Process-based principles for restoring dynamic river ecosystems

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Why process restoration?

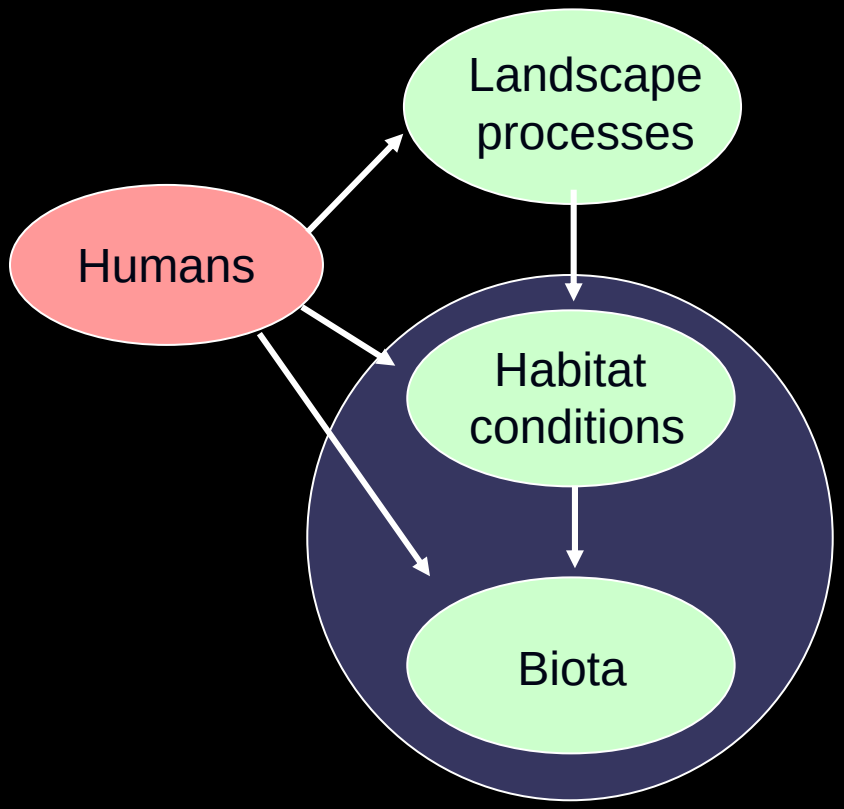
- Organisms are adapted to local habitat conditions
- Habitats are dynamic in space and time

Why process restoration?

- Piece-meal targets
  - US Endangered Species Act
  - US Clean Water Act
- Fragmented actions
  - Difficult to address causes
  - Difficult to restore ‘enough’

Process-based restoration

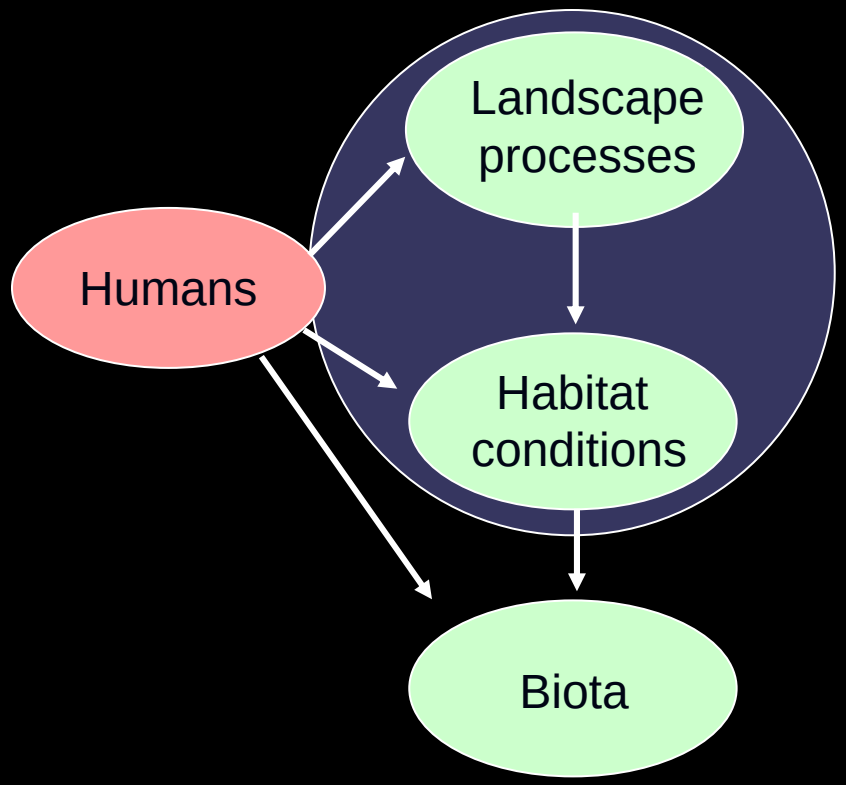
- Restoration is often focused in the channel



Process-based restoration

- Process restoration focuses on causes of habitat change

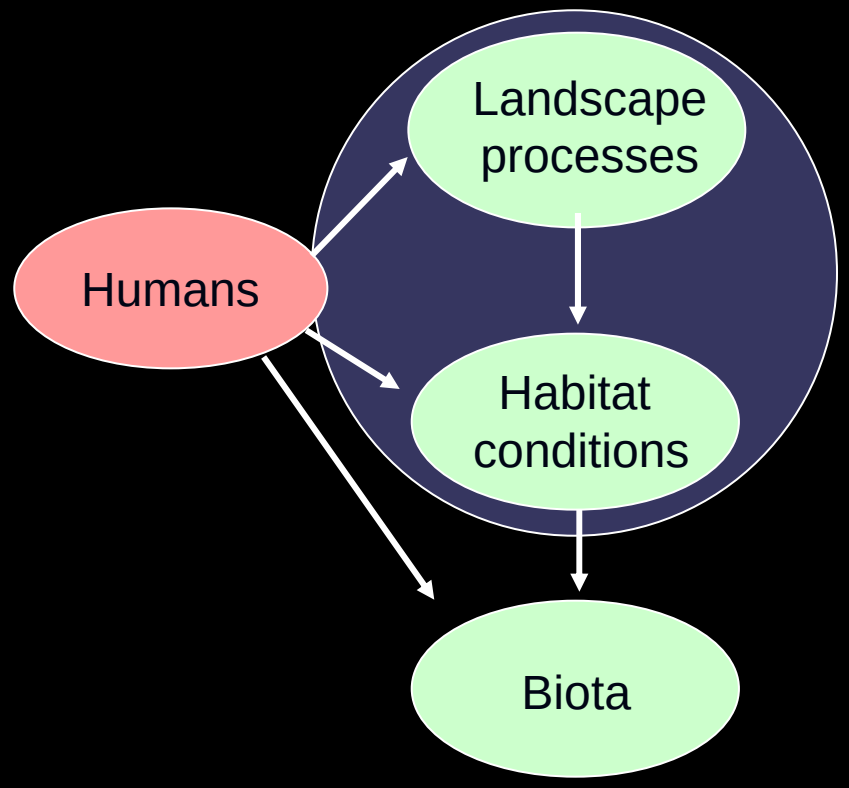
- Restoration is often focused in the channel

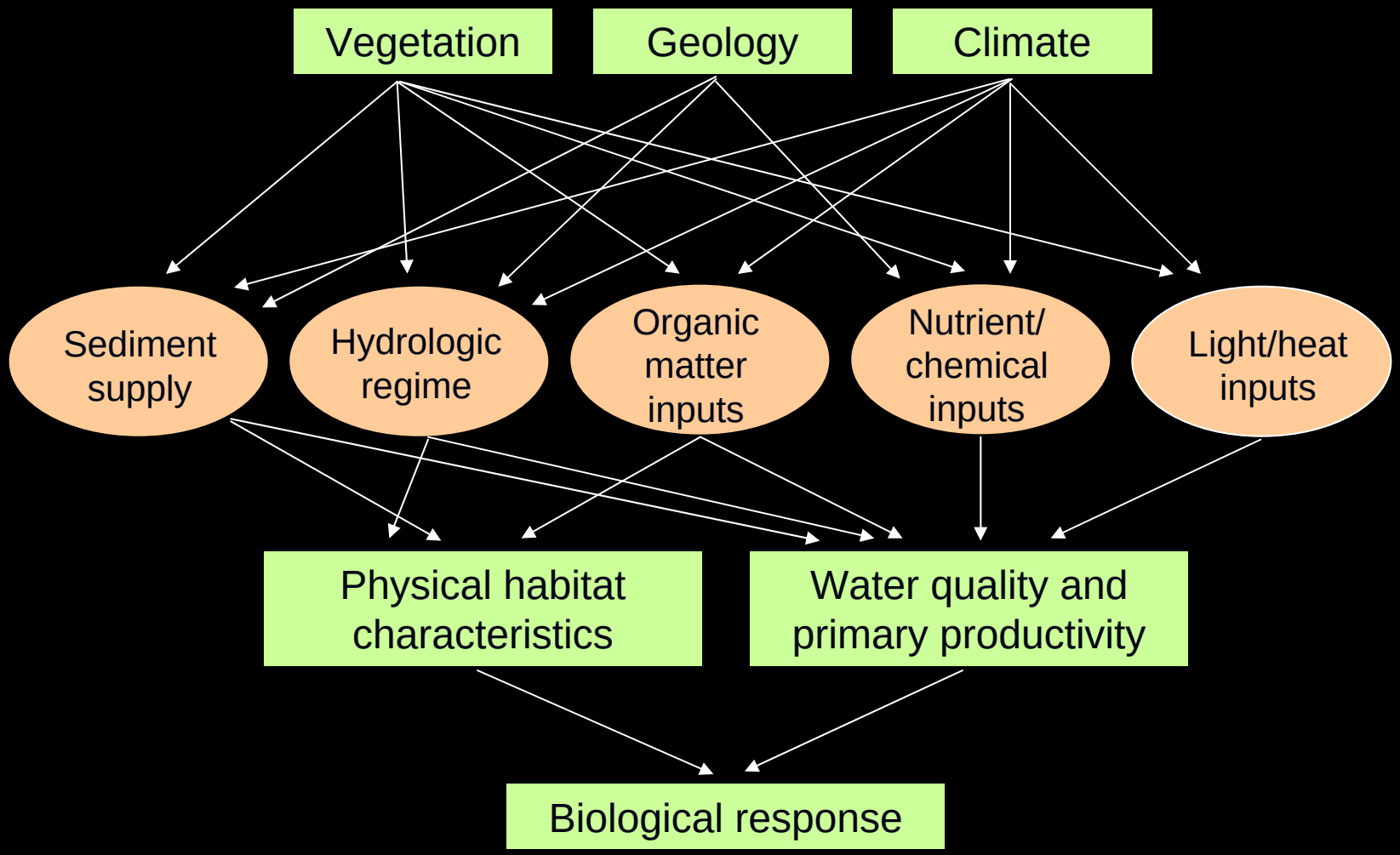


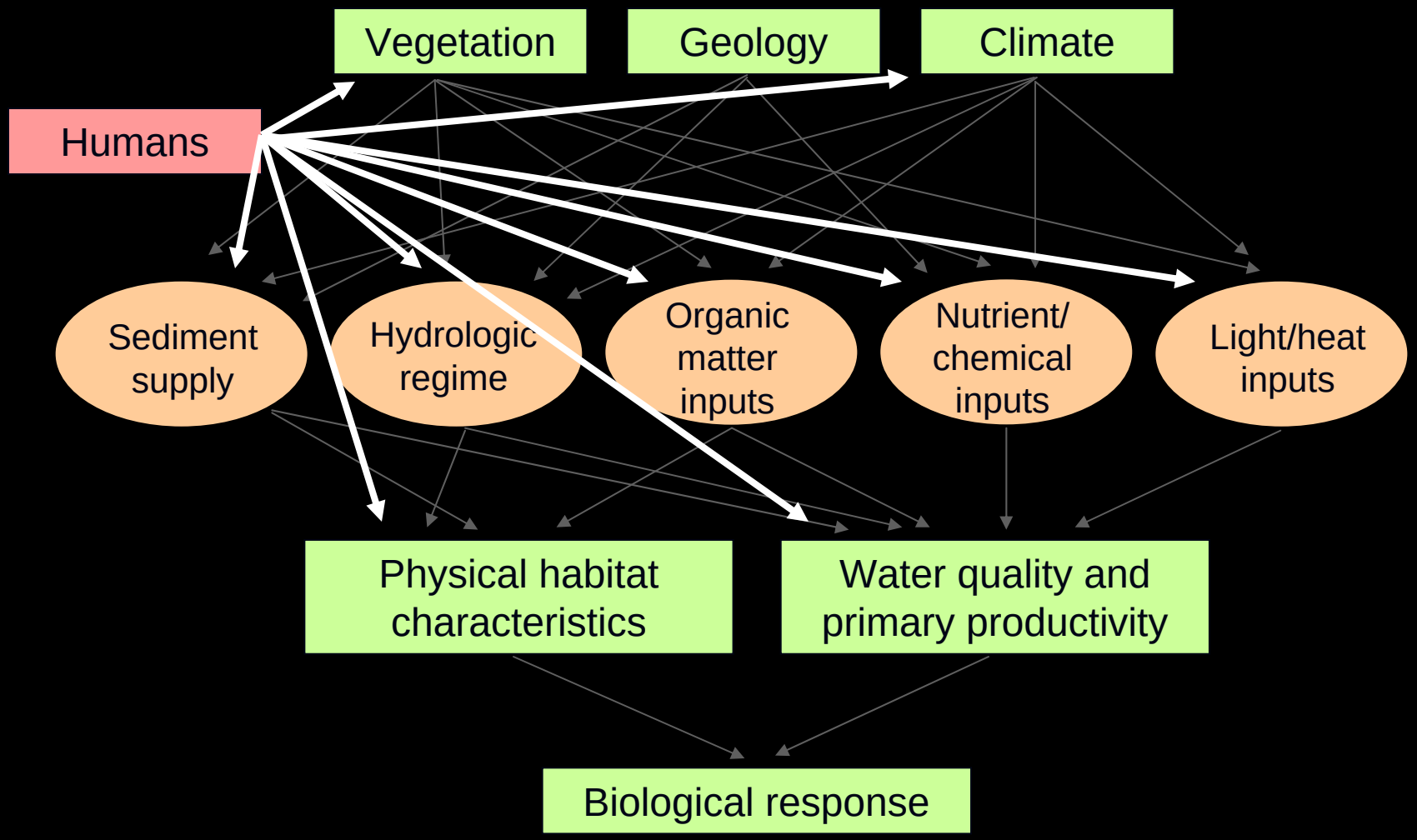
Process-based principles

1. Address causes of ecosystem change
2. Match scale of restoration with scale of physical and biological processes
3. Be explicit about expected outcomes
4. Be explicit about recovery time

Address causes of change

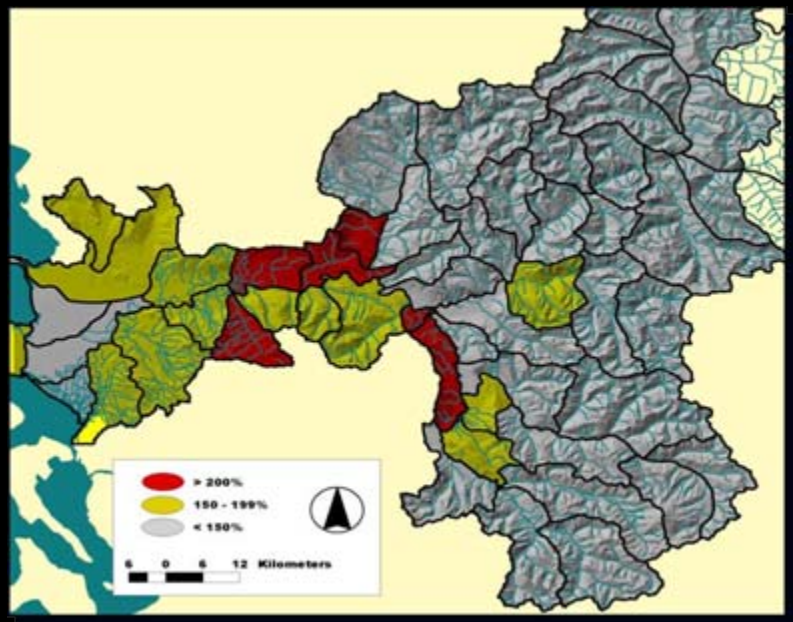


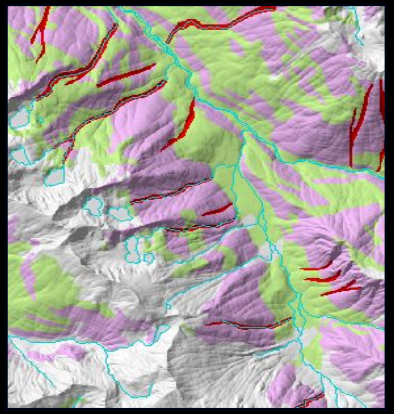

Vegetation
Geology
Climate
Sediment supply
Hydrologic regime
Organic matter inputs
Nutrient/ chemical inputs
Light/heat inputs
Physical habitat characteristics
Water quality and primary productivity
Biological response

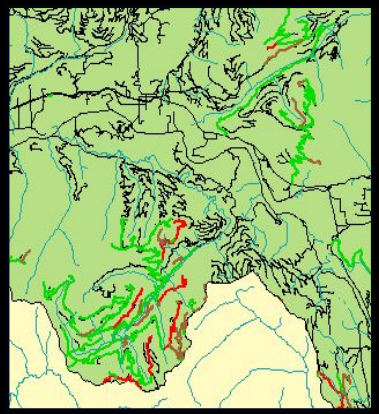

Vegetation
Geology
Climate
Humans
Sediment supply
Hydrologic regime
Organic matter inputs
Nutrient/ chemical inputs
Light/heat inputs
Physical habitat characteristics
Water quality and primary productivity
Biological response

Address problems at the source

- Non-point sediment sources
  - Humid mountains

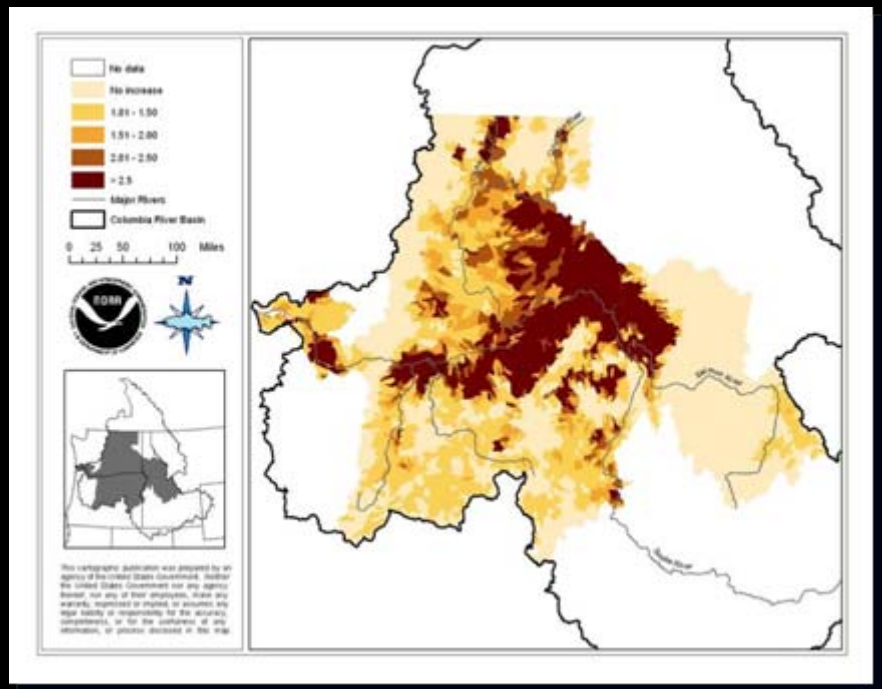






Address problems at the source

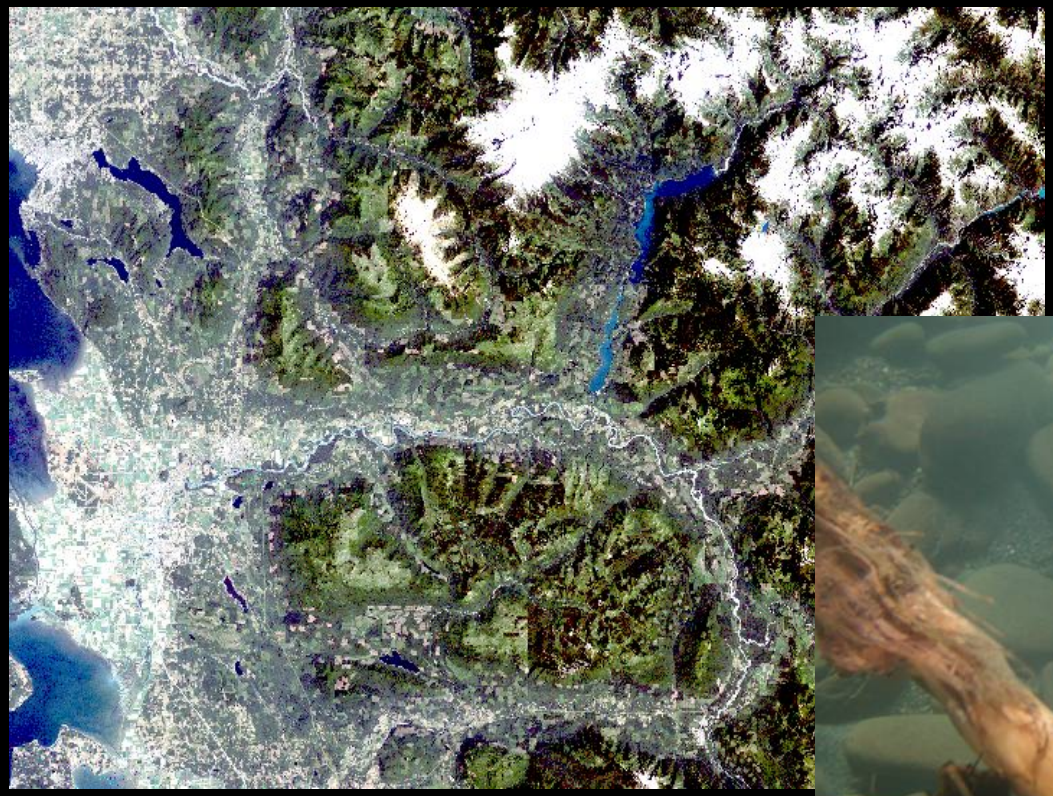
- Non-point sediment sources
  - Semi-arid interior



Address problems at the source

- Longitudinal connectivity
  - Integrity of flow and sediment regimes
- Vertical connectivity
  - Bed elevation, groundwater connections
- Lateral connectivity
  - Floodplain dynamics

Scale of restoration must match physical and biological process scales



Scales of process restoration

- Basin scale
  - Non-point processes

- Sediment supply
- Hydrologic processes
  - Urban
  - Rain-on-snow
- Water quality
- Riparian functions
- Floodplain dynamics
- Inaccessible habitat
  - Stream blockages

Scales of process restoration

- Reach scale
  - Localized effects

- Sediment supply
- Hydrologic processes
  - Urban
  - Rain-on-snow
- Water quality
- Riparian functions
- Floodplain dynamics
- Inaccessible habitat
  - Stream blockages

Scales of process restoration

- Sediment supply
- Hydrologic processes
  - Urban
  - Rain-on-snow
- Water quality
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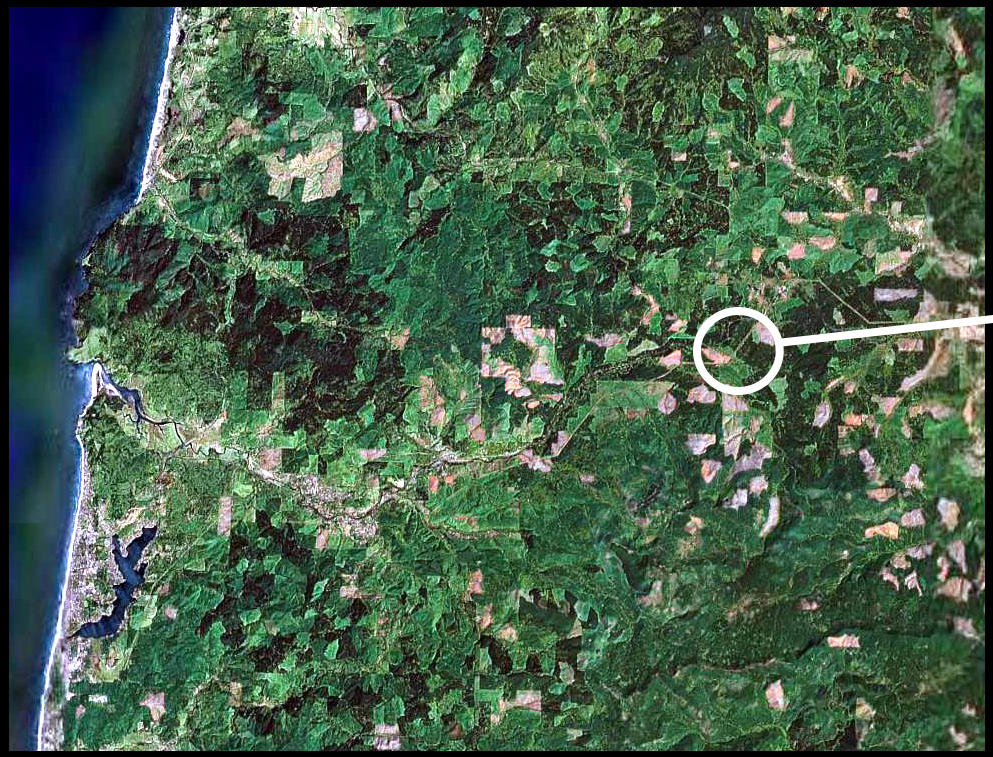
- Floodplain dynamics
- Connectivity
  - Migration pathways
- Inaccessible habitat
  - Stream blockages

Match scale of biological processes

- Scale of salmon life cycle larger than that of most landscape processes



Match scale of biological processes

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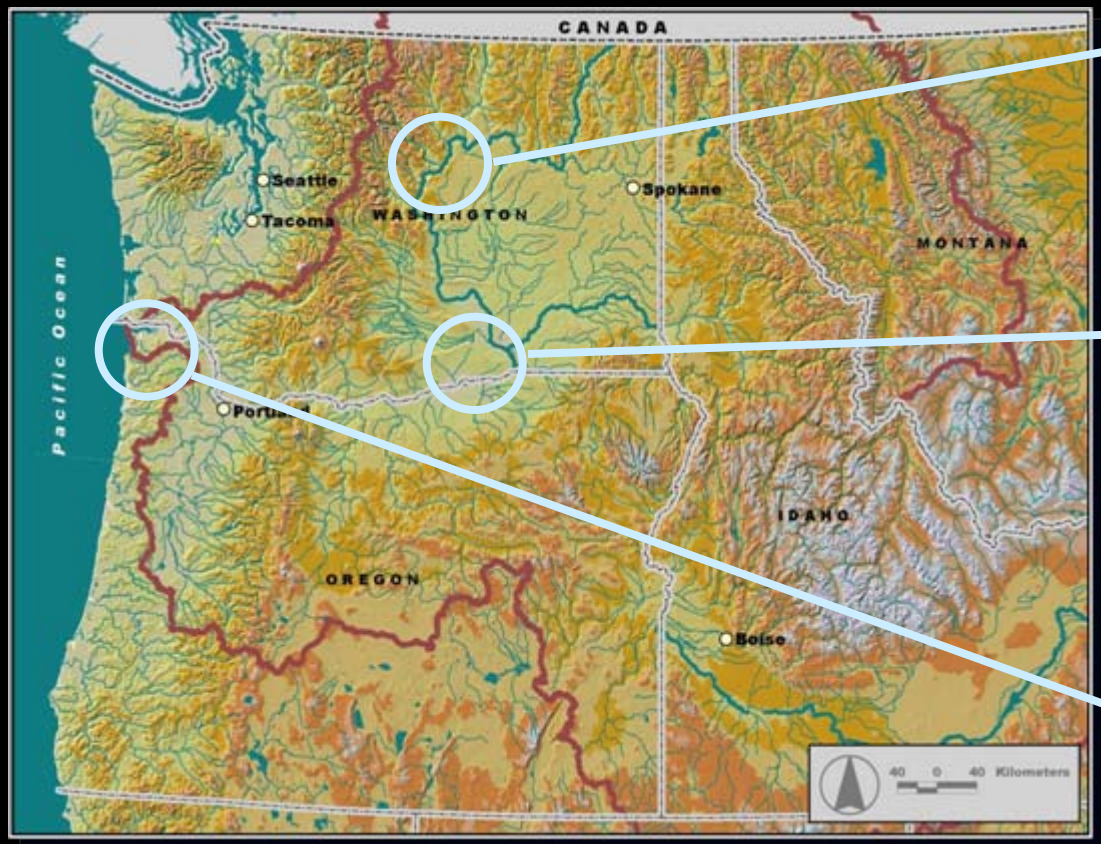
Match scale of biological processes

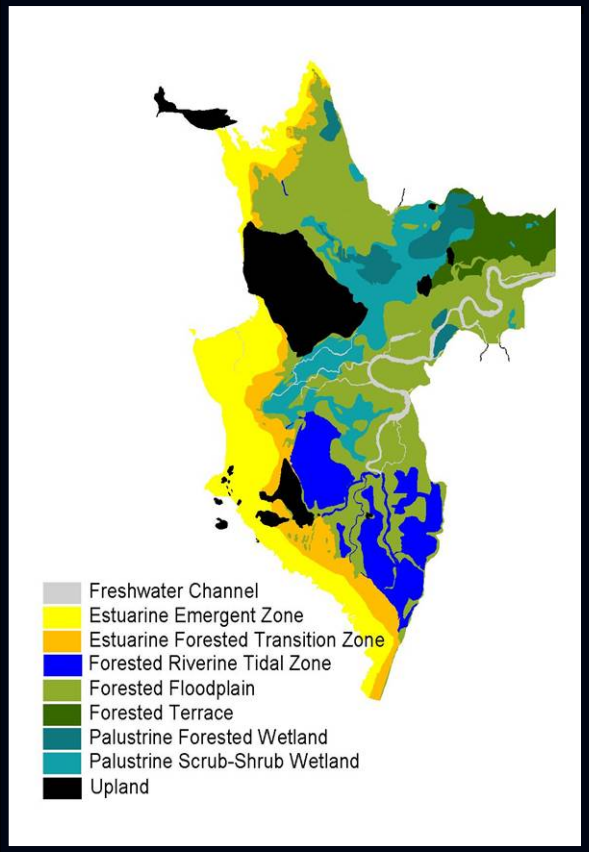
- Interior Columbia salmon

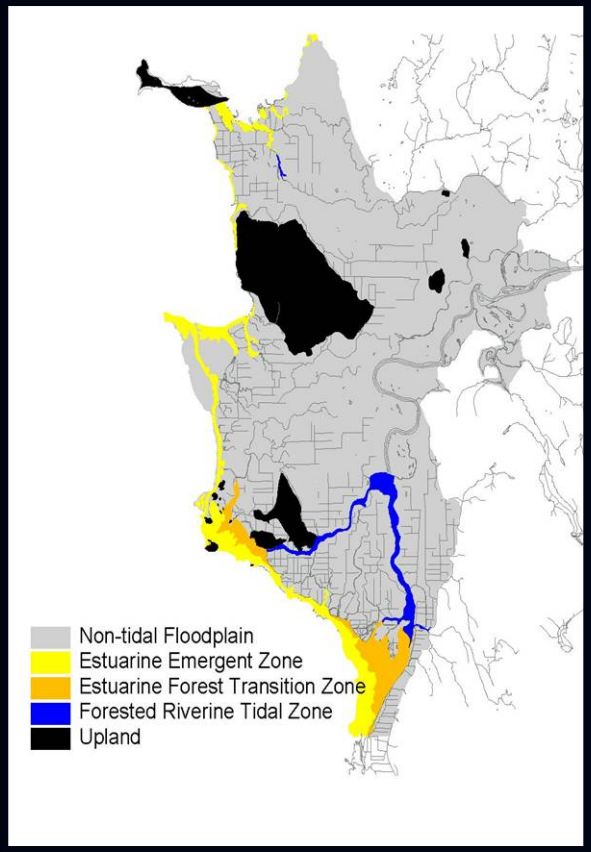


Be explicit about expected outcomes

- Understand natural potential
- Describe target conditions clearly

Historical data: habitat change



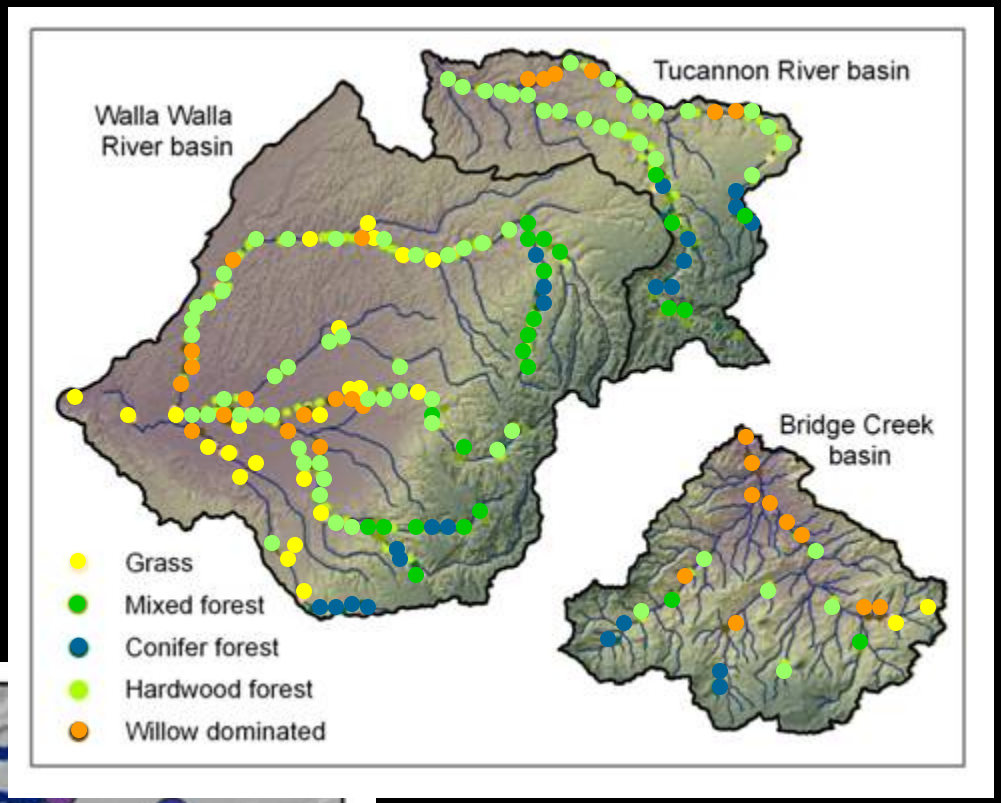


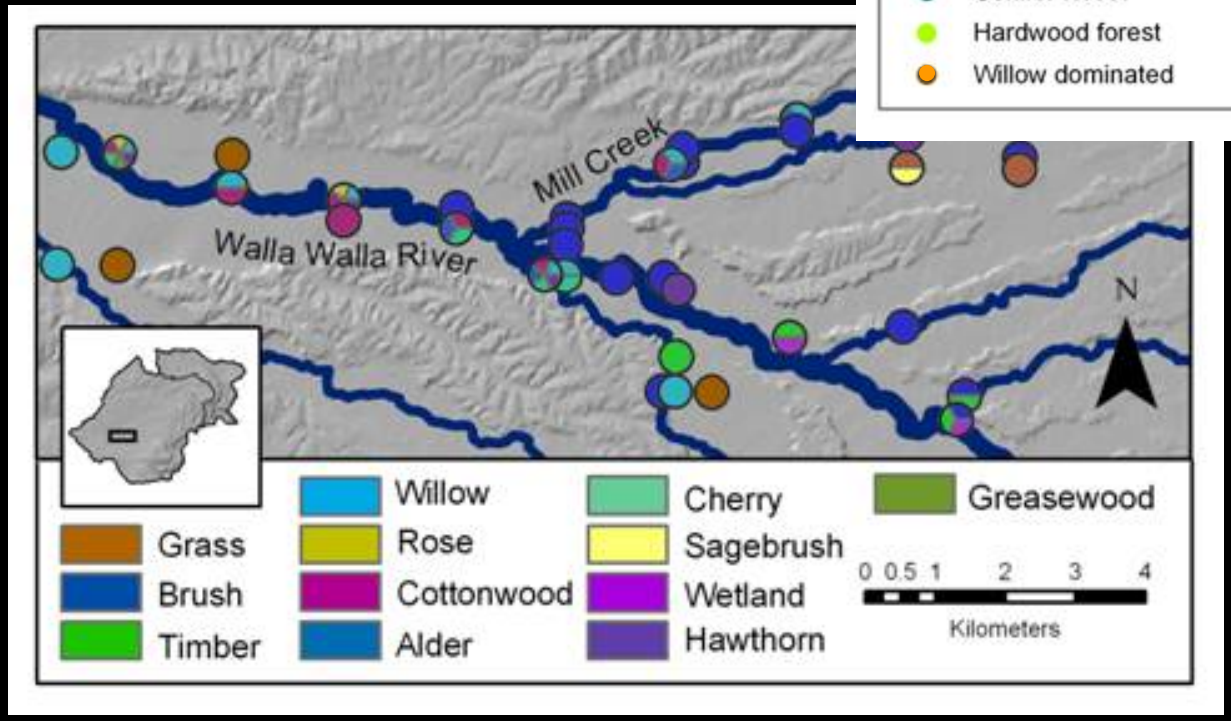
Wetland type	Decrease in area
Riverine Tidal	-84%
Estuarine Forested Transition	-66%
Estuarine Emergent Marsh	-68%
Total	-72%

B. Collins 2000 (University of Washington) and

E. Beamer, unpublished (Skagit System Cooperative)

Historical data: riparian potential





Reference sites: tributary pool area

- Present-day habitat inventory
- Reference site data to estimate historic conditions

	Channel Slope		
	<2%	2%-4%	>4%
Unlogged	64	54	35
Agriculture	47	N/A	N/A
Forestry	61	29	27
Rural	61	36	36

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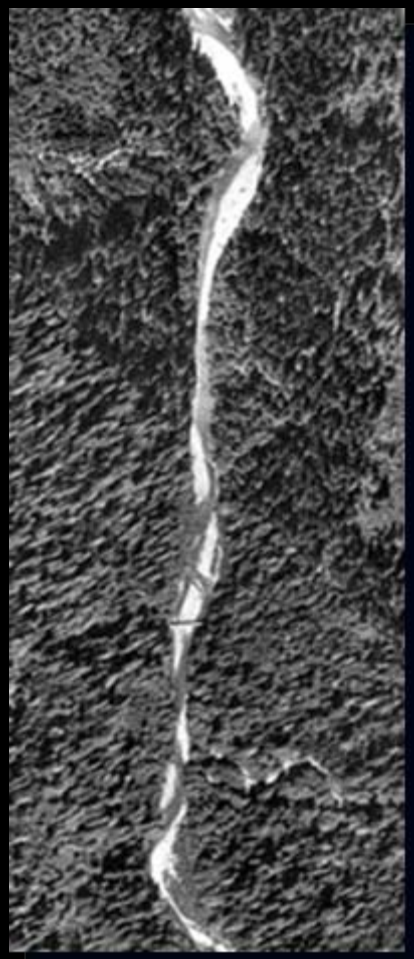
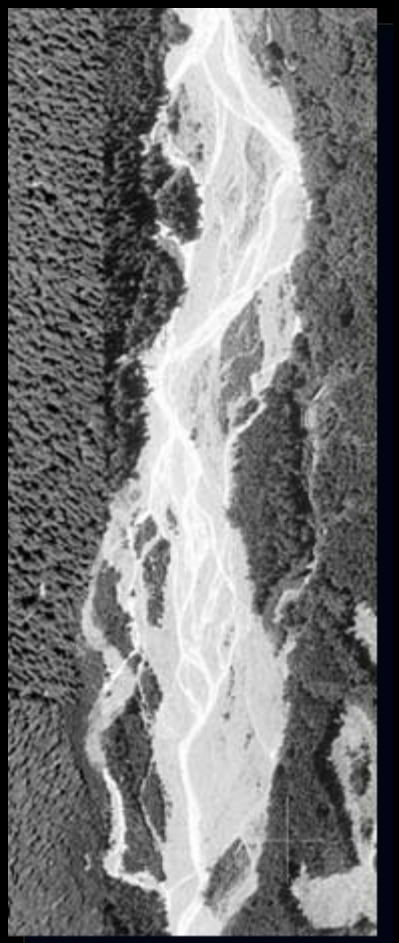
Reference sites: channel pattern



Straight

Meandering

Island Braided

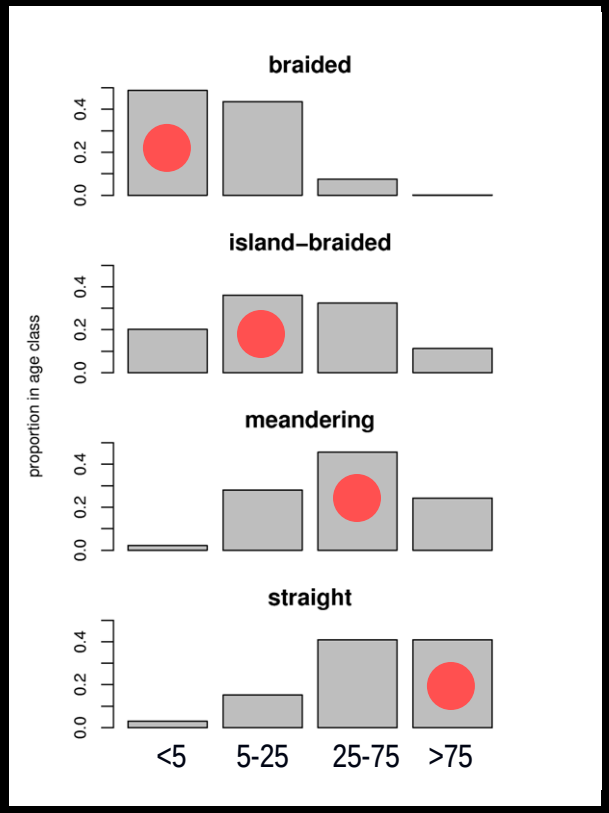


Braided

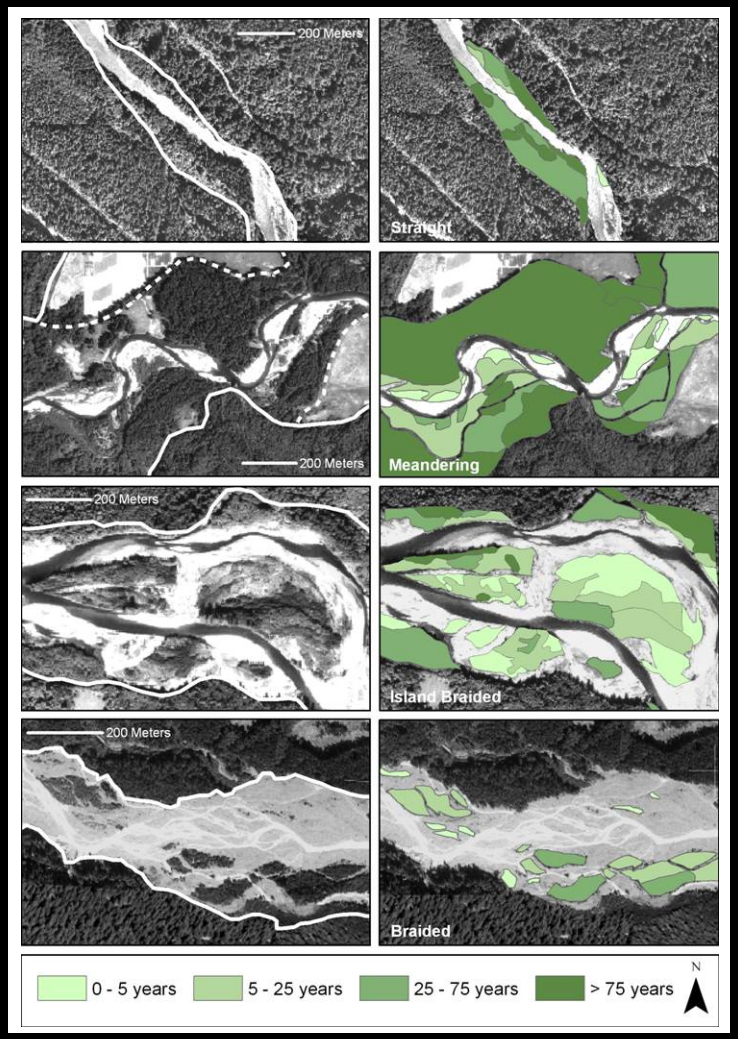
Increasing lateral migration rate

Reference sites: channel pattern

- Patch age distributions



Increasing age

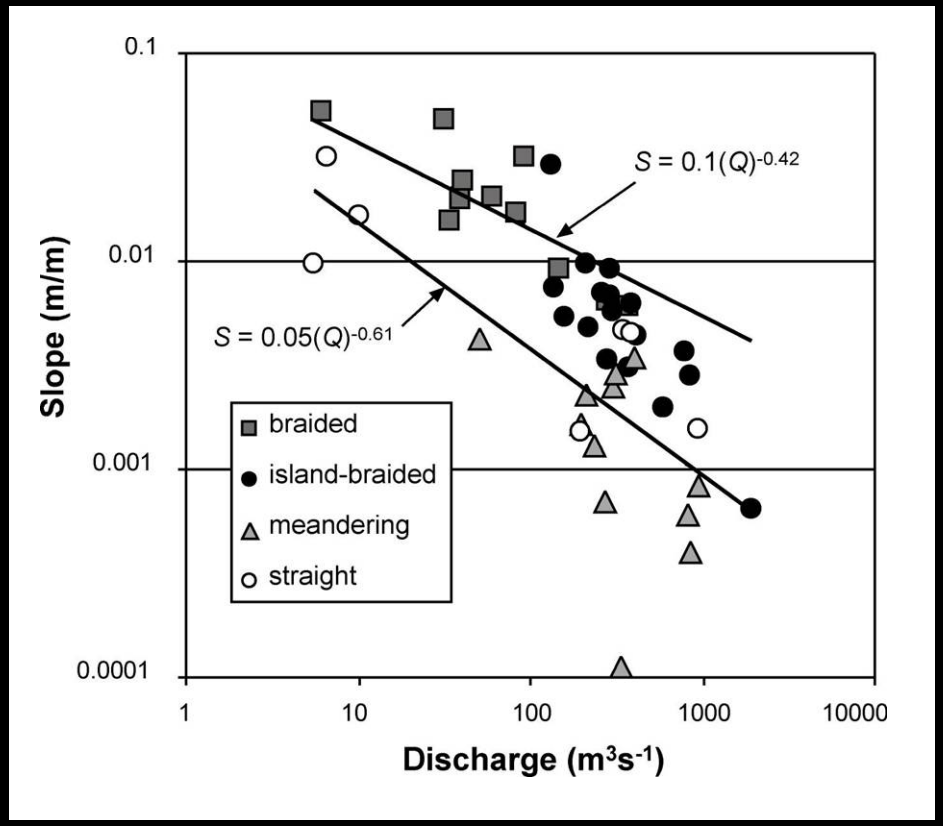


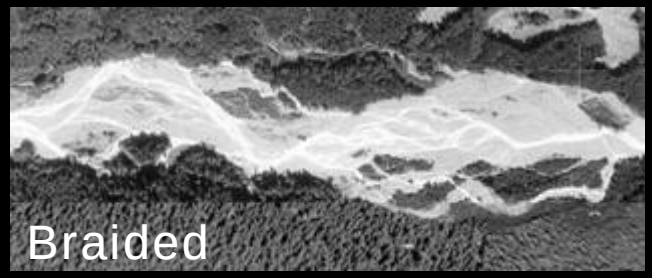
Reference sites: channel pattern

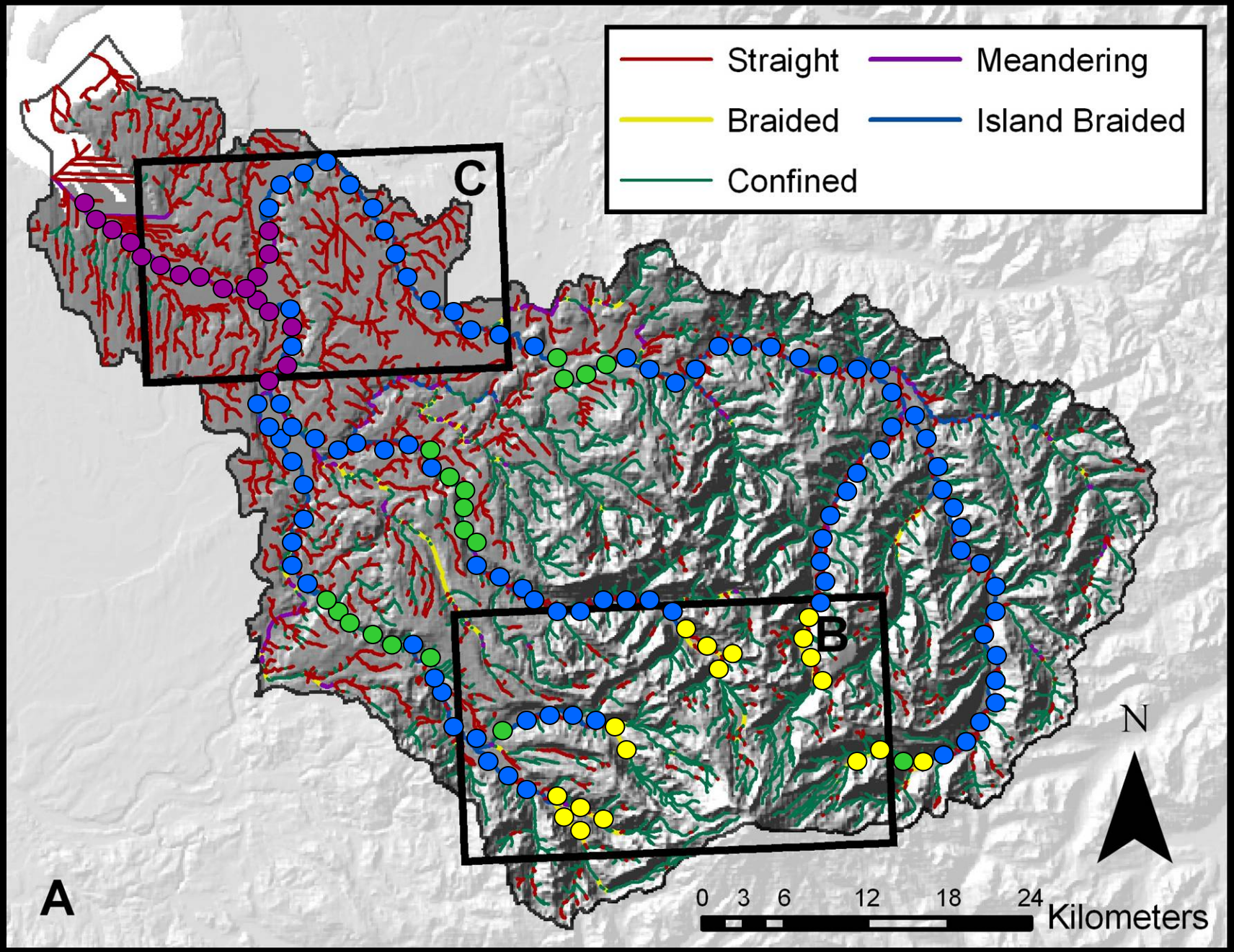
Increasing migration rate

	Straight	Meander-ing	Island-braided	Braided
Median age of floodplain surfaces	65	48	23	6
Floodplain erosion return interval	89	60	33	8

Reference sites: channel pattern

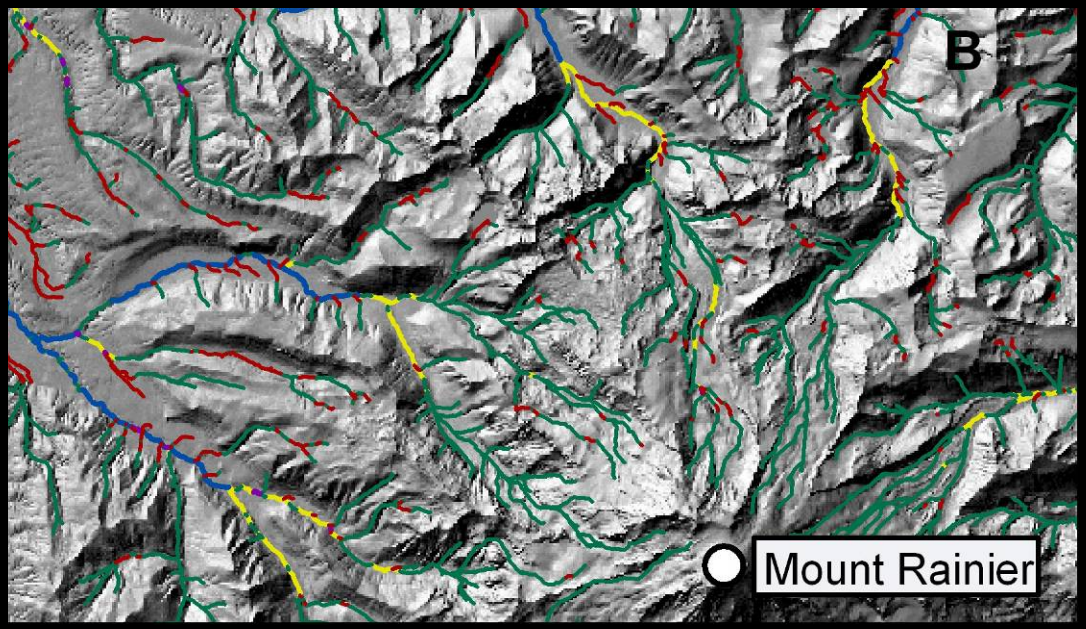





Straight
Meandering
Braided
Island Braided
Confined
C
B
A
N
0 3 6 12 18 24
Kilometers

Theoretical prediction

- Premise: basin topography and hydrology control channel morphology
- Simple mechanistic models
- Process-based framework

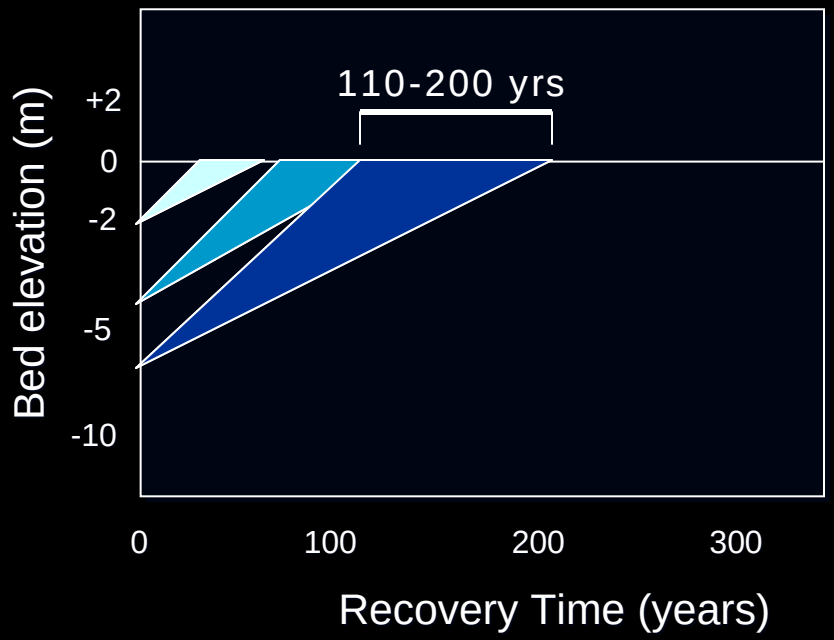


Be explicit about recovery time

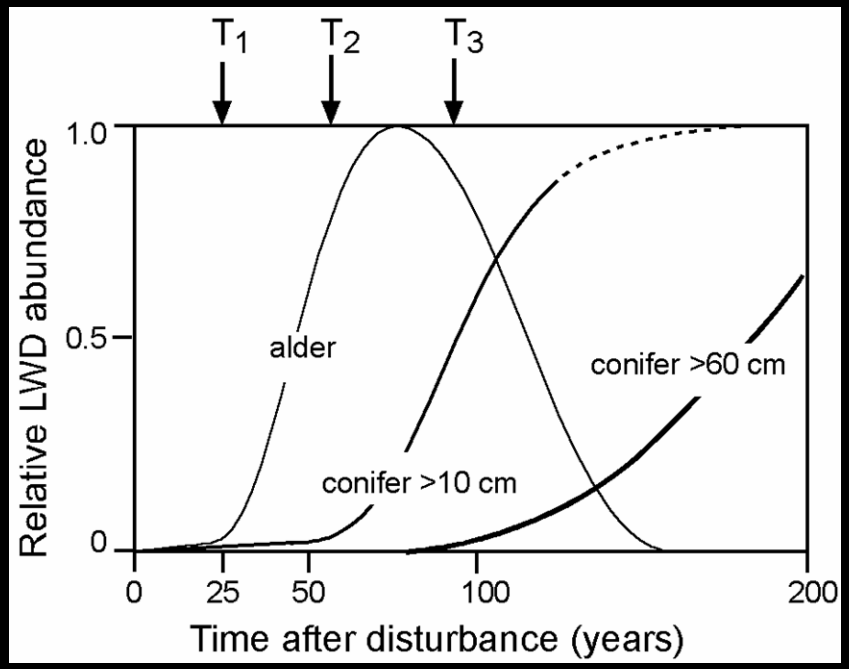
- Some processes are slow to show results
  - Riparian restoration (10s – 100s of years)
  - Erosion controls (10s of years)

- Some processes yield nearly instant results
  - Restore migration pathways
  - Restore flow and sediment connectivity

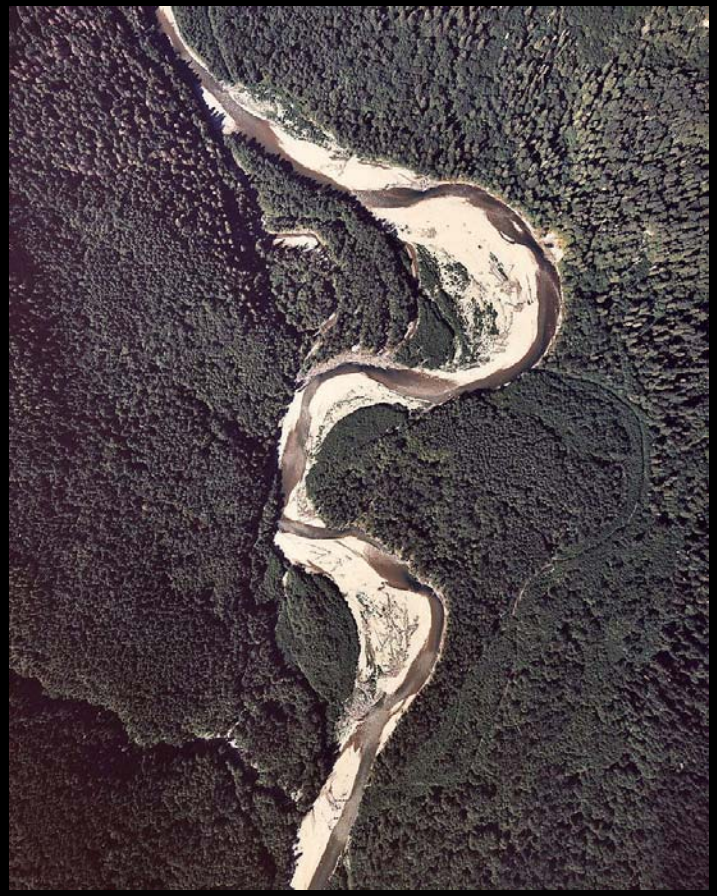
Restoring incised streams



Restoring riparian functions



Summary



- Avoids common pitfalls
  - Created habitats outside the range of natural potential
  - Structures overwhelmed by untreated system drivers
- Sustainable
  - Processes maintain habitat diversity
- Tempers expectations

Summary

1. Address causes of ecosystem change
2. Match scale of restoration with scale of physical and biological processes
3. Be explicit about expected outcomes
4. Be explicit about recovery time

- Process restoration
  - Beechie, T., G. Pess, M. Pollock, M. Ruckelshaus, and P. Roni. In press. Restoring rivers in the 21st century: science challenges in a management context. Proceedings of a conference on The Future of Fishery Research in North America, in Seattle, WA. Sponsored by AIFRB
  - Beechie, T. and S. Bolton. 1999. An approach to restoring salmonid habitat-forming processes in Pacific Northwest watersheds. Fisheries 24(4):6-15

- Examples of detailed steps for restoration planning
  - Beechie, T., G. Pess, P. Roni, and G. Giannico. In press. Setting river restoration priorities: a review of approaches and a general protocol for identifying and prioritizing actions. N. Am. J. Fish. Mgmt
  - Beechie, T.J., G. Pess, E. Beamer, G. Lucchetti, and R.E. Bilby. 2003. Role of watershed assessments in recovery planning for endangered salmon. Pages 194-225 in D. Montgomery, S. Bolton, D. Booth, and L. Wall, editors, Restoration of Puget Sound Rivers, University of Washington Press, Seattle
  - Beechie, T.J., E.A. Steel, P.R. Roni, and E. Quimby, editors. 2003. Ecosystem recovery planning for listed salmon: an integrated assessment approach for salmon habitat. NOAA Technical Memorandum, National Marine Fisheries Service, Seattle, Washington
  - Hyatt, T. L., T.Z. Waldo, and T.J. Beechie. 2004. A watershed-scale assessment of riparian forests, with implications for restoration. Restoration Ecology 12:175-183
  - Pess, G.R., T.J. Beechie, J.E. Williams, D.R. Whitall, J.I. Lange, and J.R. Klochak. 2003. Watershed assessment techniques and the success of aquatic restoration activities. Pages 185-2001 In R. Wissmar and P. Bisson, eds. Strategies for restoring river ecosystems: sources of variability and uncertainty in natural and managed systems. American Fisheries Society, Bethesda, MD

- Recovery time examples
  - Beechie, T.J., M.M. Pollock, S. Baker. In press. Channel incision, evolution and potential recovery in the Walla Walla and Tucannon River basins, northwestern USA. Earth Surface Processes and Landforms
  - Beechie, T.J. 2001. Empirical predictors of annual bed load travel distance, and implications for salmonid habitat restoration and protection. Earth Surface Processes and Landforms 26:1025-1034
  - Beechie, T.J, G. Pess, P Kennard, R.E. Bilby, and S Bolton. 2000. Modeling recovery rates and pathways for woody debris recruitment in northwestern Washington streams. N. Am. J. Fish. Mgmt. 20:436–452
  - Pollock, M.M., T. J. Beechie, and C.E. Jordan. 2007. Geomorphic chagnes upstreams of beaver dams in Bridge Creek, in incised stream channel in the interior Columbia River basin, eastern Oregon. Earth Surface Processes and Landforns 32:1174-1185