Stream and Watershed Restoration: guidance for restoring riverine processes and fish habitat

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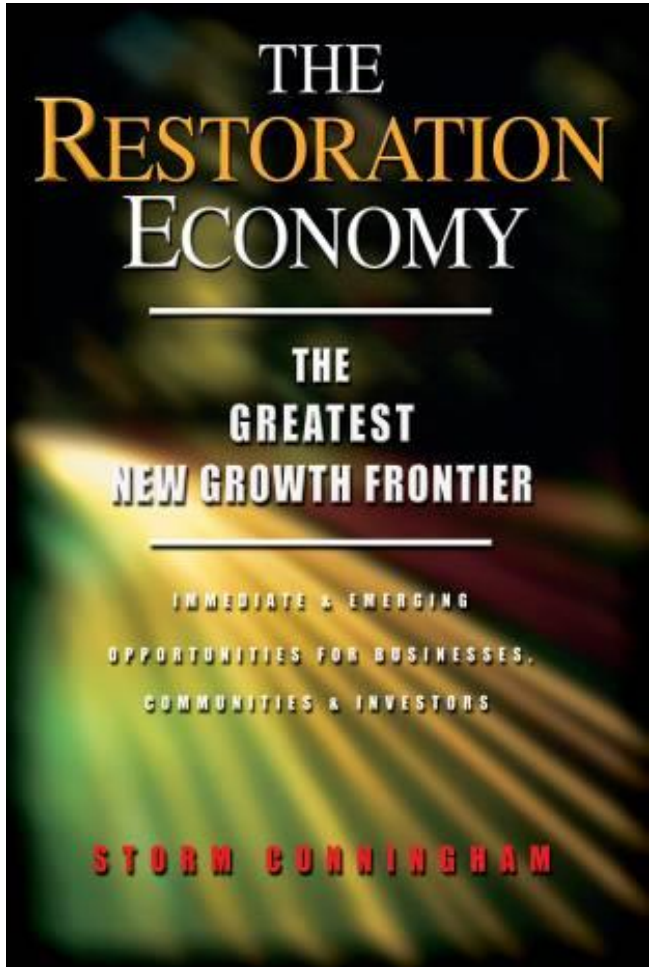
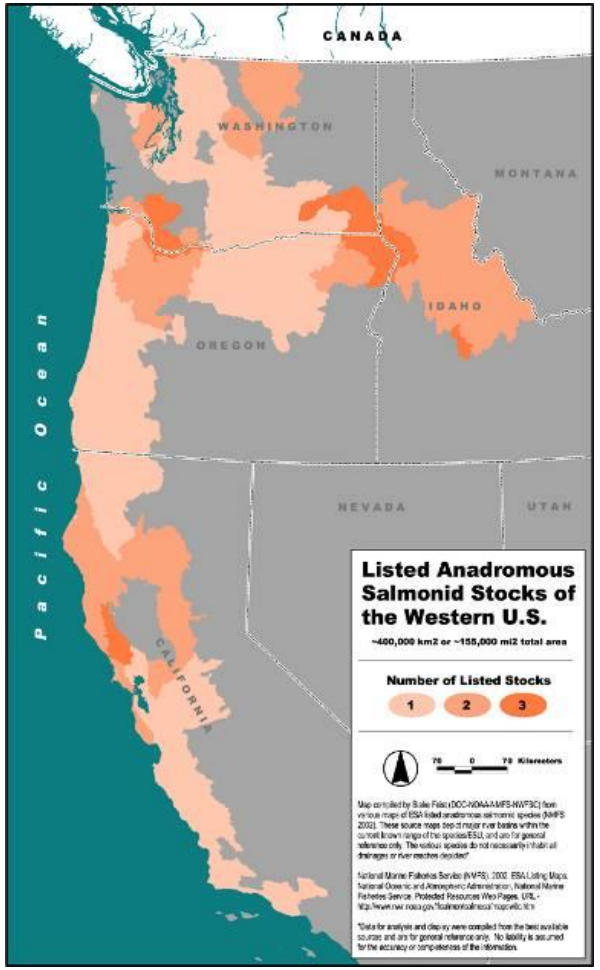
River Restoration is a Growth Industry

- How many dollars annually?

- Ecosystem restoration initiatives
  - Everglades
  - Chesapeake Bay
  - Great Lakes
  - Puget Sound
  - Pacific Coastal Salmon Recovery
  - & others





What is Restoration?

Protection	
Restoration	To return an aquatic system or habitat to its original, undisturbed state
Rehabilitation	
Improvement	
Reclamation	
Mitigation/Creation	

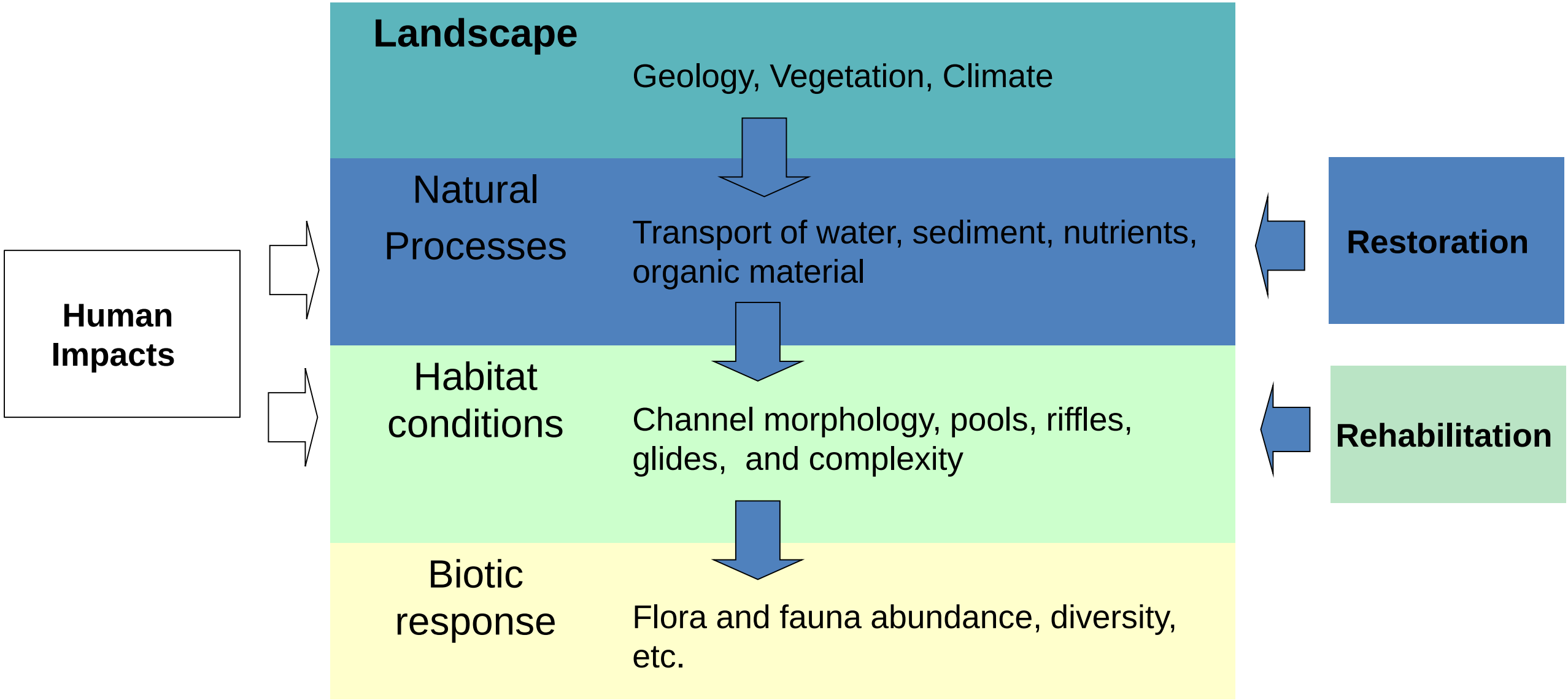
* Also called habitat enhancement

What is Restoration?

Protection	Protect existing high quality habitats
Restoration	To return an aquatic system or habitat to its original, undisturbed state
Rehabilitation	To restore or to improve some aspects of an ecosystem but not fully restore all components
Improvement	To enhance quality of habitat but not necessarily restore all functions
Reclamation	To attempt return an area to previous state but not necessarily restore all functions
Mitigation/Creation	Actions taken to compensate for adverse impacts of construction etc.

* Also called habitat enhancement

Process-Based Restoration



Reconnect Isolated Habitats

Floodplain Restoration

Roads, Hydrology and Sediment Delivery

Urban Roads

Forest Roads

Riparian Restoration Techniques

Instream Habitat Improvement







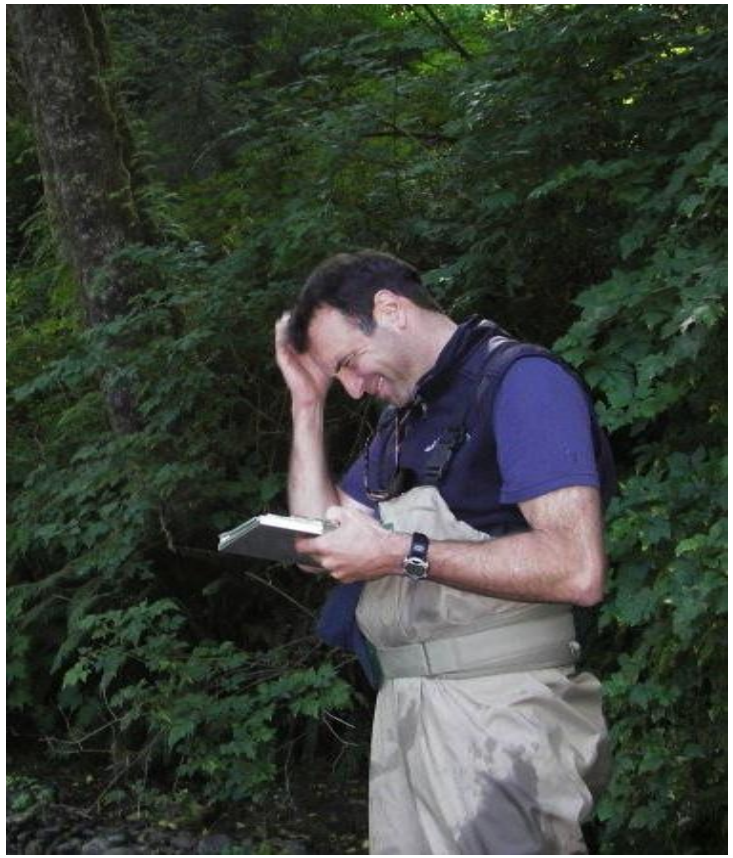




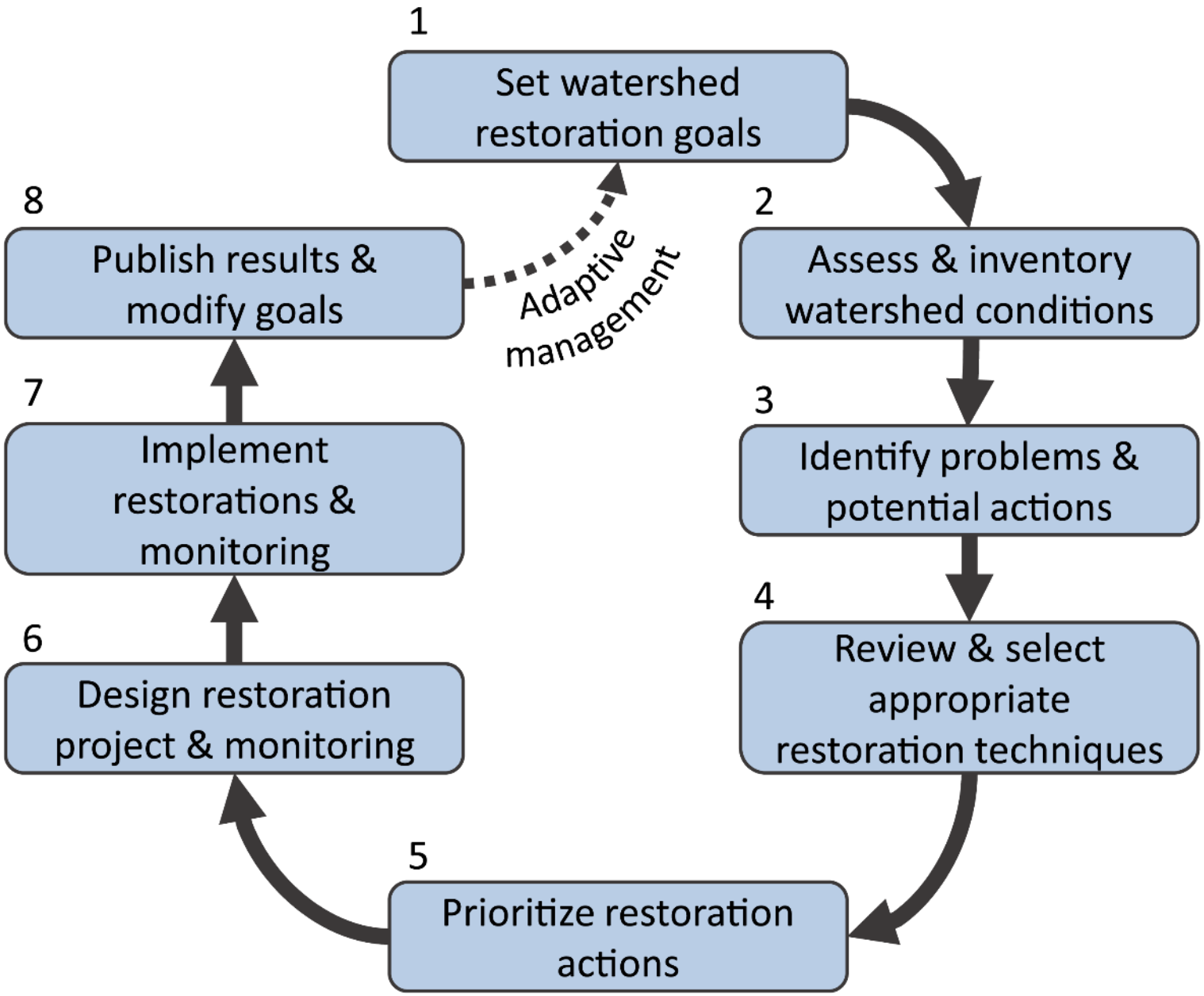

Not All Projects Are Successful

Some common problems

- Inadequate habitat assessments
- Ecosystem processes
- Limiting factors
- Design of projects
- Prioritization of projects
- Monitoring and evaluation
- Total amount of restoration



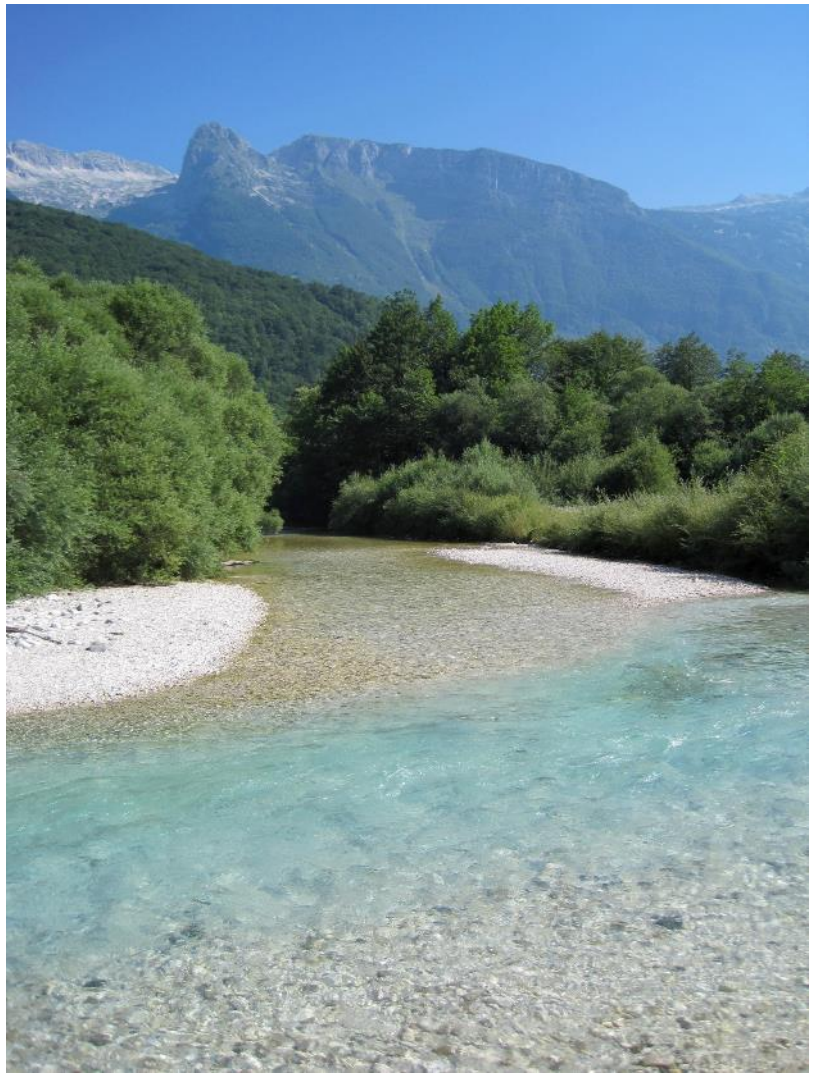
Key Steps in Restoration



Roni and Beechie 2013

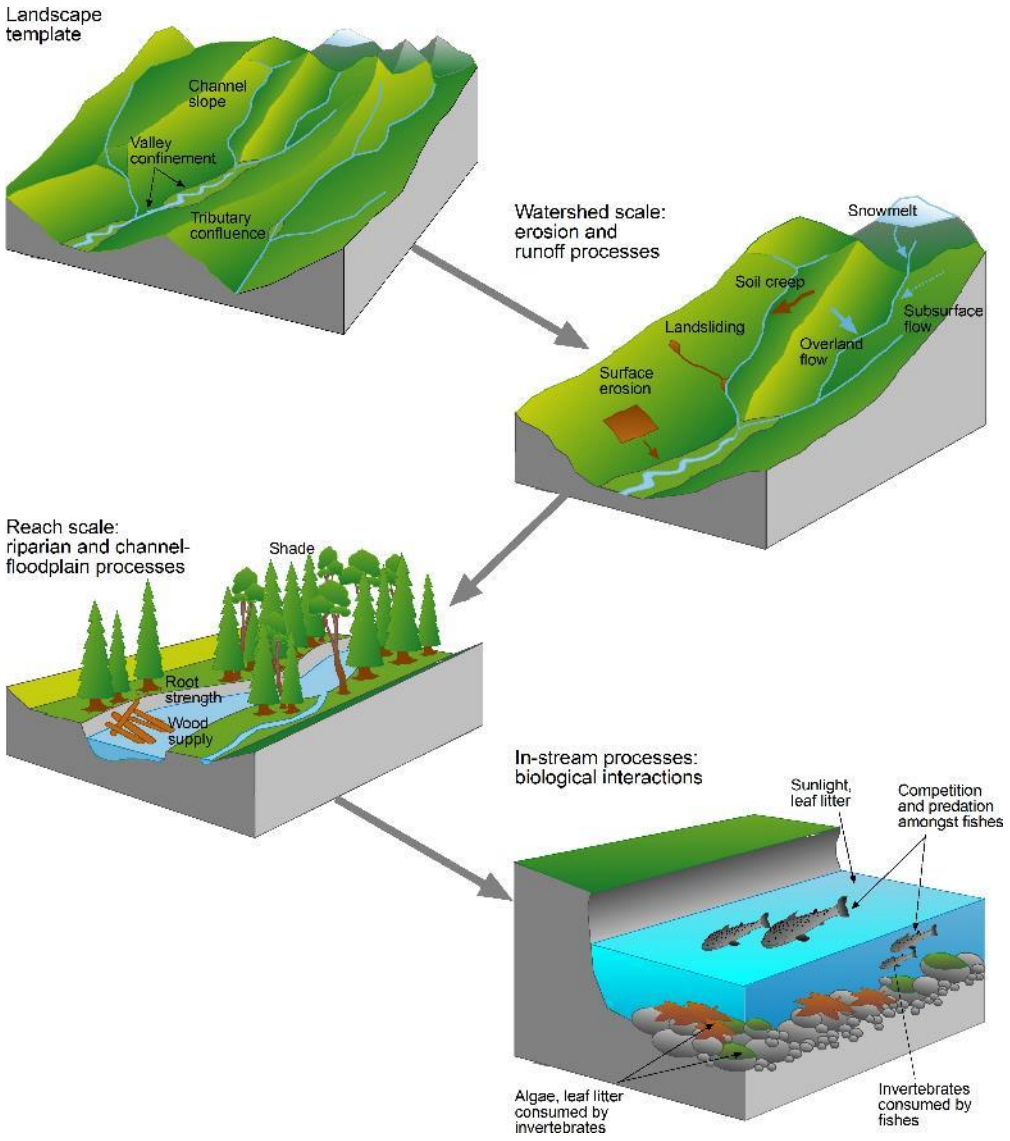
Goals & Objectives

- For restoration
- For assessment
- For restoration design
- For prioritization
- For monitoring & evaluation



Assessments – identifying problems & actions

- Historical habitat
- Current habitat
- Habitat loss
- Disrupted processes
  - Connectivity
  - Hydrology
  - Riparian
  - Sediment
  - Nutrients
- Causes of degradation



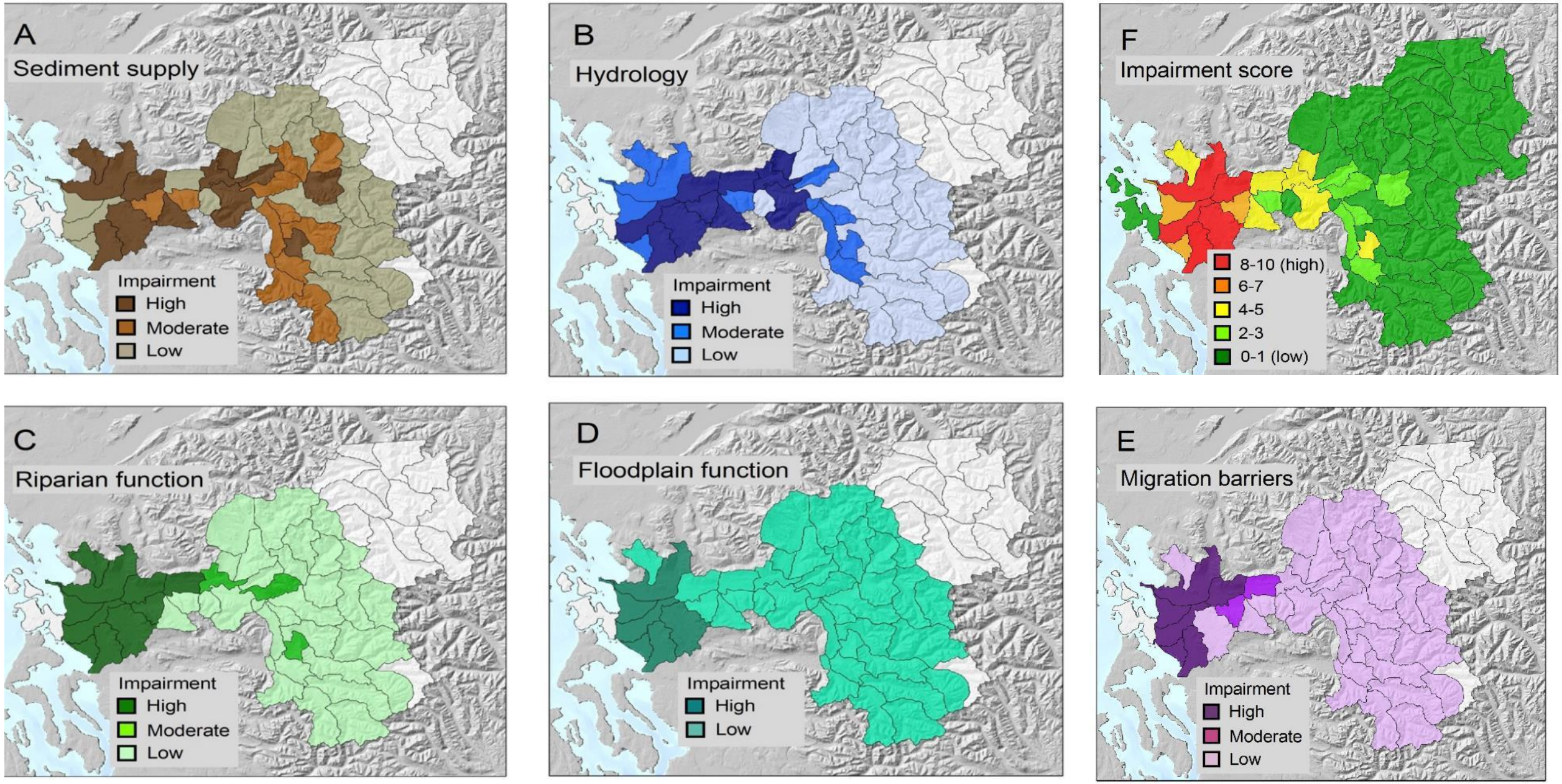
Assessments – data collection & analysis

- Remote Sensing

- Field Data Collection

- Analysis & Interpretation

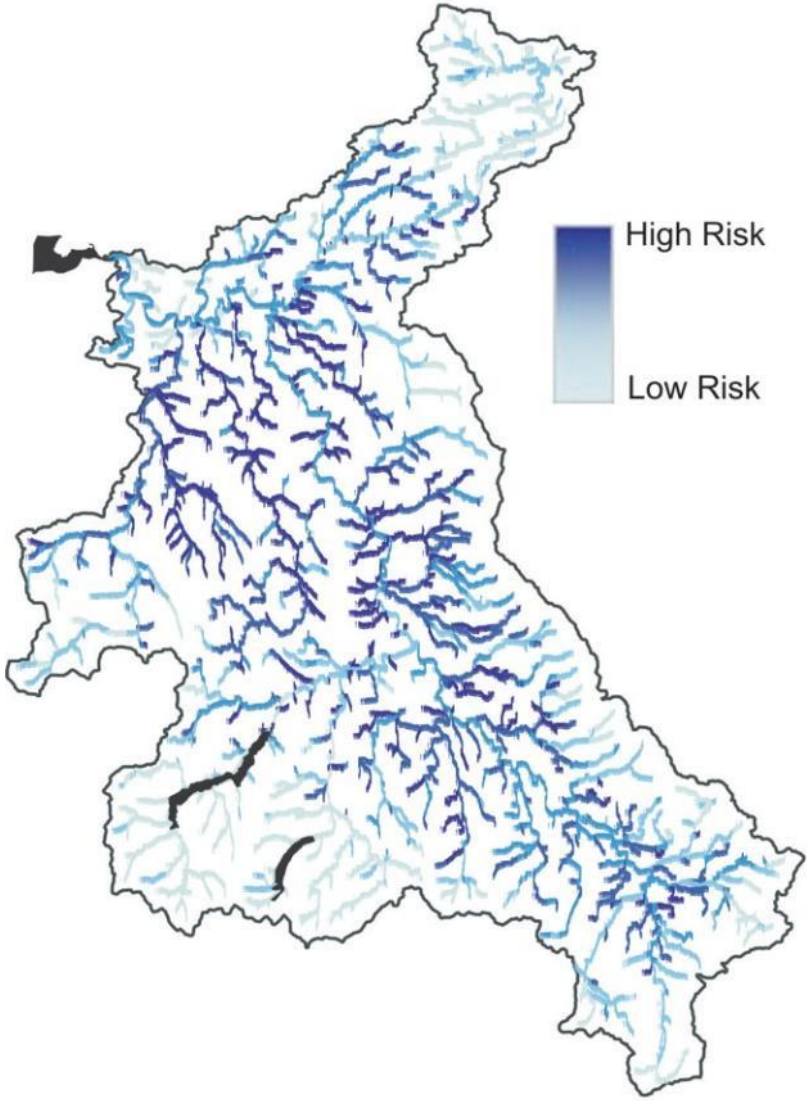
Broad Scale - Land Use Impacts & Processes



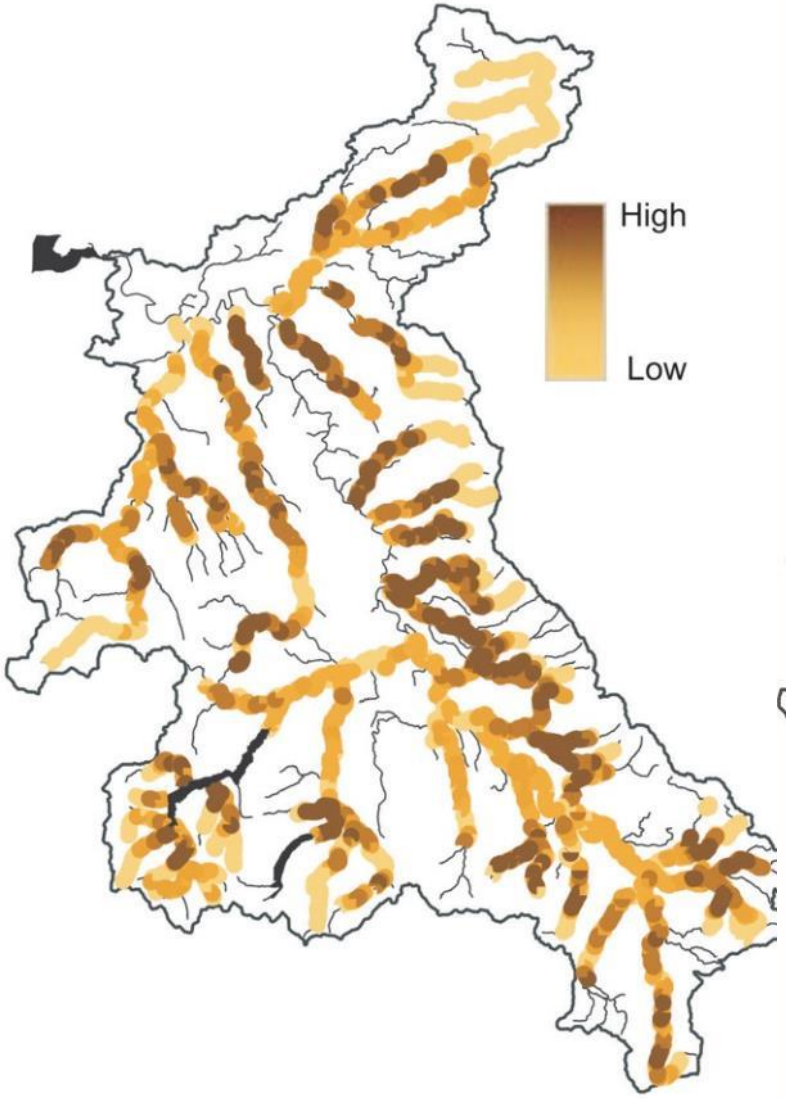
Skagit Basin, WA Beechie et al. 2013

Reach Scale – local impairments and restoration opportunities

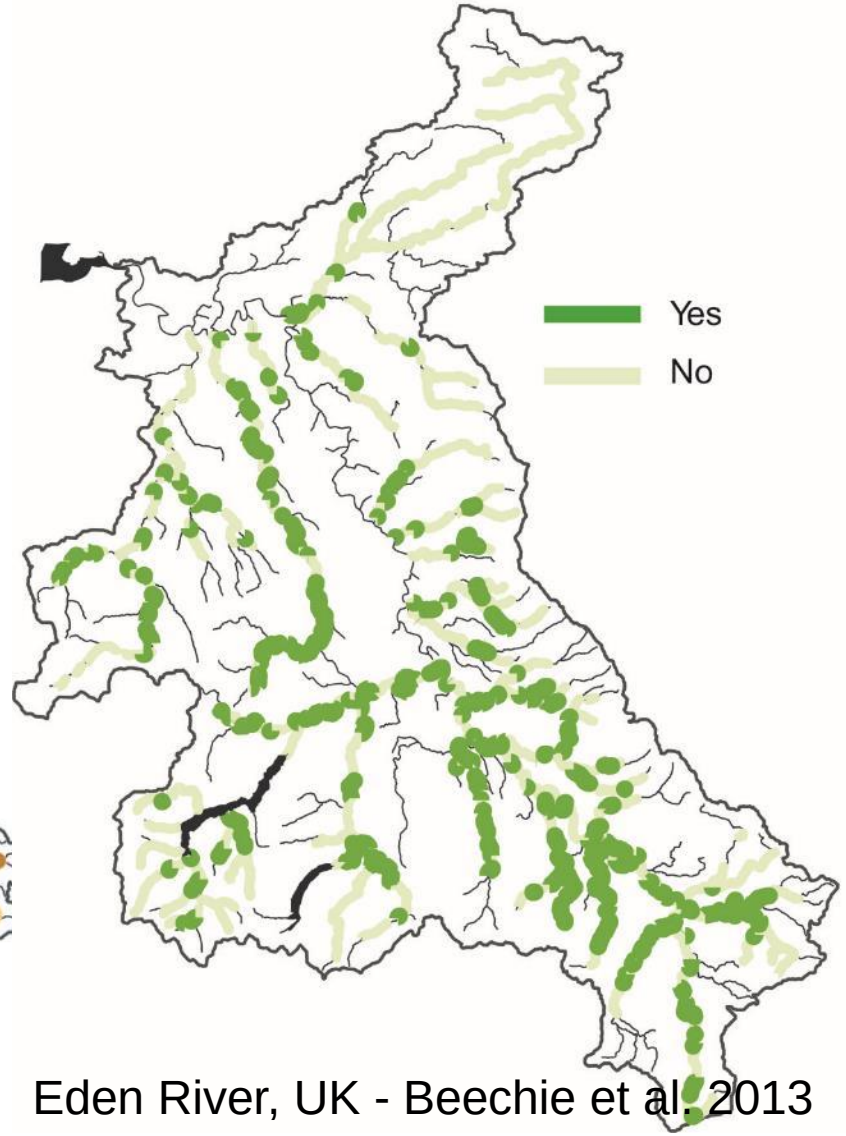
Fine Sediment



Riparian Cover

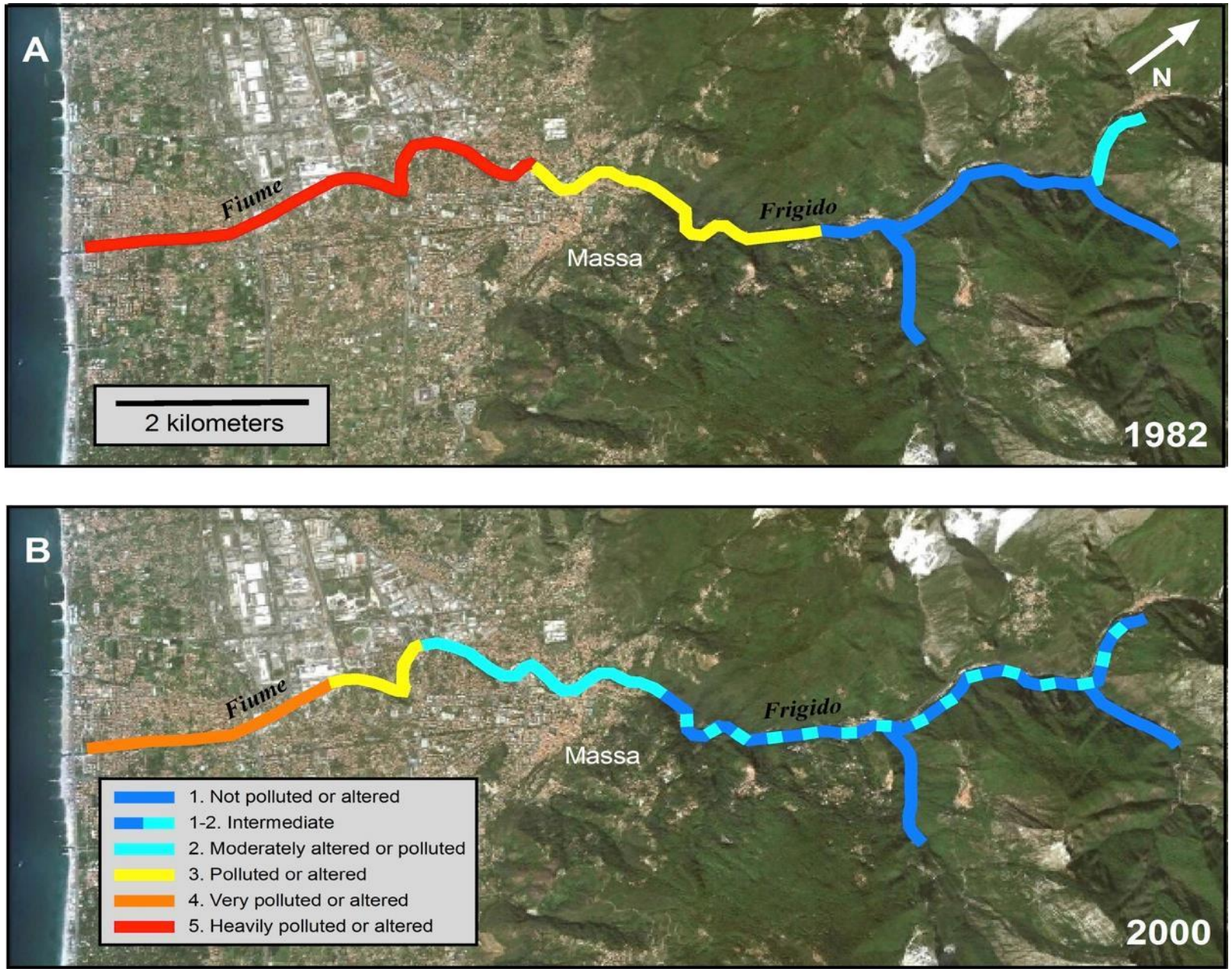


Grazing/Bank Erosion

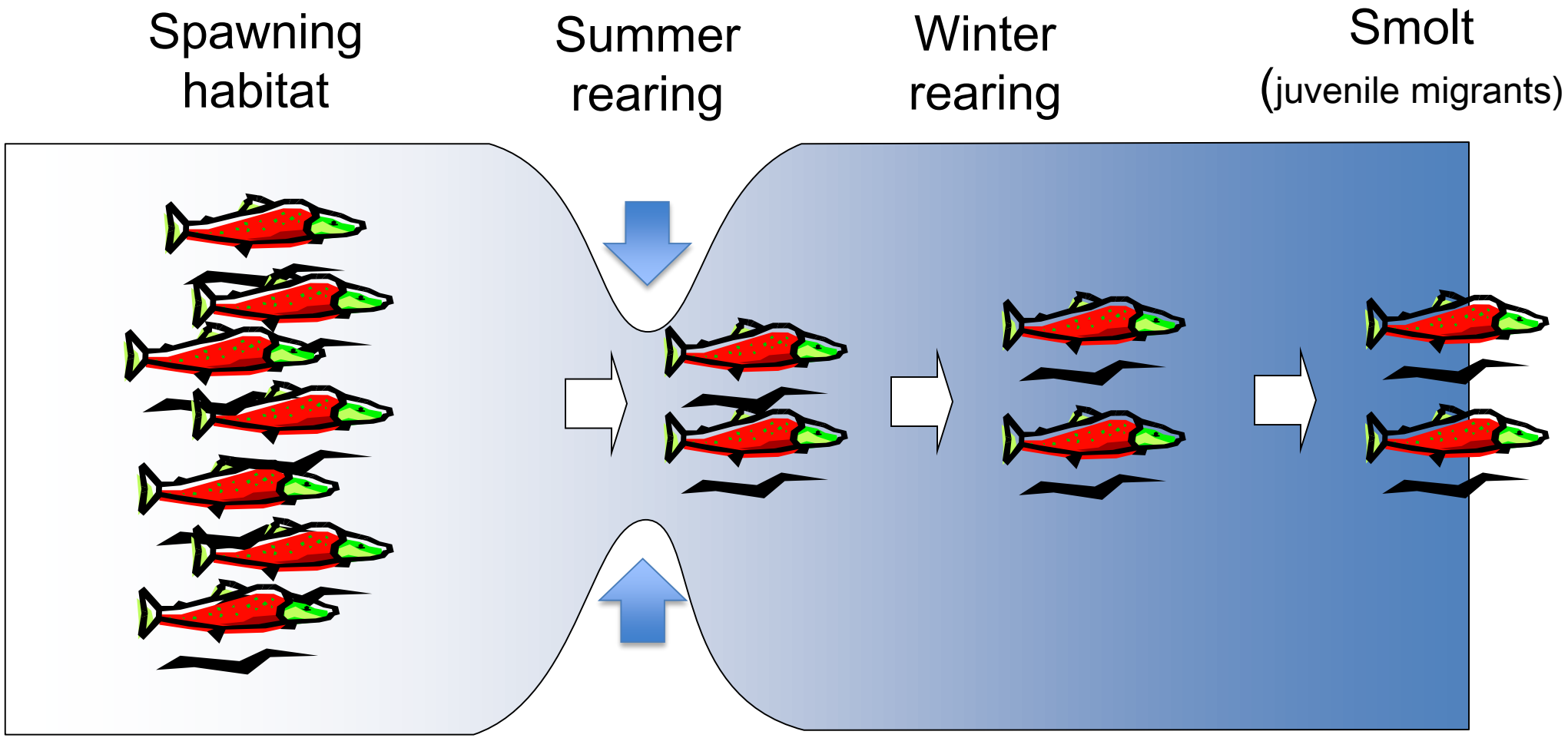


Eden River, UK - Beechie et al. 2013

Biological Assessment – IBI Example

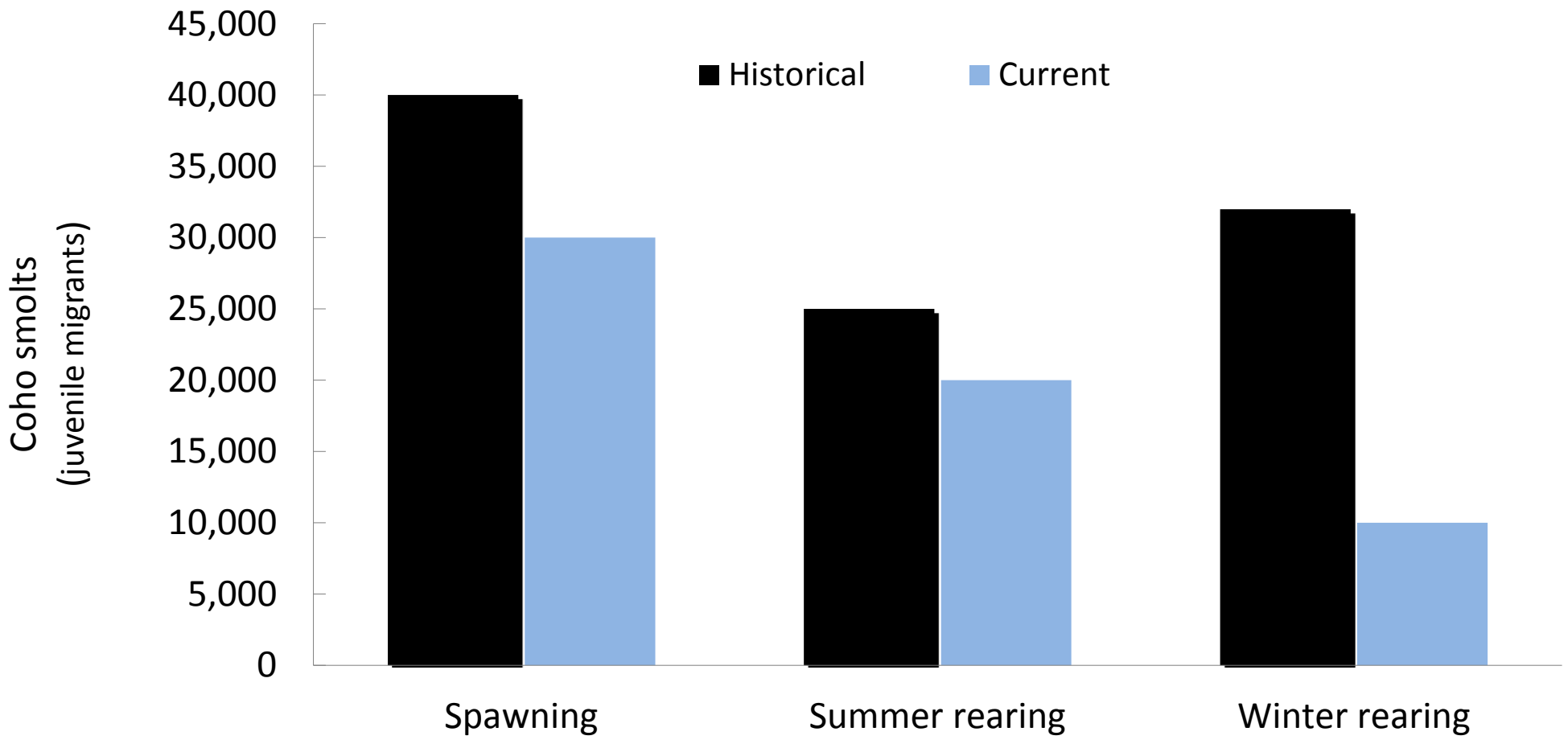


Limiting Factors Analysis to Identify Restoration



Watershed program
Northwest Fisheries Science Center
National Marine Fisheries Service

What Habitat is Limiting?

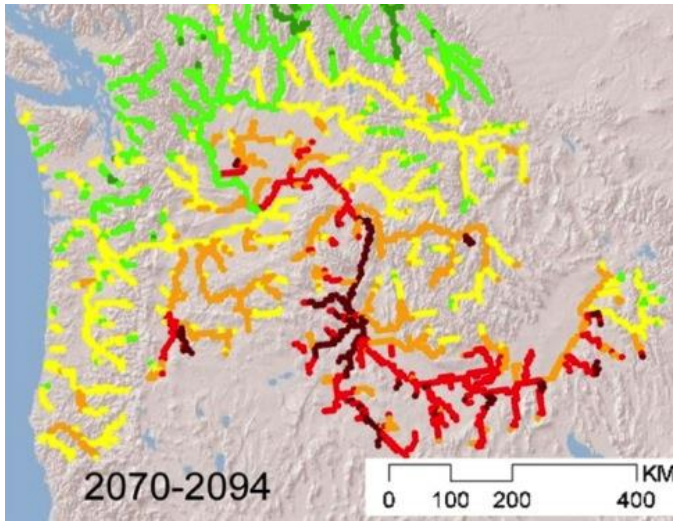


G. Pess unpublished

Selecting Restoration Techniques

- Process-based restoration vs. improvement
- Effectiveness of different techniques
- Restoration and Climate change

John McMillan photos



Time and Duration of Restoration

Restoration action	Restores Processes	Years till response	Duration of action
Barrier removal	Yes	<1	50+
Floodplain connectivity	Yes	<1	50+
Restore in-stream flow	Yes	<1	50+
Riparian planting	Yes	25-50	100+
Road removal	Yes	10-50	100+
*Instream habitat improvement	N	1-5	20-30
*Nutrient enrichment	N	<1	?

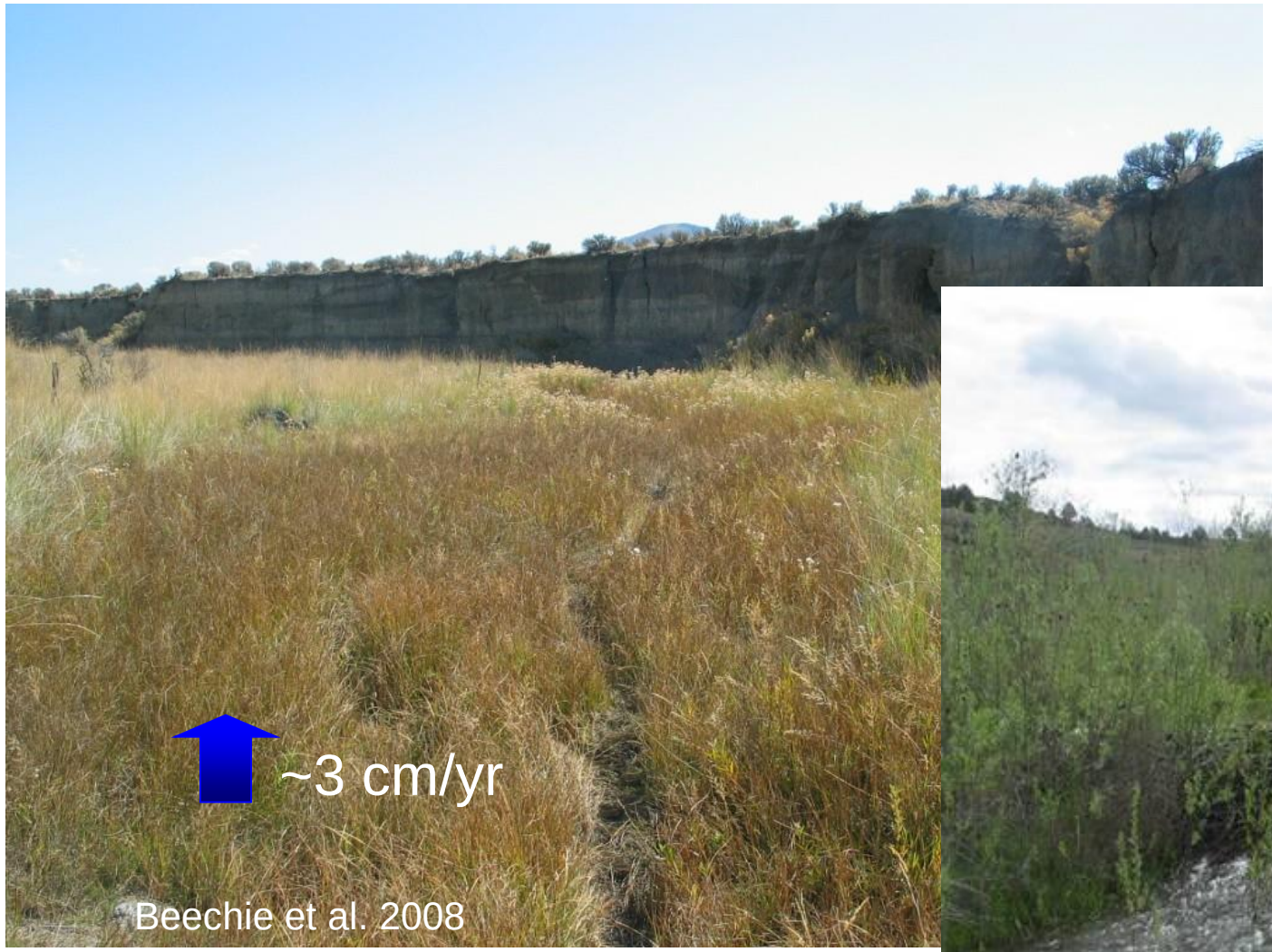
*** NEED TO BE COUPLED WITH PROCESS BASED RESTORATION** Roni et al. 2013

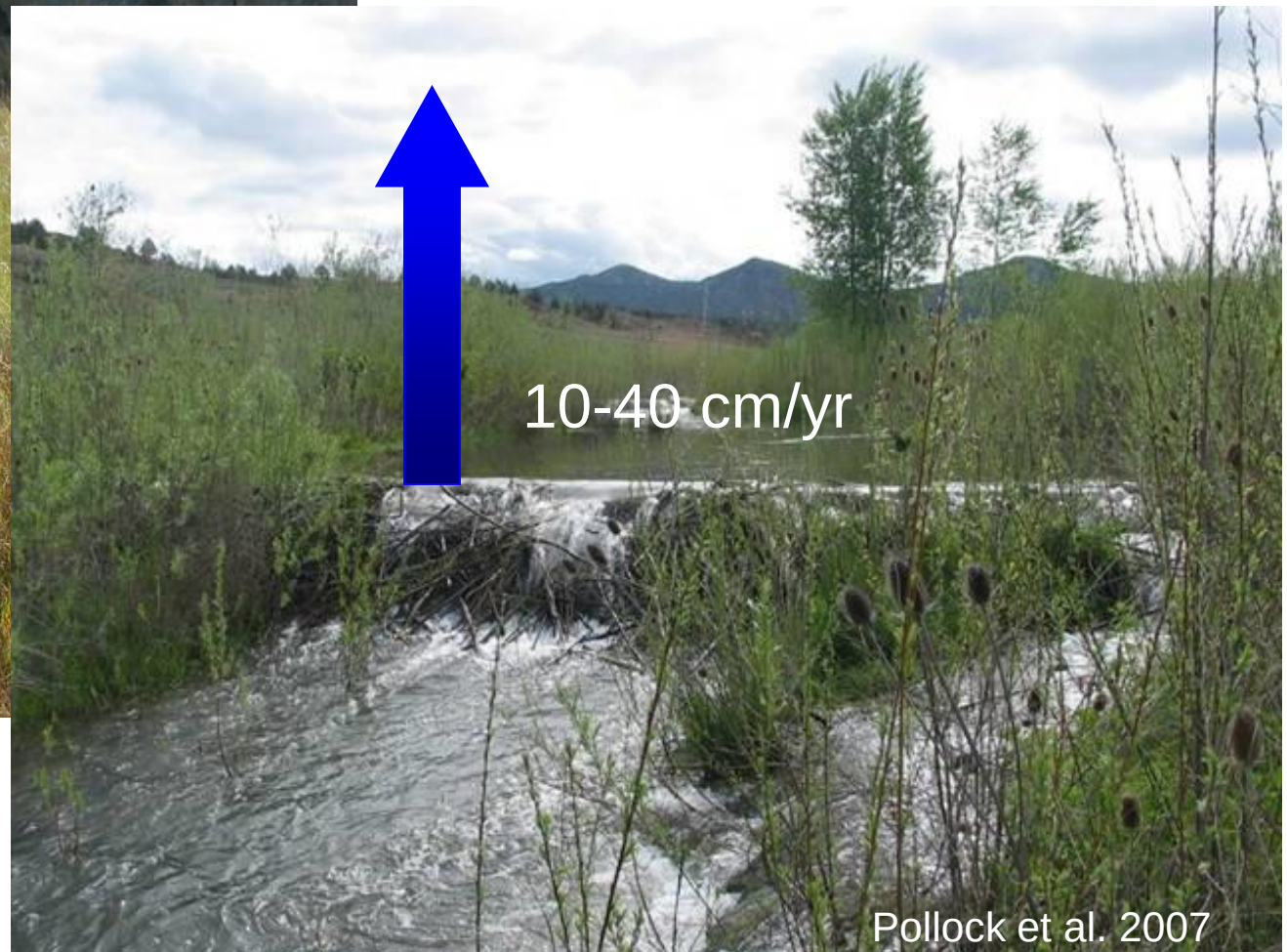
Restoration Actions & Climate change

	Does Project Ameliorate -		
Restoration action	**Temperature increase**	**Low flow decrease**	**Peak flow increase**
Barrier removal	Y	Y	N
Floodplain connectivity	Y	N	Y
Restore in-stream flow	Y	Y	N
Riparian rehabilitation	Y	M	N
Road removal	M	N	Y
Instream habitat	M	N	N
Nutrient enrichment	N	N	N

Beechie et al. 2012

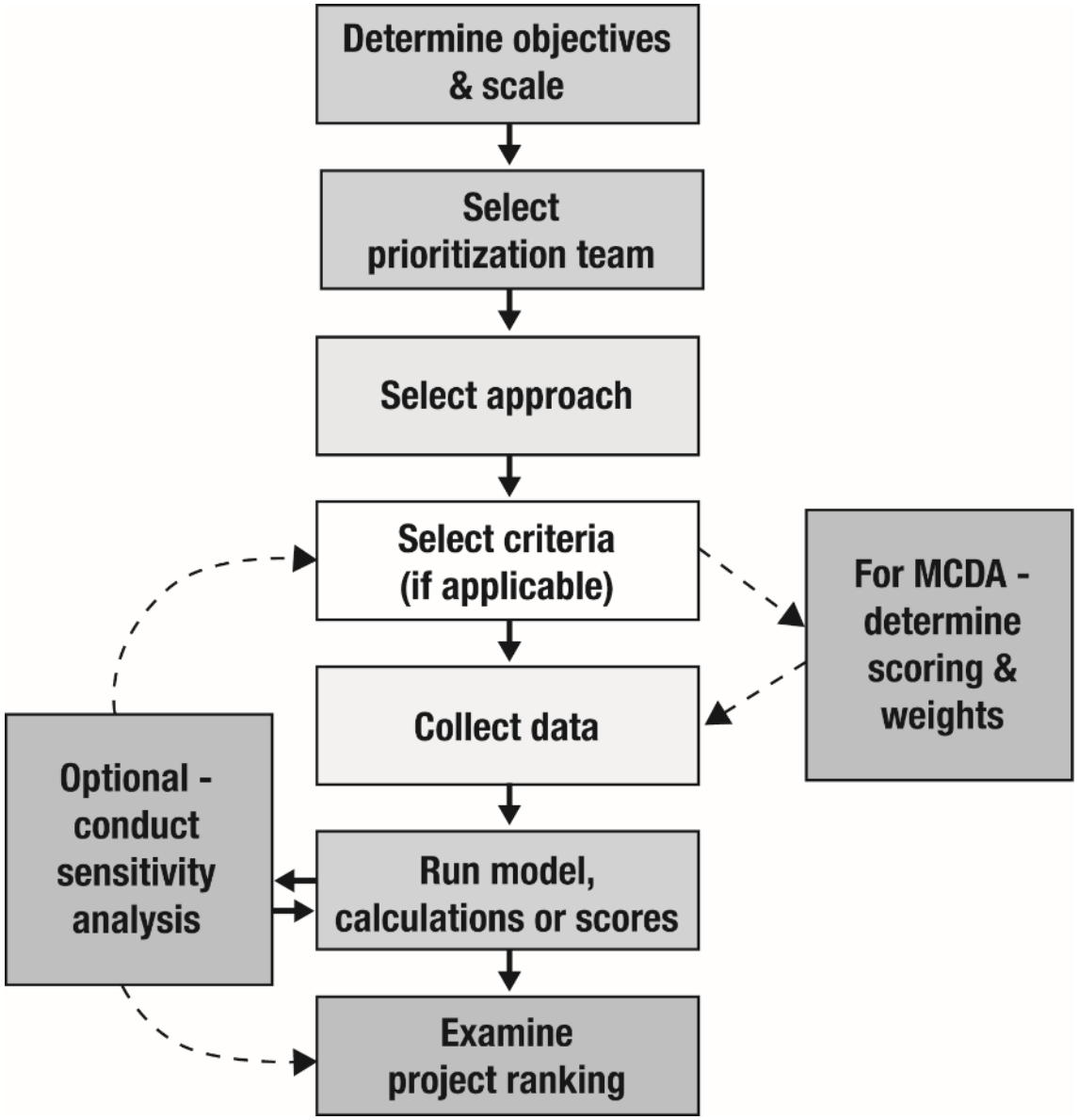
Beaver & Floodplain & Riparian Restoration





Prioritization or Sequencing Restoration

- A variety of approaches
  - Project type
  - Location
  - Complex models
  - Multi-criteria scoring systems



Roni et al. 2013

Prioritization – Common Approaches

Technique	Length treated	Fish/yr	Cost	Cost/ Fish	# Species benefiting	Restores process
Wood placement	2 km	500	$100K	$200	2	no
Floodplain reconnection	1 km	5,000	$500K	$100	5	yes
Riparian planting	5 km	?	$10K	?	4	yes
Road removal	8 km	?	$750K	?	4	yes

Roni et al. 2002, Beechie et al. 2008

Prioritization – Scoring System

Technique	Length treated	Fish/ yr	Cost	Cost/ Fish	# species	Restore process	Total score
Wood placement	2	4	3	3	2	1	**15**
Floodplain reconnection	1	5	2	4	5	5	**18**
Riparian planting	5	2	5	1	4	5	**22**
Road removal	5	2	1	1	4	5	**18**

Score of 1 to 5 – five being highest score

Proposed Restoration Project	Final Score
Reconnect isolated habitat Rkm 57	25
Remove Forest Road 37	22
Plant riparian Deer Creek Rkm 25	21
Wood Placement Clear Beaver Creek	17
Stanwood Levee Setback	17
Replace Impassible Culverts – Boulder River	17
Resurface 10 miles forest Road 37	16
Forest Glen Side Channel Reconnection	15
McDonald's farm conservation easement	14
Log Jam placement in Clear Fork	14
Wood placement in Urban streams	12
Bioengineering of South Fork Levee	11

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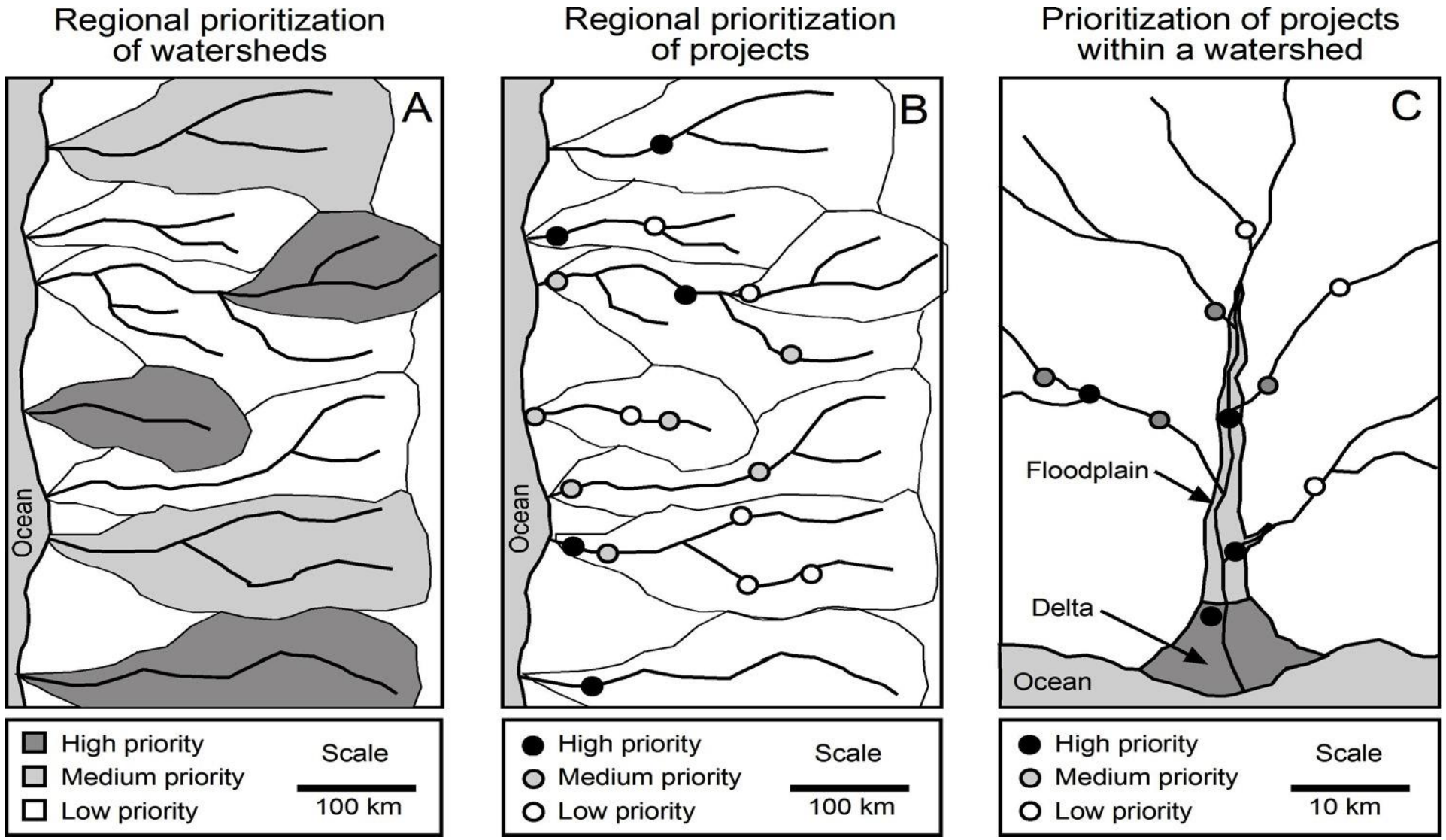
Need to Define Scores

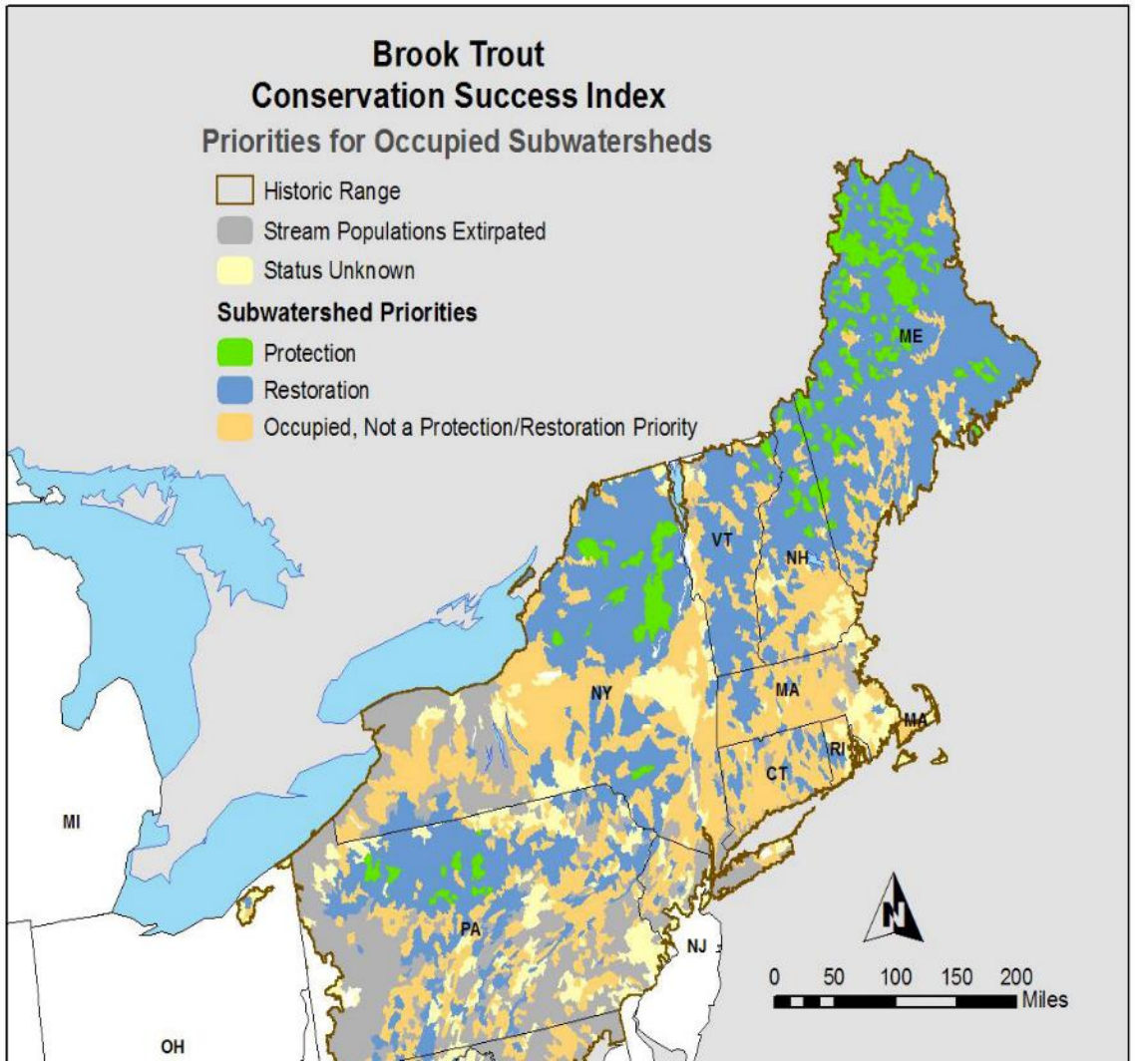
	Score (1 to 5)				
Criterion	1	2	3	4	5
Restores processes (Based on Roni et al. 2013b	Restores neither processes nor habitat	Restores physical habitat	Restores one or two processes	Restores more than two processes	Restores process and habitat or protects fully functioning habitat
Site access & logistics	Helicopter only (no roads or staging)	No roads within 0.5 km of site, but staging area if equipment/ supplies/ LWD brought in by helicopter	Roads within 0.5 km of site. No staging area.	Roads within 0.5 km of site. Good staging area.	Roads and staging area adjacent to site

Prioritization Can Occur at Multiple Levels

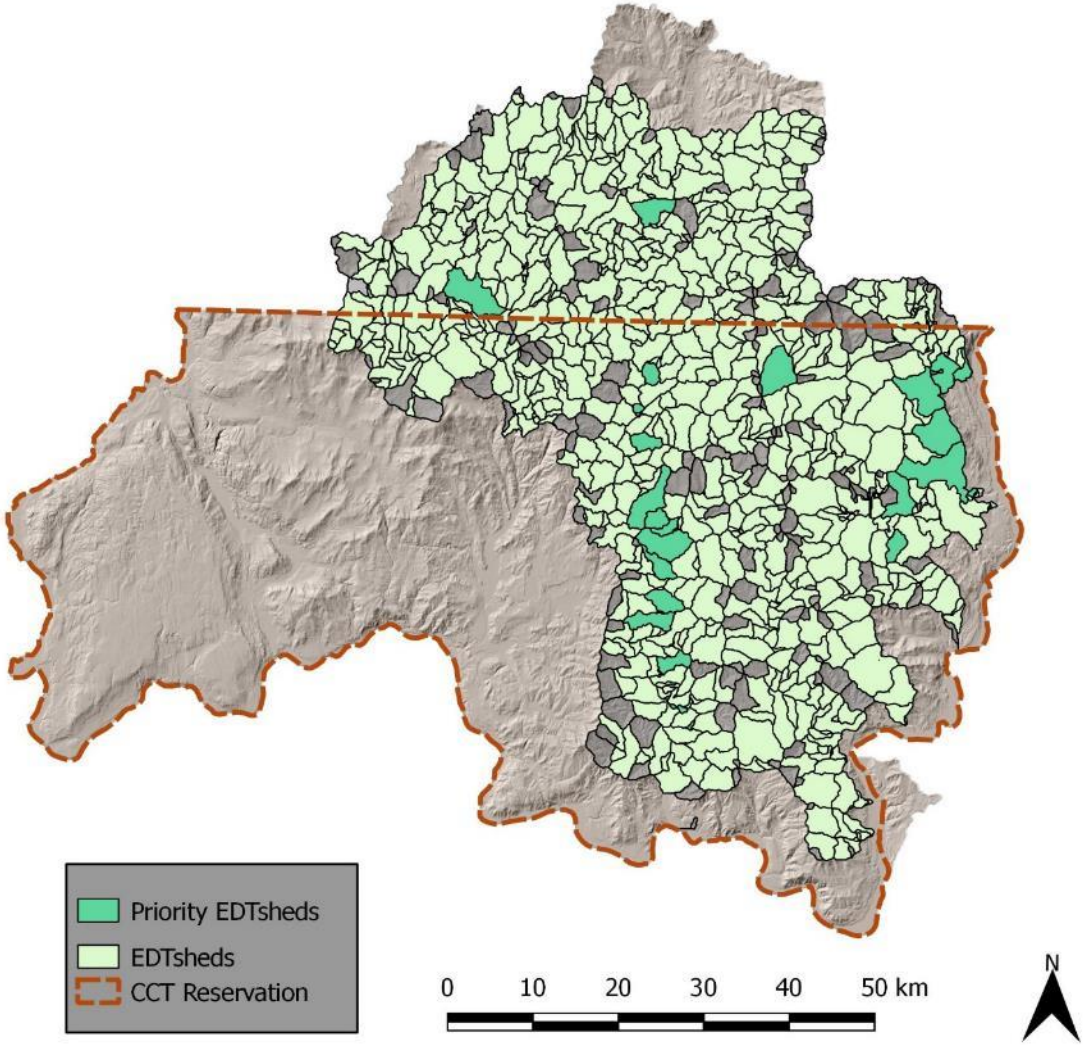


Roni, Beechie, Schmutz & Muhar 2013

Prioritizing Sub-Watersheds Examples

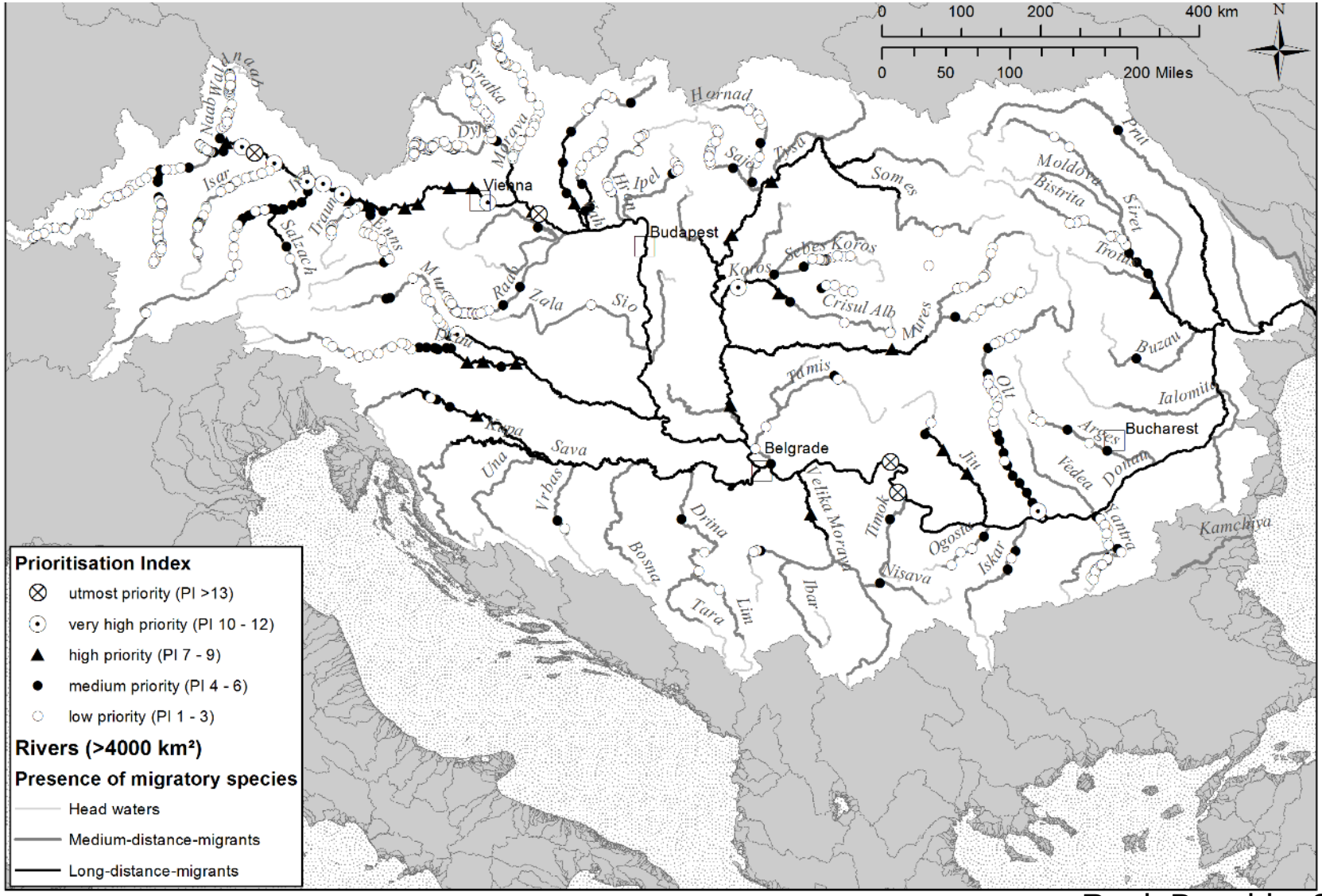


Williams et al. 2007 Trout Unlimited



Timm and Roni 2018

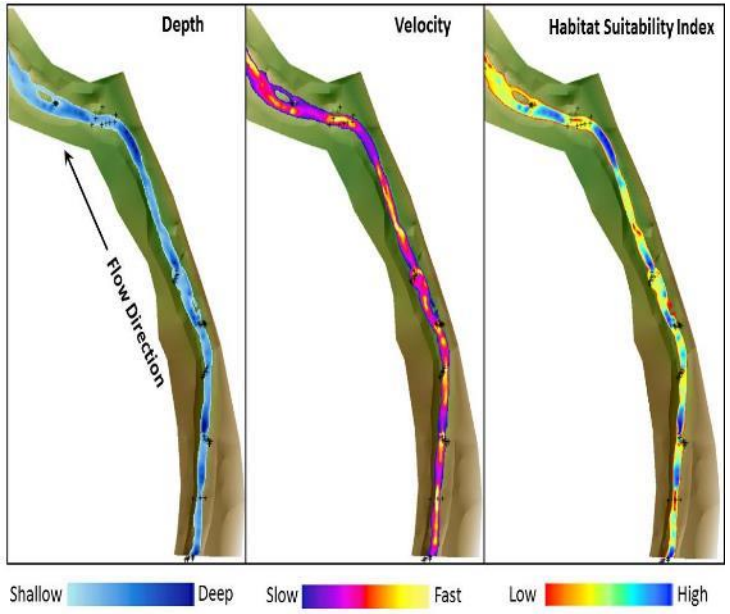
Prioritizing Barrier Removals Across a Basin - the Danube River Basin



Roni, Beechie, Schmutz & Muhar 2013

Restoration Design Steps

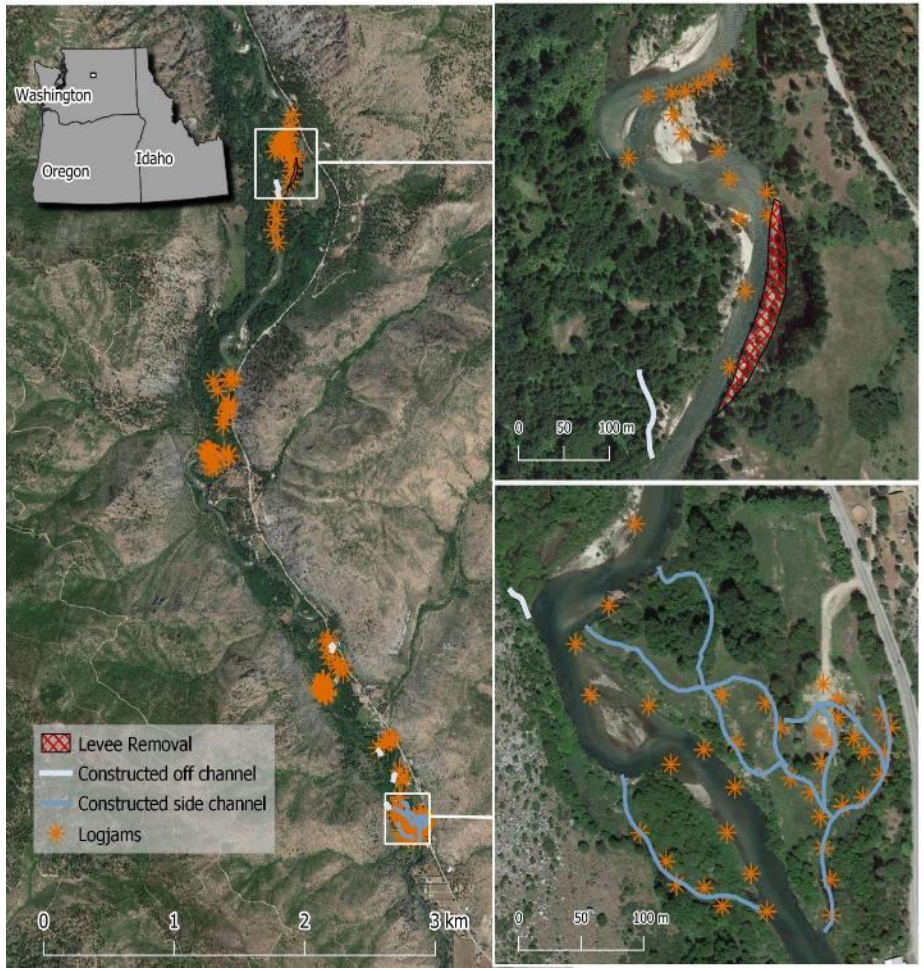
- Planning
  - Problem Identification
  - Context & assessment
  - Project goals & objectives
  - Alternatives evaluation
- Project design
- Implementation
- Monitoring & Evaluation



RiverRAT – Design Tool http://www.restorationreview.com

Project Design and Watershed Processes

- Target root causes of degradation
- Tailor actions to local potential
- Match scale of action scale of problem
- Predict restoration outcomes
- Build uncertainty into design
- Design monitoring into project



Cluer et al. 2009, 2013;, Beechie et al. 2013

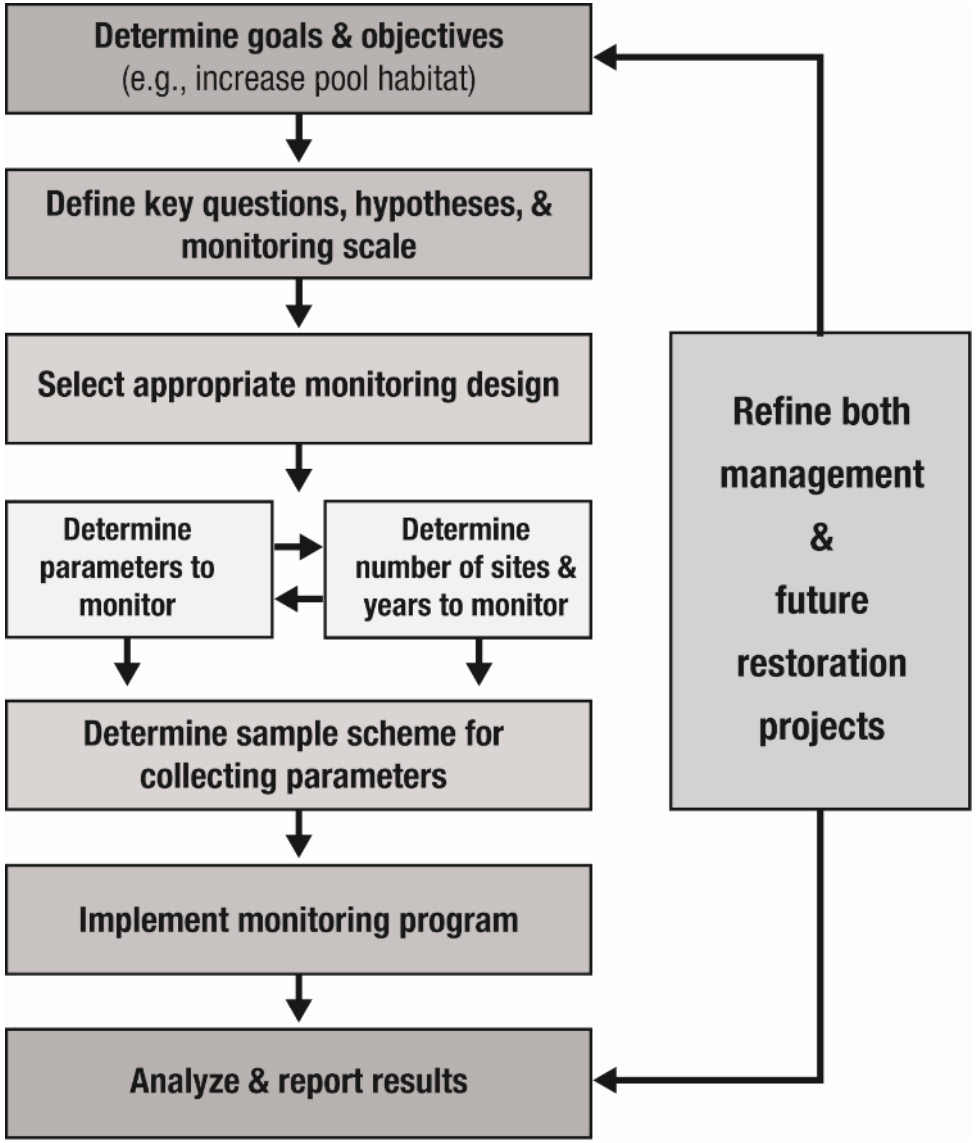
Monitoring and Evaluation

"Additional evaluation studies on stream improvement, especially with reference to the effect on the abundance of fish, are still urgently needed."

Clarence M. Tarzwell, U.S. Bureau of Fisheries, 1937

Steps for Designing a Effectiveness Monitoring Program

- Define project goals and objectives
- Define scale
- Define questions/hypotheses
- Determine monitoring design
- Spatial and temporal replication
- Select parameters
- Selecting sampling scheme/protocol
- Implement monitoring



Key Questions or Hypotheses

Reach or Project Scale

- **What is effect of <u>project x</u> on local habitat conditions or fish?**
- **What is effect of <u>project like x</u> on local habitat conditions or fish?**

Watershed Scale

- **What is effect of <u>project x</u> on watershed conditions or a fish population?**
- **What is effect of a <u>suite of projects</u> on watershed conditions or a population?**

Key Questions or Hypotheses

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Watershed Scale

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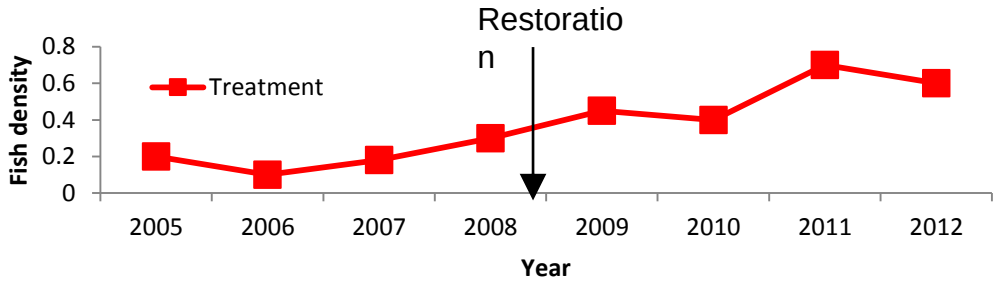
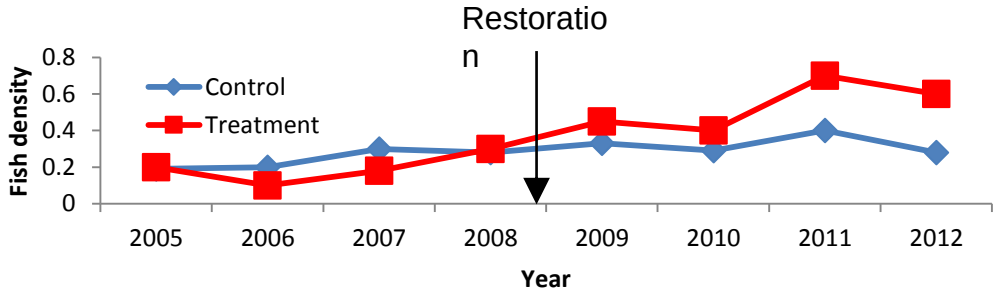
Experimental Designs

- Before-After (BA)



- Before-After Control-Impact (BACI)

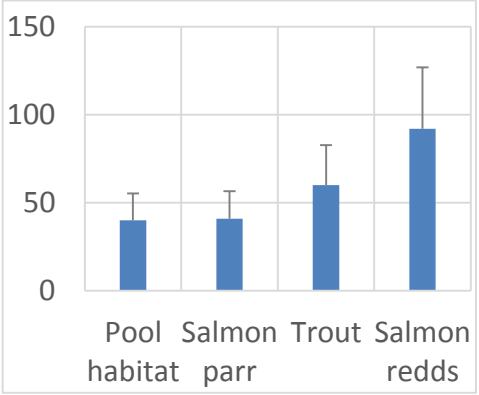


- Multiple BACI

- Extensive Post-treatment (EPT or CI)

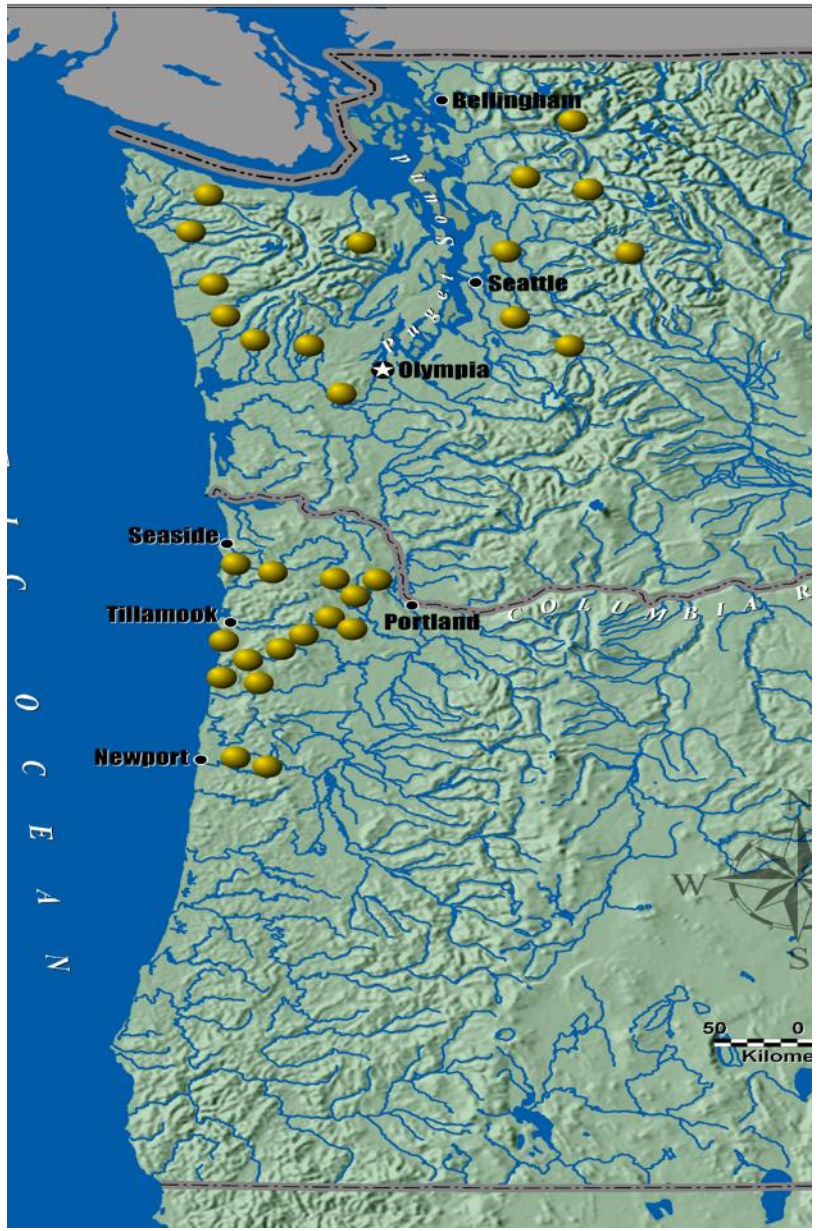
Control

Treatment

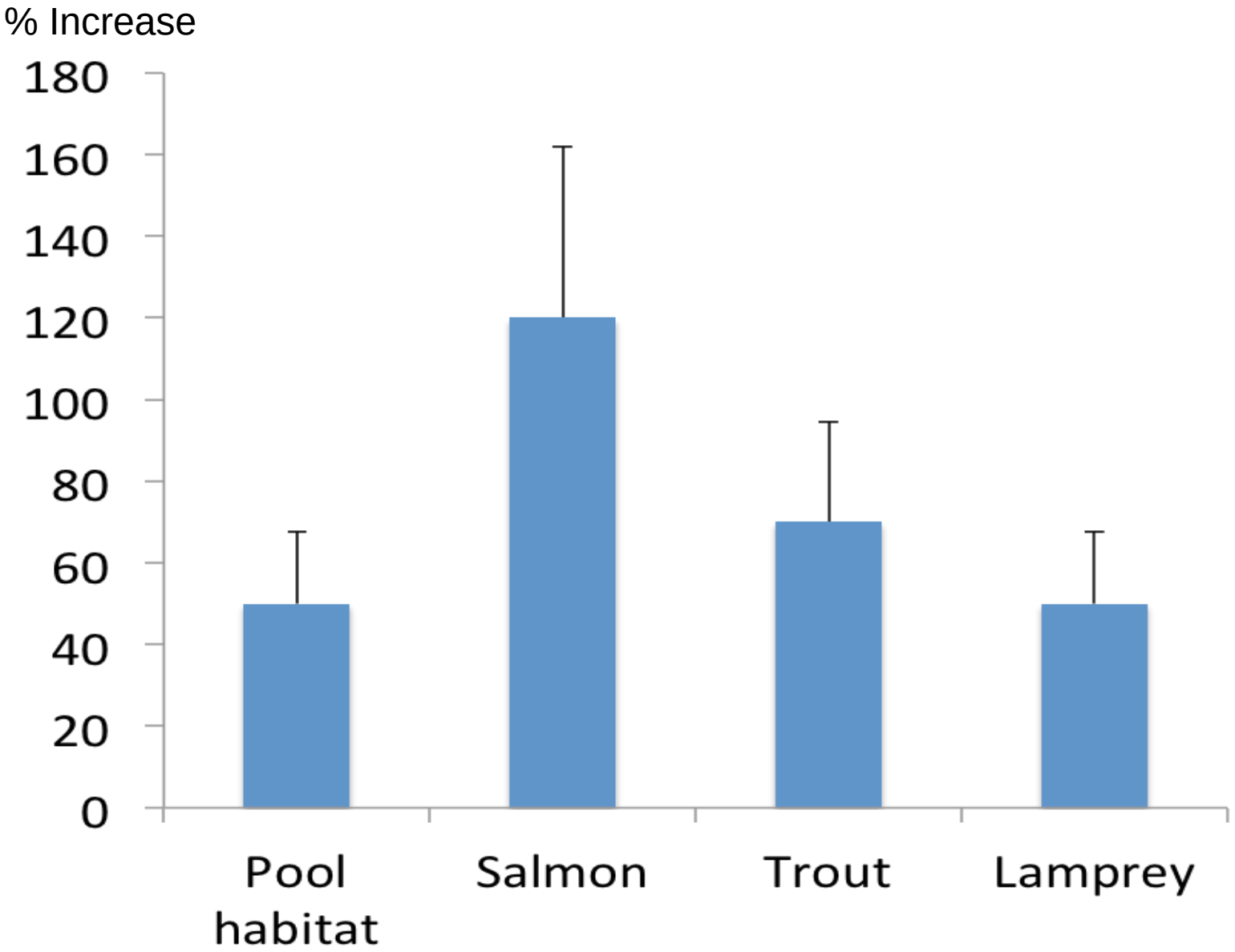


Wood Placement in Streams

- What is the average of effect of LWD placement on habitat and fish?
- Design Extensive post-treatment
- Scale - Reach scale (paired treat. and cont.)
- Replication – spatial n = 30
- Parameter – fish, habitat, macroinvertebrates
- Sampling - census of study reaches

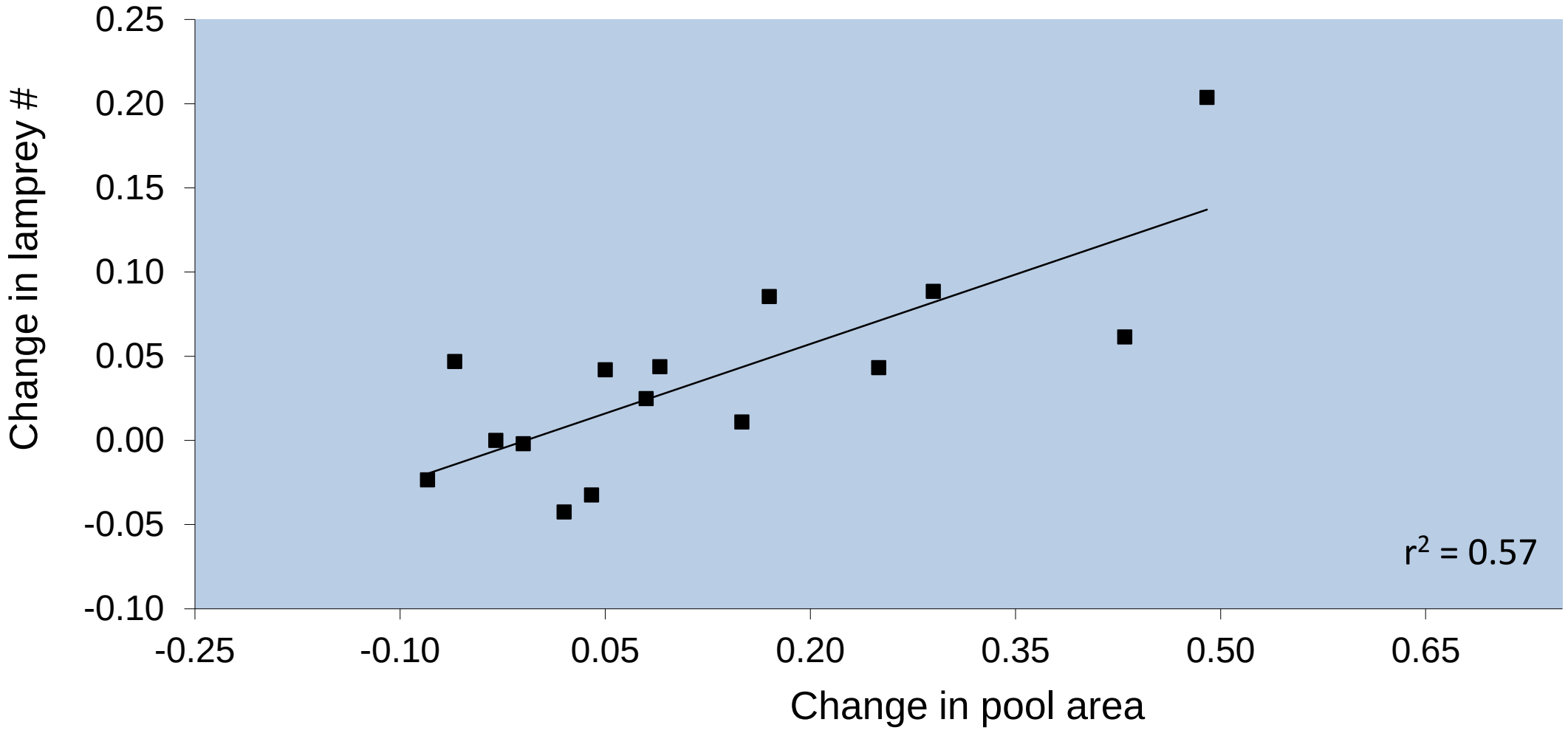


Average Response to Wood Placement



Roni & Quinn 2001

Fish Response vs. Restoration Intensity



Strengths of Monitoring Designs

	Before-after			Post-treatment
Strength	**BA**	**BACI**	**MBACI**	**EPT**
Interannual variation	X	X	X	
Correlate to physical			X	X
Broadly applicable results			X	X
Length of monitoring	10+	10+	5+	1-3
Difficulty of implementation	Low	Low	High	Medium

When Selecting Parameters

- Linked to key question/hypothesis
- Change in measurable way linked to treatment
- Have limited/manageable variability
- Cost effective in space and time

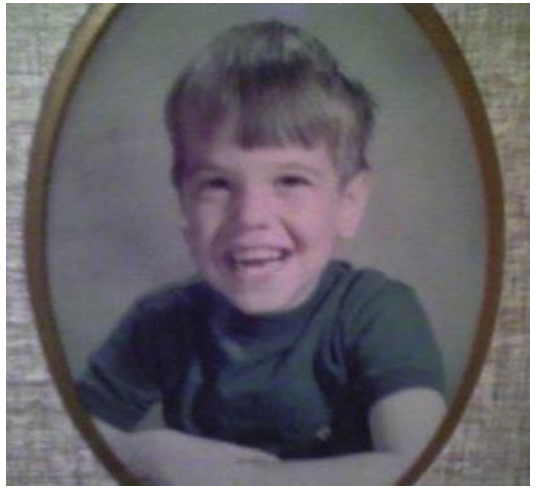
What to monitor for various actions?

Restoration Technique	Habitat	Primary production	Inverts	Fish
Culvert/Passage	X			X
Floodplain	X	X	X	X
Riparian	X	X	X	
Sediment reduction	X	X	X	?
In-stream	X		**?**	X
Nutrients	X	X	X	X

Spatial and Temporal Replication

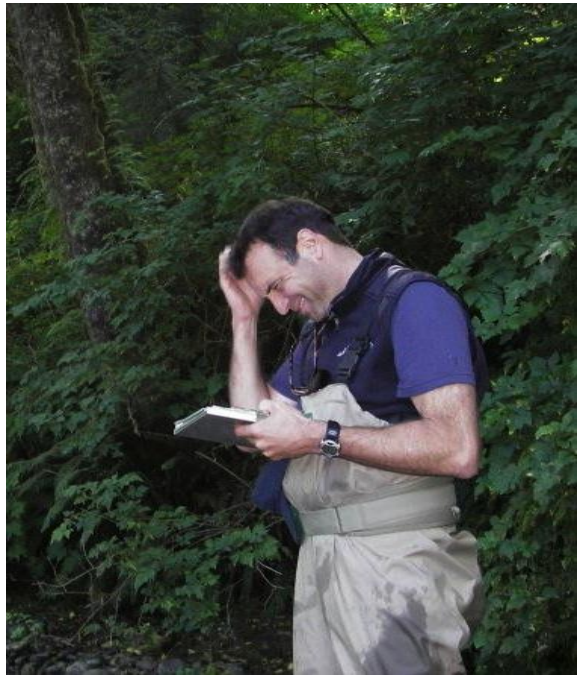
- How sites?
- How many years?

5 years?



25 years?

50 years?



Estimating Sample Size

- Variance
- Effect size*
- B = 0.80*
- α = 0.05*

* Determined by investigator (you!)

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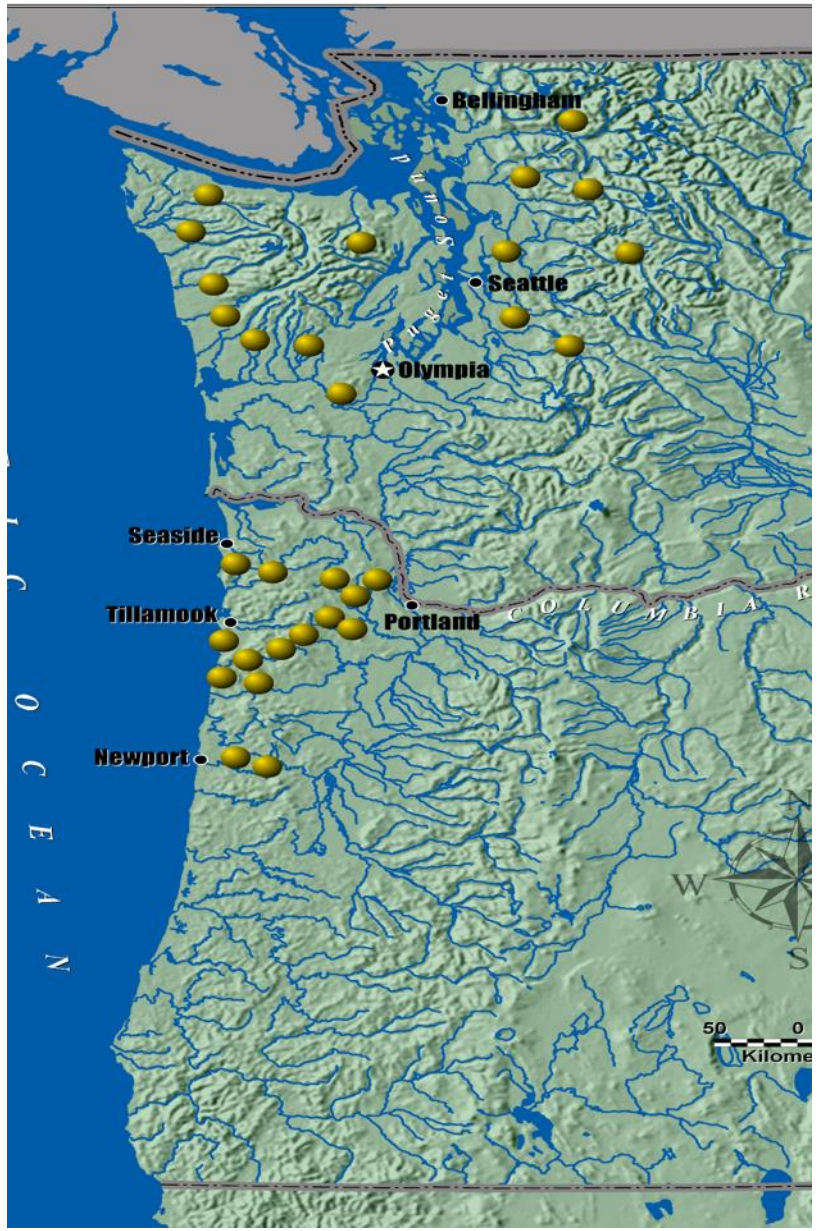
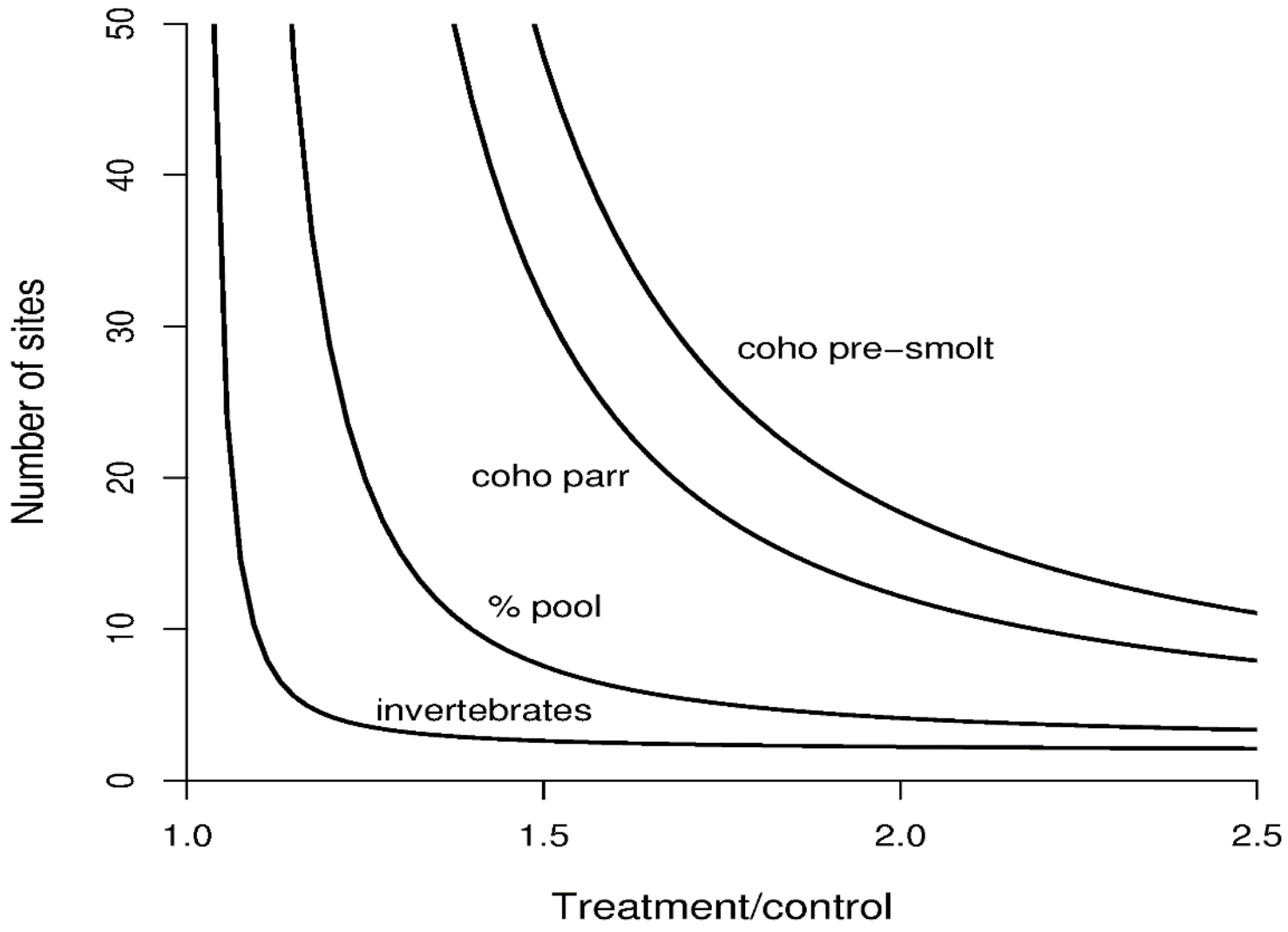
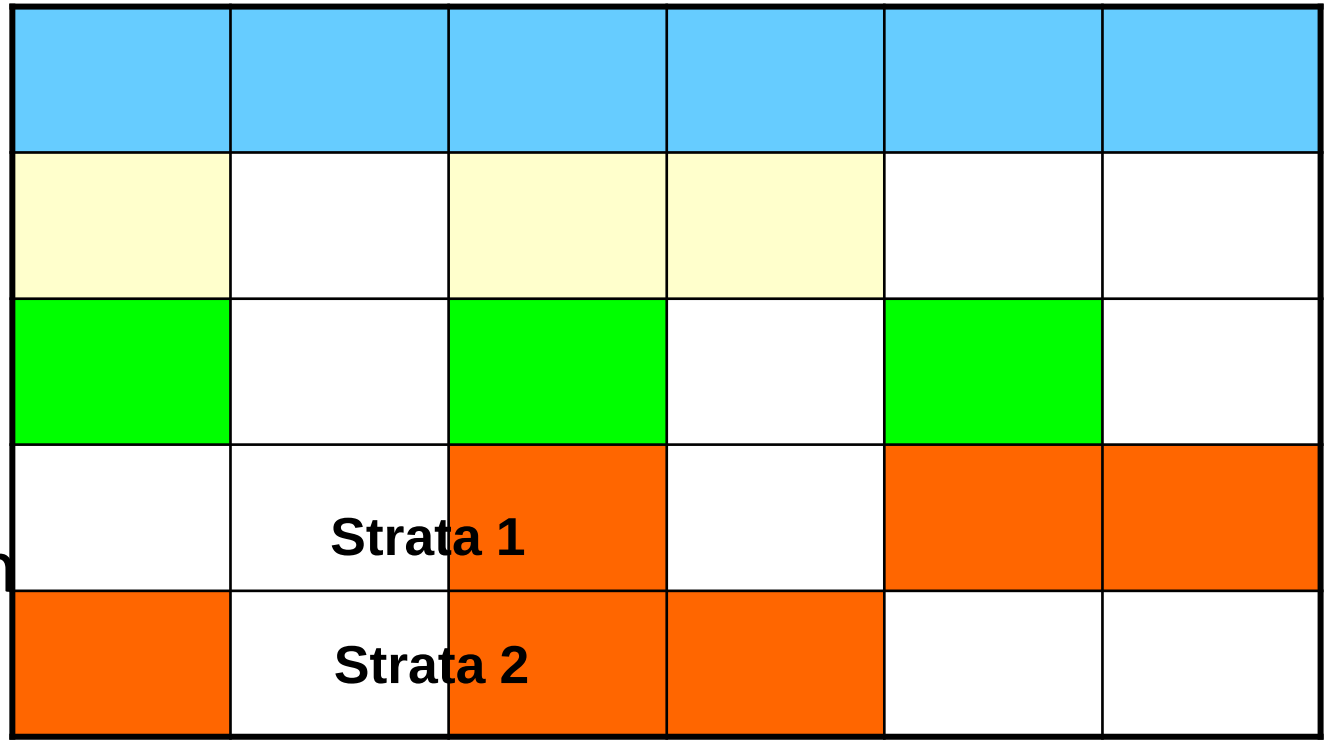


Post Treatment Design – Sample Size

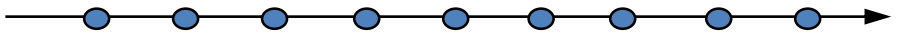


Common Sampling Schemes

- Census
- Simple random
- Systematic
- Stratified random



- Line transect



Key Questions or Hypotheses

Reach or Project Scale

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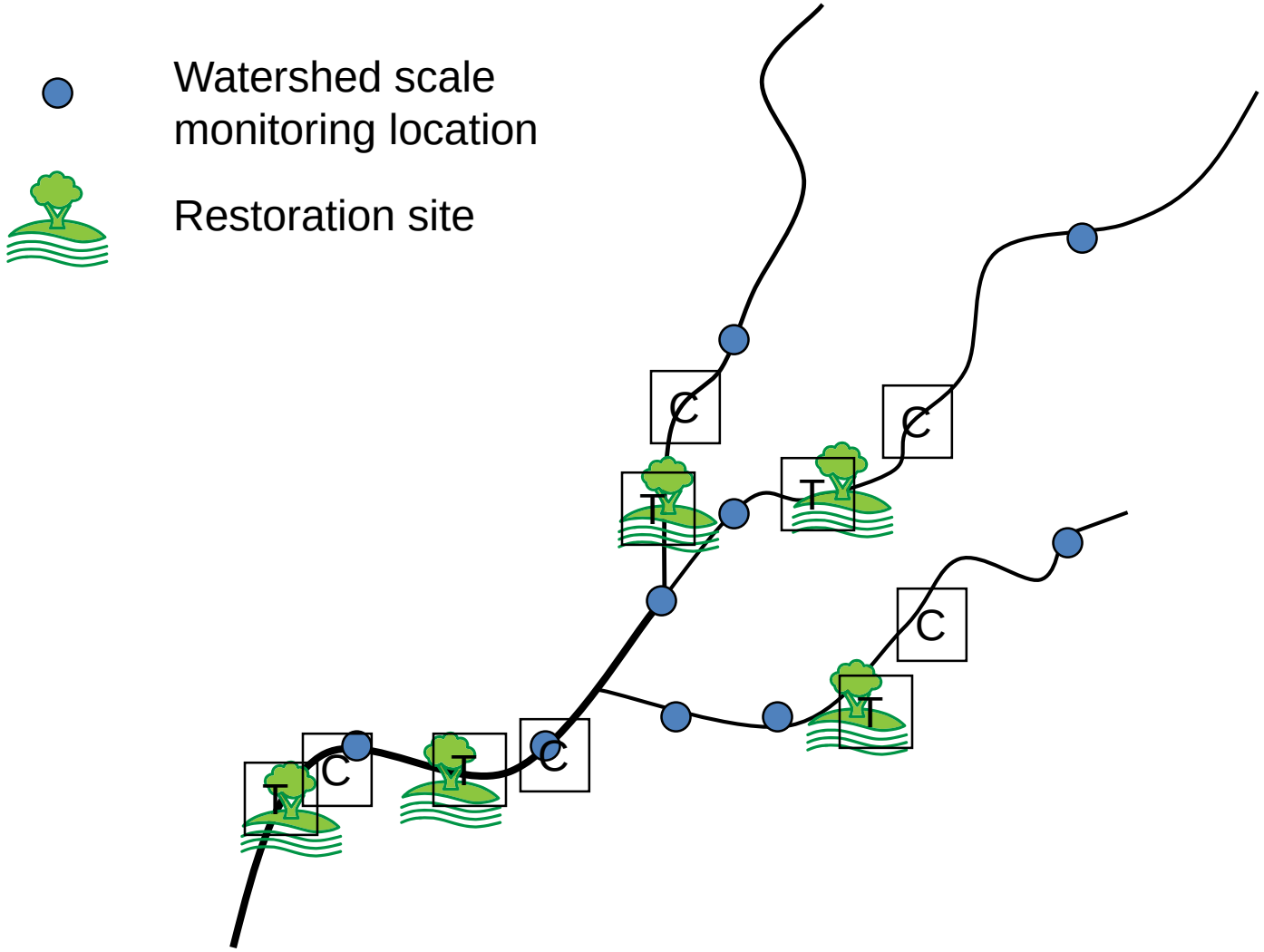
  - Sample many projects

Watershed Scale

- **What is effect of a suite of projects on watershed conditions or a population?**
  - **IMW**

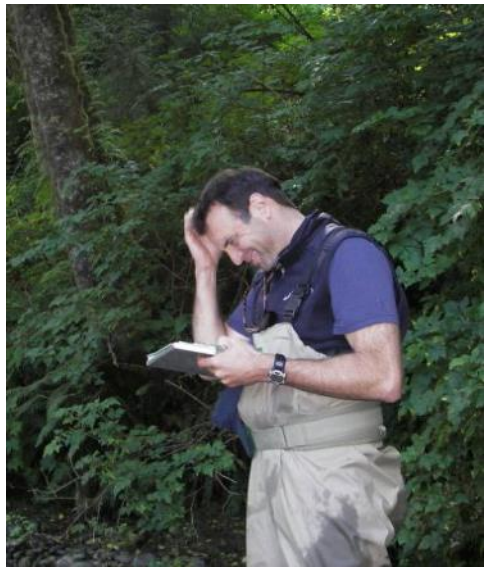
Watershed Scale vs. Reach Scale

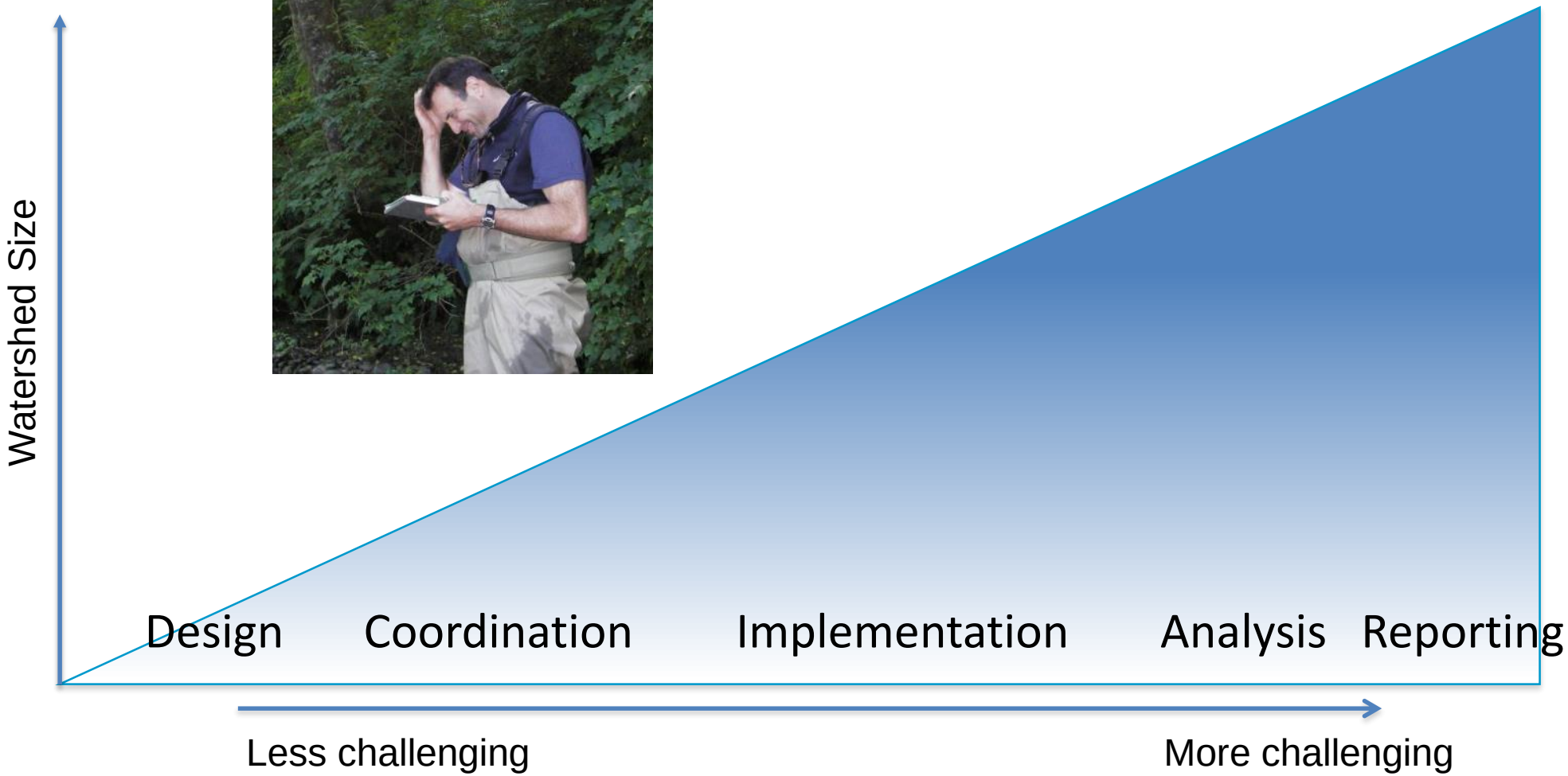


Watershed-Scale Challenges

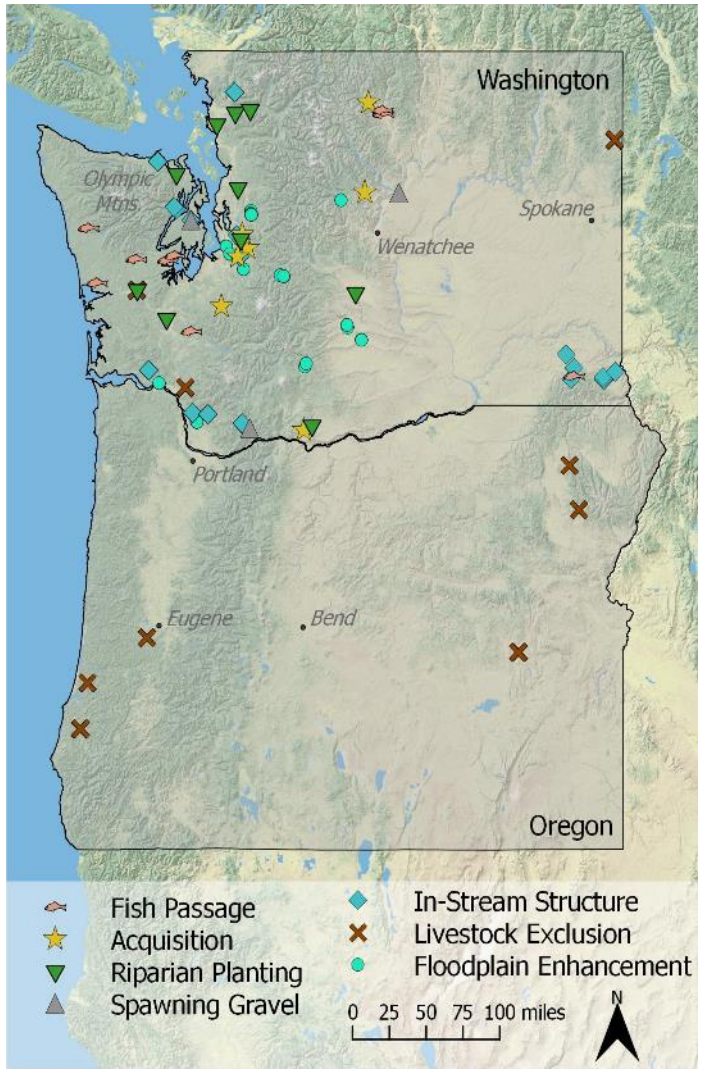
- Coordination of restoration, monitoring & other mgt. activities are critical to success!

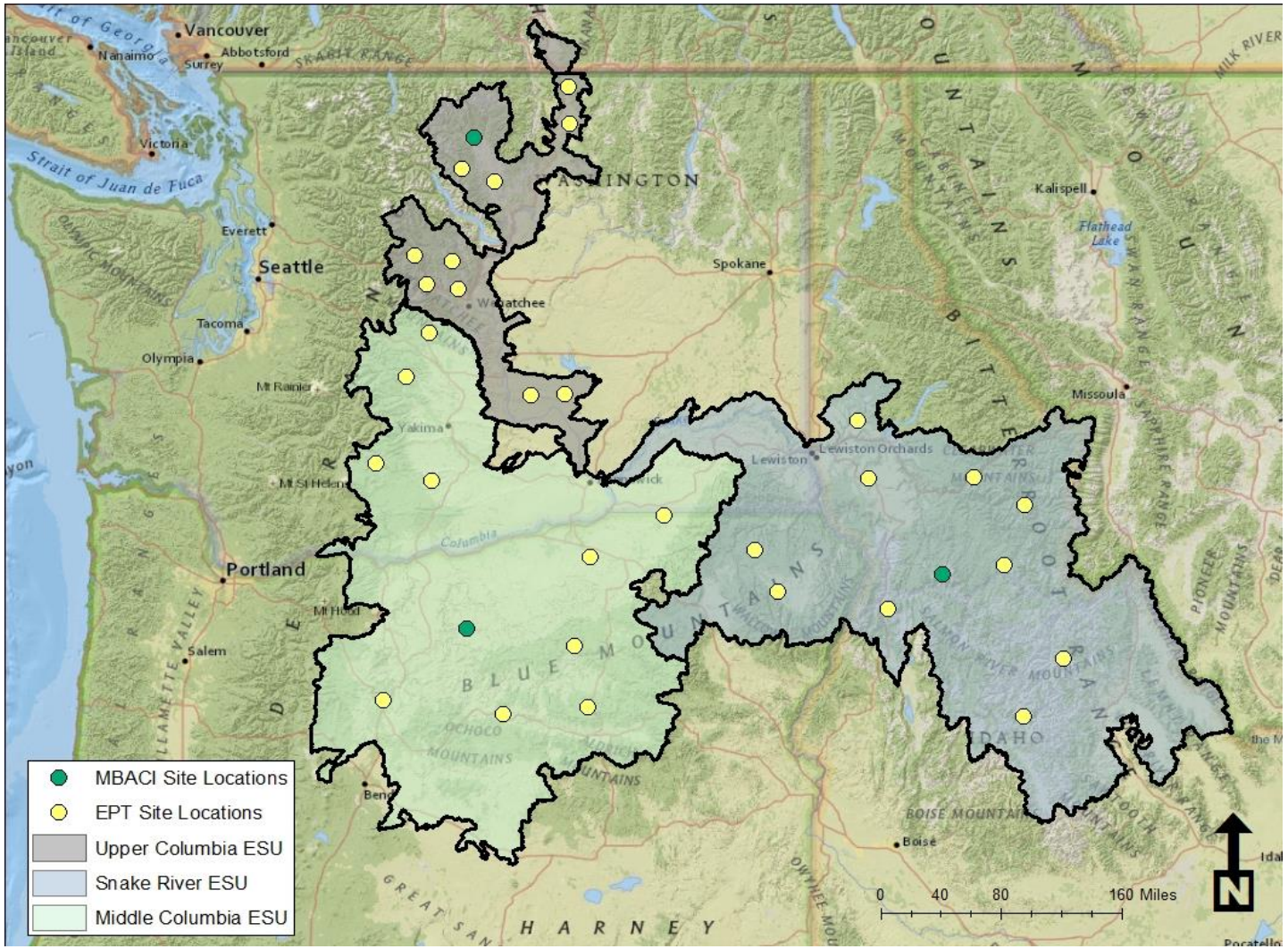
Watershed-Scale Implementation Challenges?





Evaluating a Regional Restoration Program



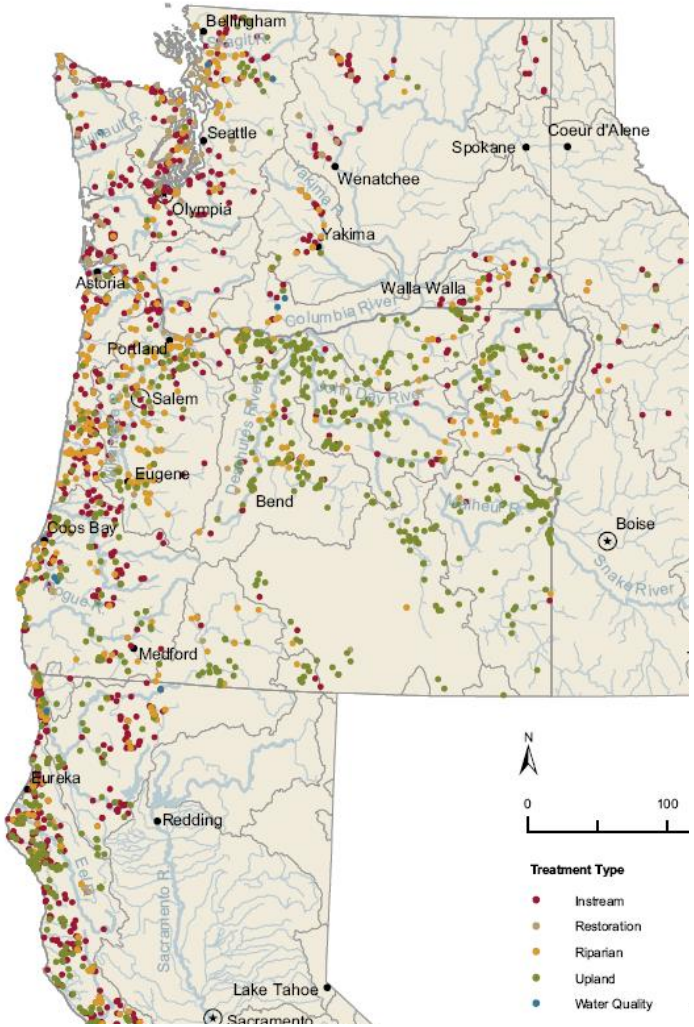


How much restoration is needed?

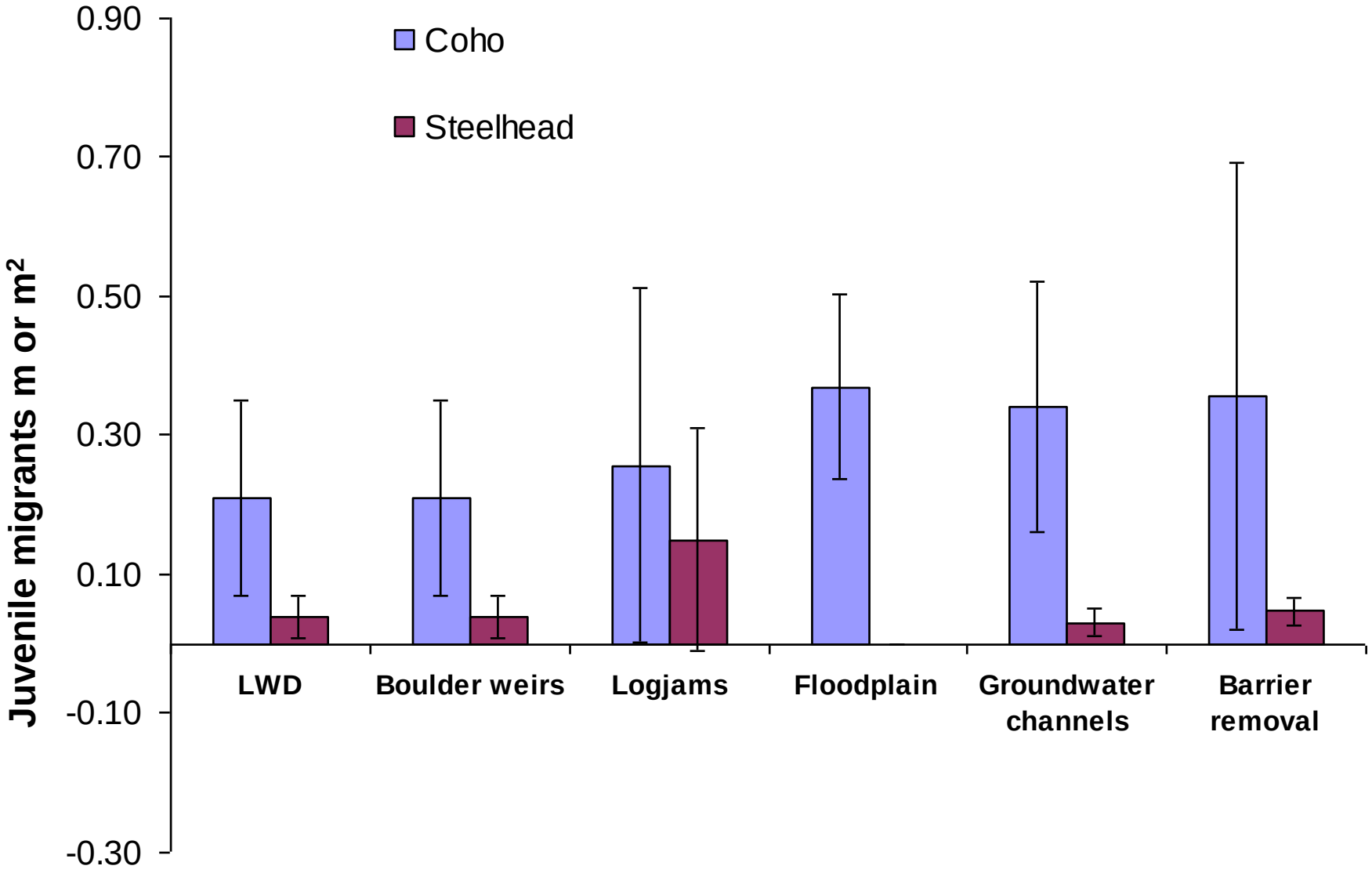
How Much Restoration Is Needed?

Restoration Activities PCSRF 2000 to 2009

Metric or Restoration Activity	All PCSRF	Per Watershed
Instream kilometers treated	1,413	3
Floodplain hectares treated	4,938	3
Barrier removal (km)	6,918	17



Mean Increase in Juvenile Migrants (smolts)

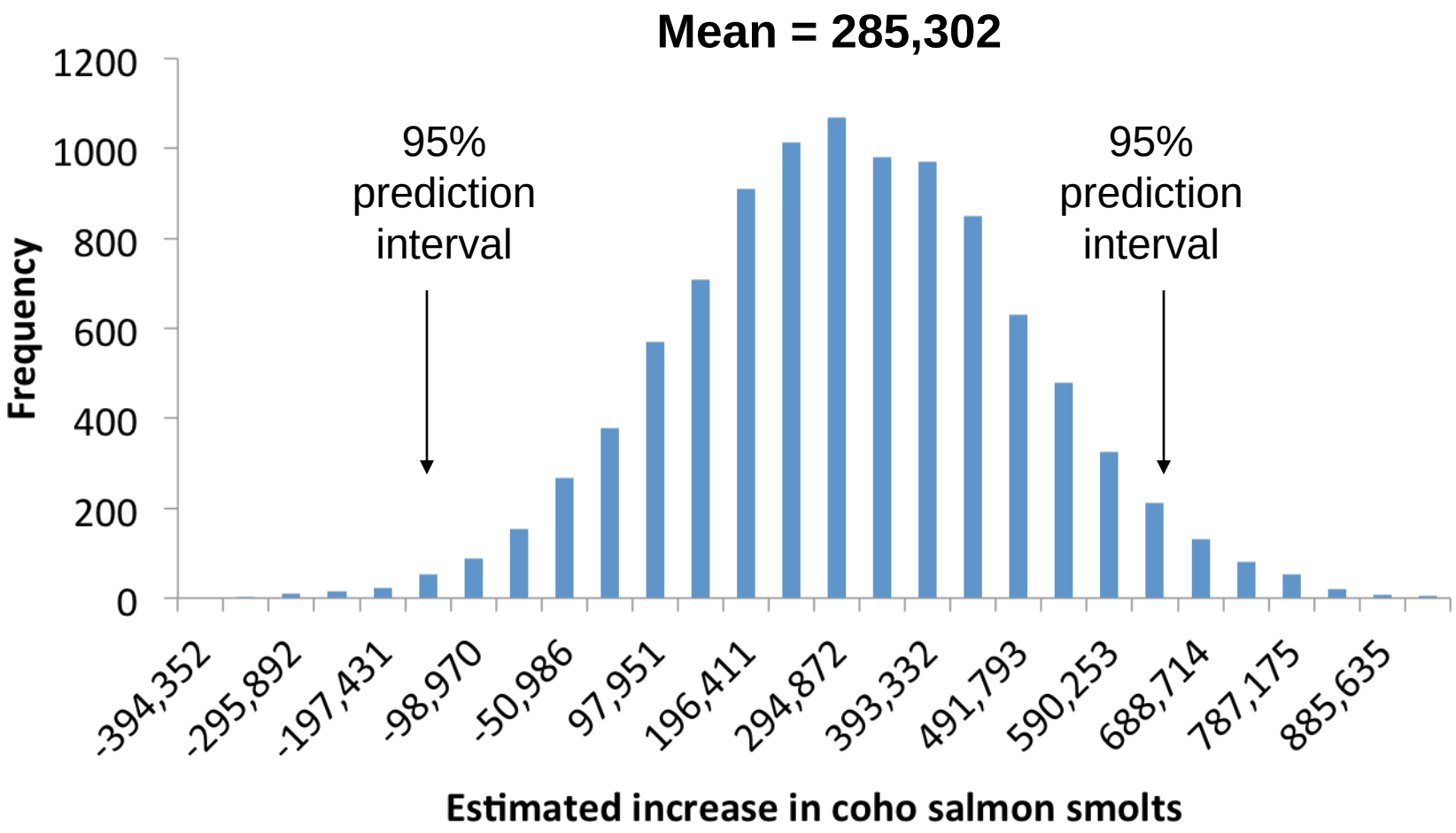


Roni et al. 2010

Restoration Actions Applied to Watershed

Salmon Habitat	Restoration type
Streams/Rivers	
small – inaccessible	Barrier removal
small - accessible	Wood (LWD) addition
medium	Boulder weirs
large	Logjams
Floodplain habitat	
lost side channels	Groundwater channels
lost sloughs	Floodplain reconnection

Increase in Juvenile Salmon (smolts)
Scenario 1 – Restore All Habitat in a Watershed



Roni et al. 2010

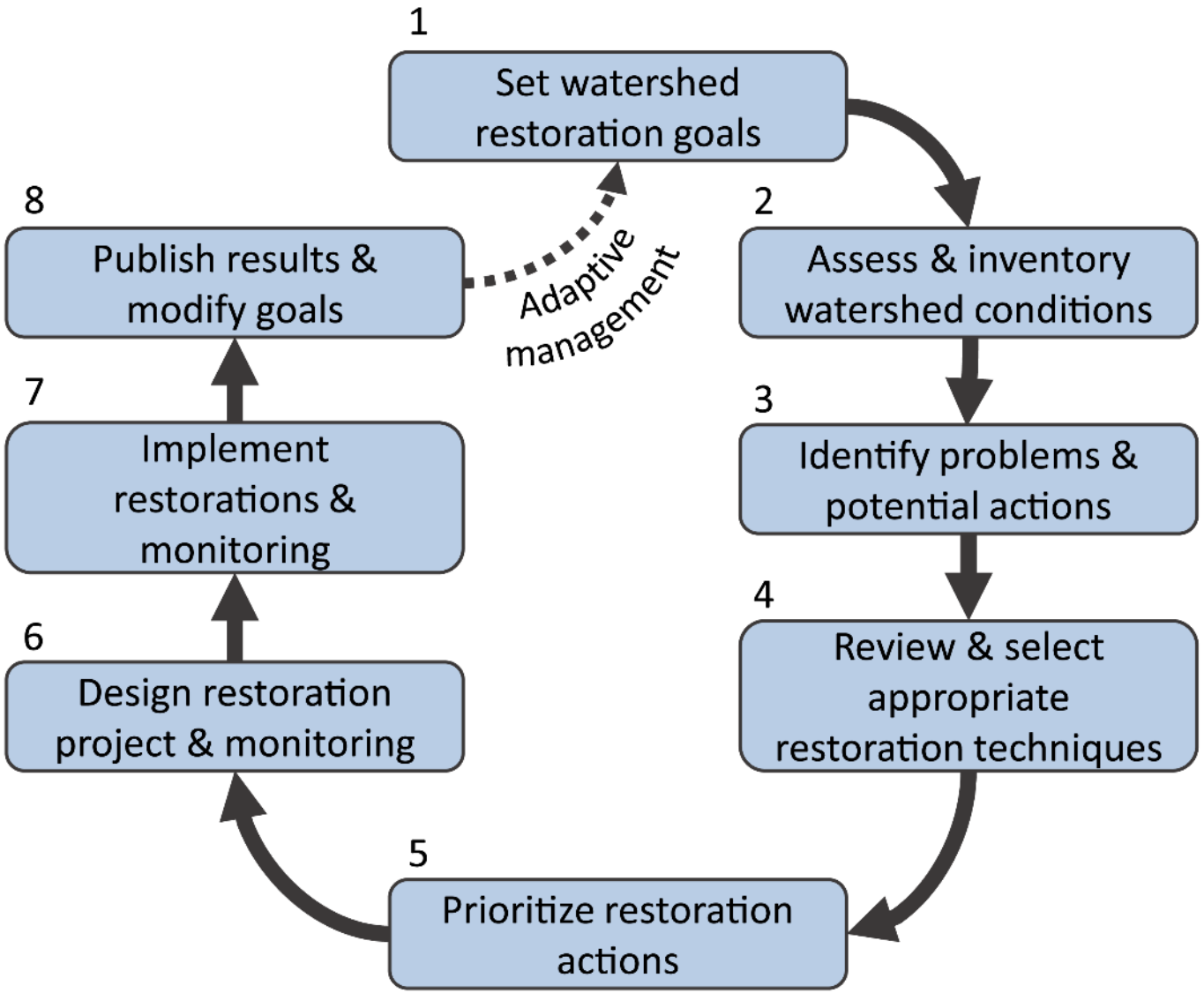
Summary of Estimates in Model Watershed

Strategy	Coho Smolts (juvenile migrants)	Steelhead smolts (juvenile migrants)
Pre-restoration production	230,501	22,386
Scenario 1 – Restore All	285,302	28,001
Scenario 2 - Historic	15,022	1,195
Minimum detectable difference (25%)**	57,625	5,596

** Need to restore about 20% of watershed to achieve this

Roni et al. 2010

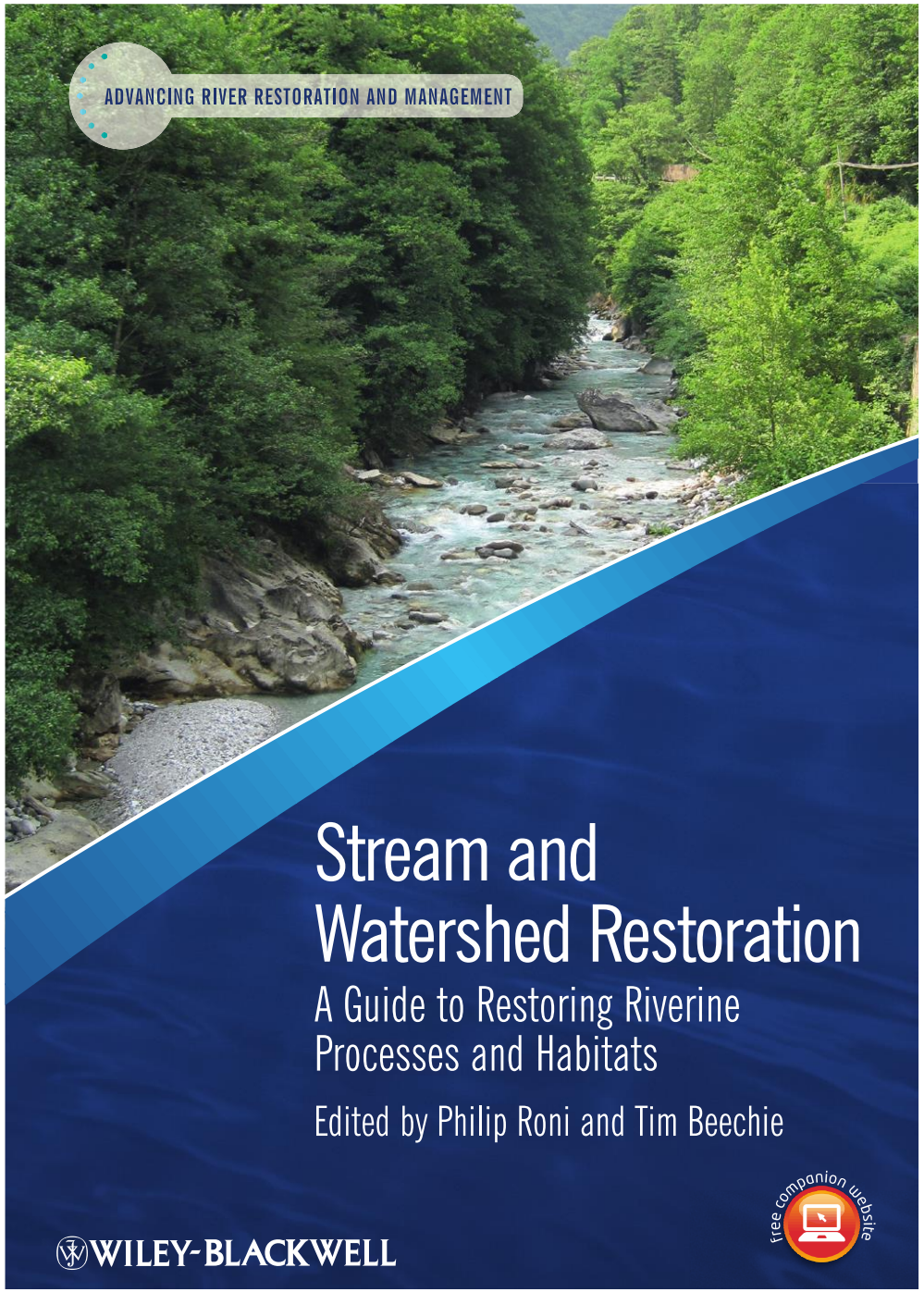
Key Steps in Restoration

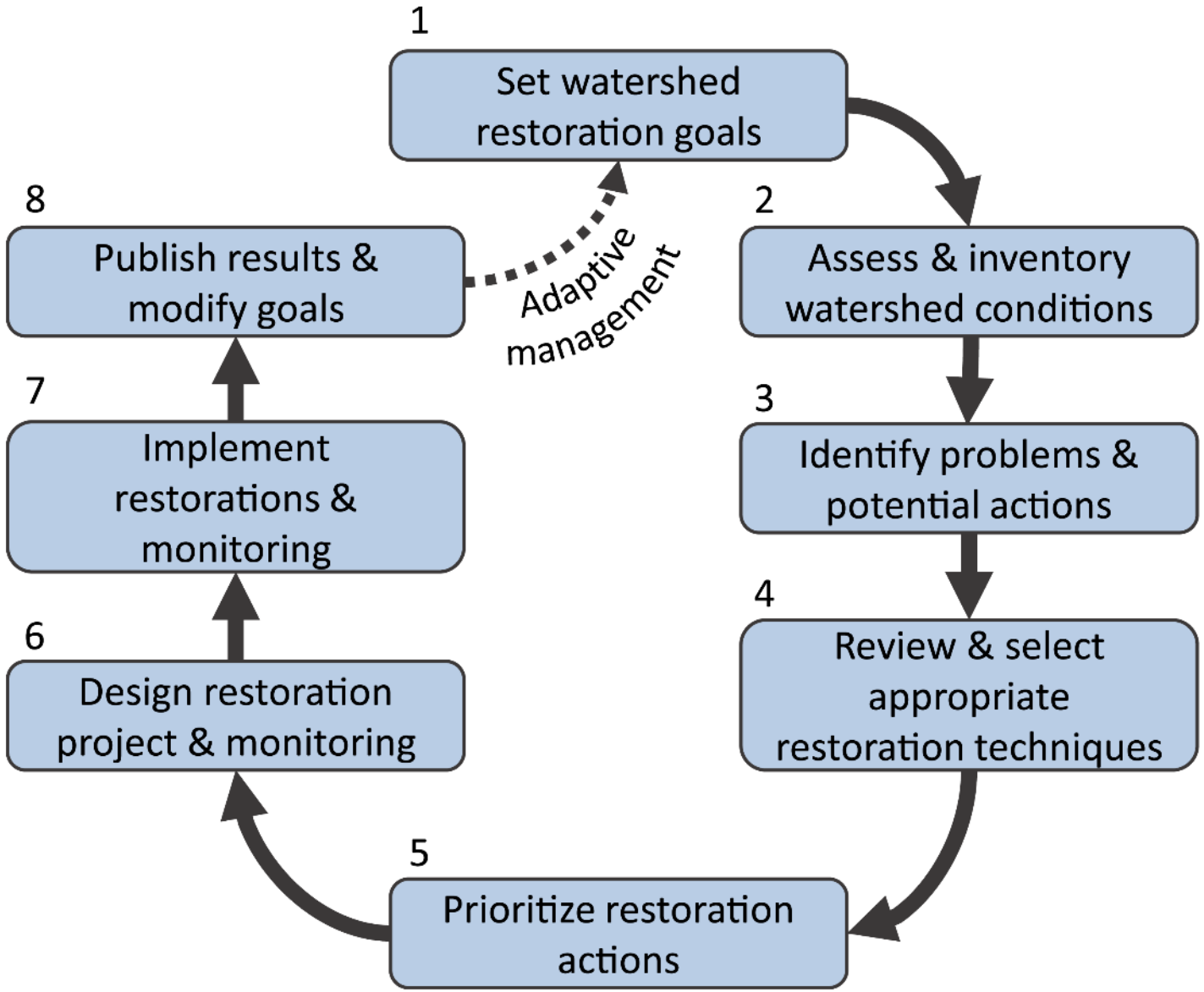


Roni and Beechie 2013

Key Points

- **Several Steps to Restoration Process**
  - Successful restoration requires following all of them
- **Assessment of Watershed Conditions Critical**
  - Current, historic and habitat loss, causes of degradation
- **Project selection**
  - Processes, duration, longevity & climate change
- **Prioritization**
  - Multi-metric scoring systems most transparent
- **Monitoring and evaluation**
  - Defining questions/hypotheses is critical
  - Amount and intensity of restoration are important


ADVANCING RIVER RESTORATION AND MANAGEMENT
Stream and Watershed Restoration
A Guide to Restoring Riverine Processes and Habitats
Edited by Philip Roni and Tim Beechie
free companion website
WILEY-BLACKWELL


1
Set watershed restoration goals
2
Assess & inventory watershed conditions
3
Identify problems & potential actions
4
Review & select appropriate restoration techniques
5
Prioritize restoration actions
6
Design restoration project & monitoring
7
Implement restorations & monitoring
8
Publish results & modify goals
Adaptive management