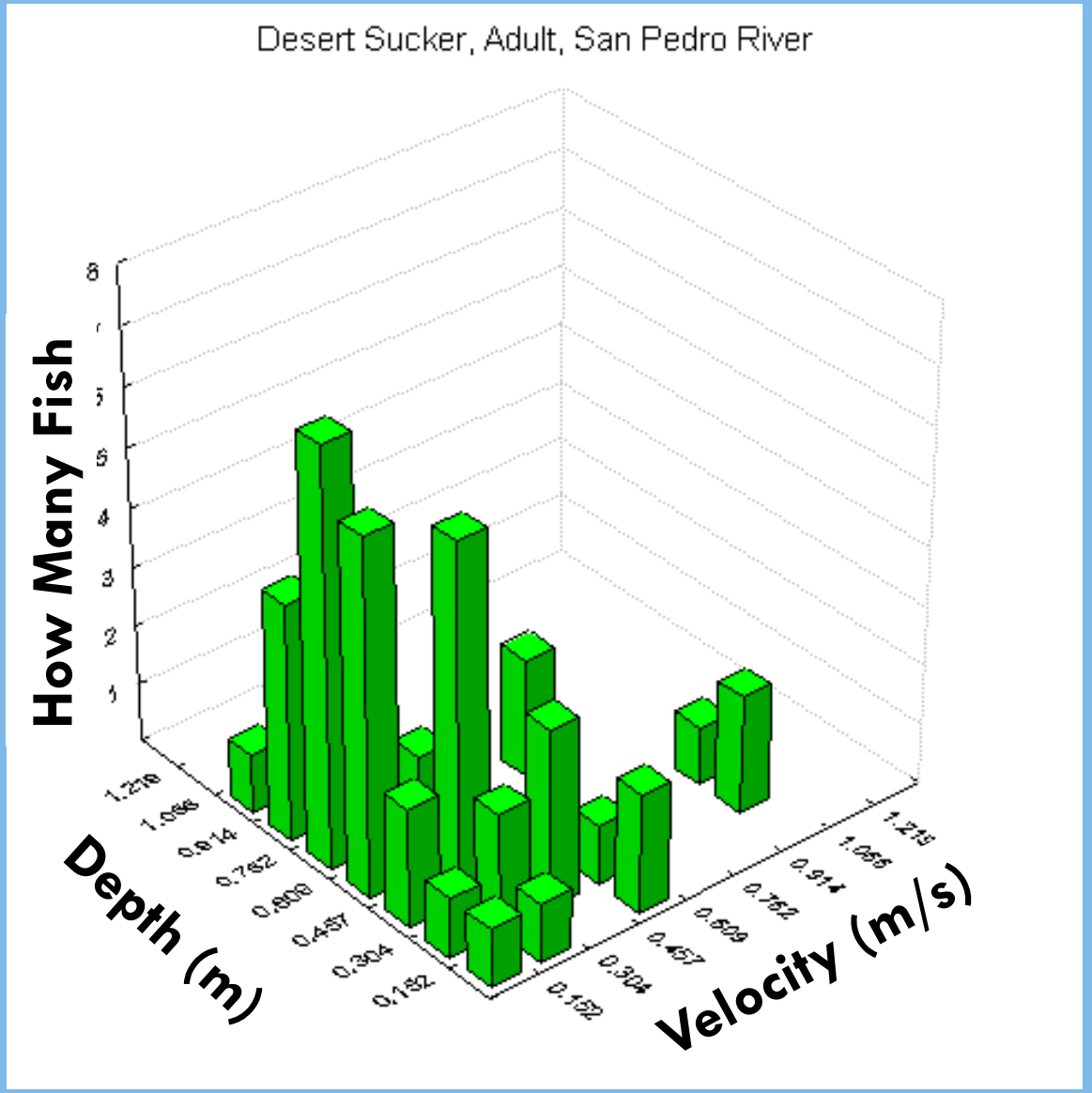
Pools – Fr = 0.1 to 0.2
Runs – Fr = 0.3 to 0.7
Riffles and Rapids Fr = 0.7 to 0.9

TWO IMPORTANT QUESTIONS UPON WHICH HABITAT CRITERIA ARE BASED

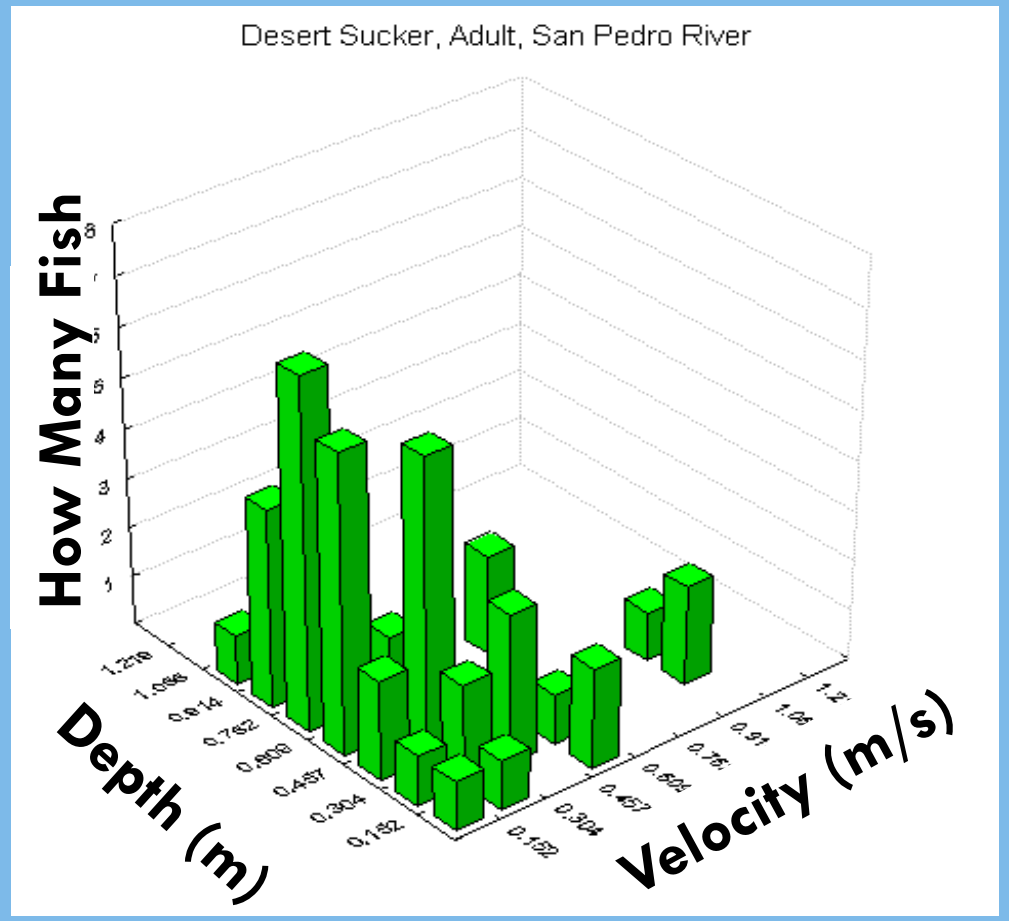
How many fish are there in a river?

What depths and velocities do they prefer?

HABITAT CRITERIA BASED ON DEPTH AND VELOCITY



HABITAT CRITERIA



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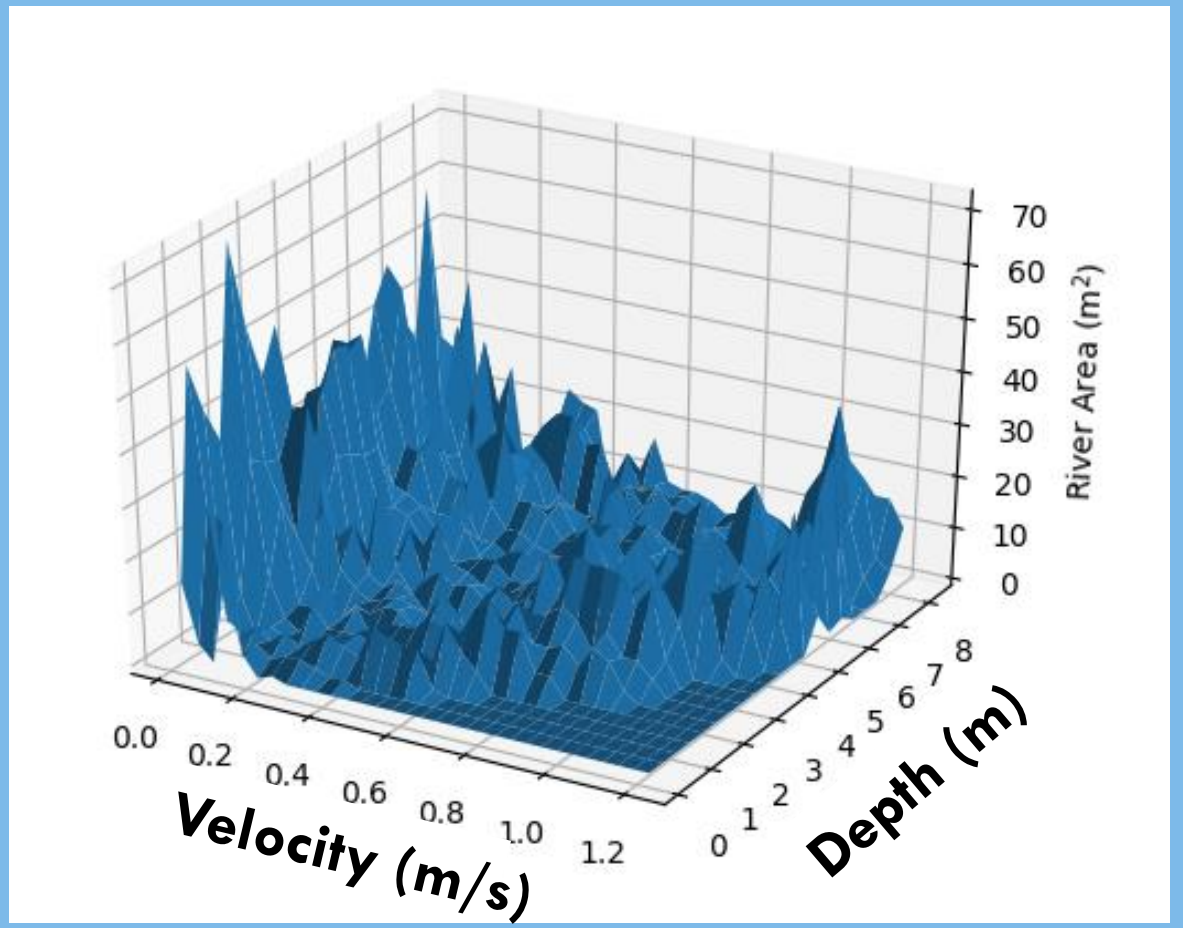
Abundance of Habitat
Depth - Velocity



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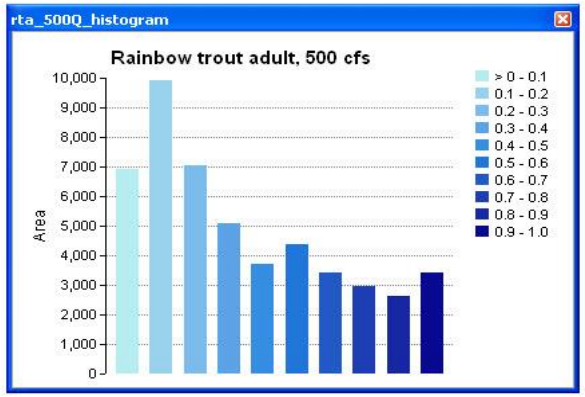
Potential Number of Fish an Environmental Flow could Support

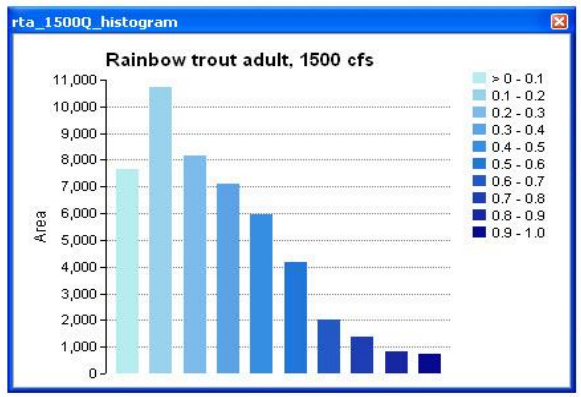
Use computer models and/or River Mapping results to determine abundance (graph inserts) and spatial distribution (maps) relative to changes in discharge.

Pair with maps of riparian vegetation, large wood, substrate, temperature, chemistry

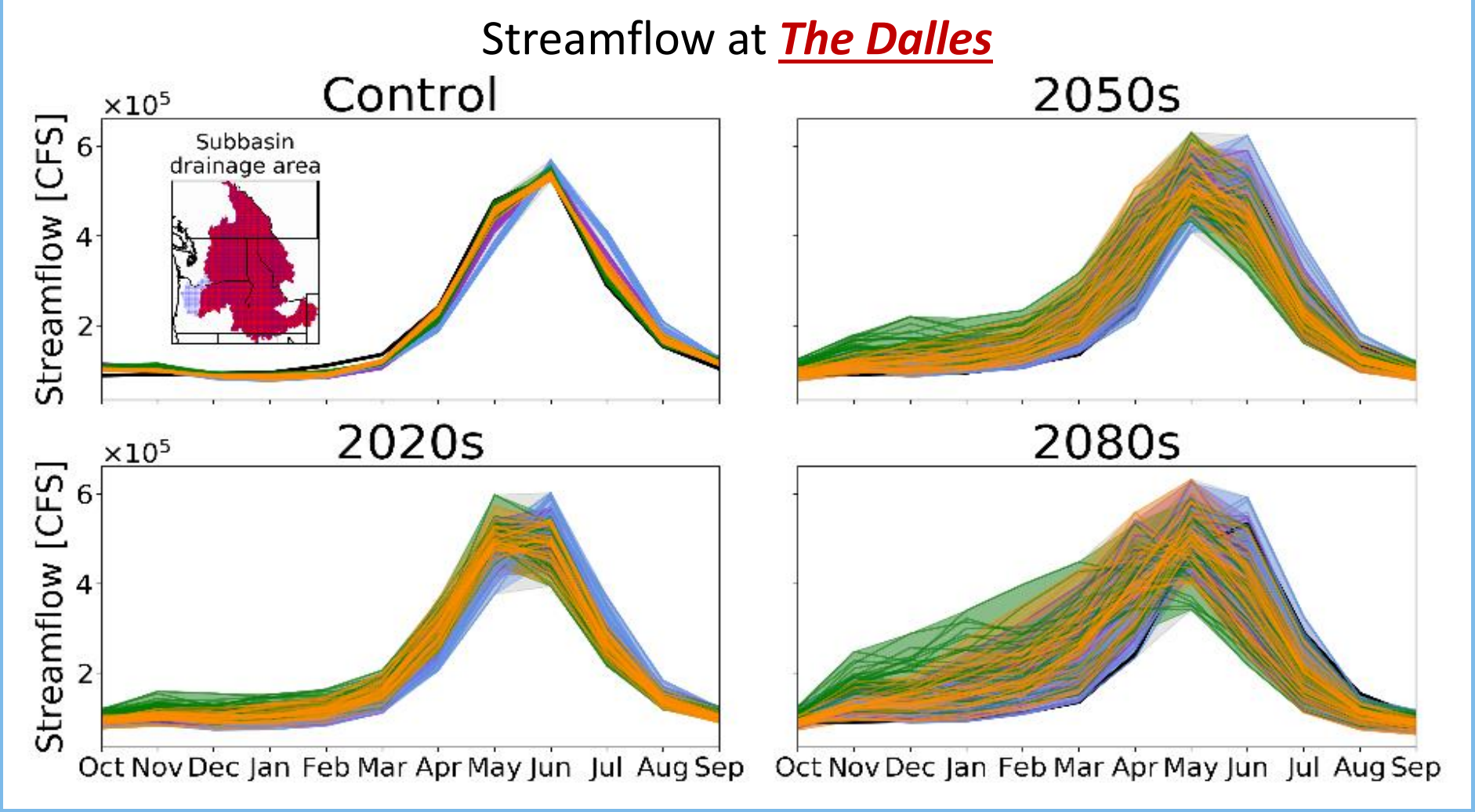
Rainbow Trout Habitat
@ 500 cfs



Rainbow Trout Habitat
@ 1500 cfs



Climate Change & Future River Flow



Courtesy Dr. Nijssen, University of Washington:

River Management Joint Operating Committee (RMJOC). (2018). Climate and Hydrology Datasets for RMJOC Long-Term Planning Studies, Second Edition: Part 1 - Hydroclimate Projections and Analyses. Retrieved from https://www.bpa.gov/p/Generation/Hydro/Pages/Climate-Change-FCRPS-Hydro.aspx

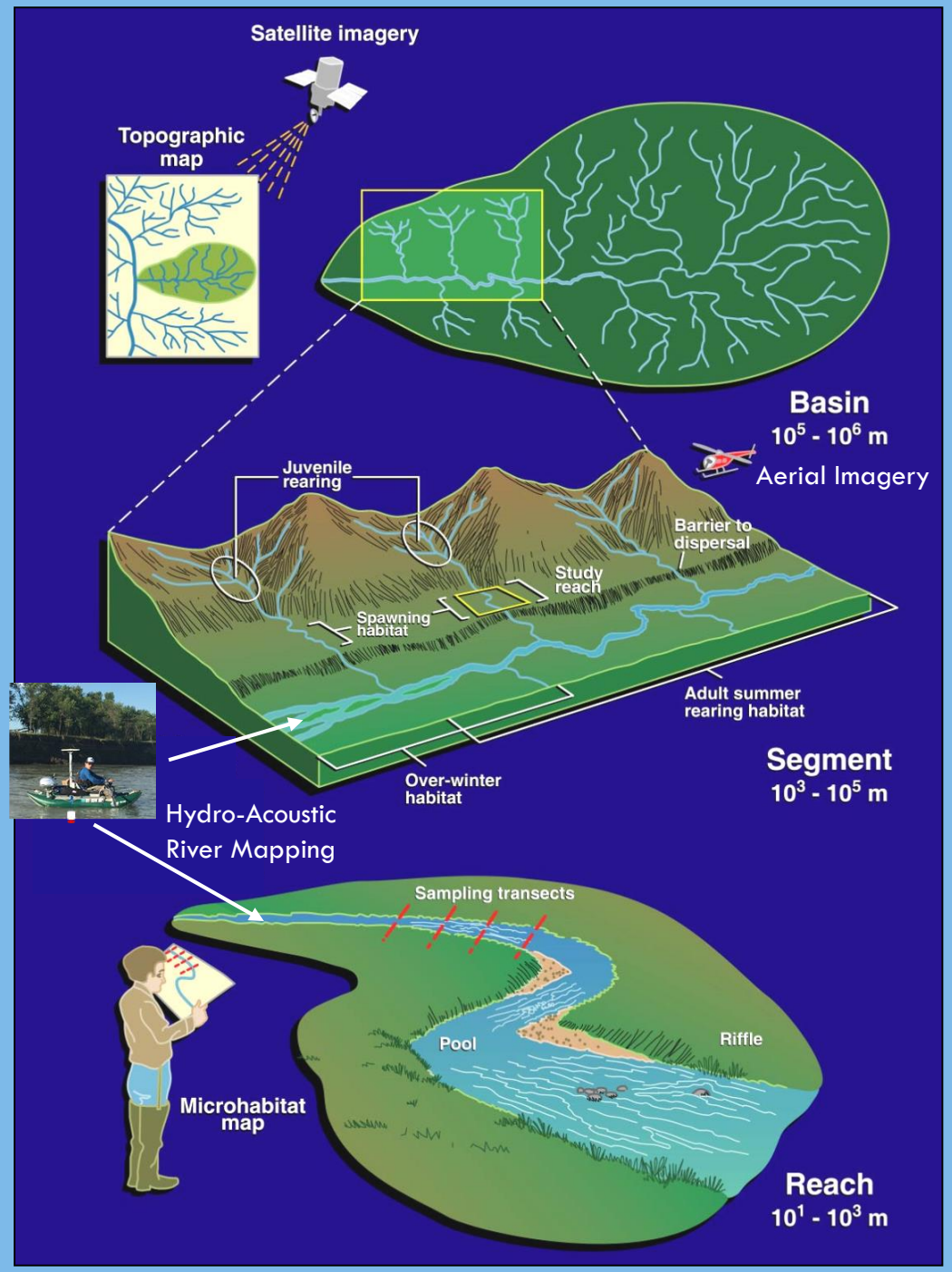
(Fausch, Torgersen, Baxter, and Li 2002)

"A CONTINUOUS VIEW OF THE RIVER IS NEEDED TO UNDERSTAND FISHES AND THEIR HABITAT"

1) Need to know the **TOTAL ABUNDANCE AND SPATIAL DISTRIBUTION** of **aquatic habitat** and how it changes with discharge.

2) The **metrics** of **Water Depth and flow Velocity** provide a **common "cash" currency** for quantifying aquatic habitat relative to proposed regulated environmental flow regimes.

3) Many different types of data need to be used.



What is important in determining how water management decisions are related to overall ecosystem health?

Important theoretical guidelines:

- ***Applying ecological theory to management practice.***
- ***Make water management decisions based on a continuous view of the river from headwaters to the sea.***
- ***Understand that rivers must flood and connect to their floodplains to maintain ecosystem function.***
- ***Understand that a wide mosaic of habitat supports the highest level of biodiversity and a constant shift in the habitat mosaic during floods is required to maintain ecosystem function.***

Important Applied guidelines:

- ***The metrics of water depth and flow velocity provide a common "cash" currency for quantifying aquatic habitat relative to proposed regulated environmental flow regimes.***
- ***Use empirical depth and velocity data over modeling when ever possible and do so at the same scale that the organisms use the river.***
- ***Often many different types of data need to be used to make decisions.***

Recognizing diverse cultural perspectives, is there a specific insight that could contribute to water use and water management?

- ***We must understand and recognize how western immigrants captured a river to harness the economic fortune at the expense of the river, the biota who need the river and the native people and their culture who depend and define their origin stories and existence based on the river and the salmon.***
- ***We must acknowledge and recognize that the distribution of wealth made from capturing the river needs to be equitably shared with all people in the Columbia River basin.***

Are there upcoming opportunities or policy windows for improved integration?

- ***Yes, the current renegotiation of the Columbia River Treaty is an opportunity.***
- ***It must include ecosystem function as a co-equal goal to hydropower and flood control.***
- ***Both US Tribes and Canadian First Nation people must be at the negotiation table.***