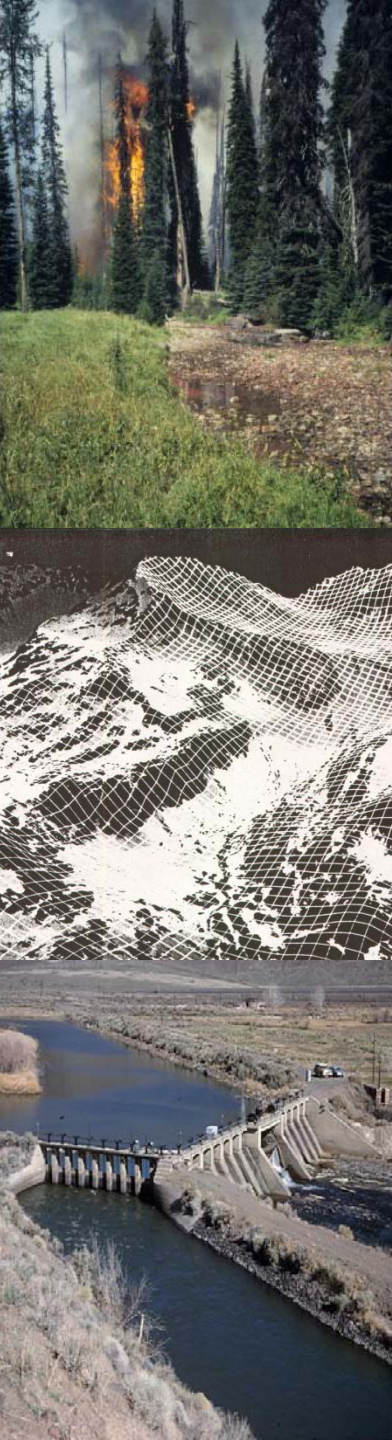




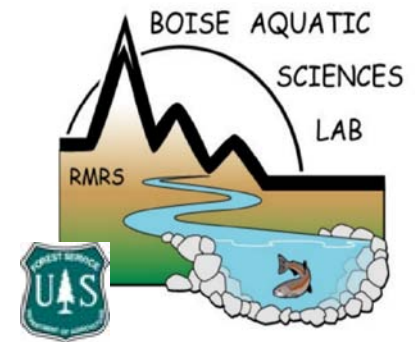
Climate Change and Management

How do we use all of this ??

Bruce Rieman¹

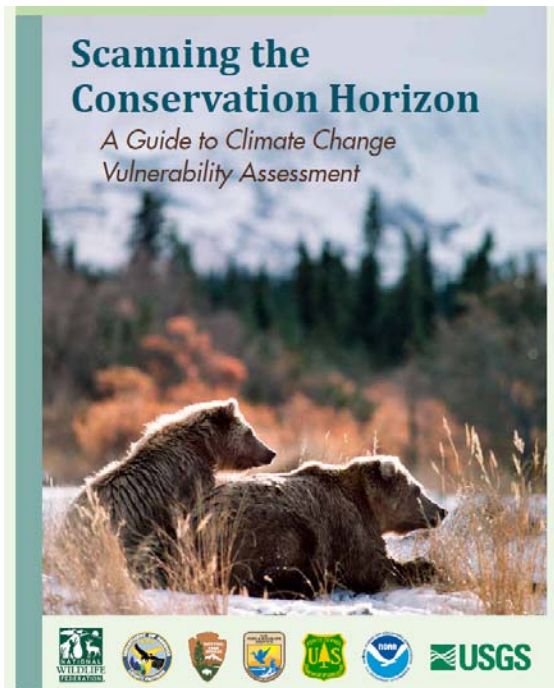
*Rocky Mountain Research Station
Boise Aquatic Sciences Laboratory*

¹ Seeley Lake Field Laboratory and Retirement Home

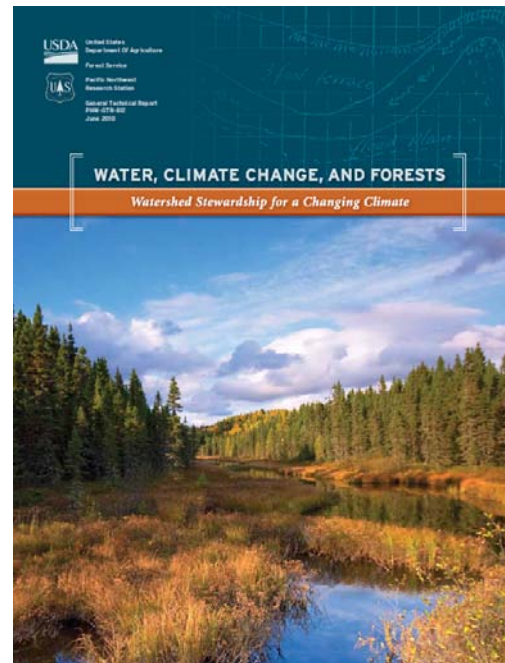


Acknowledgments:

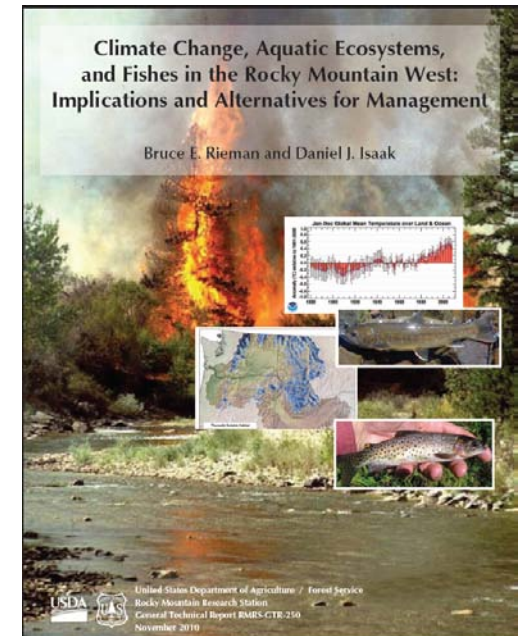
Dan Isaak
Charlie Luce
Doug Peterson
Seth Wenger



Glick et al. 2011. National Wildlife Federation, Washington, DC



Furniss, et al. 2010. USFS PNW, Portland OR



Rieman, and Isaak. 2010. USFS RMRS, Fort Collins, CO

How do we use all of this ??

Anticipate: *What's changing, where; consider vulnerability*

Adapt: *Actions to conserve or restore resilience; accept or even facilitate change*

Prioritize: *A strategy to focus limited resources*

Collaborate: *It's a huge challenge, flood of information*

Monitor/Revise: *Substantial uncertainty remains*

Anticipate

- Warming streams

- Timing
- Extremes
- Variability

- Changing hydrology

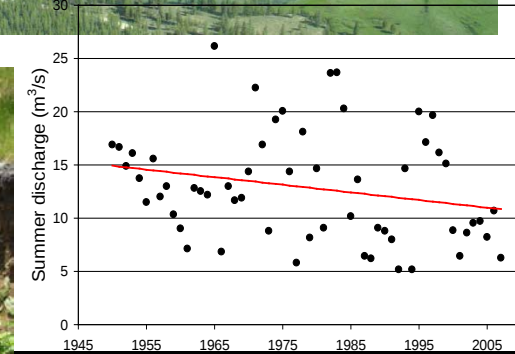
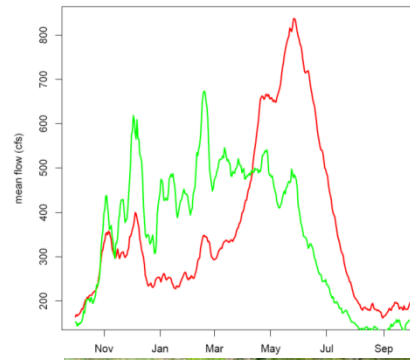
- Timing
- Extremes
- Variability

- Disturbance regimes

- Frequency
- Magnitude
- Extent

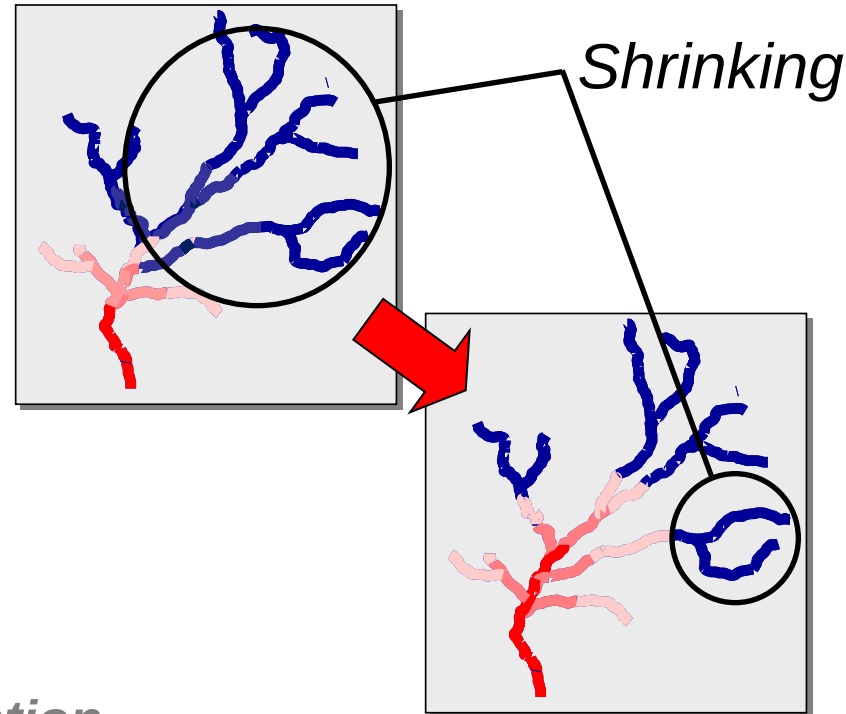
- Changing habitats

- Succession/evolution
- Capacity and suitability
- Connections
- Extent



Anticipate

- *Biotic conditions, individuals, populations, communities*



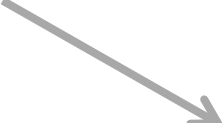
*decoupling in timing, spawning, incubation, emergence;
altered food webs, energetics, competition and growth;
access, migration and dispersal;
invasion, predation, parasitism, disease;
population size, extent, diversity and resilience*

Anticipate

Global Climate Models

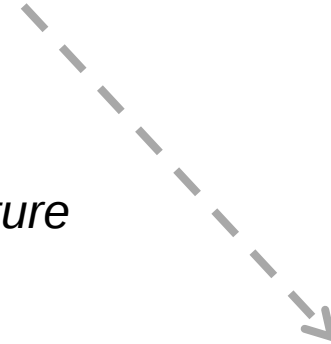


Downscaled Climate Predictions



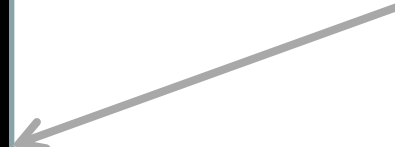
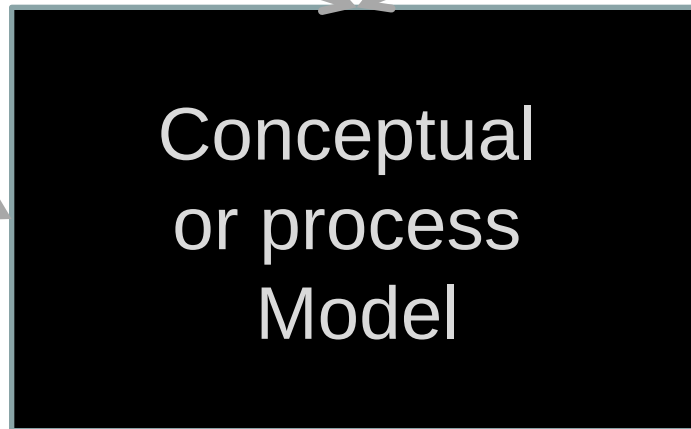
*Local Flow
Predictions*

*Local Temperature
Predictions*



Biotic Context

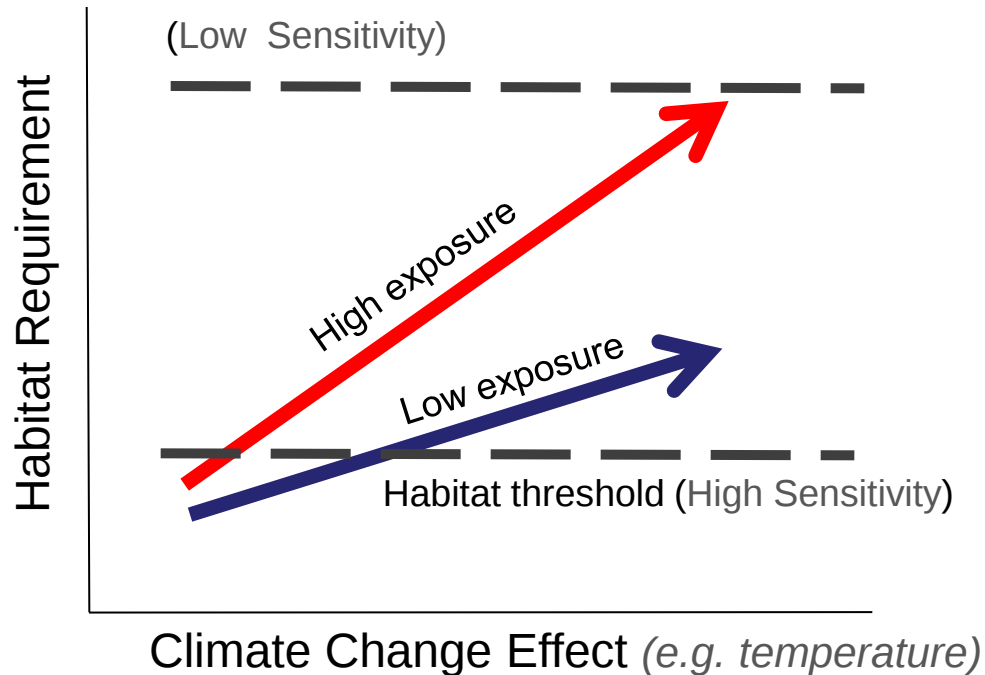
Landscape Context



Population Vulnerability

Anticipate *Vulnerability*

Conceptual Model



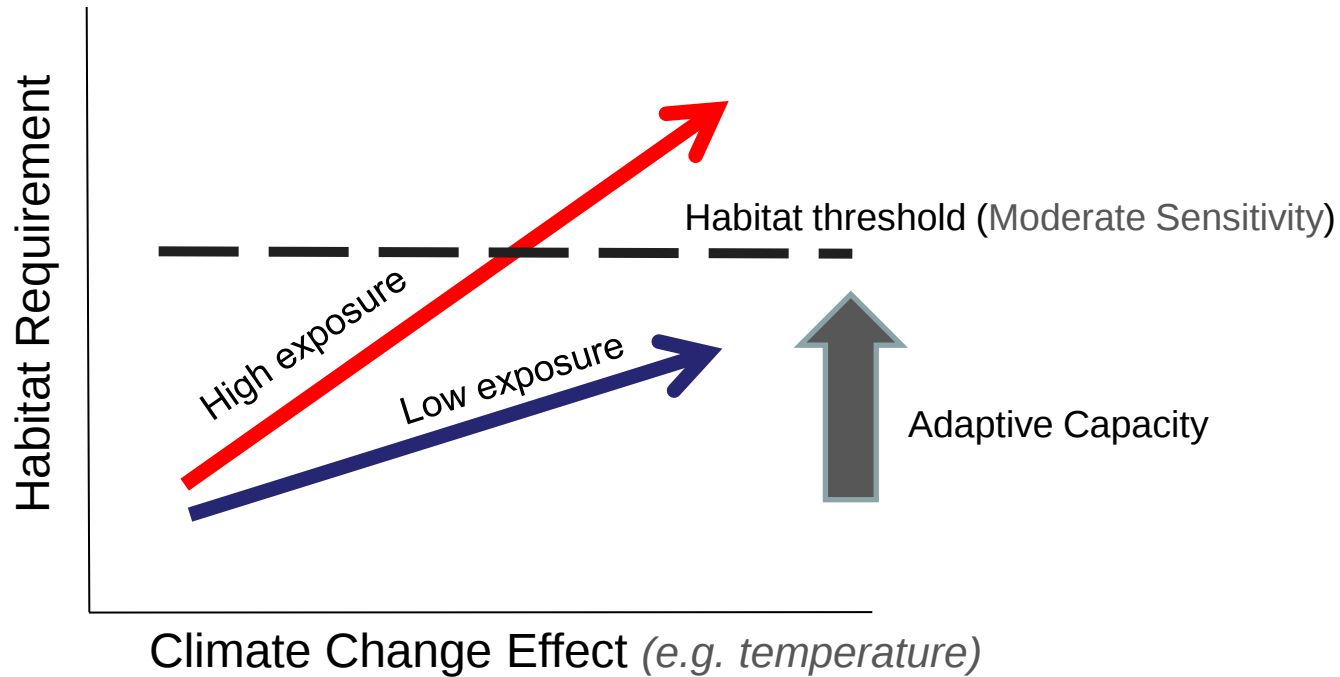
Vulnerability = sensitivity x exposure x adaptive capacity

IPCC 2007

Williams, et al. 2008. *PloS Biology* 6(12): 2621

Glick et al., 2011. *Scanning the horizon*. National Wildlife Federation, WA

Anticipate *Vulnerability*



Vulnerability = sensitivity x exposure x adaptive capacity

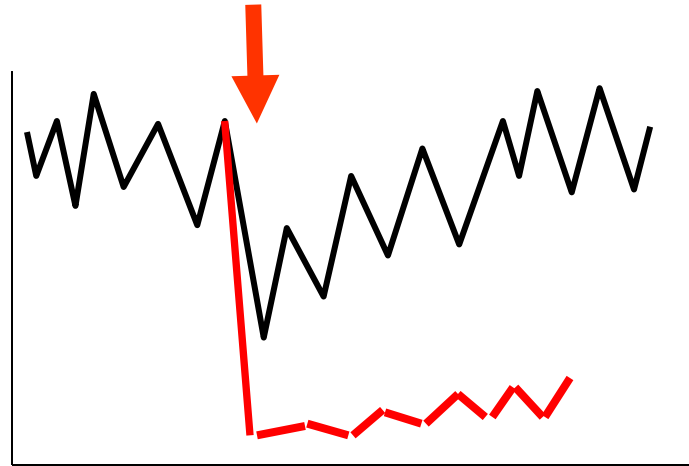
IPCC 2007

Williams, et al. 2008. *PloS Biology* 6(12): 2621

Glick et al., 2011. *Scanning the horizon*. National Wildlife Federation, WA

Anticipate

Vulnerability and Resilience



*Resilience = capacity to absorb disturbance or change
and continue to function*

Anticipate

Vulnerability and Resilience

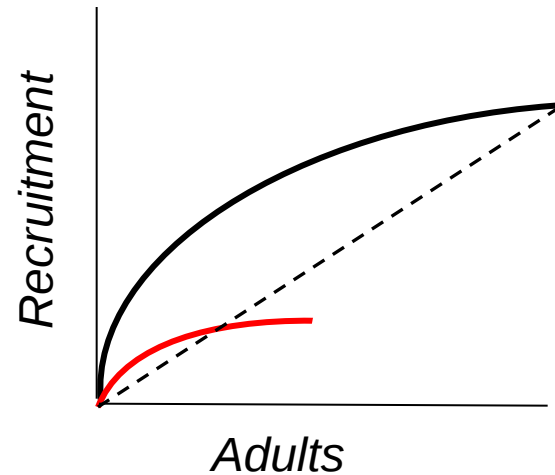
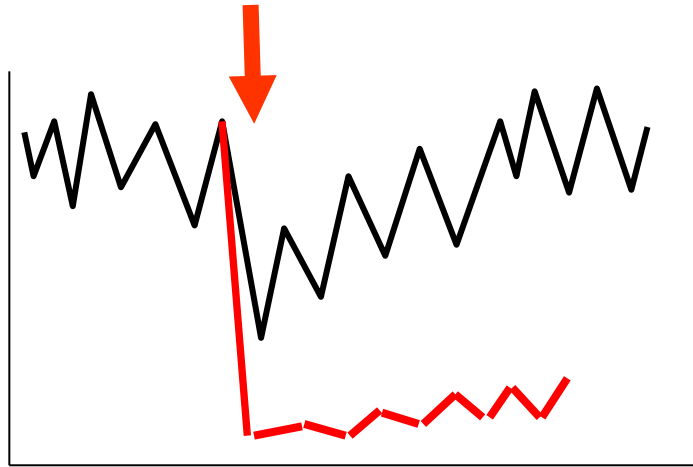


- **Productivity** (*population growth rate*)
- **Spatial structure**
- **Diversity and capacity to adapt**

Anticipate

- **Productivity**

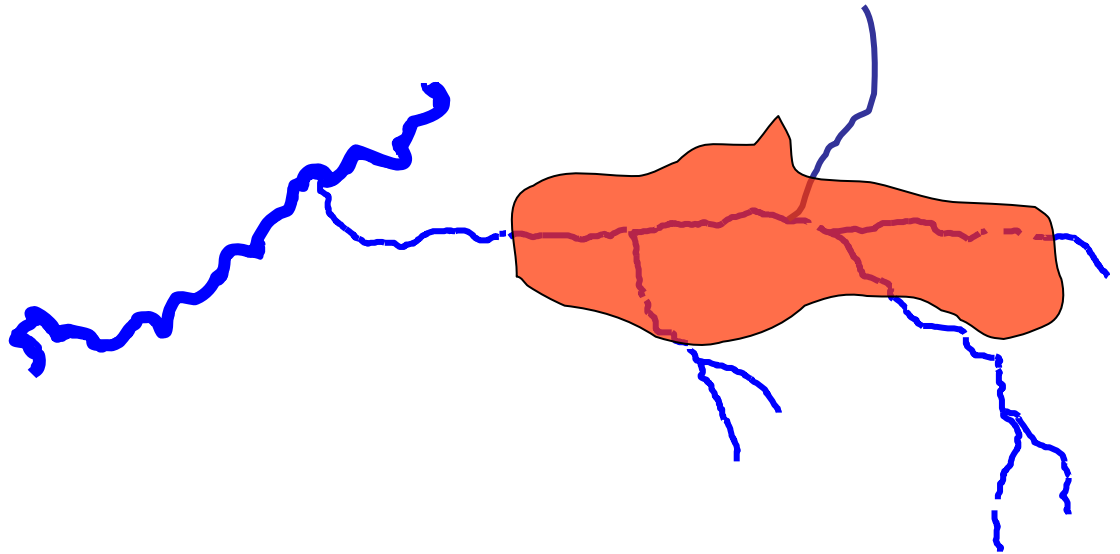
- Spatial structure
- Diversity and capacity to adapt



Growth, reproduction, survival, and abundance

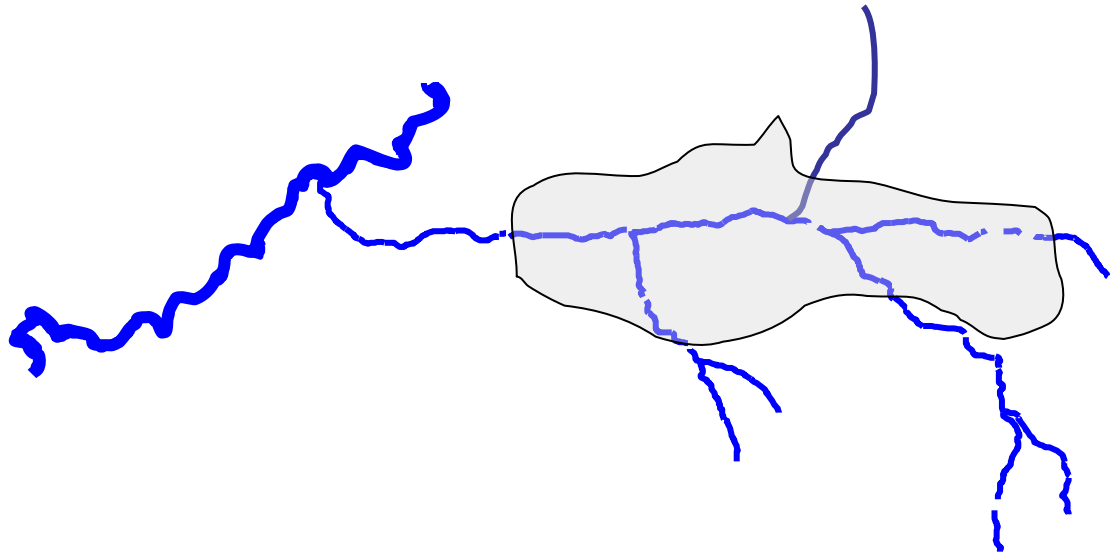
Anticipate

- Productivity or population growth rate
- **Spatial structure**
- Diversity and capacity to adapt



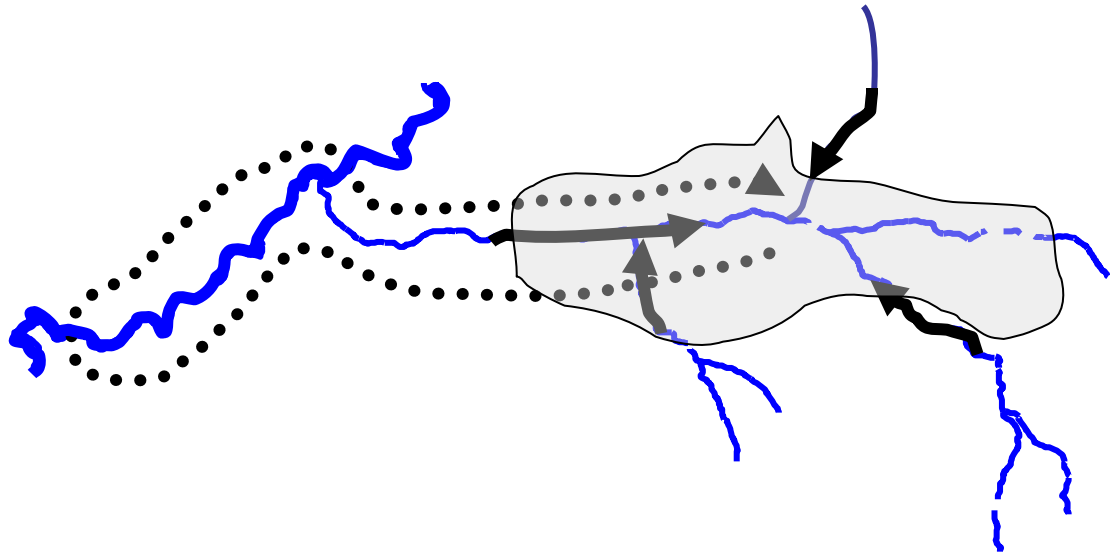
Anticipate

- Productivity or population growth rate
- **Spatial structure**
- Diversity and capacity to adapt



Anticipate

- Productivity
- **Spatial structure**
- Diversity and capacity to adapt



- *Habitat network extent vs. disturbance*
- *Connectivity*

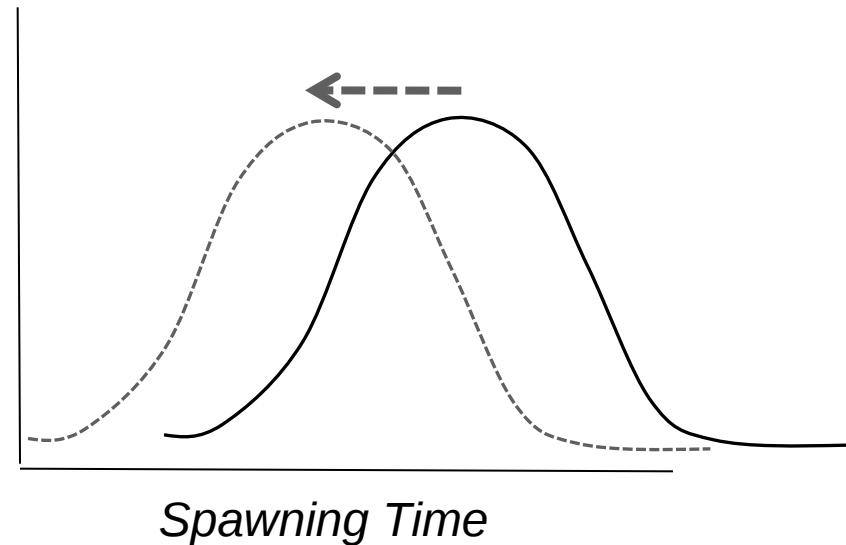
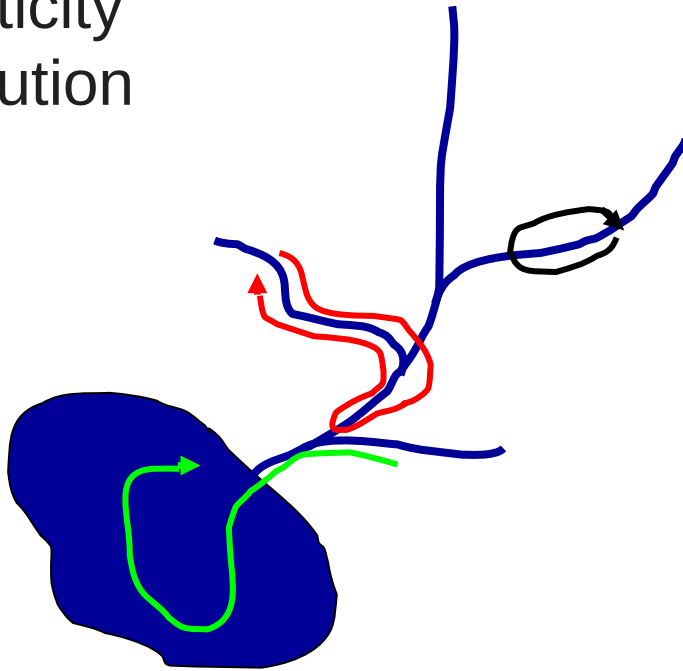
Anticipate

- Productivity
- Spatial structure
- Diversity and capacity to adapt**

Hedging, life history expression

Plasticity

Evolution



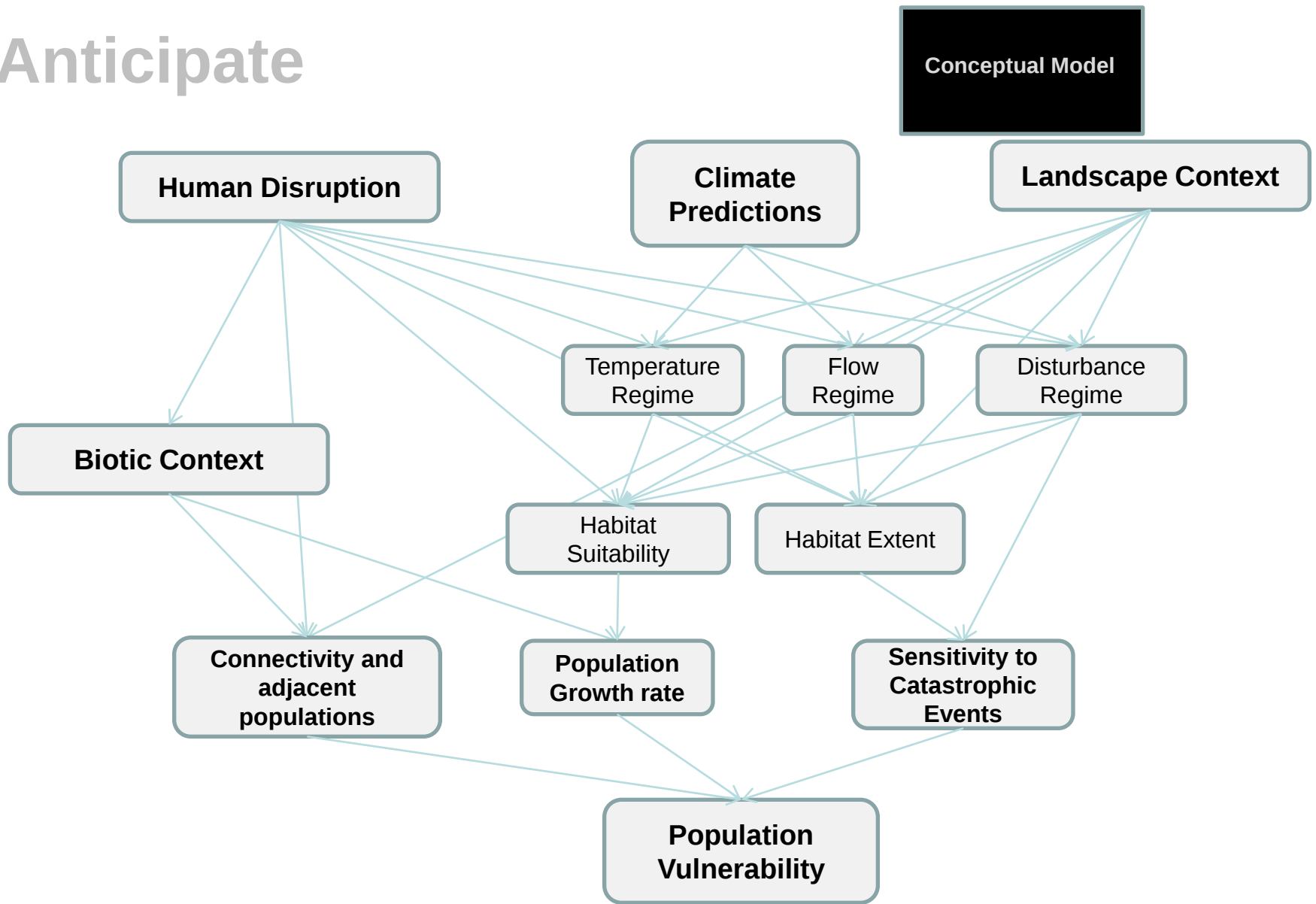
Portfolio Effects

Hilborn et al. 2003. PNAS 100: 6564

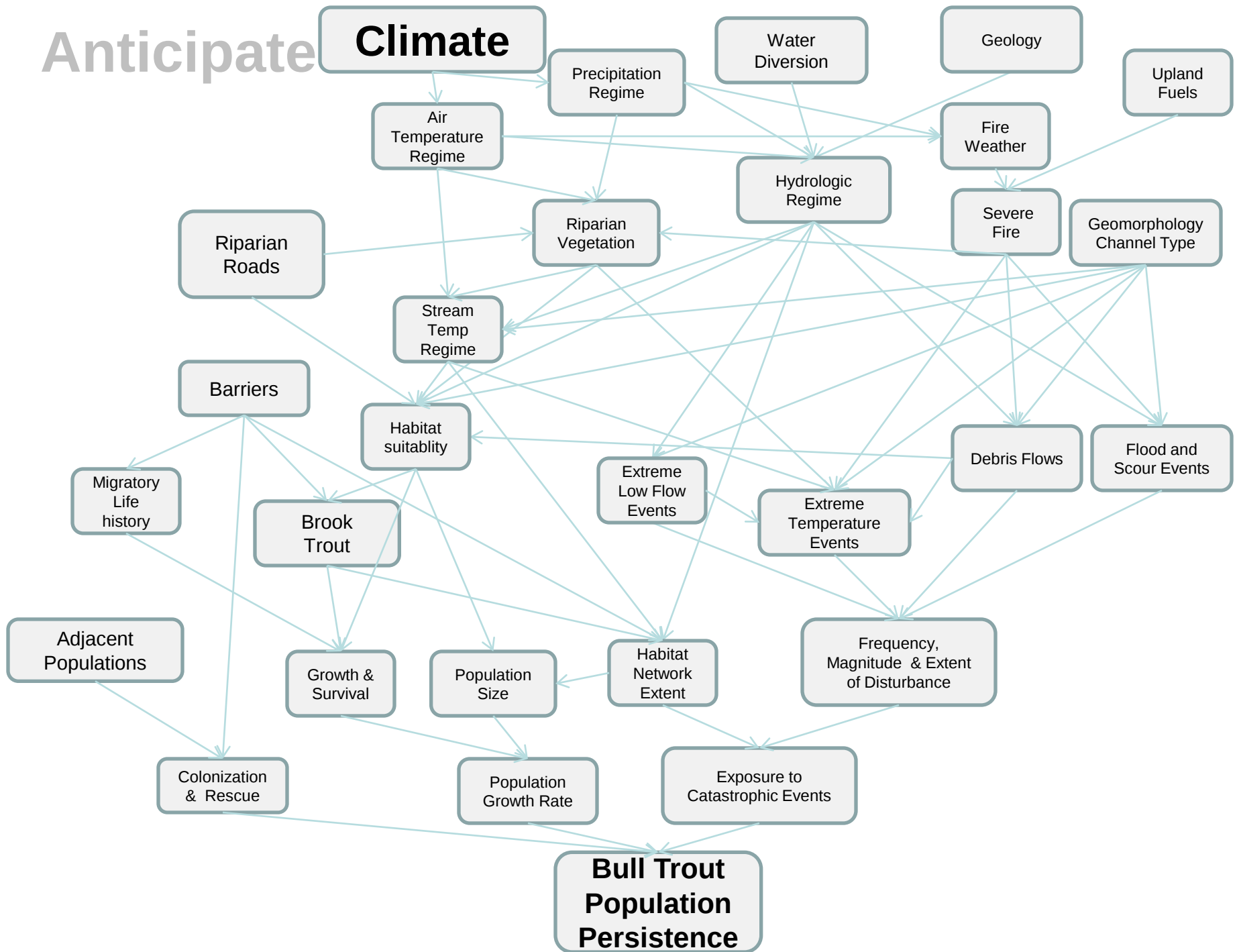
Schindler et al., 2010. Nature 465: 609

Moore et al., 2010. Conservation Letters 3: 340

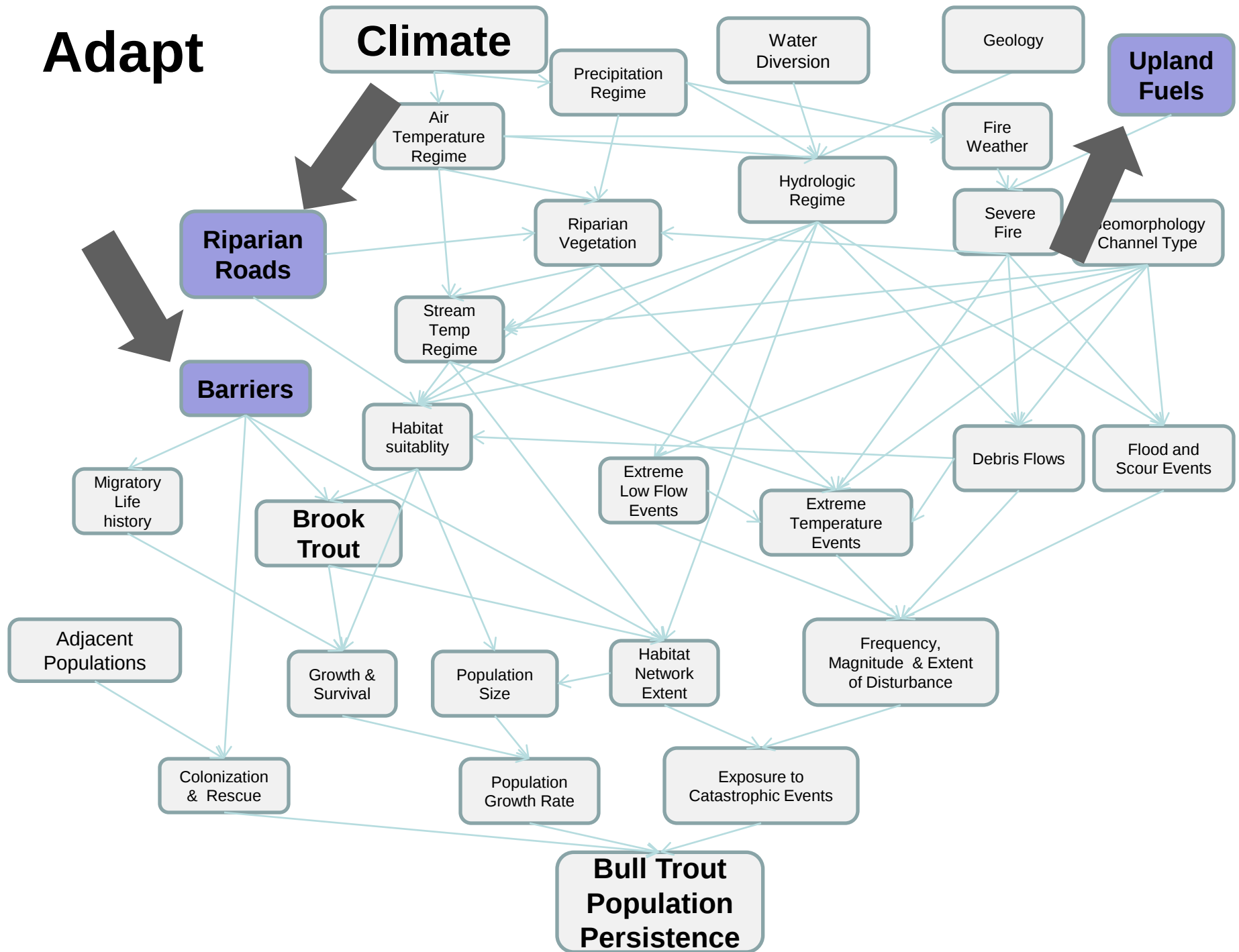
Anticipate



Anticipate

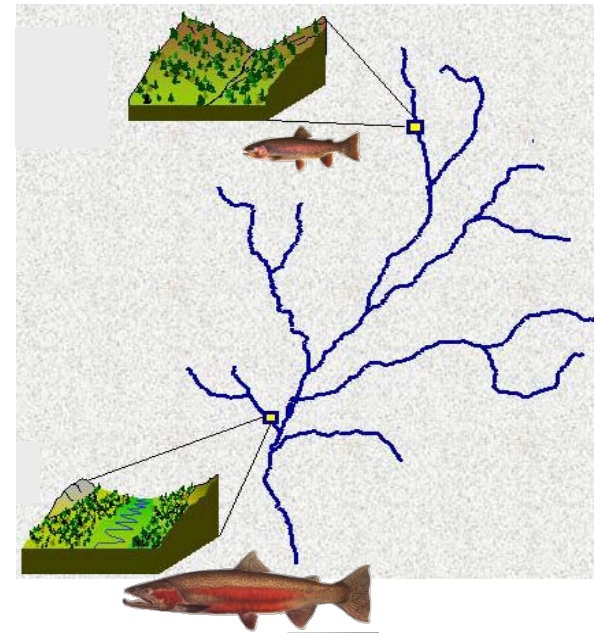


Adapt



Adapt– *Conserve and restore resilience*

- **Productivity** – *reduce non-climate stresses, restore watershed process*
- **Spatial structure** – *reconnect, expand, create redundancy*
- **Capacity to adapt** – *conserve, restore diversity, representation*



Adapt– *Conserve and restore resilience*

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- ***Accept or even facilitate change***



Adapt– *Conserve and restore resilience*

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What we can do hasn't really changed...

“No regrets” in the face of uncertainty

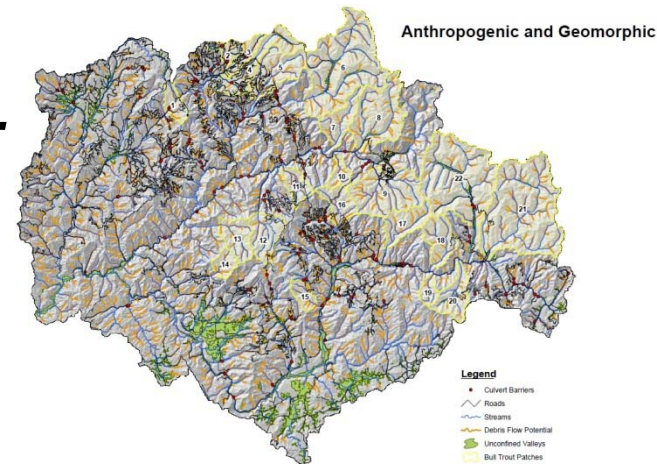
Adapt– *Conserve and restore resilience*

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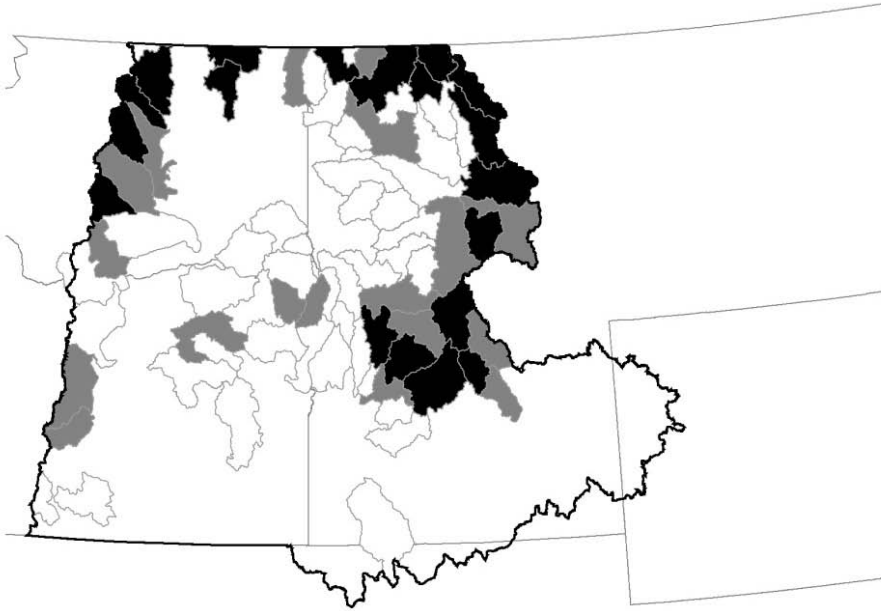
Where *we do it could be changing...*



Prioritize

Vulnerability

*Sensitivity and exposure
resilience*



*Vulnerability of bull trout
to climate change*

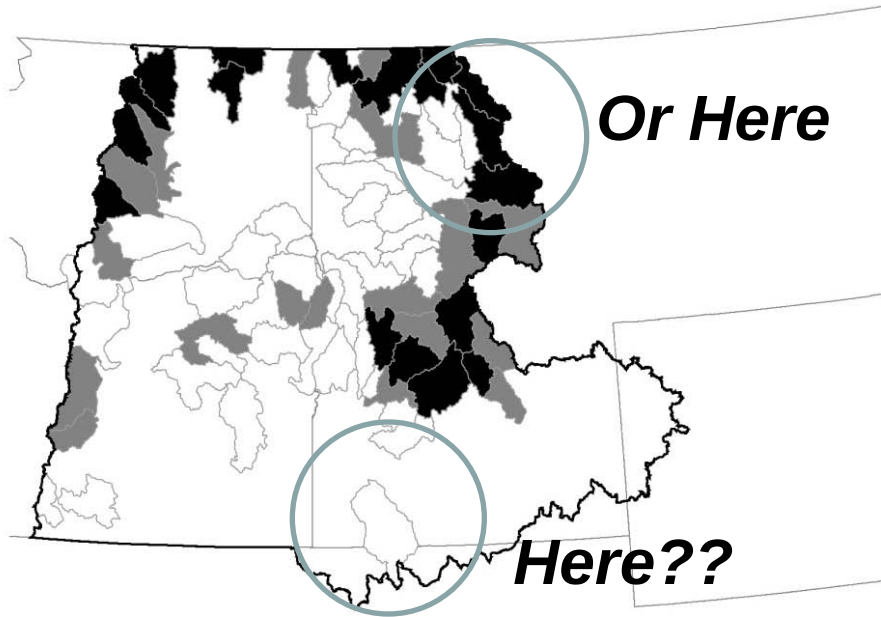
*Rieman et al., 2007
TAFS 136:1552*

Vulnerability as a context for prioritization

Prioritize

Vulnerability

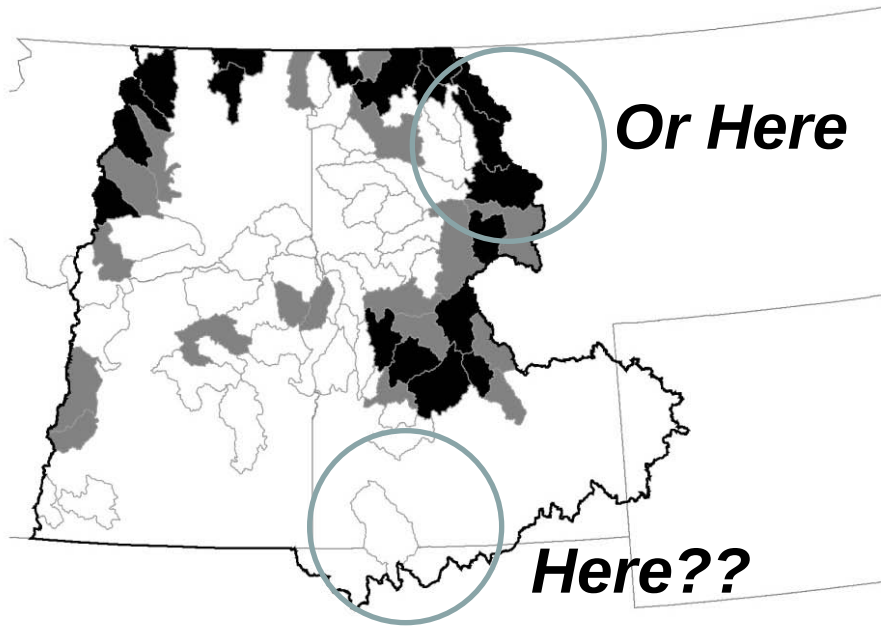
*Sensitivity and exposure
resilience*



*Vulnerability of bull trout
to climate change*

Vulnerability as a context for prioritization

Prioritize



*Vulnerability of bull trout
to climate change*

Vulnerability

*Sensitivity and exposure
resilience*

Feasibility

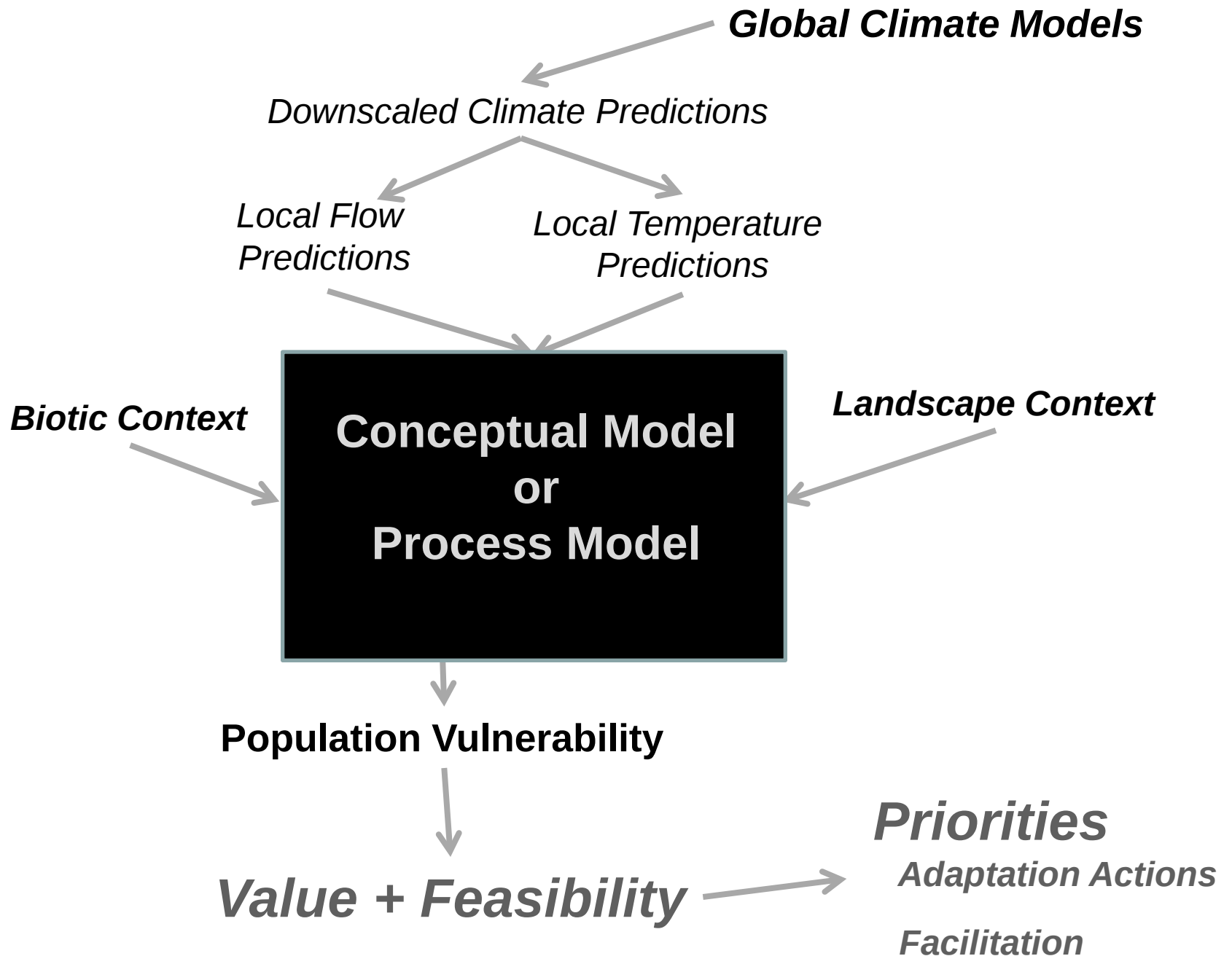
*secure vs. restore
cost*

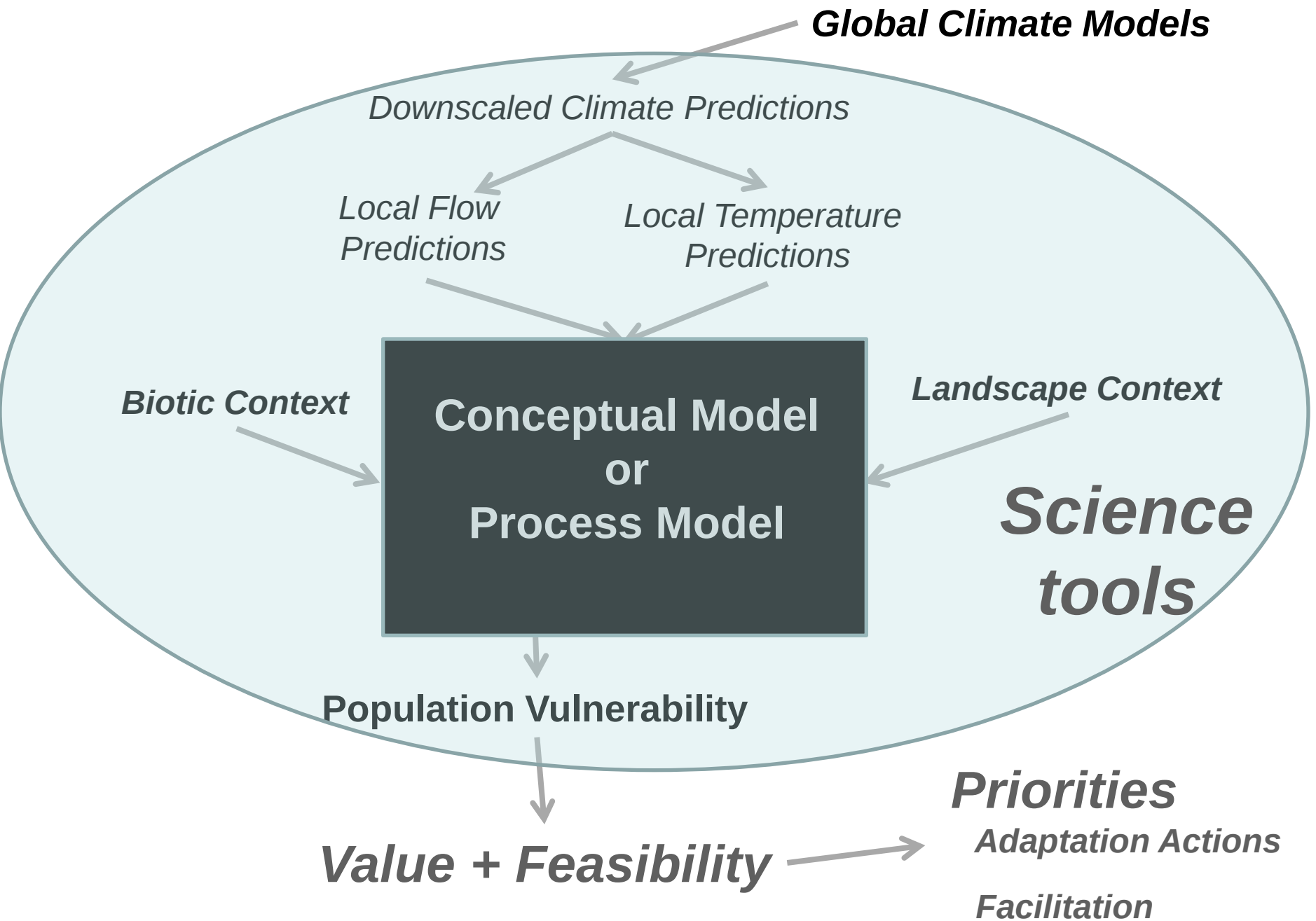
Conservation value

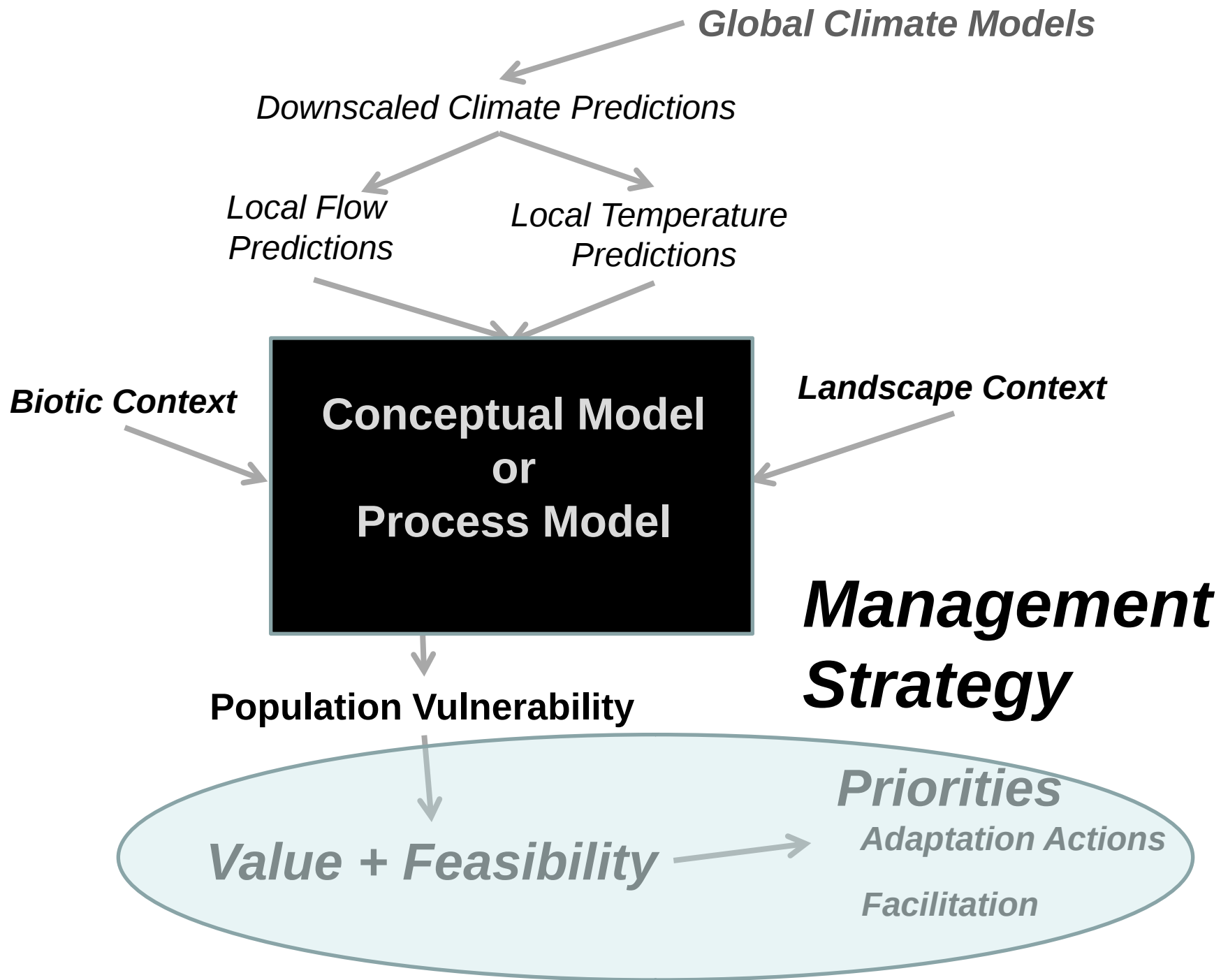
*evolutionary legacy (**diversity**)
ecological function or role*

Vulnerability as a context for prioritization

Priority = vulnerability x feasibility x value







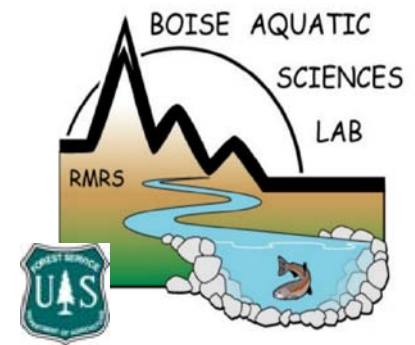
Climate Change Effects and Management

How do we use all of this ??

Glick et al., 2011. Scanning the horizon: a guide to climate change vulnerability assessment. National Wildlife Federation, Washington, DC
<http://www.nwf.org/Global-Warming.aspx>

Furniss and 12 co-authors. 2009. Water Climate and Forests: Watershed Stewardship for a changing climate, USDA Forest Service, PNW-GTR-812 Portland, OR. <http://www.fs.fed.us/pnw/>

Rieman and Isaak. 2010. Climate change, aquatic ecosystems, and fishes in the Rocky Mountain West. USDA Forest Service RMRS-GTR-250, Fort Collins, CO.
<http://treesearch.fs.fed.us/pubs/37029>



Anticipate

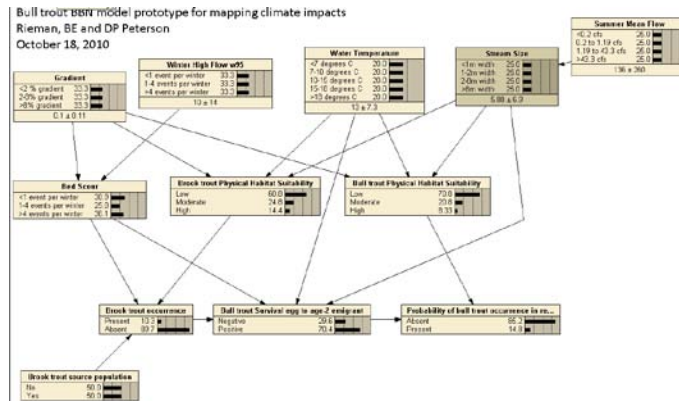
Model Implementation

Rule based models

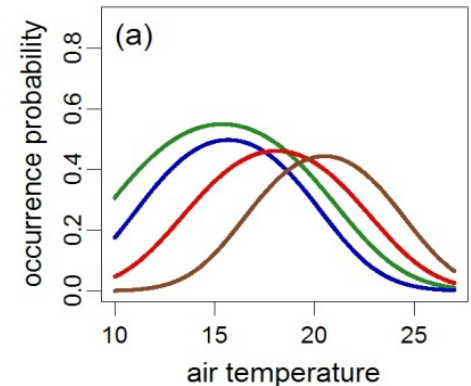
Connectivity 2
Population growth 10
Sensitivity to events 6

Vulnerability Score 18

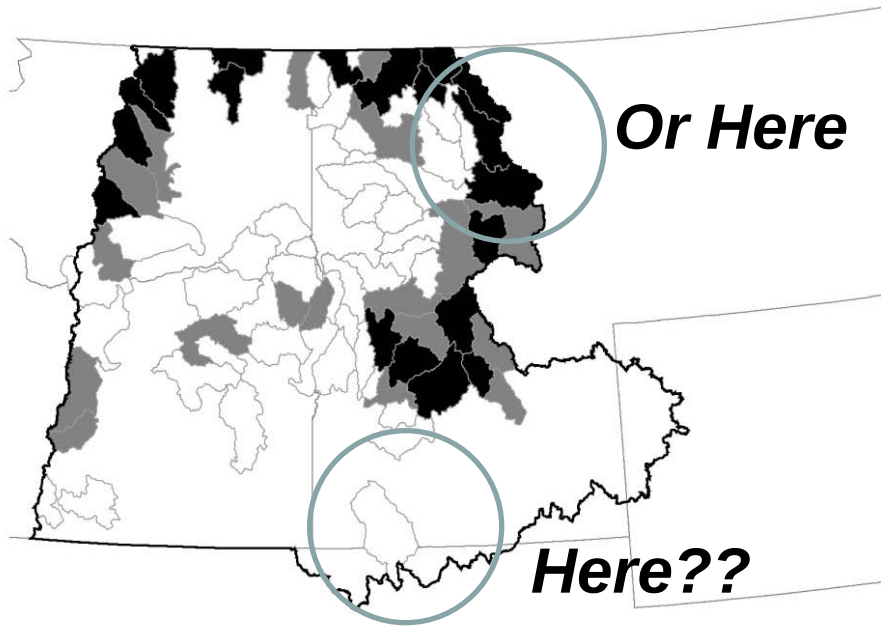
Process Models



Statistical Models



Prioritize



Vulnerability

*Sensitivity and exposure
resilience*

Feasibility

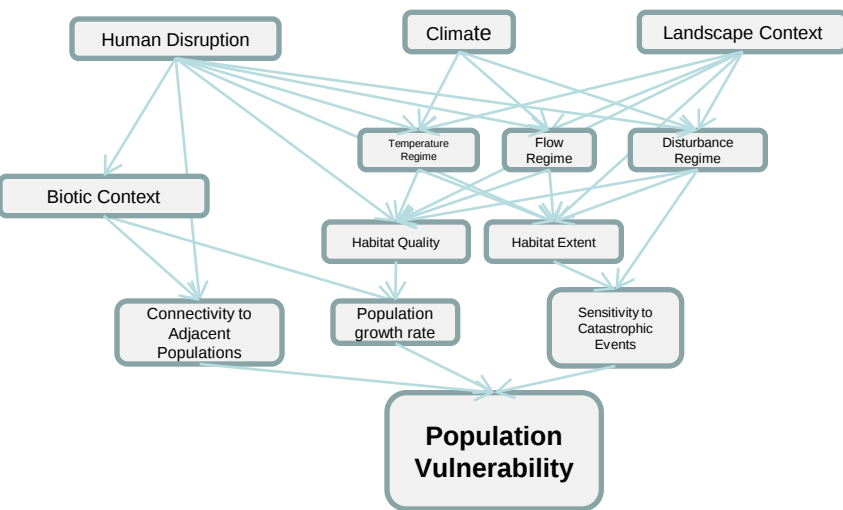
*secure vs. restore
cost*

Conservation value

*species (rarity)
resilience
representation (**diversity**)
redundancy*

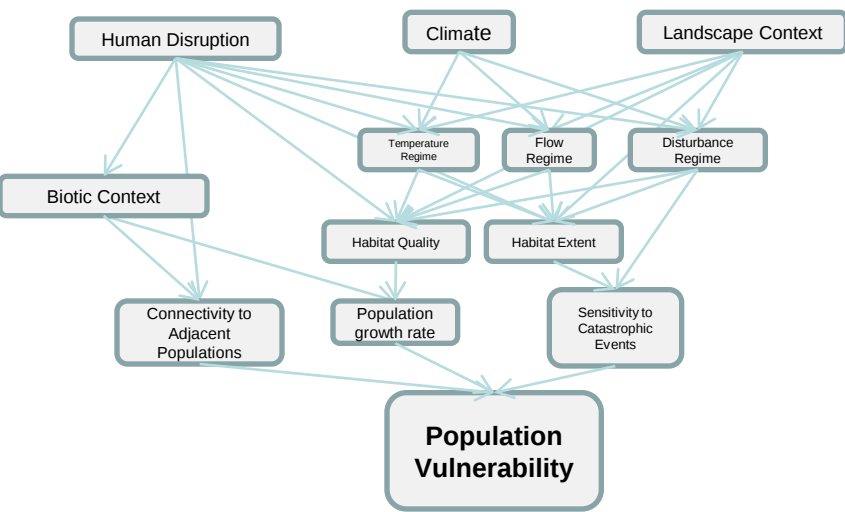
A Conservation/Restoration Strategy ?

- *Conserve or secure what already works, build from strengths*
- *Concentrate limited resources, “modularity” (complete systems)*
- *Balance diversity, redundancy, modularity*
- *Forego lost causes... facilitate transitions?*



Population based Fine Filter or “bottom up”

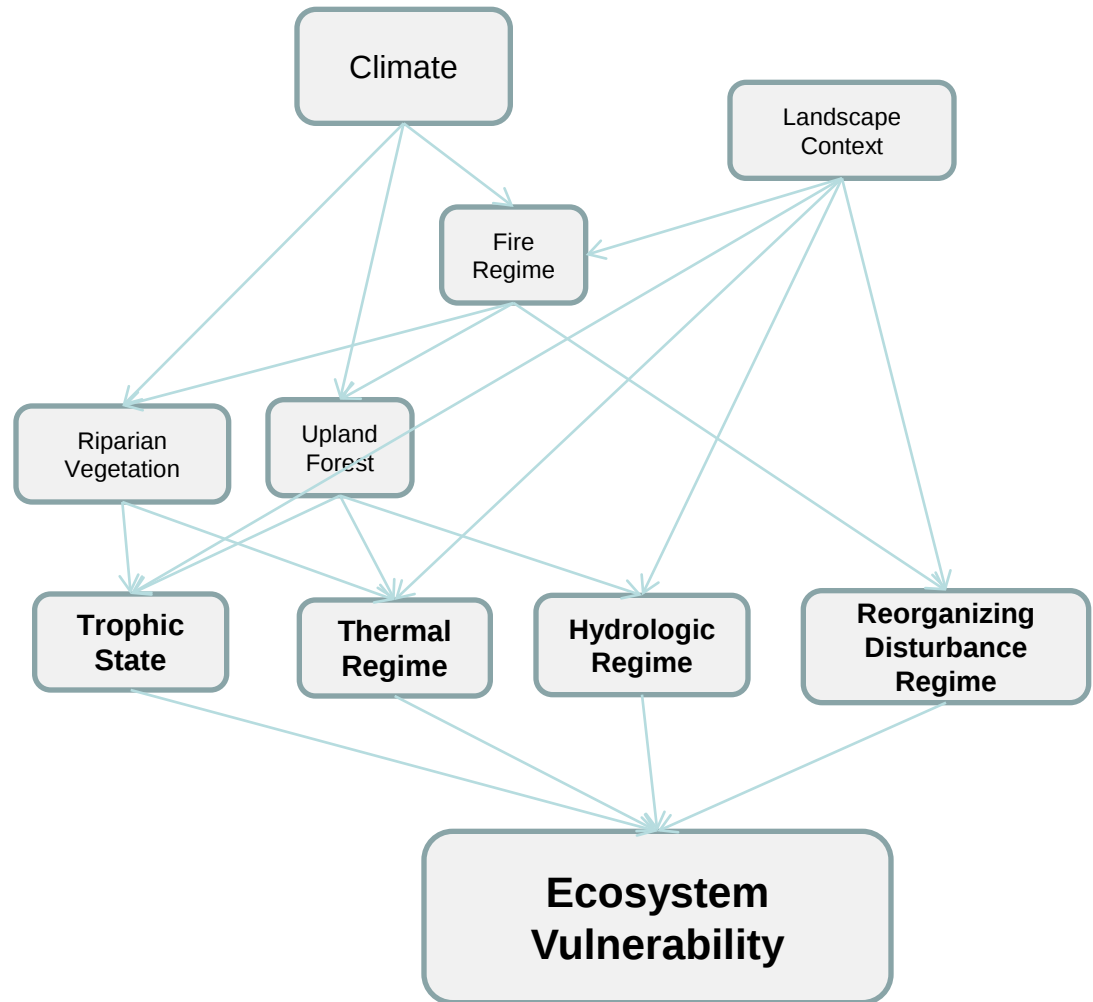
Glick et al., 2010



***Population based
Fine Filter
or “bottom up”***

Glick et al., 2010

***Ecosystem based
Coarse Filter
or “top down”***



Adapt

- **Productivity... *reduce non- climate stresses***
- Spatial structure
- Capacity to adapt

Restore quality and capacity of habitats



Adapt

- Productivity...
- Spatial structure**
- Capacity to adapt

*Restore and expand
connectivity and extent of
habitats*

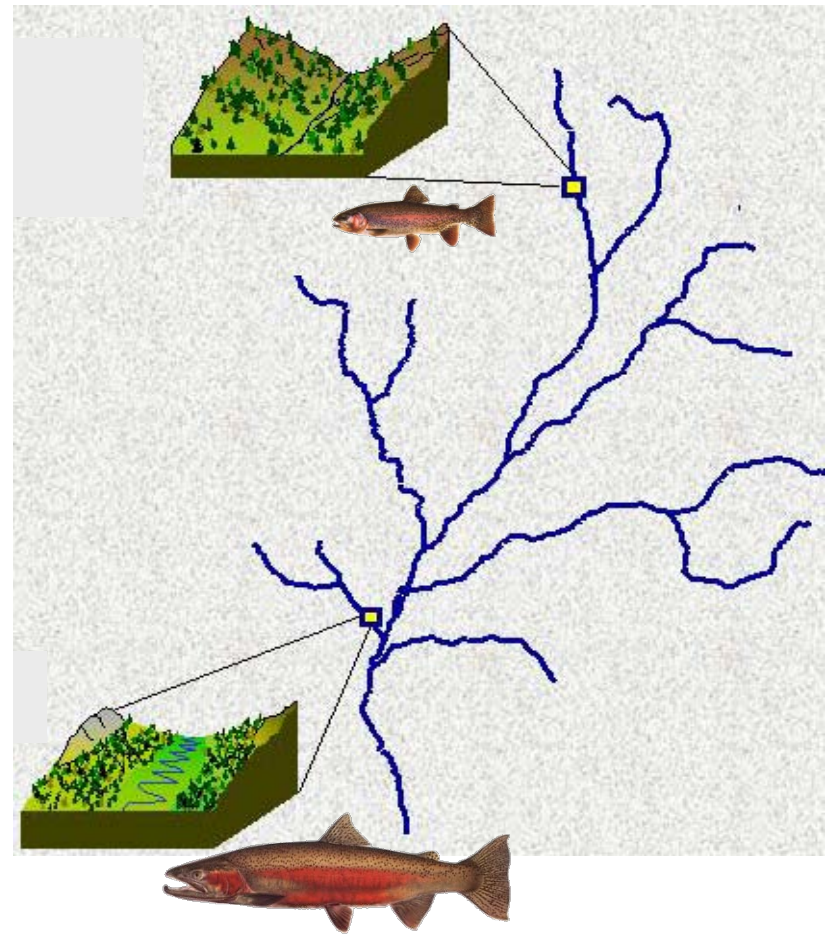
*Control extent of
disturbance*



Adapt

- Productivity...
- Spatial structure
- Diversity and Capacity to adapt

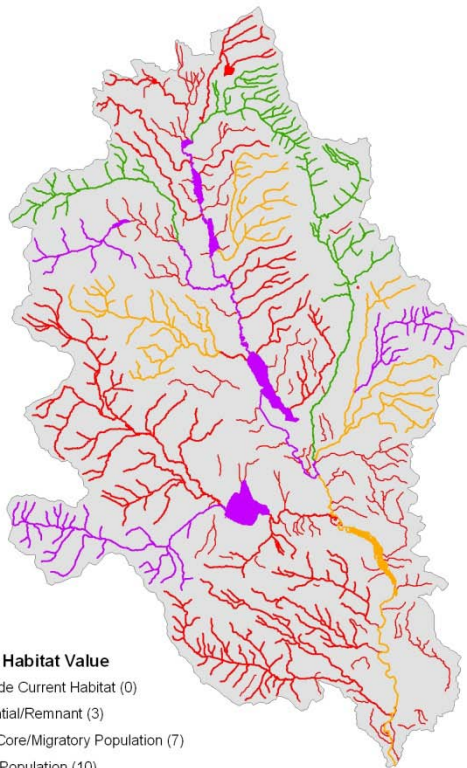
*Conserve and restore diversity
representation, connectivity
and size of habitats*



Values

Critical habitat native fisheries

Bull Trout Habitat Values in the Clearwater



Bull Trout Habitat Value

- Outside Current Habitat (0)
- Potential/Remnant (3)
- Non-Core/Migratory Population (7)
- Core Population (10)

Clearwater Watershed

0 2 4 8 Miles

Westslope Cutthroat H.



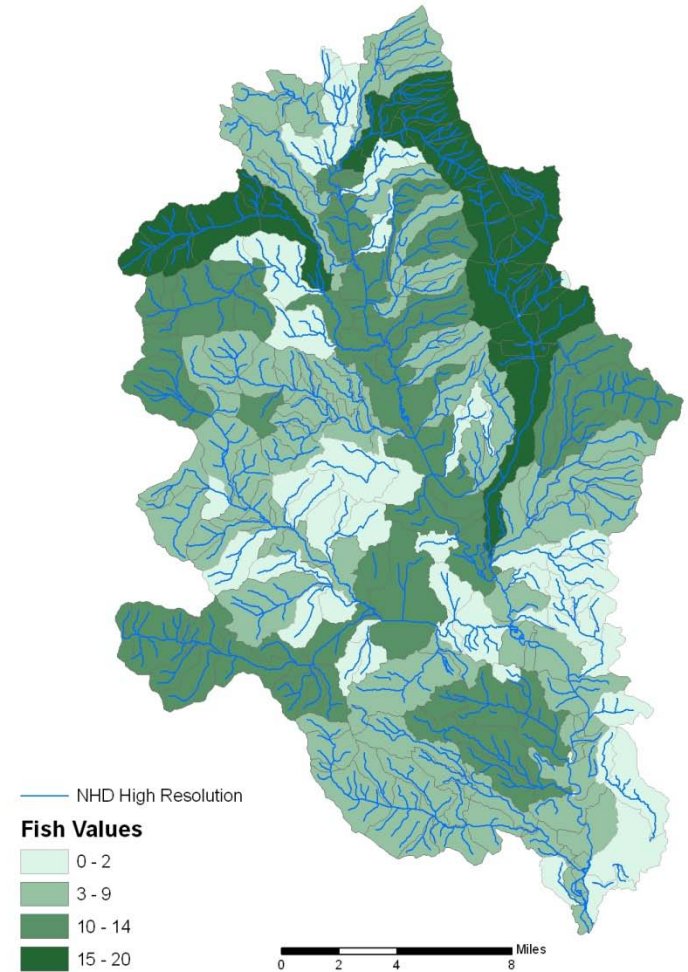
Cutthroat Habitat Value

- Outside Current Habitat
- Resident/Remnant/Migratory Corridor
- Migratory Population (5)
- Genetically (or Potentially) Pure (10)

Clearwater Watershed

0 2 Miles

Sum of Fish Values in the Clearwater



NHD High Resolution

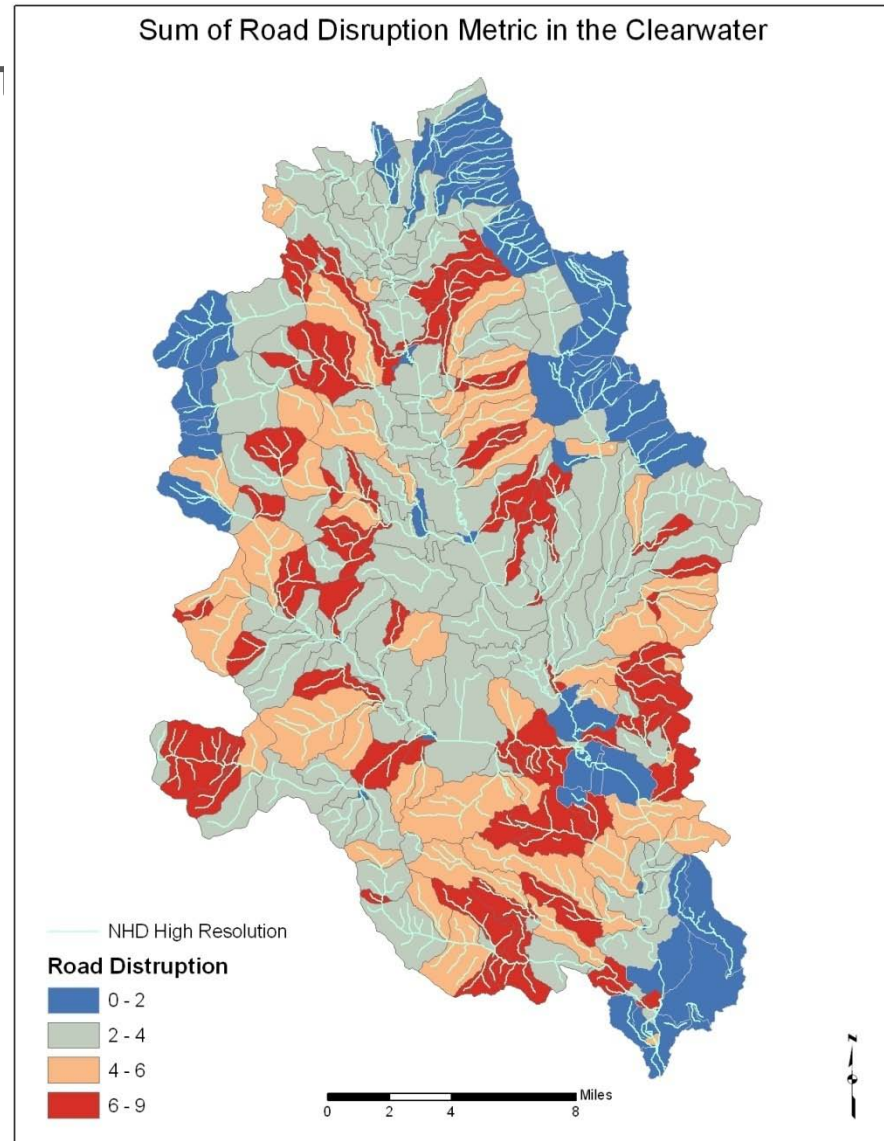
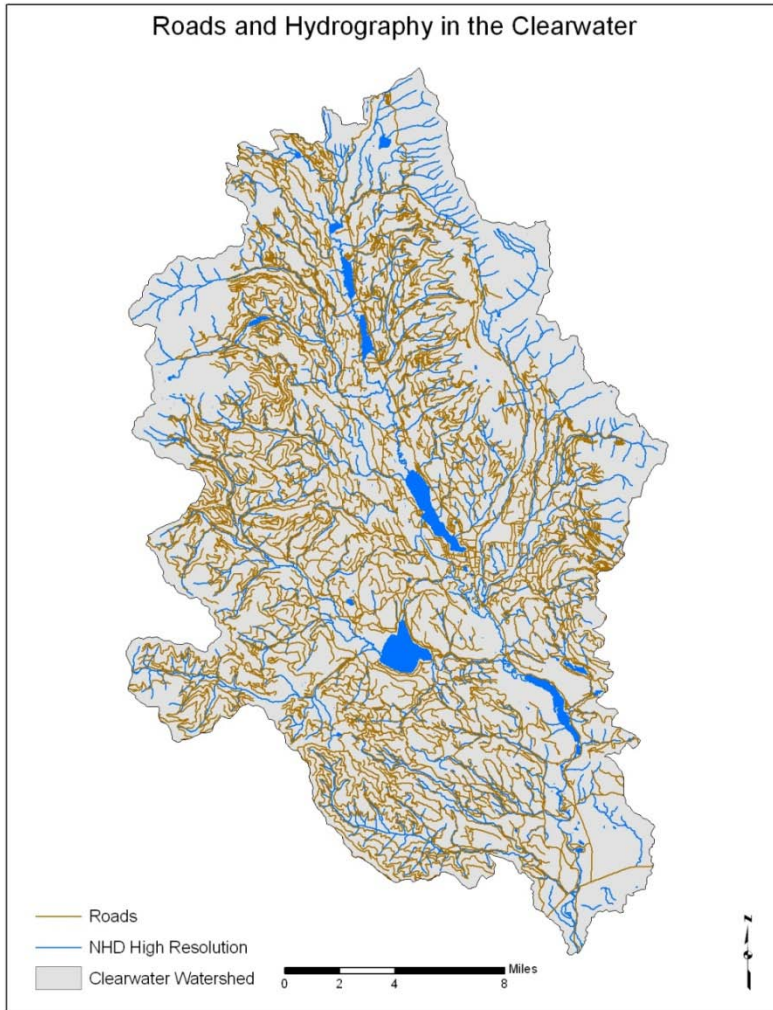
Fish Values

- 0 - 2
- 3 - 9
- 10 - 14
- 15 - 20

0 2 4 8 Miles

Watershed condition (USFS, S. Hendrickson)

Roads as an index to watershed condition



A Test Case with Fish....

Objectives and Priorities

Value x Watershed Condition

<i>Fish Value</i>	<i>Local Watershed Condition</i>		
	<i>High</i>	<i>Moderate</i>	<i>Low</i>
<i>High</i>	Maintain	Restore 1	Restore 2
<i>Moderate</i>	Maintain 2	Restore 2	Restore 3
<i>Low</i>	Other Causes?		Don't Worry

Conserve what already works, build from strengths
Focus resources, greatest benefit least cost

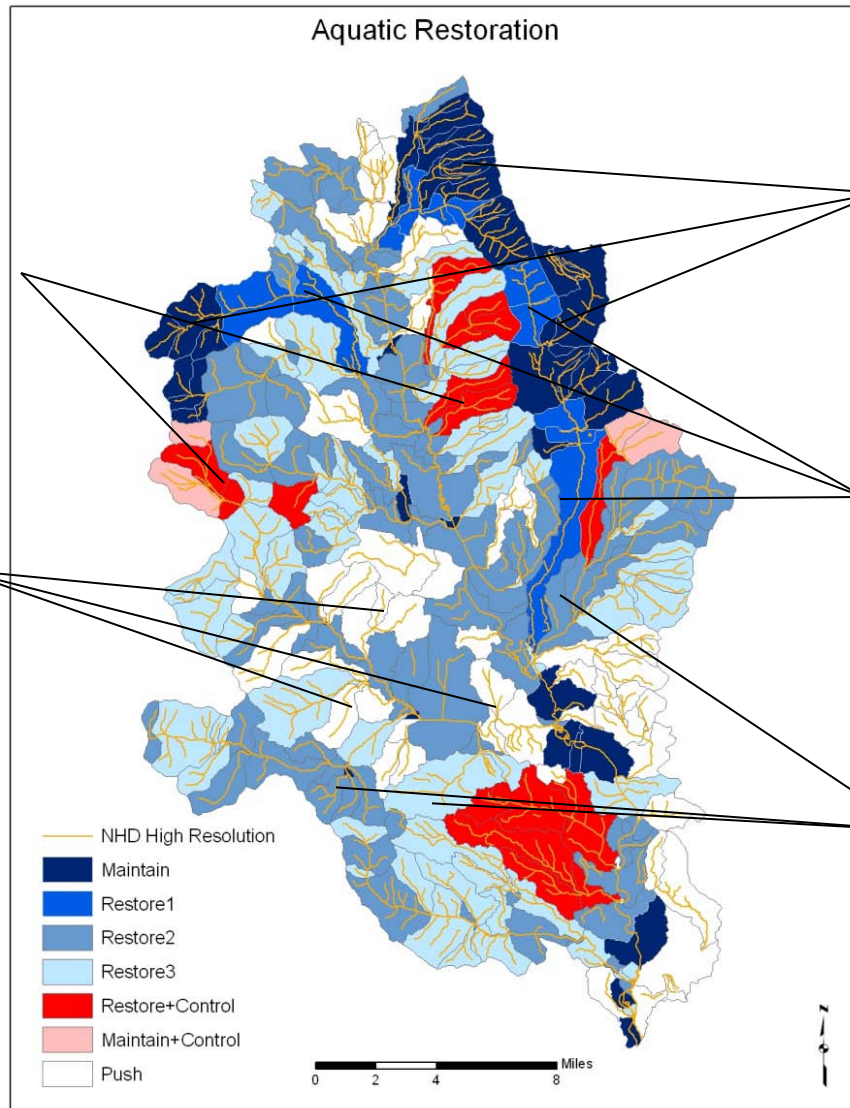
Managing Forests and Water

Objectives and Priorities

Control

Aggressive fire
suppress, fuels
mitigation

Don't Worry



Maintain

Tradeoffs in space
forest maintenance
low impact restoration

Restore 1

Focused aquatic restoration
synergies or tradeoffs
in space

Restore 2, 3

Long term investment
tradeoffs in time, more
aggressive forest
restoration