Incorporating Ecological Theory into Stream Restoration Practices

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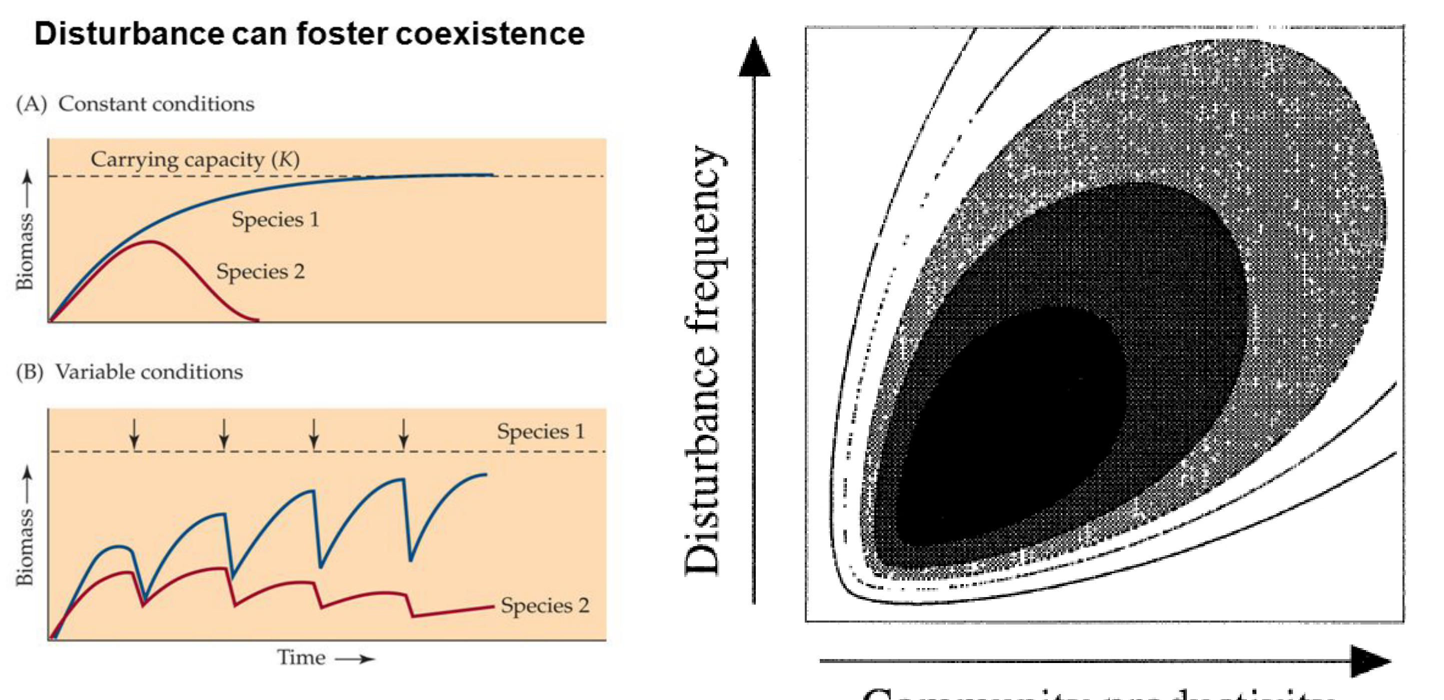
What is Ecological Theory?

- Natural Selection
  - Species and Individuals compete with each other
  - There is natural genetic variation within a population
  - Most individuals die before reproducing
  - Individuals with genetics best suited for current environmental conditions will survive
  - The characteristics, behavior and genetics of species changes as natural selective pressures change
- Non-equilibrium conditions allow more species to co-exist
  - Environmental variation and the coexistence of species
  - Disturbance and the coexistence of species
  - Intermediate Disturbance Hypothesis
  - Dynamic Equilibrium Model of species coexistence
  - Principle of Competitive Exclusion / L-V equations (stability = fewer species)

Dynamic Equilibrium Model: Disturbance and productivity primary drivers of species diversity



(2014), Fig. 19.12, after Huston (1979) *The American Naturalist*

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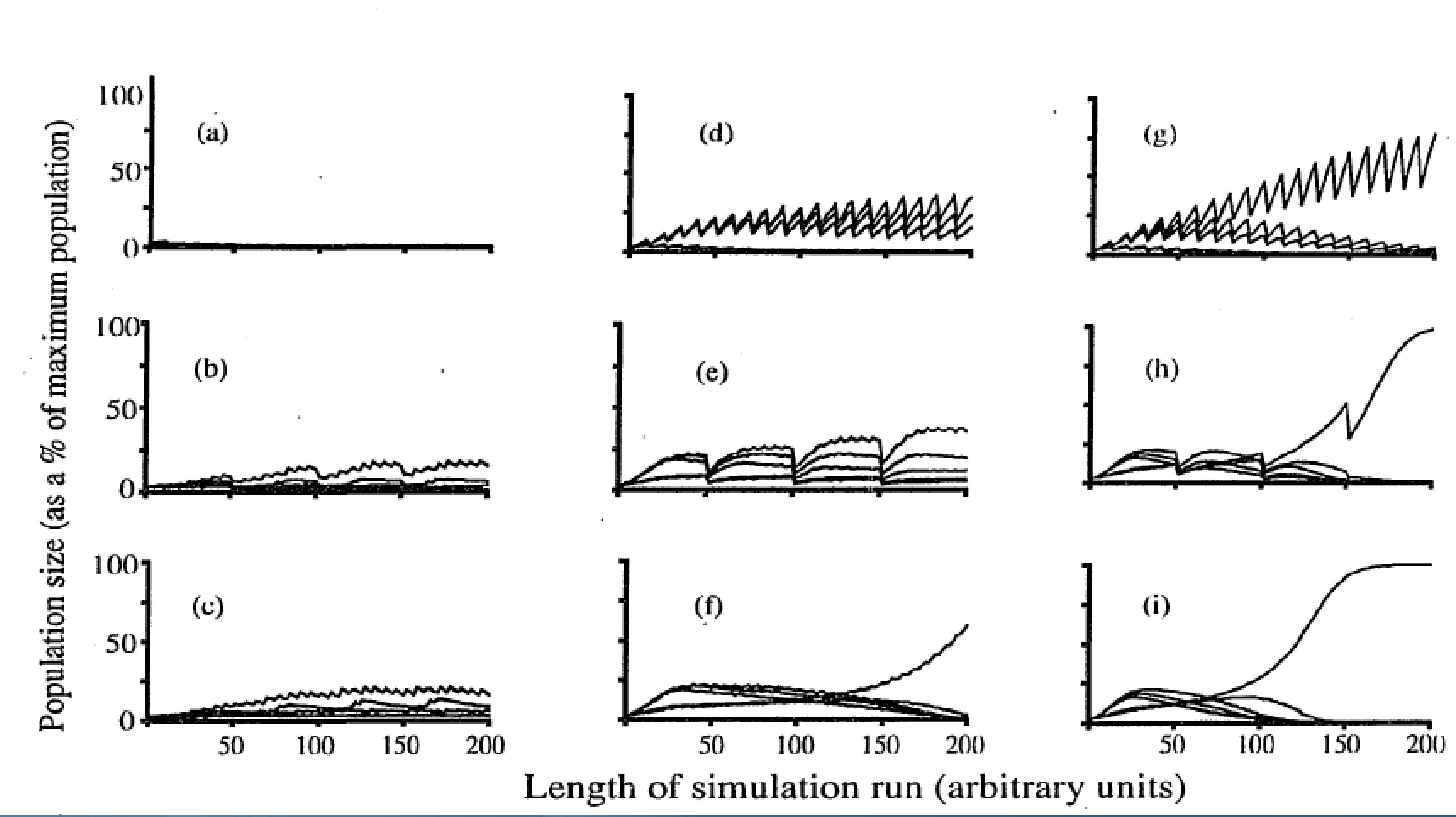
Species diversity is maximized at intermediate levels of disturbance and environmental fluctuations



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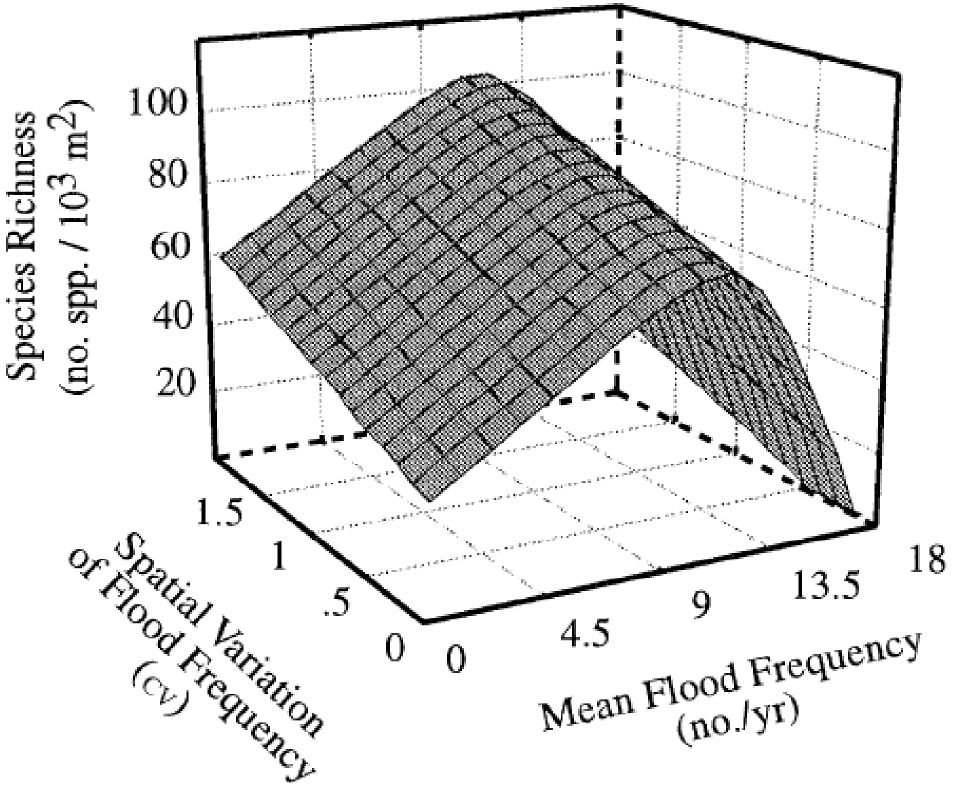


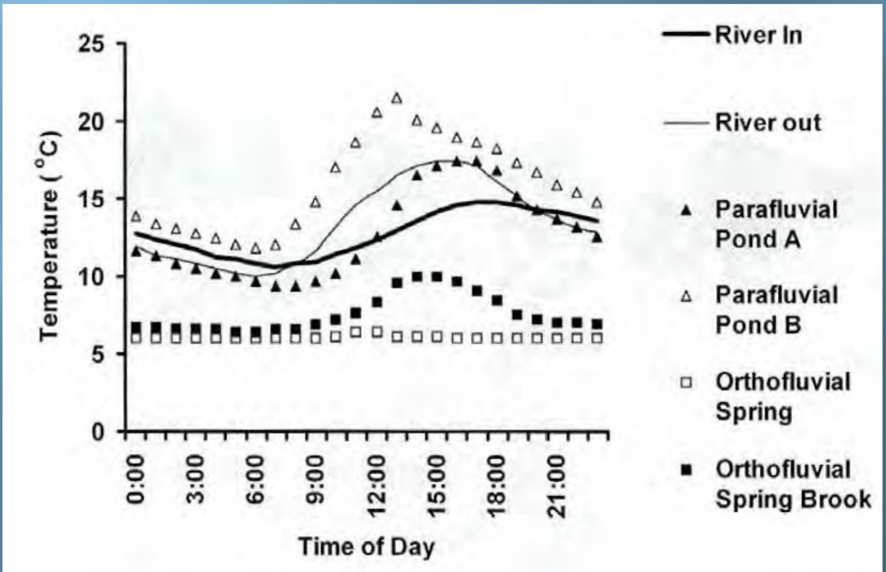
Empirical evidence consistent with models-intermediate disturbance and EV = high diversity

Beaver ponds-spatially variable, frequently disturbed = high diversity

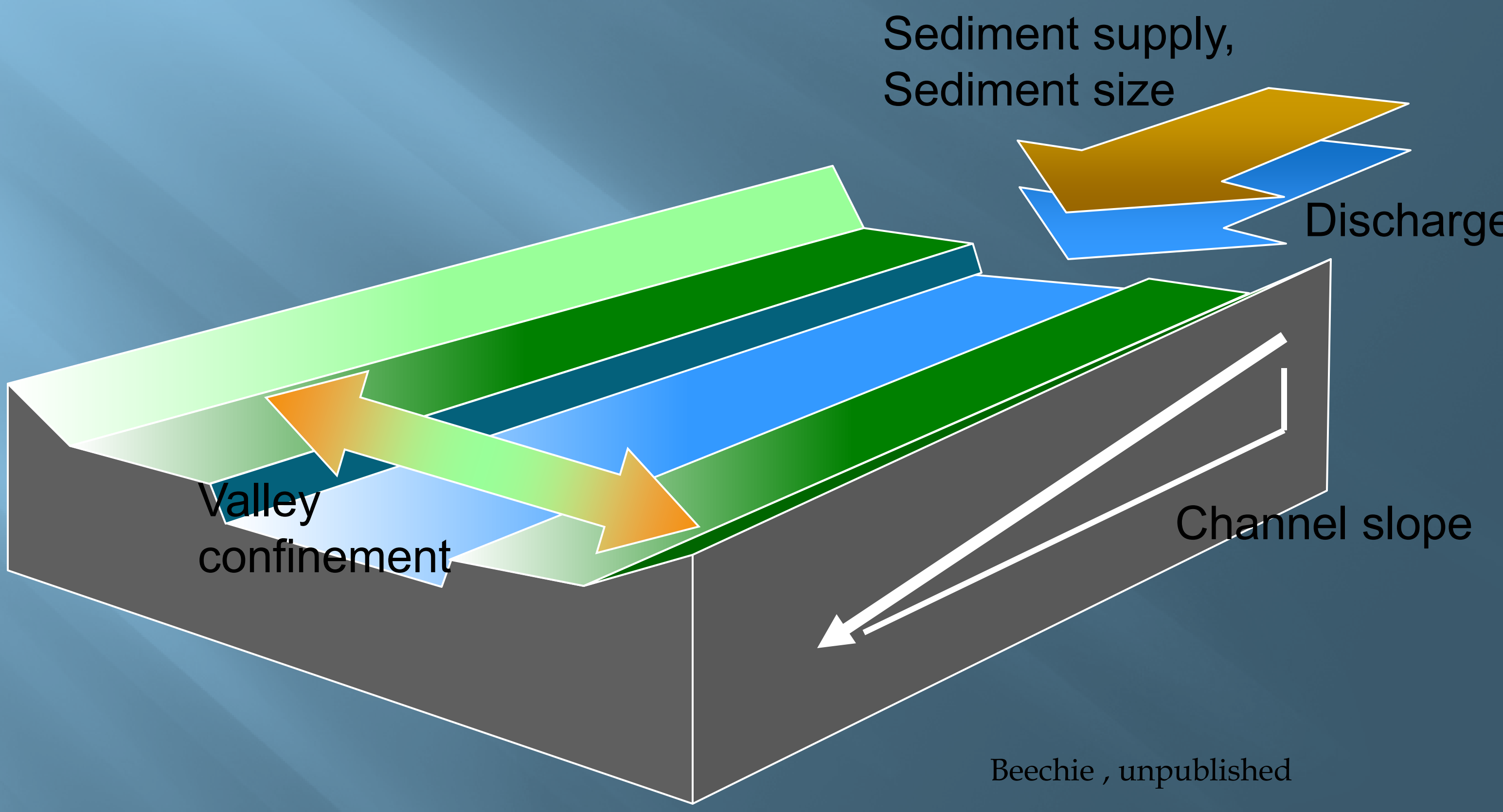
Meanwhile, back at the ranch…

Shifting habitat mosaic

The elements that define riverine habitats tend to persist in natural river systems (and are constrained or eliminated by human alteration), and that the distribution of the habitat patches (mosaics) changes spatially over time due to primary drivers, particularly flooding, channel avulsion, cut and fill alluviation (erosion and deposition of fine and coarse sediments), deposition of wood recruitment and regeneration of riparian vegetation. Stanford et al. 2005.



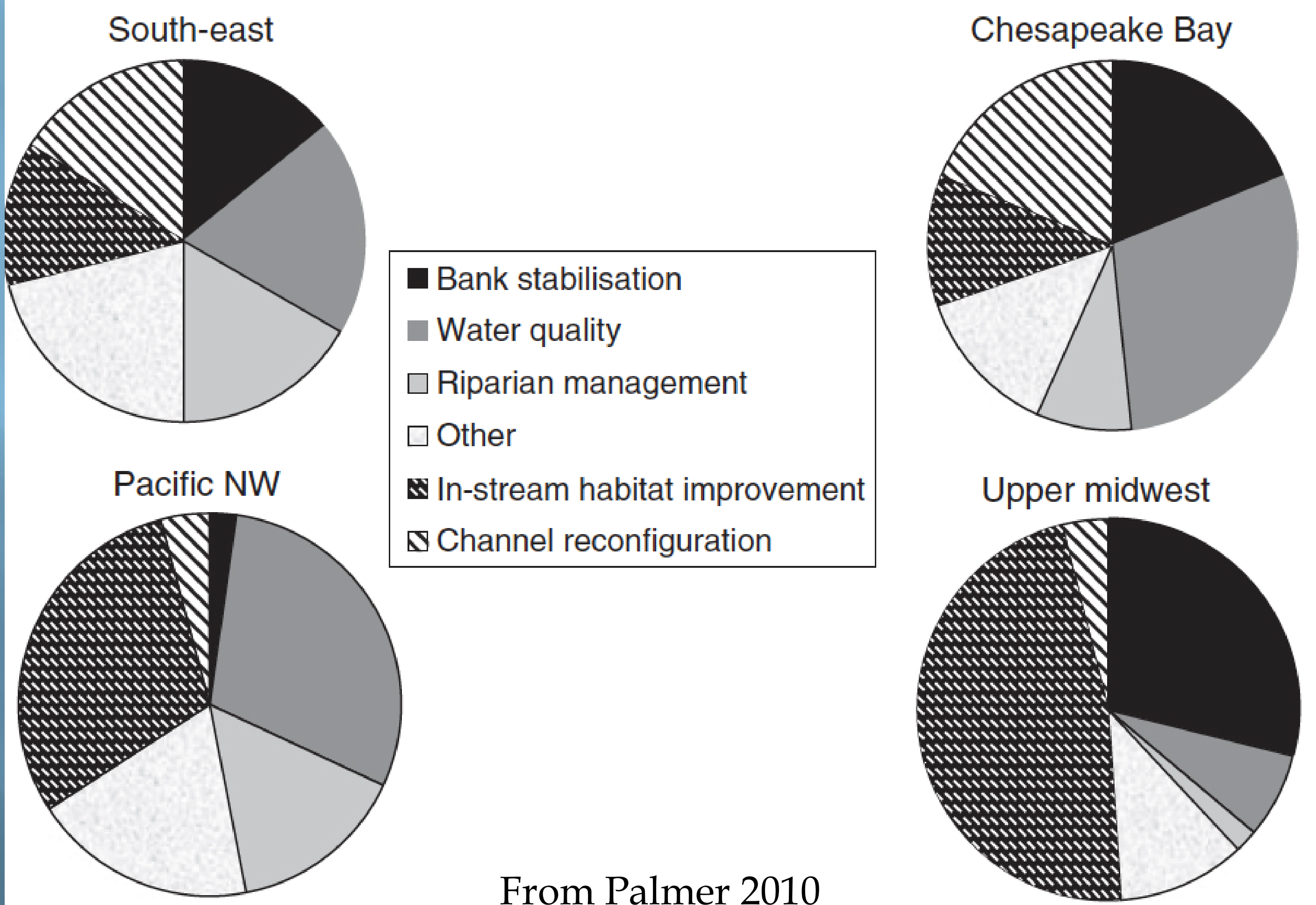
Factors Controlling Channel Formation



Beechie , unpublished

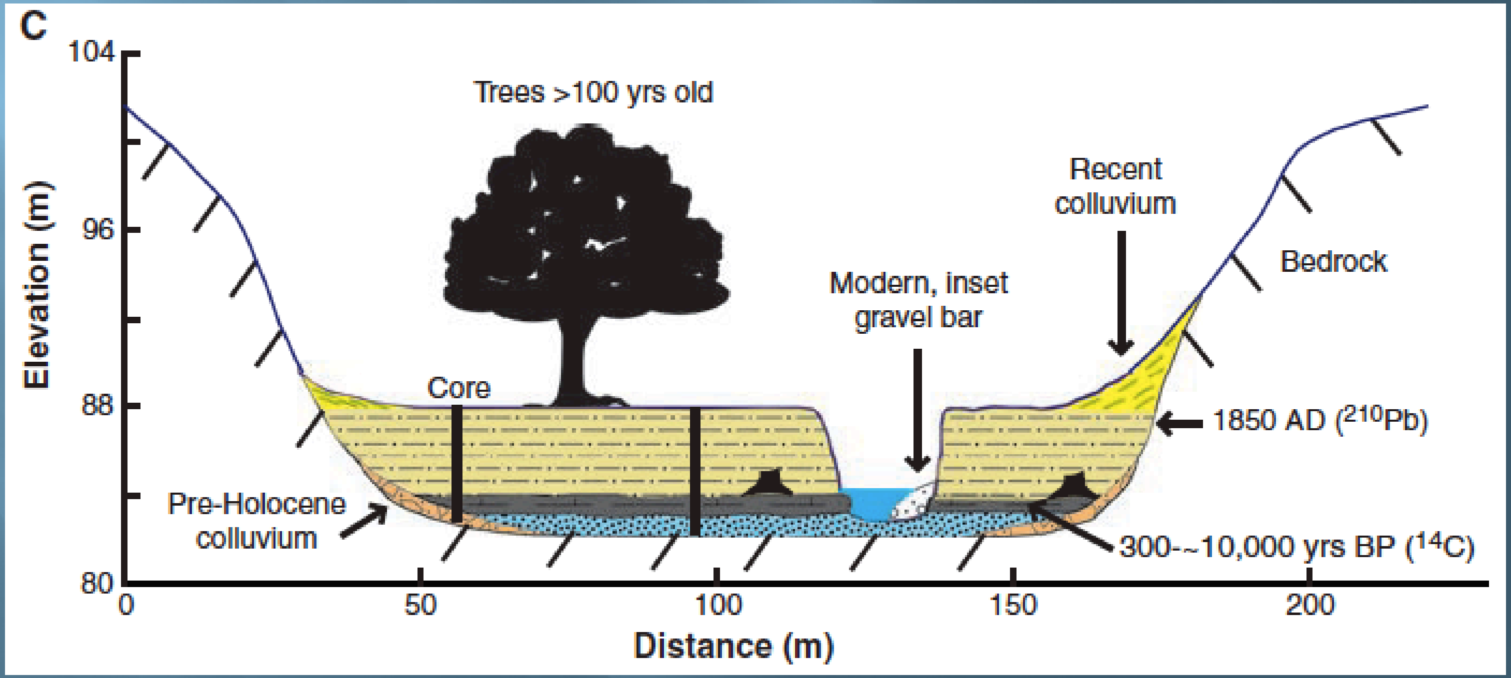
Meanwhile, back at the ranch…

Restoration consisted mostly of bank stabilization, instream habitat improvement and channel reconfiguration (2010)



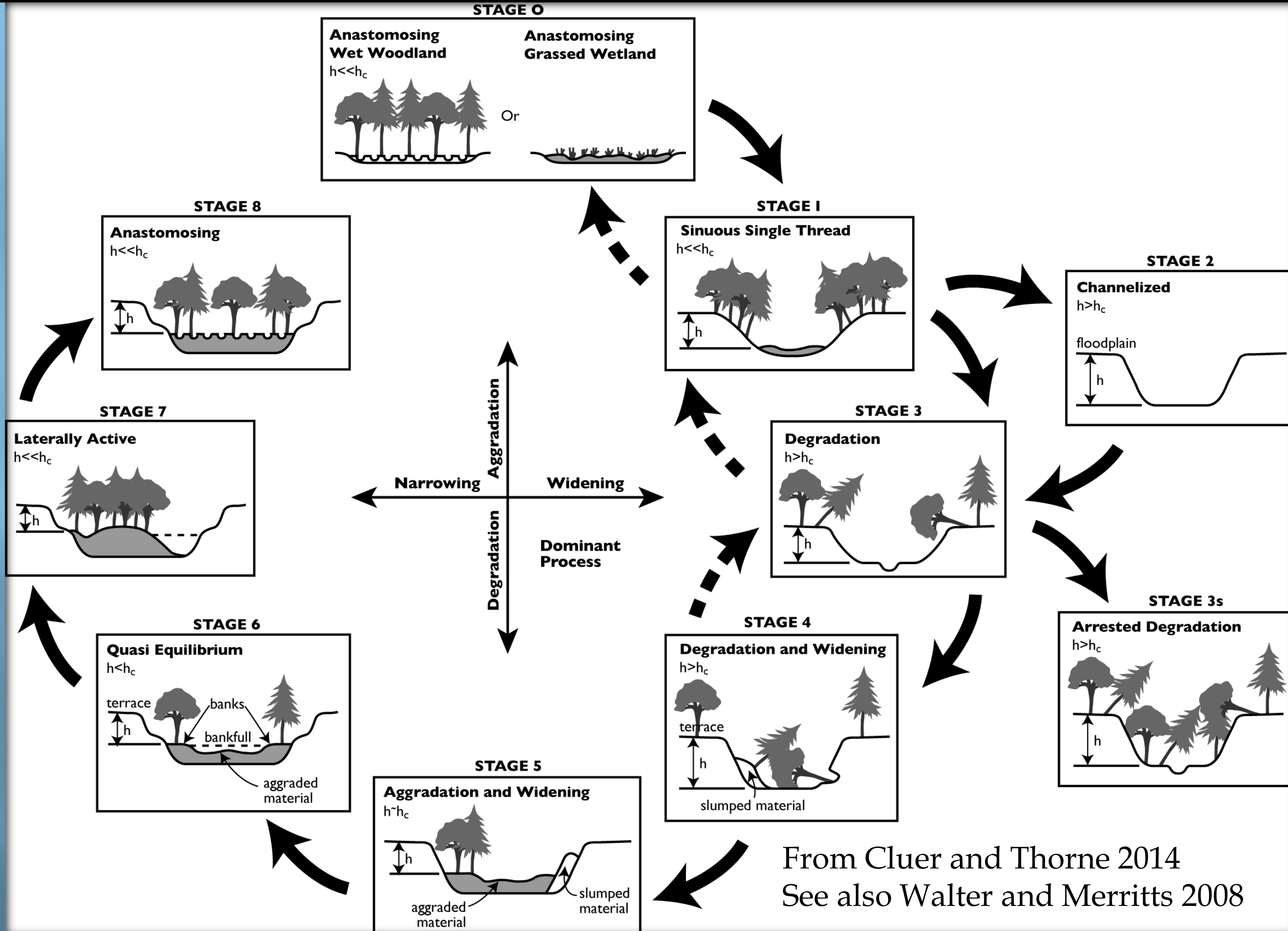
From Palmer 2010

"Gravel-bedded streams are thought to have a characteristic meandering form bordered by a self-formed, fine-grained floodplain. This ideal guides a multibillion-dollar stream restoration industry. We have mapped and dated many of the deposits along mid-Atlantic streams that formed the basis for this widely accepted model. These data, as well as historical maps and records, show instead that before European settlement, the streams were small anabranching channels within extensive vegetated wetlands that accumulated little sediment but stored substantial organic carbon."-Walter and Merritts 2008.



Meanwhile, back at the ranch…

The Stage Zero Channel as a Recovery Goal



From Cluer and Thorne 2014
See also Walter and Merritts 2008

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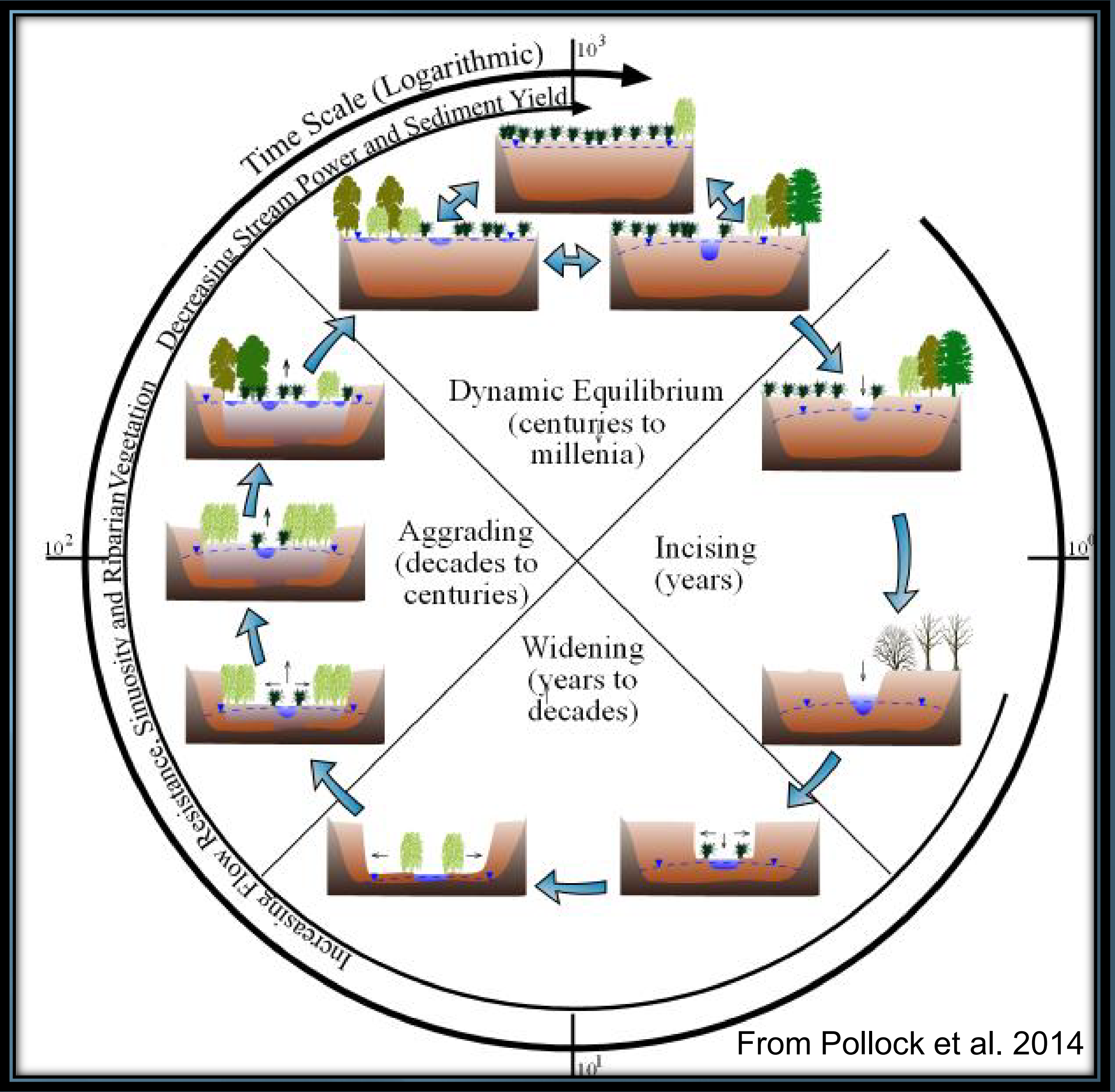
Stream Evolution Models add vertical component

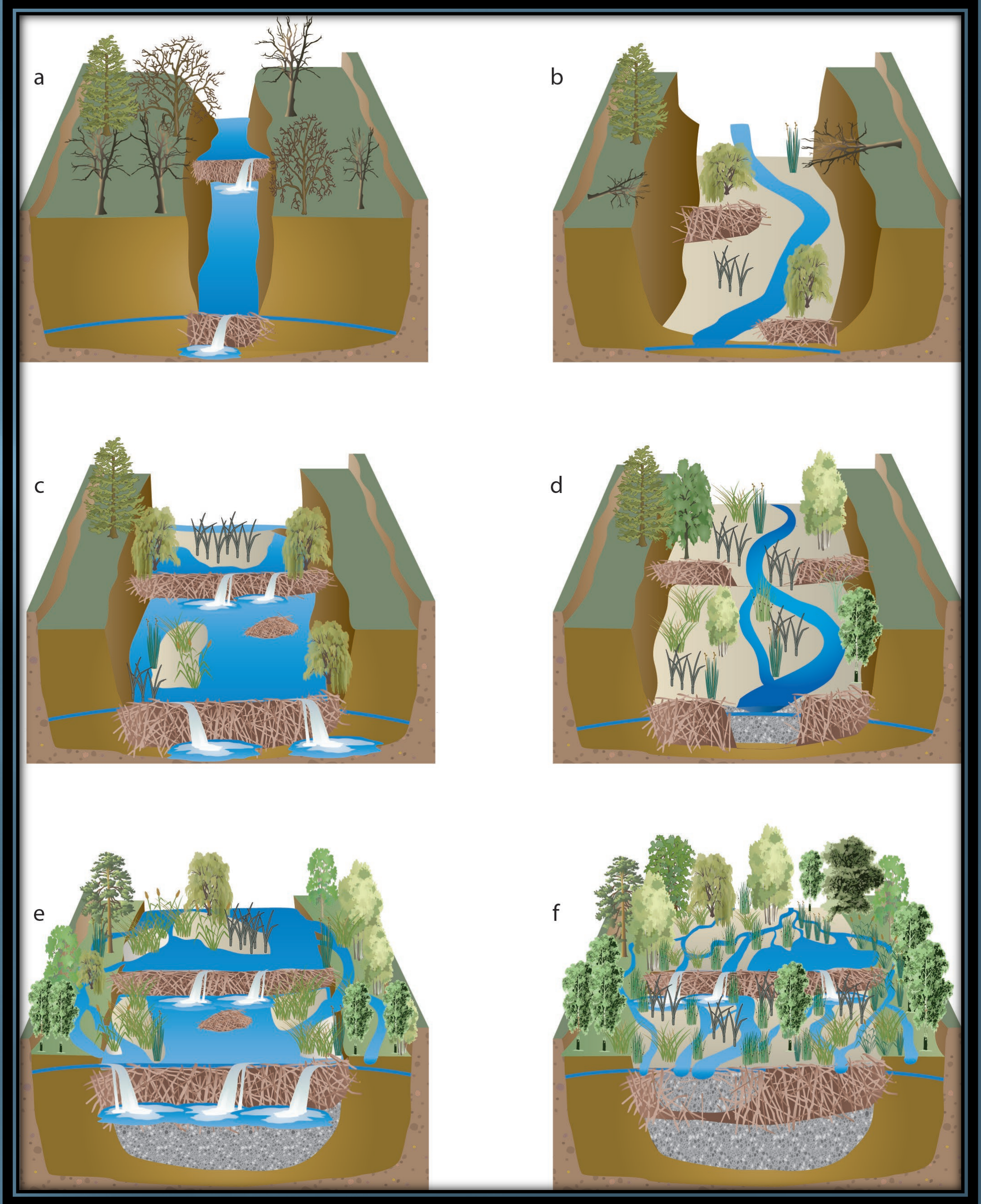


From Pollock et al. 2014

Beaver

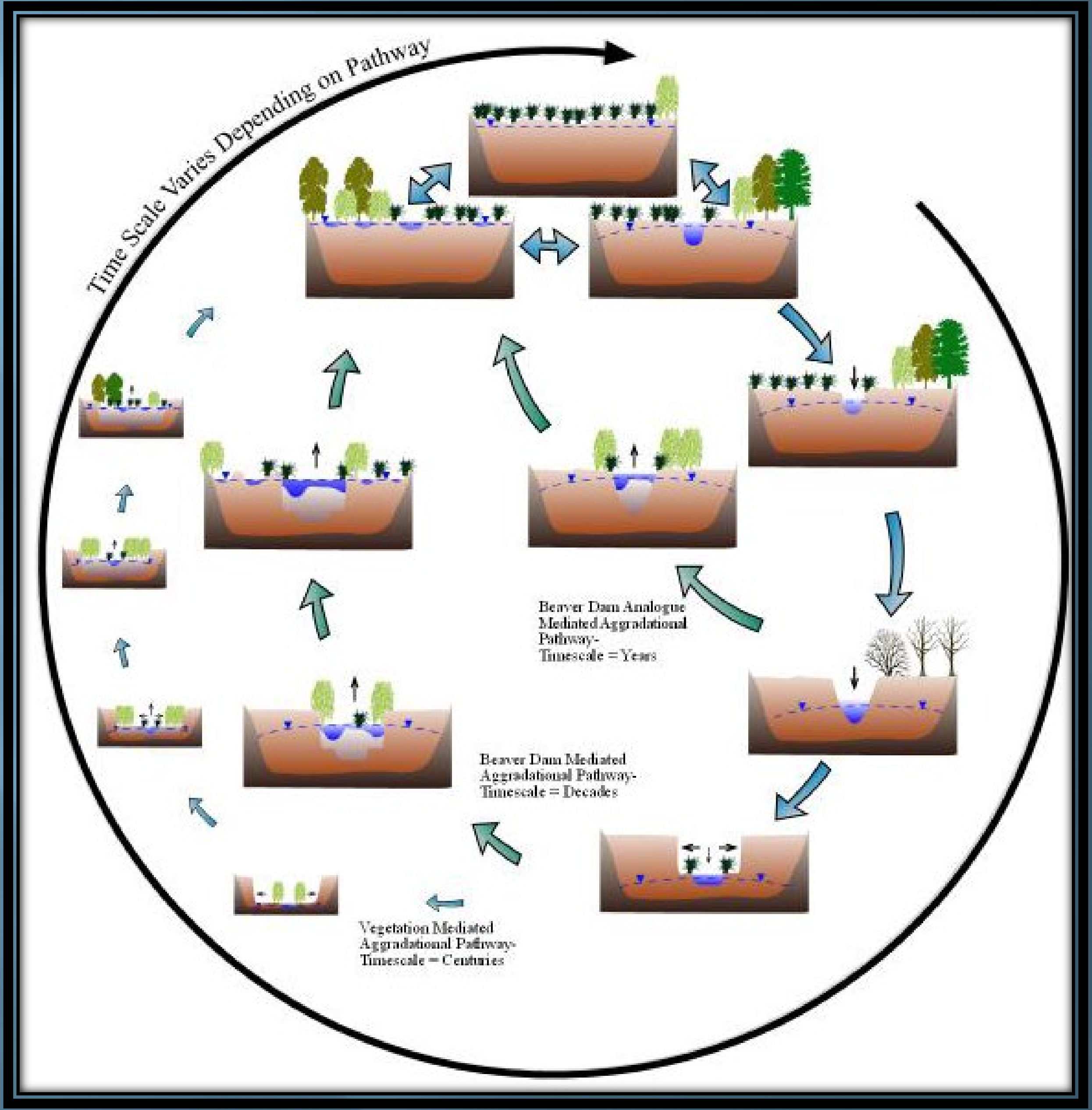
Create a three-dimensional shifting mosaic,

a structurally complex, biologically diverse habitat



From Pollock et al. 2014

Dams Can Substantially Accelerate Recovery



Meanwhile, back at the ranch…

Priniciple of Fluvial Geomorphology

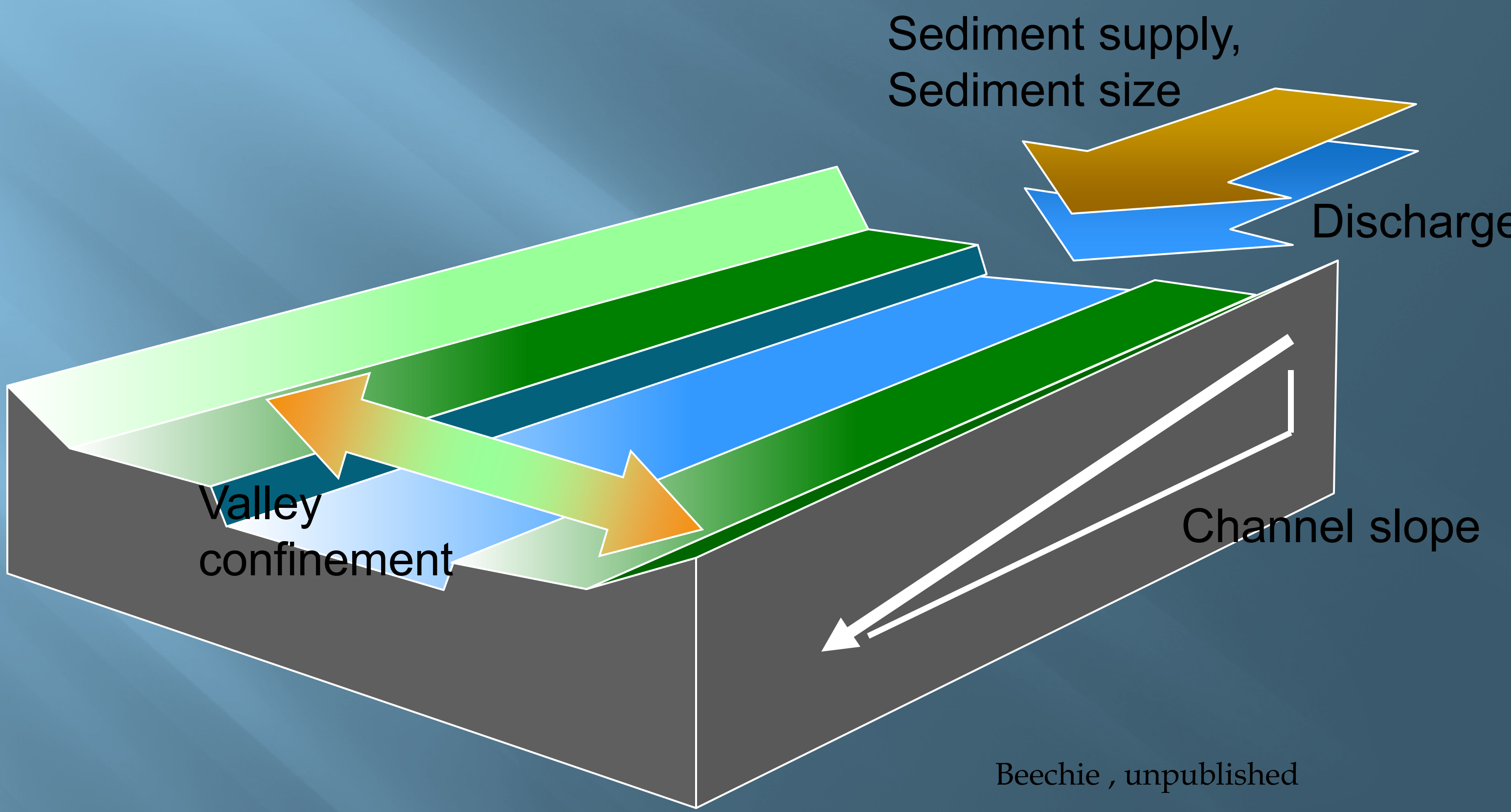
The concept of channel form equilibrium:

- that a river channel's form is self-adjusting to the prevailing watershed conditions that control the amount of sediment and water delivered to the channel and
- that the dominant or effective discharge controls the size and shape of the channel and that
- this discharge corresponds to bankfull discharge (the point at which flow leaves a channel and spreads out over the floodplain) and that such discharge occurs about 2 out of every 3 years.
- That the channel is stable (sediment inputs = sediment outputs)

Adding Life To Fluvial Geomorphology

- Dynamism is essential for biological diversity (disturbance, environmental variation, shifting mosaic, habitat complexity)
- Stochastic outcomes (probability-based, not deterministic)
- Natural selective pressures-
  - Most individuals die before reproducing
  - Natural variation occurs-those adapted to the existing conditions survive and reproduce
  - Species evolve (Life history strategies and behaviors change over time)
- Focus on net long-term benefit to species and habitat, less concerned with short-term impacts or benefits (i.e. effects on individuals within a population)
- Explicitly recognizes the interactions between biological and physical processes in the restoration process

Factors Controlling Channel Formation



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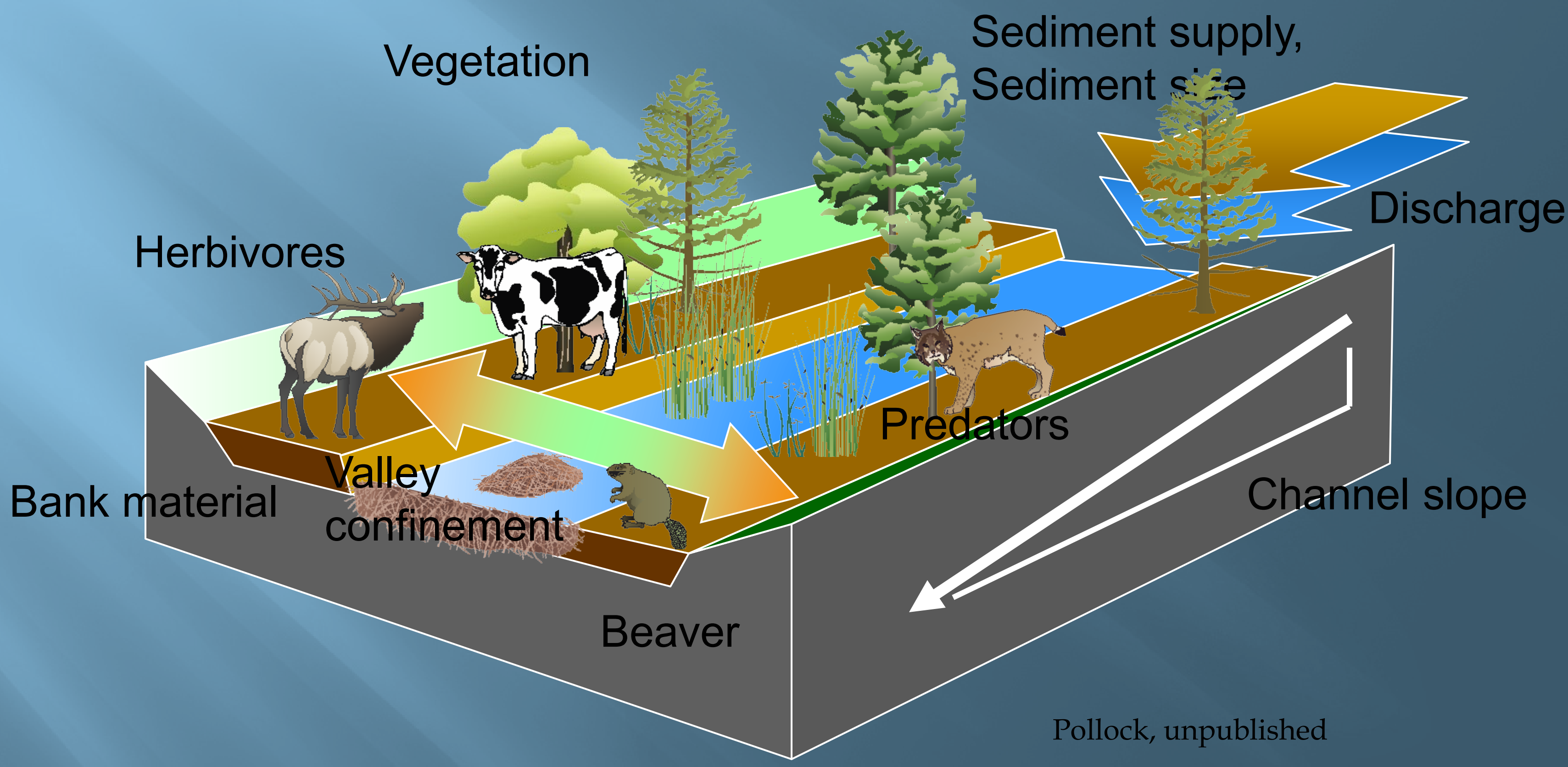
Factors Controlling Channel Formation



Pollock, unpublished

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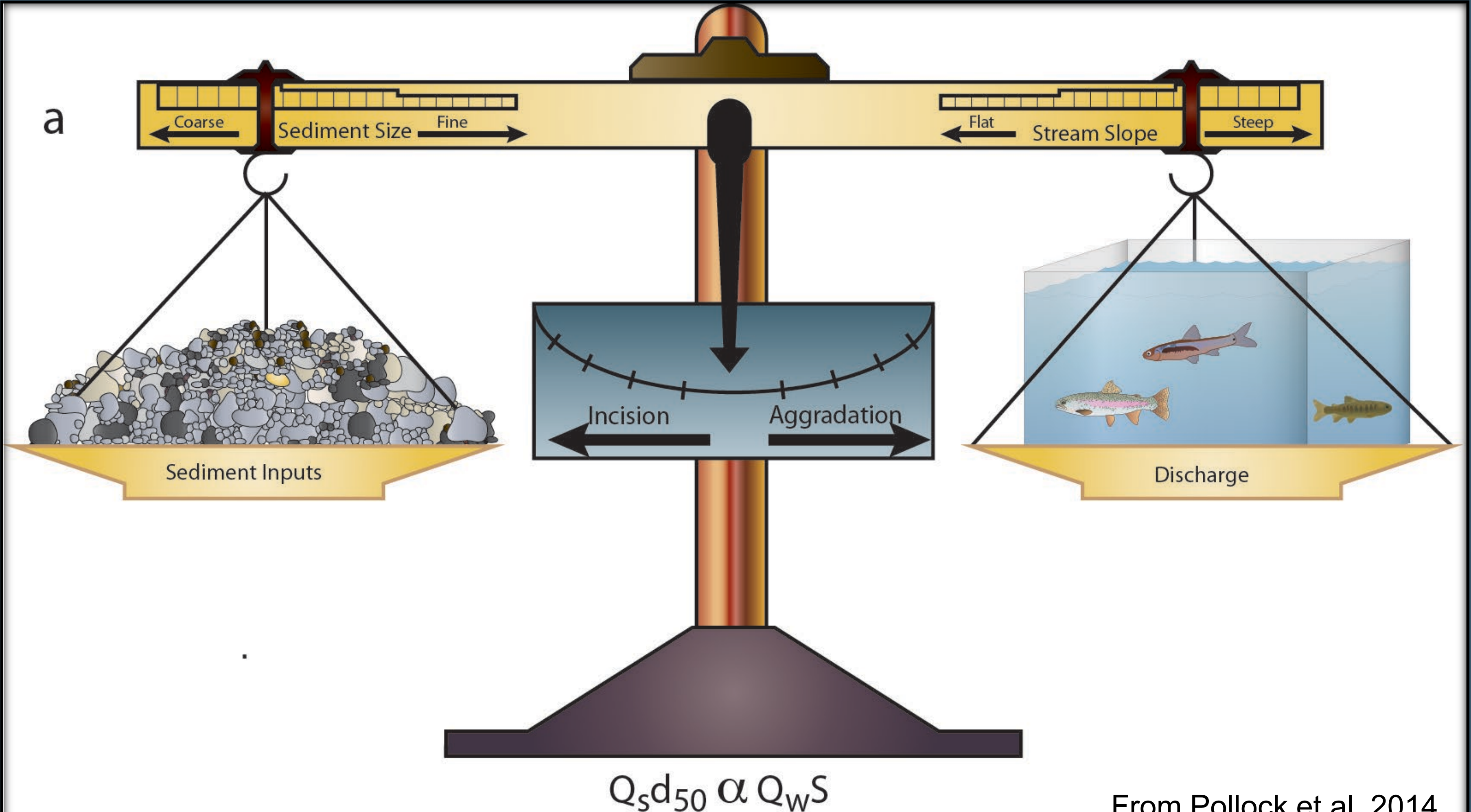
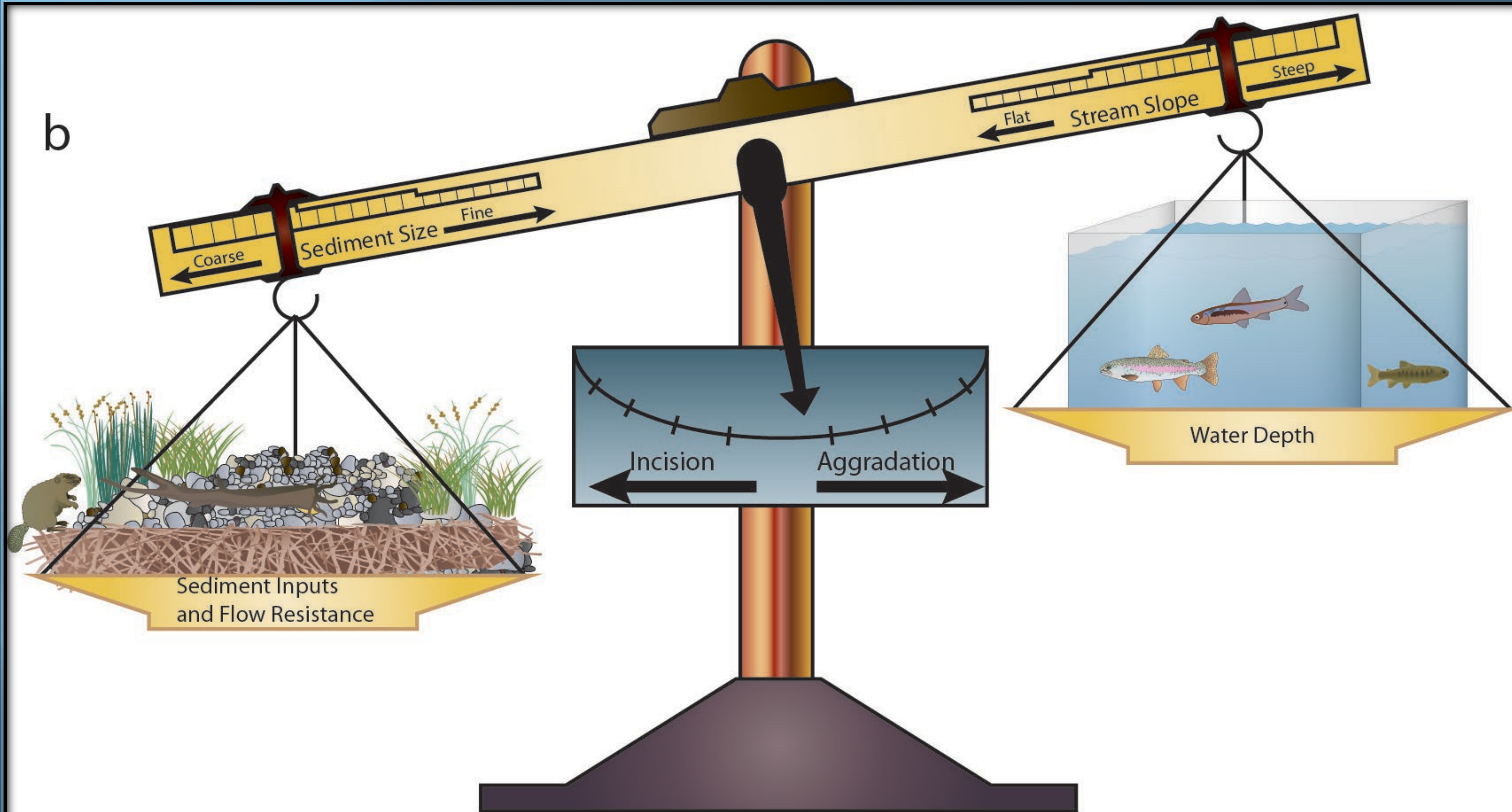
How Does Life Build Stream Habitat?



From Pollock et al. 2014

By Increasing Flow Resistance



$$nQ_sd_{50} \alpha D_wS$$

From Pollock et al. 2014

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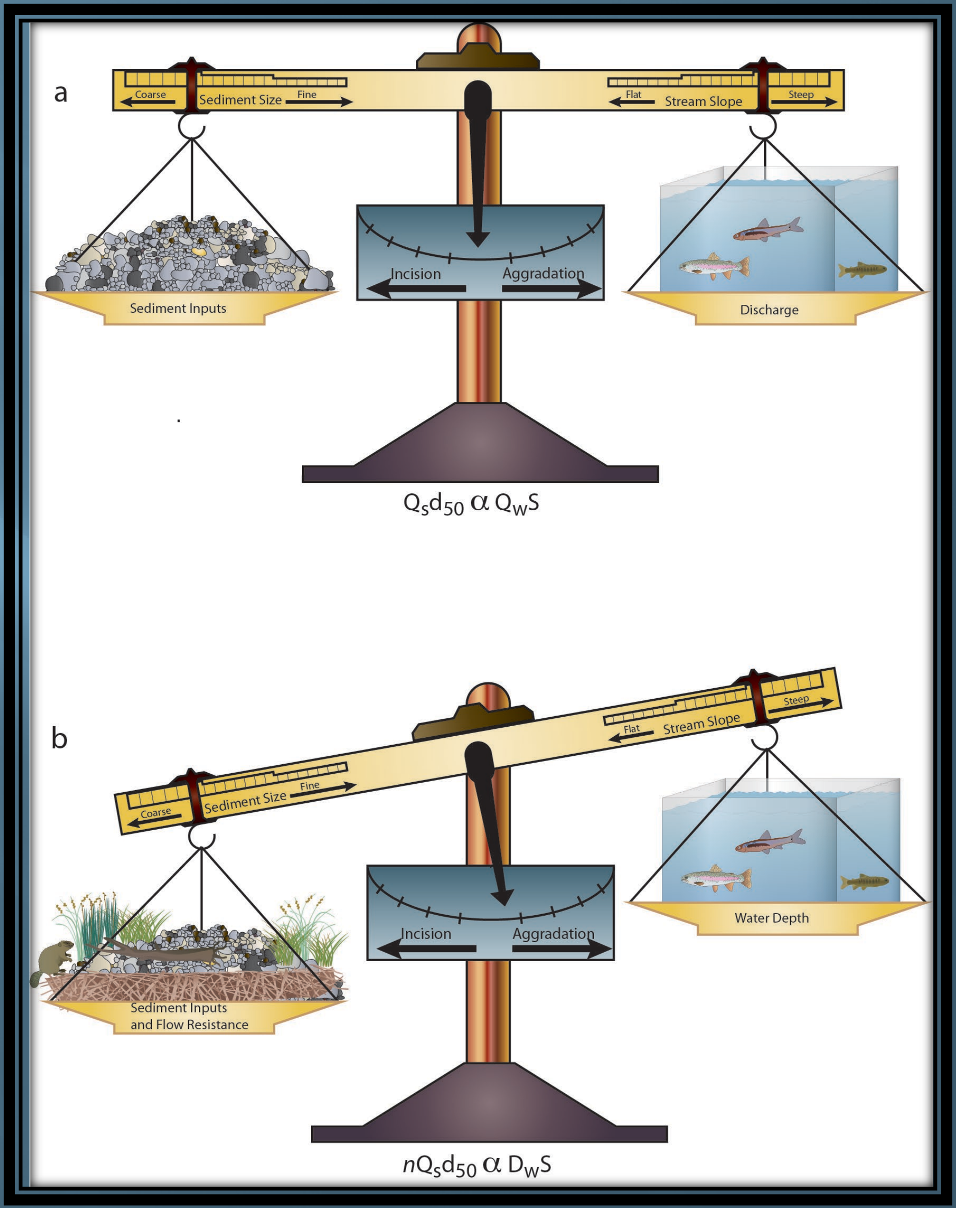
Continuity of Sediment Transport or Habitat formation?



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Obstructions that Cause Deposition

- **Beaver Dams**
- **Live Vegetation**
- **Large Wood**
- **Landslides**
- **Alluvial Fans**
- **Sea Level Rise**
- **Tectonics**

Increasing Time Scales

Key Functions:

- **Increase flow resistance,**
- **Lower slope**
- **Reduce stream power/unit width**

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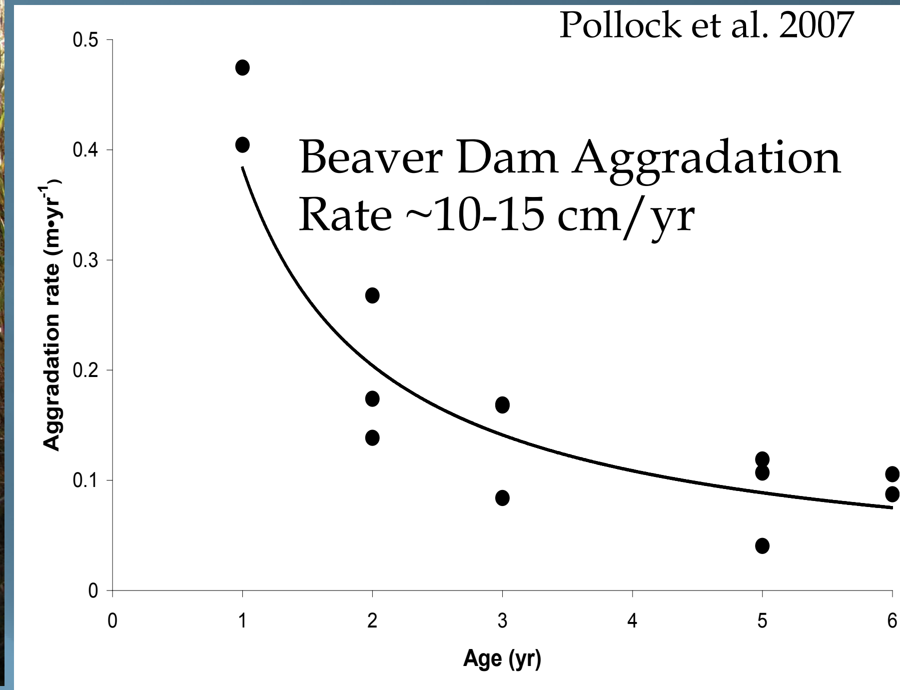
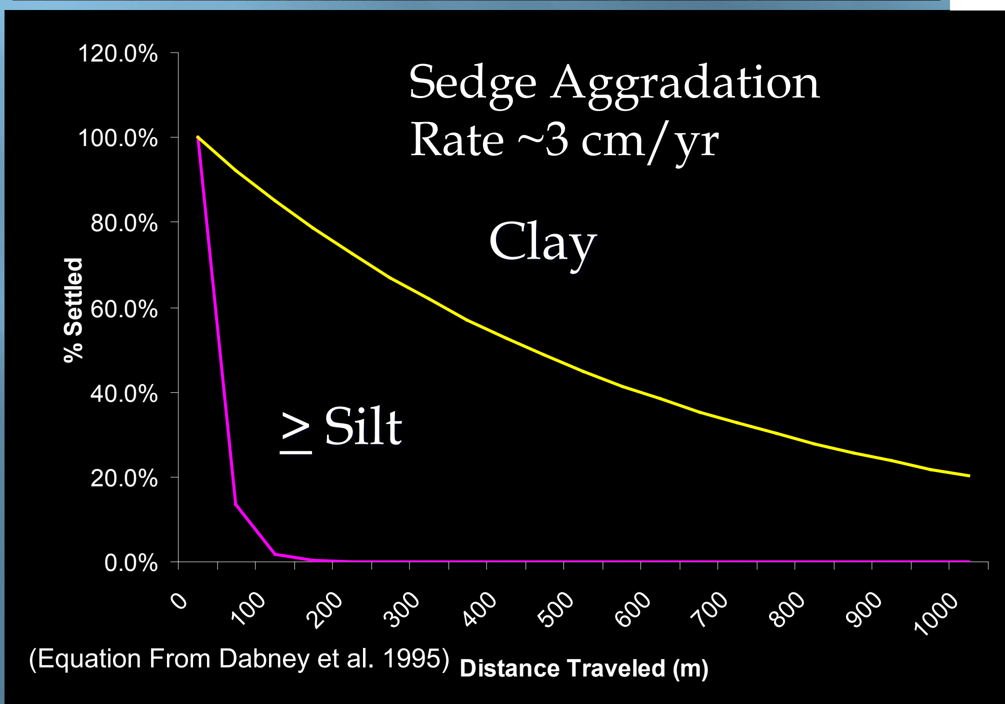
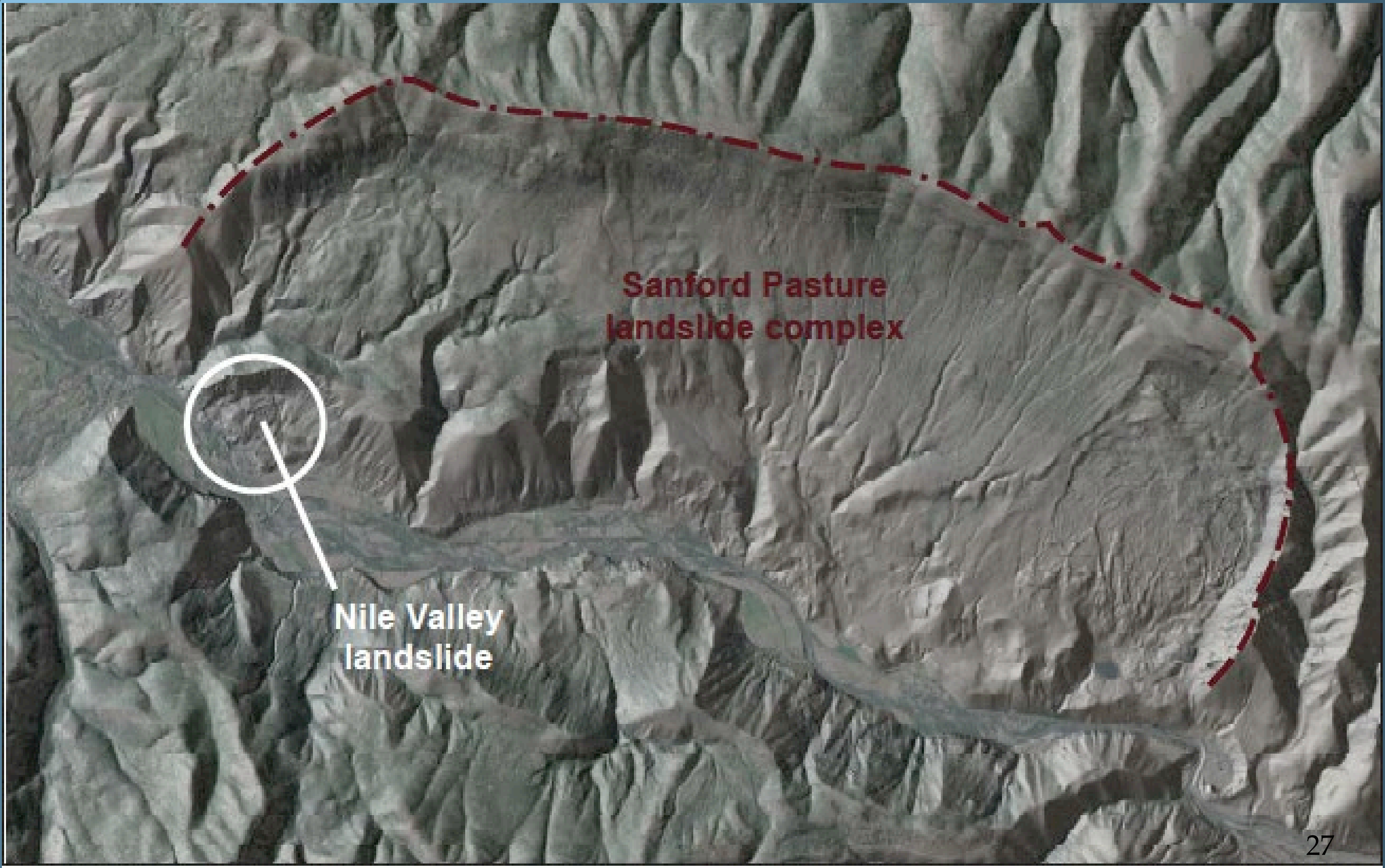
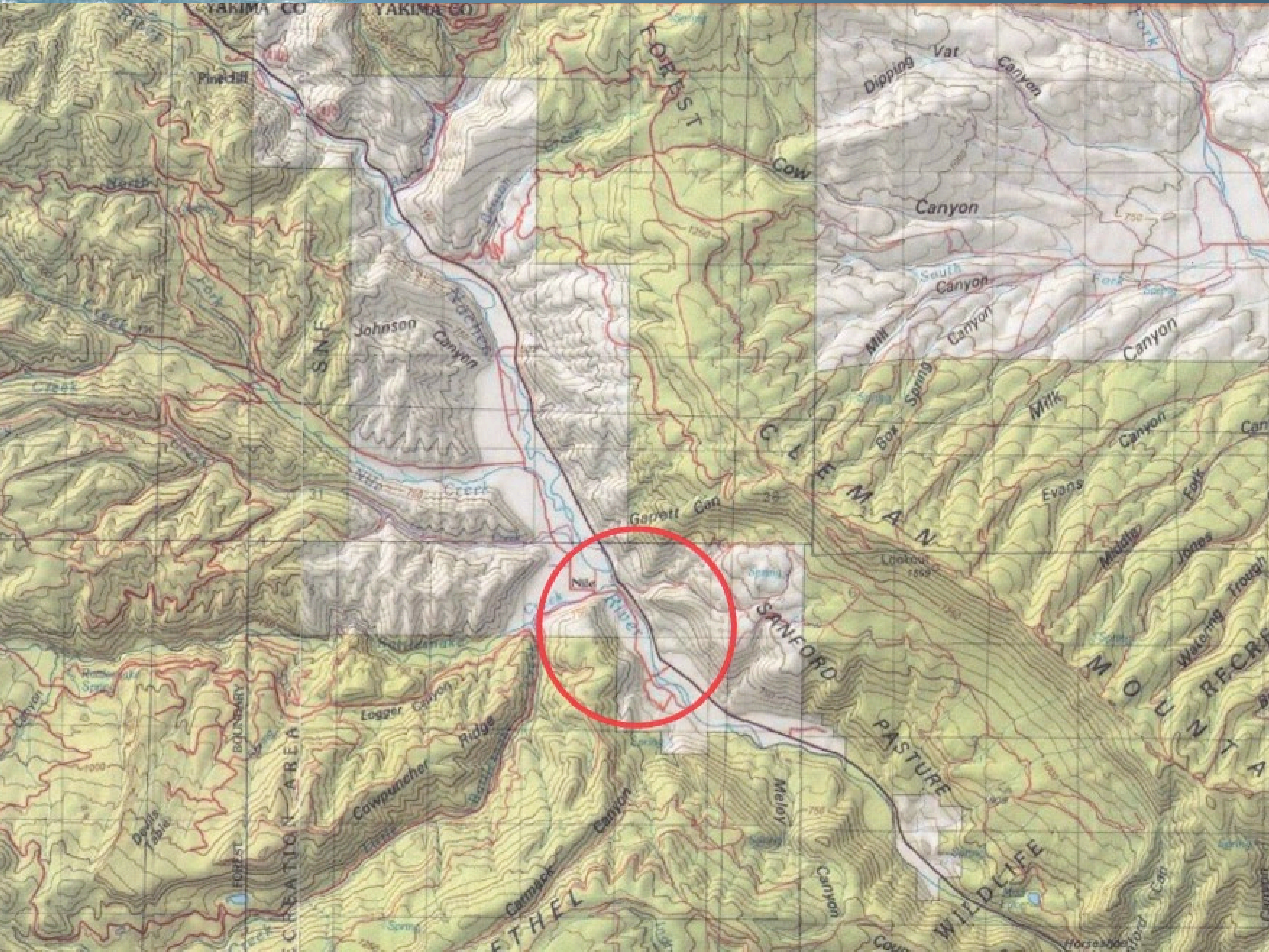




Sediment retention: Beaver Dams v. Sedges

Landslides-Naches River, WA (Nile Valley)





YAKIMA CO
YAKIMA CO
FOREST
Cow
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Mill
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Johnson
Canyon
Naches
SNF
Nile
Creek
Gapett Can
Nile
River
Creek
CLEMAN
MOUNTAIN
Box
Spring
Milk
Canyon
Evans
Middle
Fork
Jones
Watering
Trough
Lookout
SANFORD
PASTURE
WILDLIFE
RECREATION AREA
Logger
Canyon
Cowpuncher
Ridge
Devils
Table
BOUNDARY
FOREST
Canyon
Meloy
Canyon
Spring

Landslides Create Good Salmon Habitat

Controls on valley width in mountainous landscapes: The role of landsliding and implications for salmonid habitat

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ABSTRACT

A fundamental yet unresolved question in fluvial geomorphology is what controls the width of valleys in mountainous terrain. Establishing a predictive relation for valley floor width is critical for realizing links between aquatic ecology and geomorphology because the most productive riverine habitats often occur in low-gradient streams with broad floodplains. Working in the Oregon Coast Range (western United States), we used airborne lidar to explore controls on valley width, and couple these findings with models of salmon habitat potential. We defined how valley floor width varies with drainage area in a catchment that exhibits relatively uniform ridge-and-valley topography sculpted by shallow landslides and debris flows. In drainage areas >0.1 km², valley width increases as a power law function of drainage area with an exponent of ~0.6. Consequently, valley width increases more rapidly downstream than channel width (exponent of ~0.4), as derived by local hydraulic geometry. We used this baseline valley width–drainage area function to determine how ancient deep-seated landslides in a nearby catchment influence valley width. Anomalously wide valleys tend to occur upstream of, and adjacent to, large landslides, while downstream valley segments are narrower than predicted from our baseline relation. According to coho salmon habitat-potential models, broad valley segments associated with deep-seated landsliding resulted in a greater proportion of the channel network hosting productive habitat. Because large landslides in this area are structurally controlled, our findings indicate a strong link between geologic properties and aquatic habitat.

sediment by providing space for the formation of debris flow fans. In addition, low-gradient broad valleys with old-growth forest store the great majority of above-ground and below-ground carbon in mountain streams (Wohl et al., 2012). Understanding the links between hillslope processes and riverine habitat is particularly important for Pacific salmon (*Oncorhynchus* spp.) because these fish are intricately tied to Pacific Rim topography (Montgomery, 2000; Waples et al., 2008).

The goals of this paper are twofold. First, we seek to define an empirical relation between valley width and drainage area (akin to hydraulic geometry for river channels) in a setting with negligible influence from variable rock properties and deep-seated landslide activity. Our approach uses high-resolution topography generated from airborne lidar to define this baseline

Sea Level Rise-
A Grade Changer

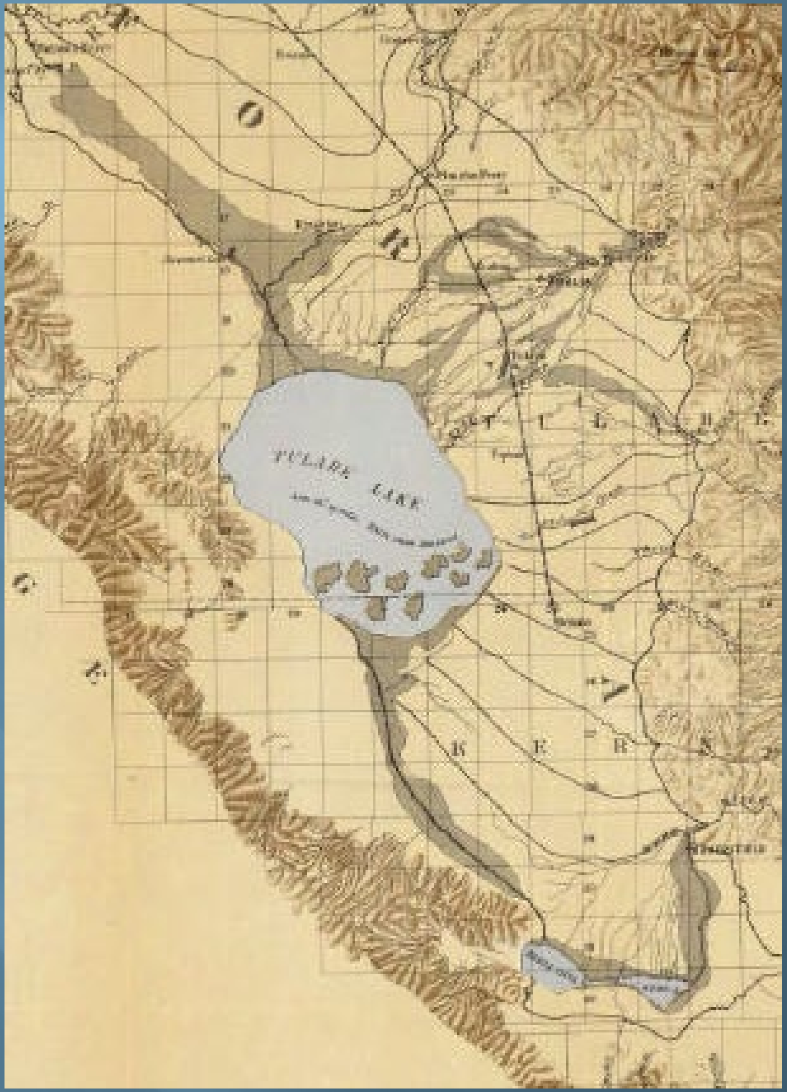
If all the ice melts, >200 ft sea level rise

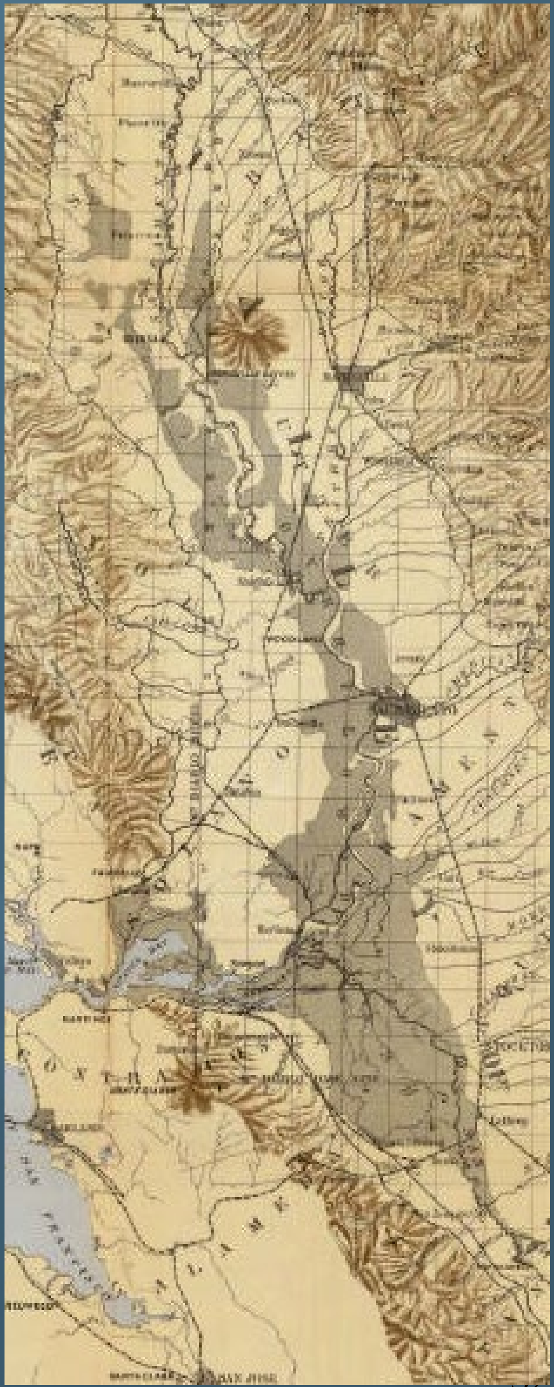
- 1-4 foot rise predicted in next 85 yr, but predicted rates keep increasing.
- Circa 5000 yrs for 200 foot rise (big error bars), but on the scale of the rise and fall of civilizations
- Need sediment to counteract rising seas.

National Geographic 2014

Sacramento-San Joaquin Rivers-150 ybp

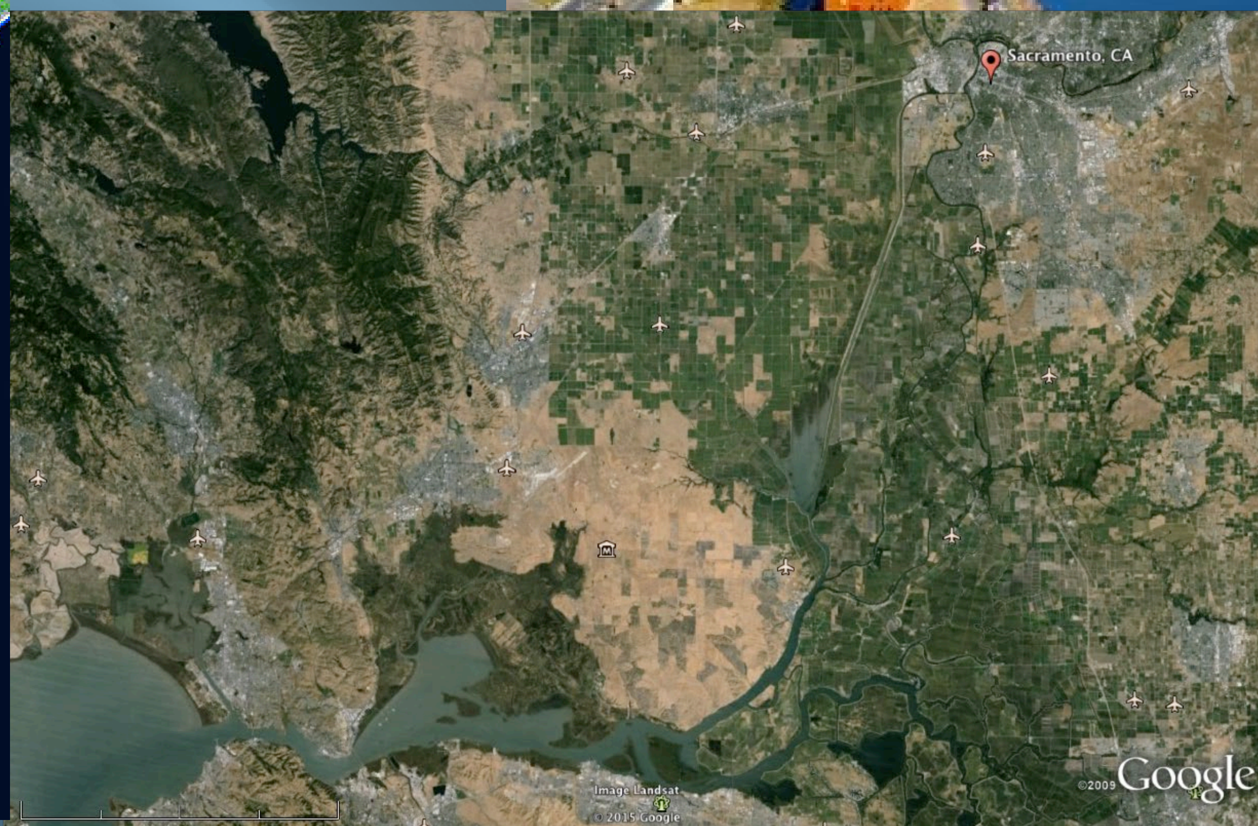
150 years ago, 5% of California was "wetlands", mostly in the Central Valley, really more of a wetland-river complex.





Really Big Low Head Dams as Tide Barriers-

-St Petersburg-16 mi
Venice-1.5 mi (3 openings)
Carquinez Strait? -1 mi



Questions?

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