USGS
science for a changing world

Fish and fire

FIRE & AQUATIC ecosystems

A selected tour of findings since the 2001 Fire and Aquatic Ecosystems workshop

Jason Dunham

Forest and Rangeland Ecosystem Science Center

PNW

FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

Boise Aquatic Sciences Lab
U.S. Forest Service
Rocky Mountain Research Station
BOISE, IDAHO

JOINT FIRE SCIENCE PROGRAM

FIRESCIENCE.GOV
Research Supporting Sound Decisions

National Fire Plan
Managing the Impact of Wildfires on the Communities and the Environment

U.S. Department of the Interior
U.S. Geological Survey

The role of climate and vegetation change in shaping past and future fire regimes in the northwestern US and the implications for ecosystem management - Cathy Whitlock, Sarah L. Shafer, Jennifer Marlon

An environmental narrative of Inland Northwest United States forests, 1800–2000 -Paul F. Hessburg, James K. Agee

Fire and riparian ecosystems in landscapes of the western USA-Kathleen A. Dwire, J.Boone Kauffman

Postfire erosional processes in the Pacific Northwest and Rocky Mountain regions -Steven M. Wondzell, John G. King

Climatic controls on fire-induced sediment pulses in Yellowstone National Park and central Idaho: a long-term perspective - Grant A. Meyer, Jennifer L. Pierce

Effects of post-wildfire erosion on channel environments, Boise River, Idaho - Lee Benda, Daniel Miller, Paul Bigelow, Kevin Andras

Time, space, and episodicity of physical disturbance in streams -Daniel Miller, Charlie Luce, Lee Benda

Wildfire effects on stream food webs and nutrient dynamics in Glacier National Park, USA - Craig N Spencer, Kristin Odney Gabel, F.Richard Hauer

Responses of stream benthic macroinvertebrates to fire - G. Wayne Minshall

Fire and amphibians in North America -David S. Pilliod, R.Bruce Bury, Erin J. Hyde, Christopher A. Pearl, Paul Stephen Corn

Effects of fire on fish populations: landscape perspectives on persistence of native fishes and nonnative fish invasions -J.B. Dunham, M.K. Young, R.E. Gresswell, B.E. Rieman

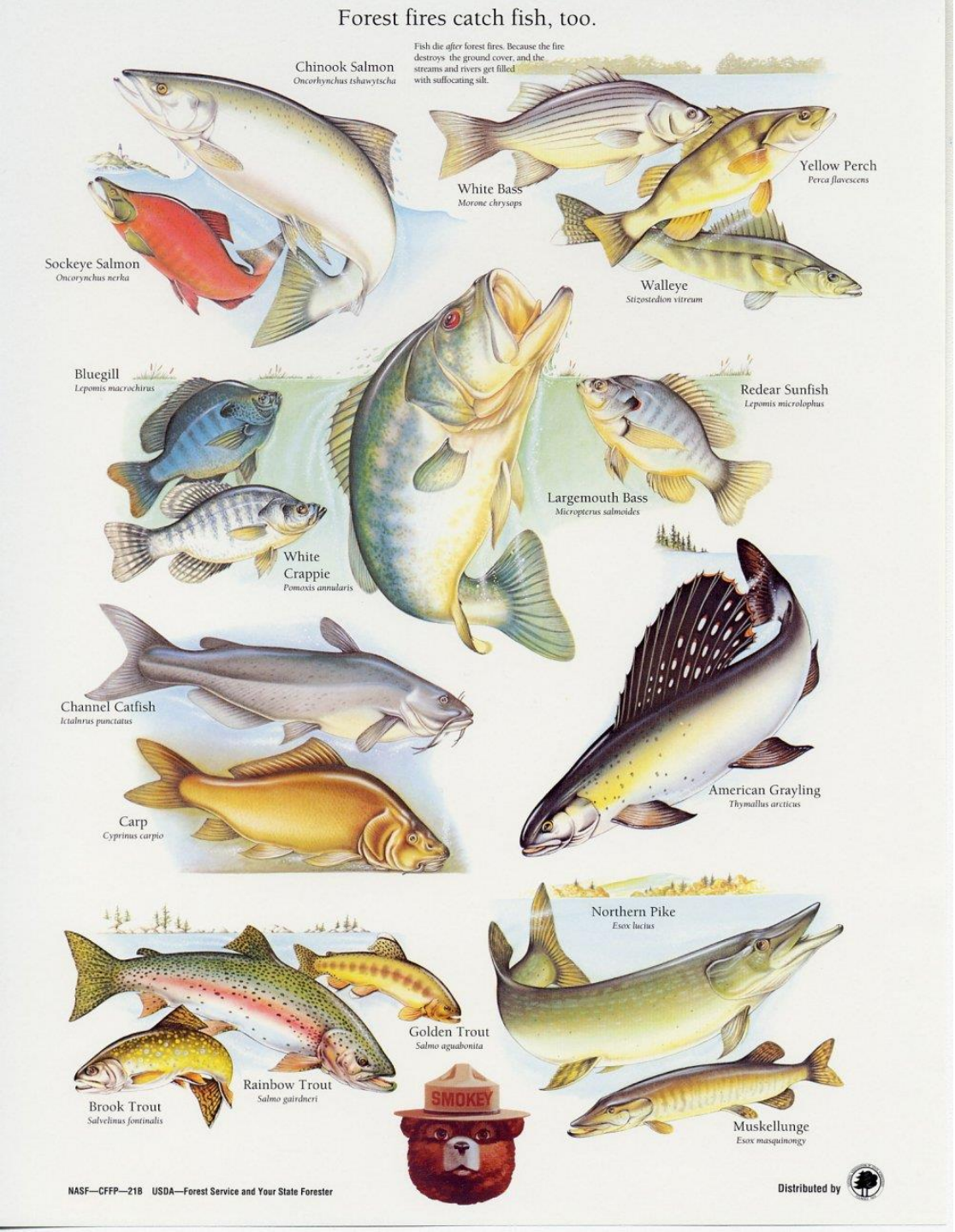
Status of native fishes in the western United States and issues for fire and fuels management - Bruce Rieman, Danny Lee, Dave Burns, Robert Gresswell, Michael Young, Rick Stowell, John Rinne, Philip Howell

Fire and aquatic ecosystems of the western USA: current knowledge and key questions -Peter A. Bisson, Bruce E. Rieman, Charlie Luce, Paul F. Hessburg, Danny C. Lee, Jeffrey L. Kershner, Gordon H. Reeves, Robert E. Gresswell

2003

Forest Ecology and Management
Volume 178, Issues 1–2,
Pages 1-230
13 full articles

The Effect of Wildland Fire on Aquatic Ecosystems in the Western USA.

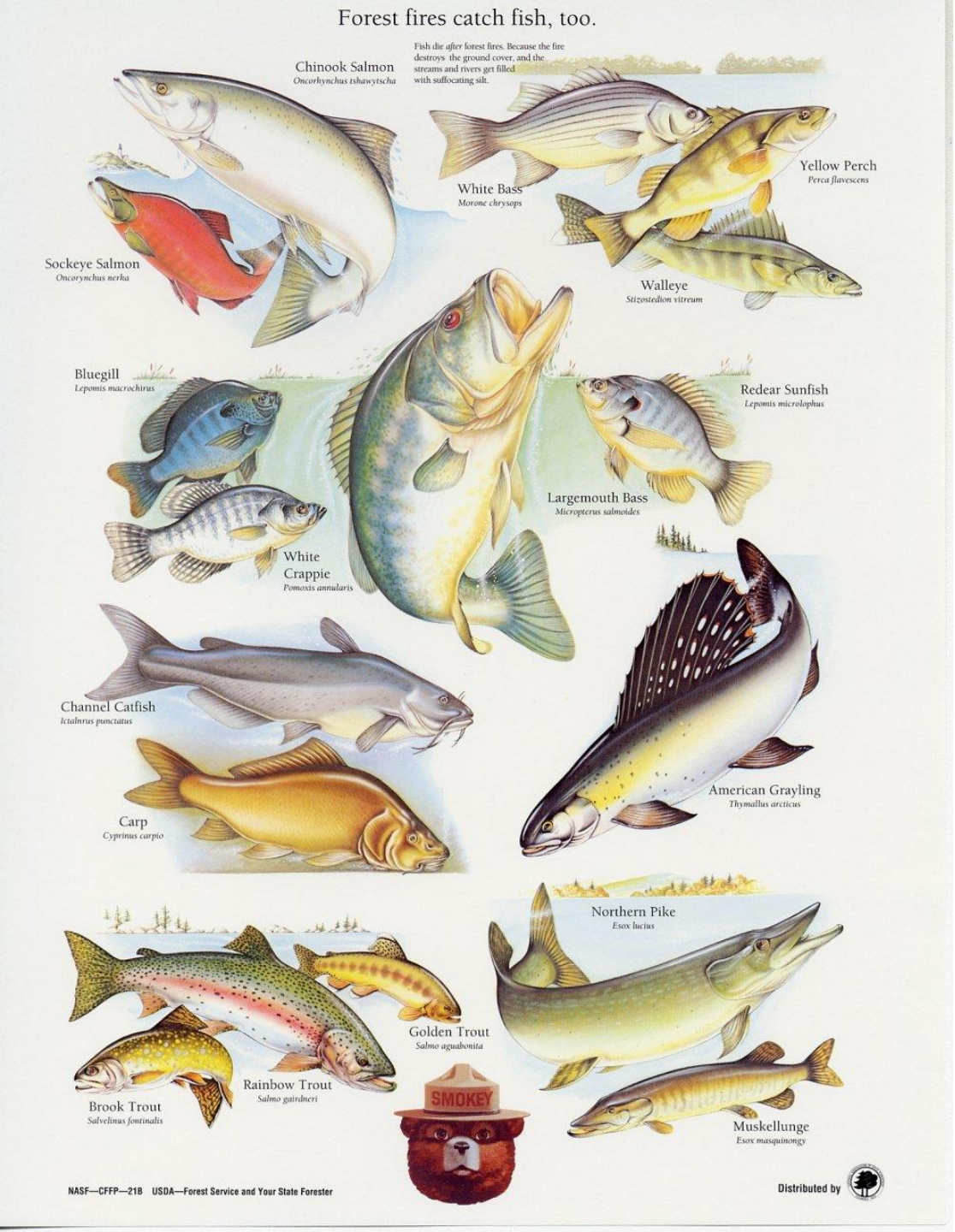


Wildfire and Fish

The old view

"Forest fires catch fish, too

Fish die after fires because the fire destroys the ground cover and the streams and rivers get filled with suffocating silt"

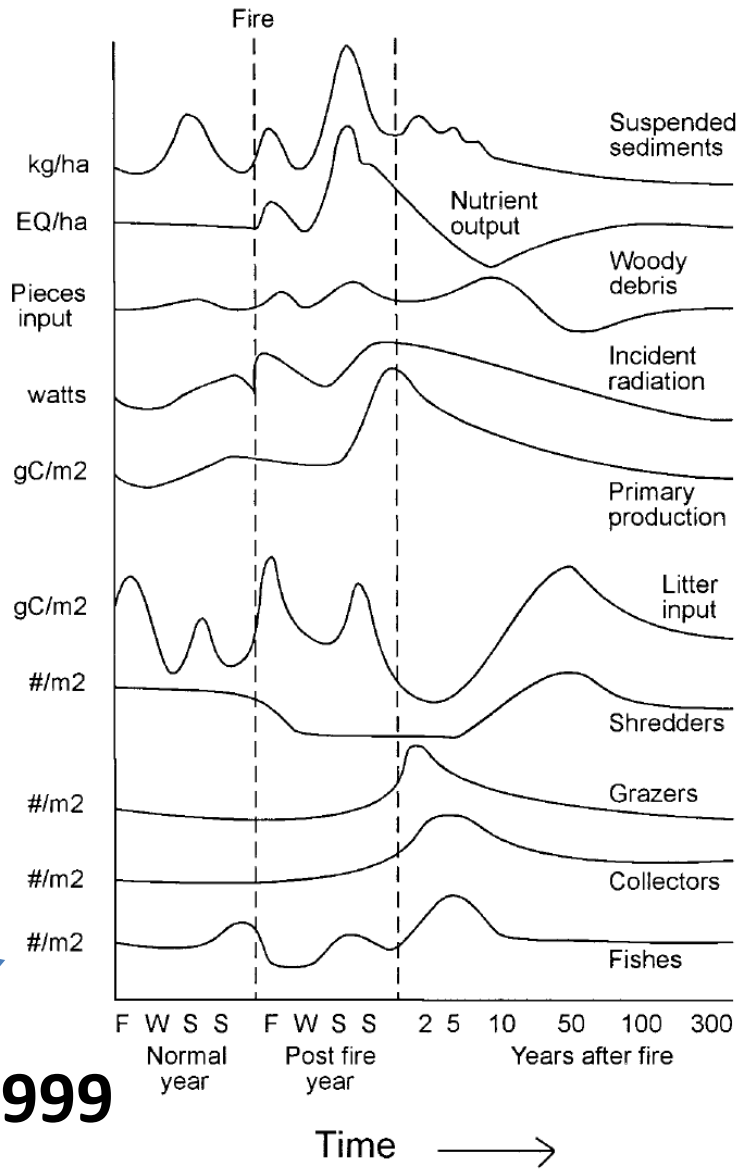


Alternative view

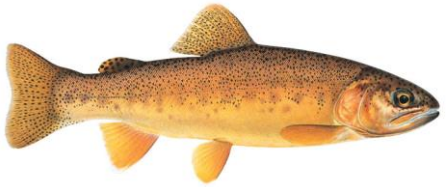
- Wildfire is a natural process
- Fish populations have persisted for millennia in fire- and disturbance-prone landscapes
- **So what's really going on here???**

Natural processes and wildfire

Minshall et al. 1989



Gresswell 1999



Natural processes and wildfire

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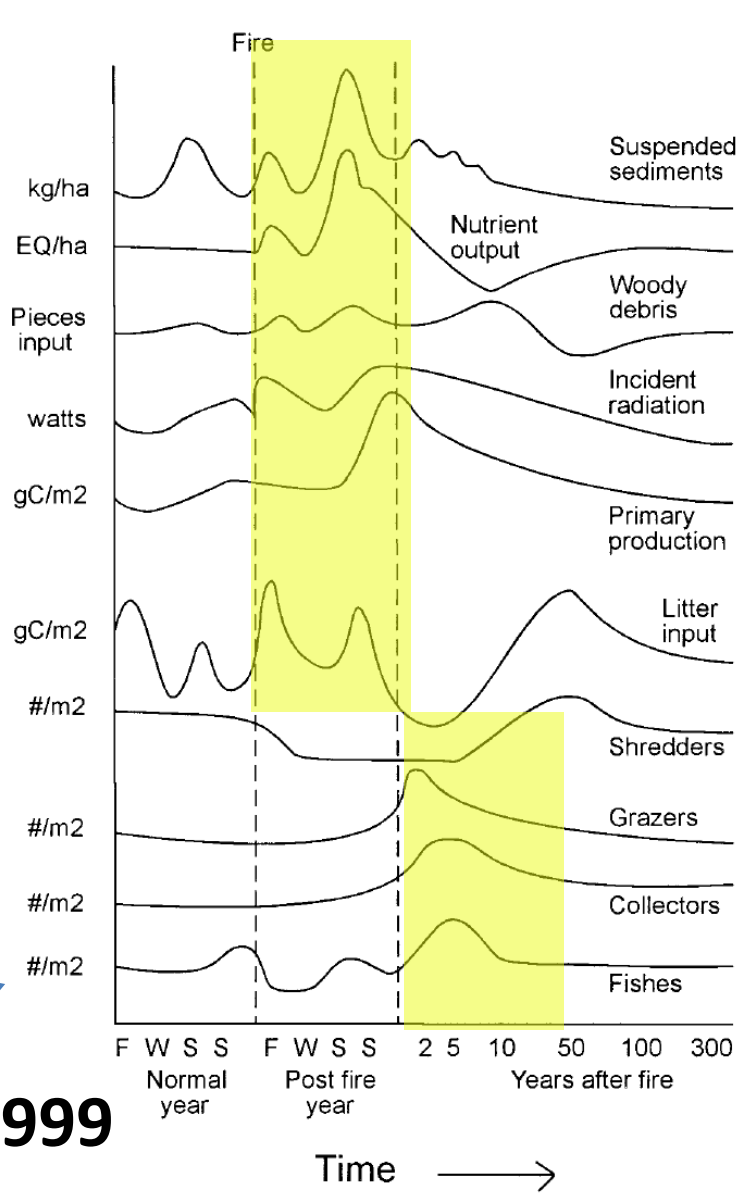
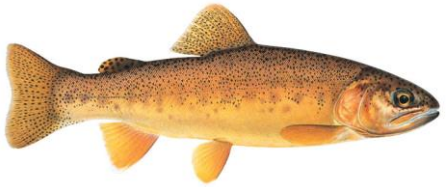
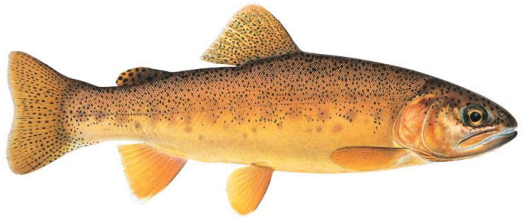
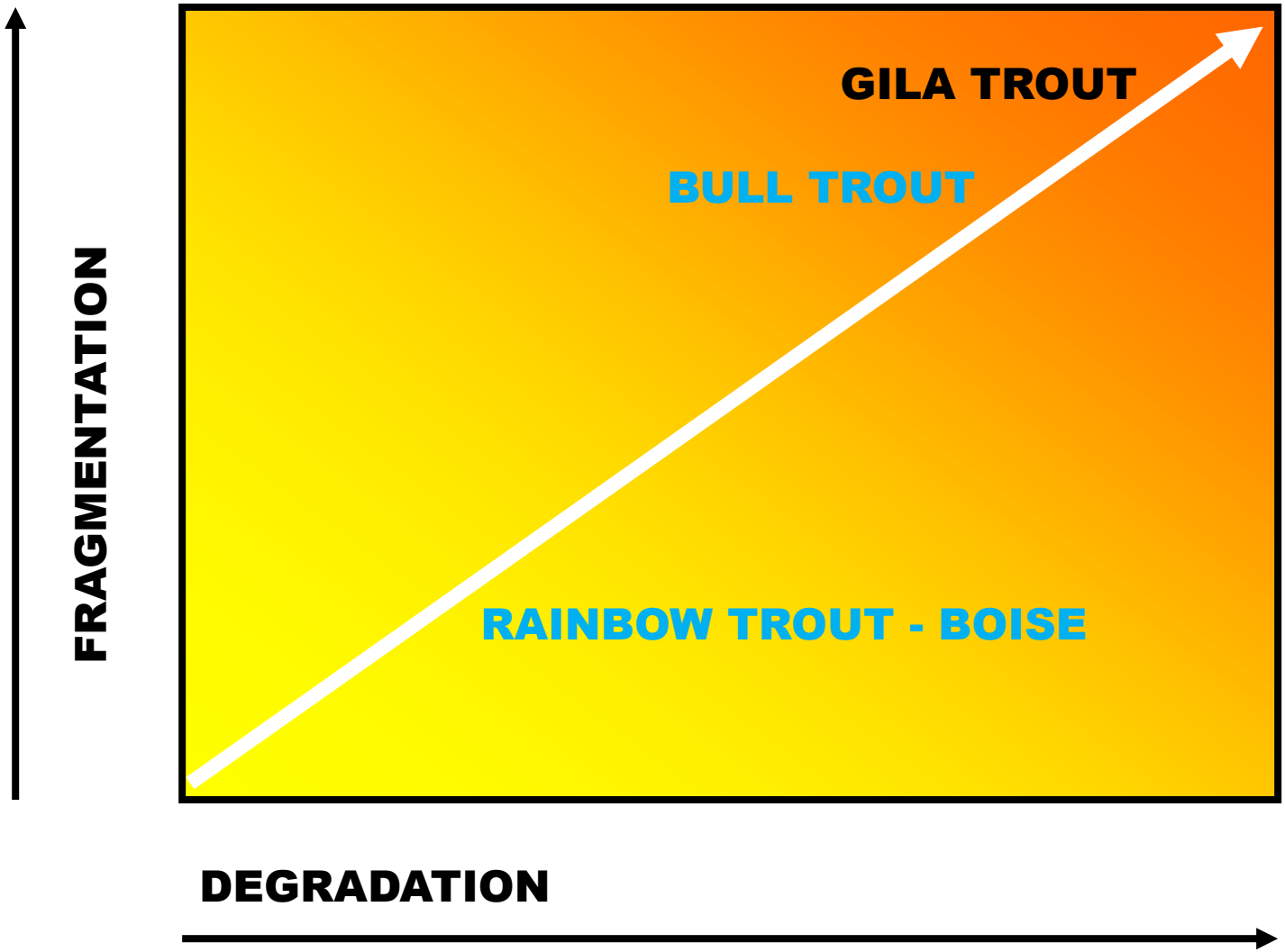


Gresswell 1999



When and where is *wildfire* a threat?





Dunham et al. (2003)

A tale of two trout

- Rainbow (former steelhead) – Boise River
  - Changes in ecosystems and fish in the face of fire
  - Natural processes and resilience

- Bull trout – Boise River and beyond
  - Fire, fragmentation, and persistence
  - When/where is fire a threat???

Rainbows and resilience

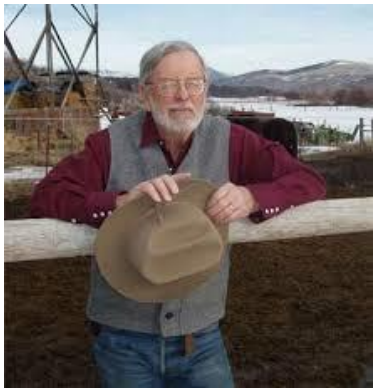
Wildfire effects on small streams

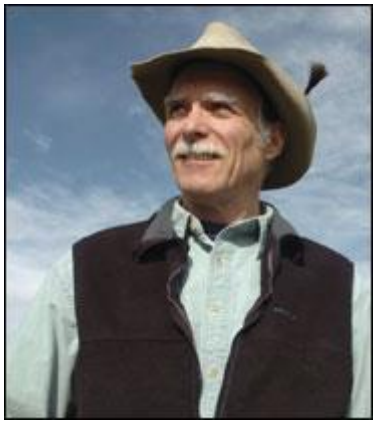
- Channel disturbance
- Temperature

Fish Responses

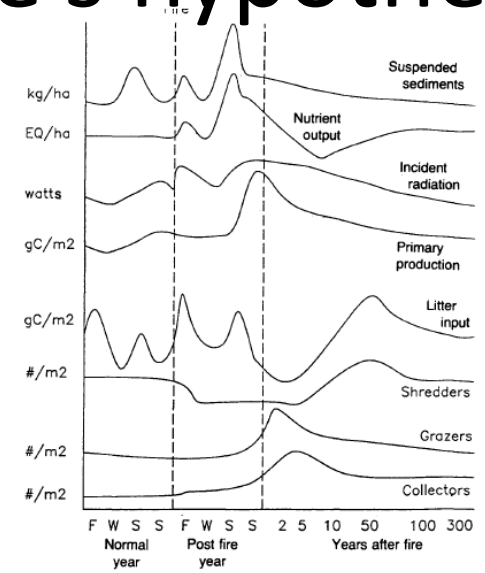
- Population
- Individuals

All trout illustrations by Joe Tomelleri



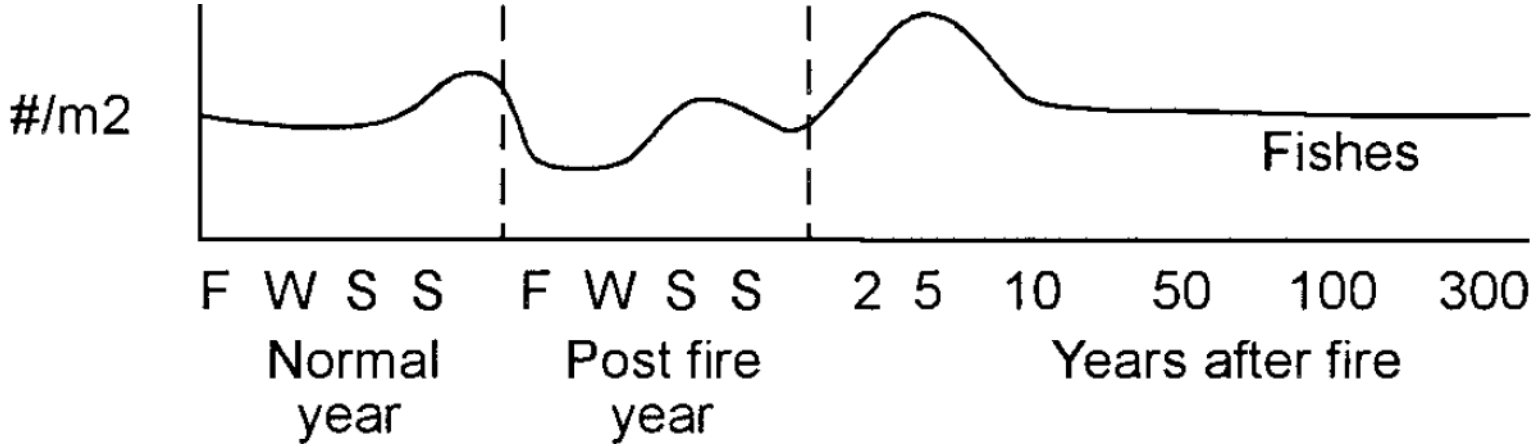


Wayne's hypotheses

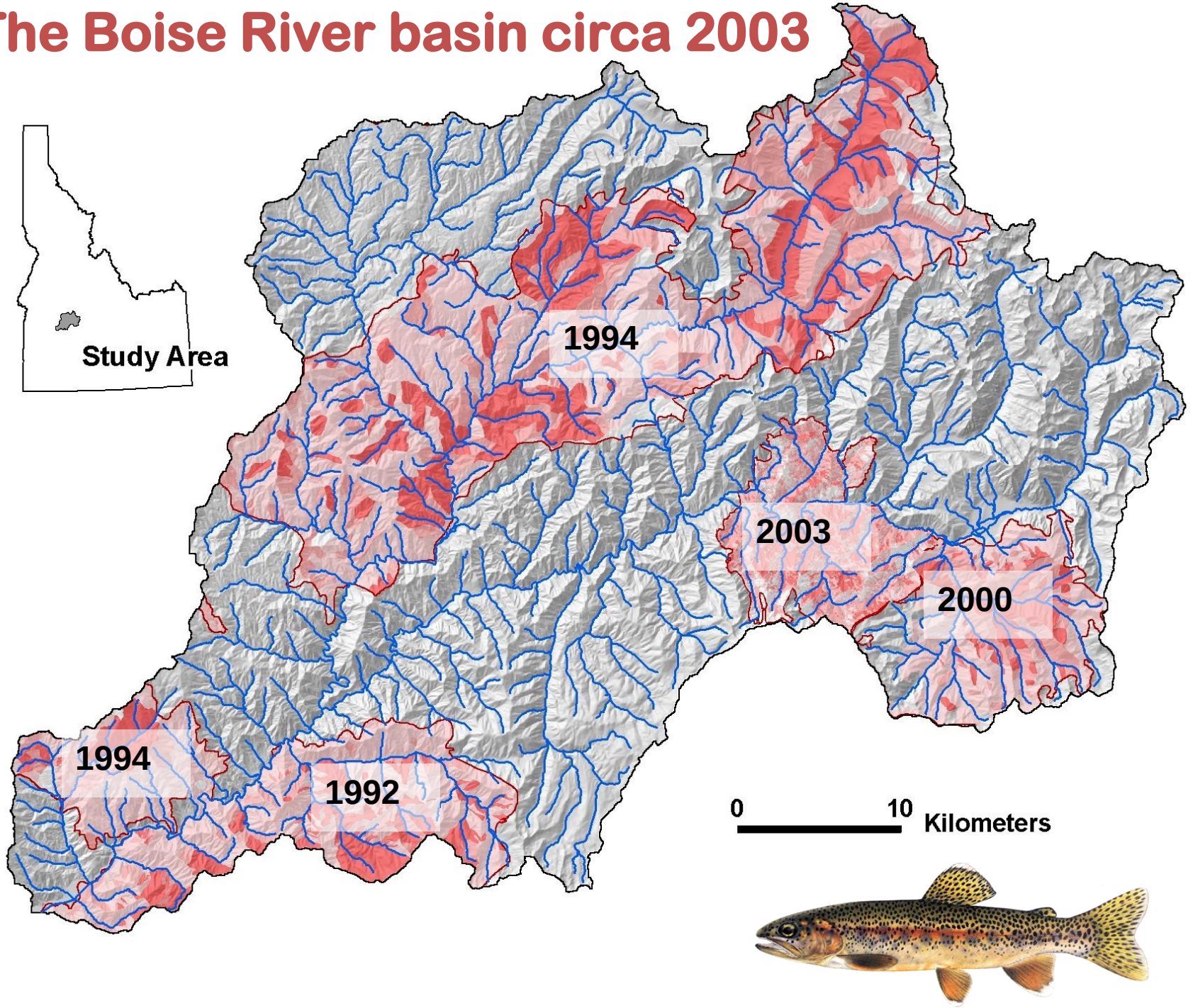


Shift to autotrophy
Productivity pulse?

Bob's hypothesis



The Boise River basin circa 2003



"Space for time" substitution Summer of 2003

Undisturbed

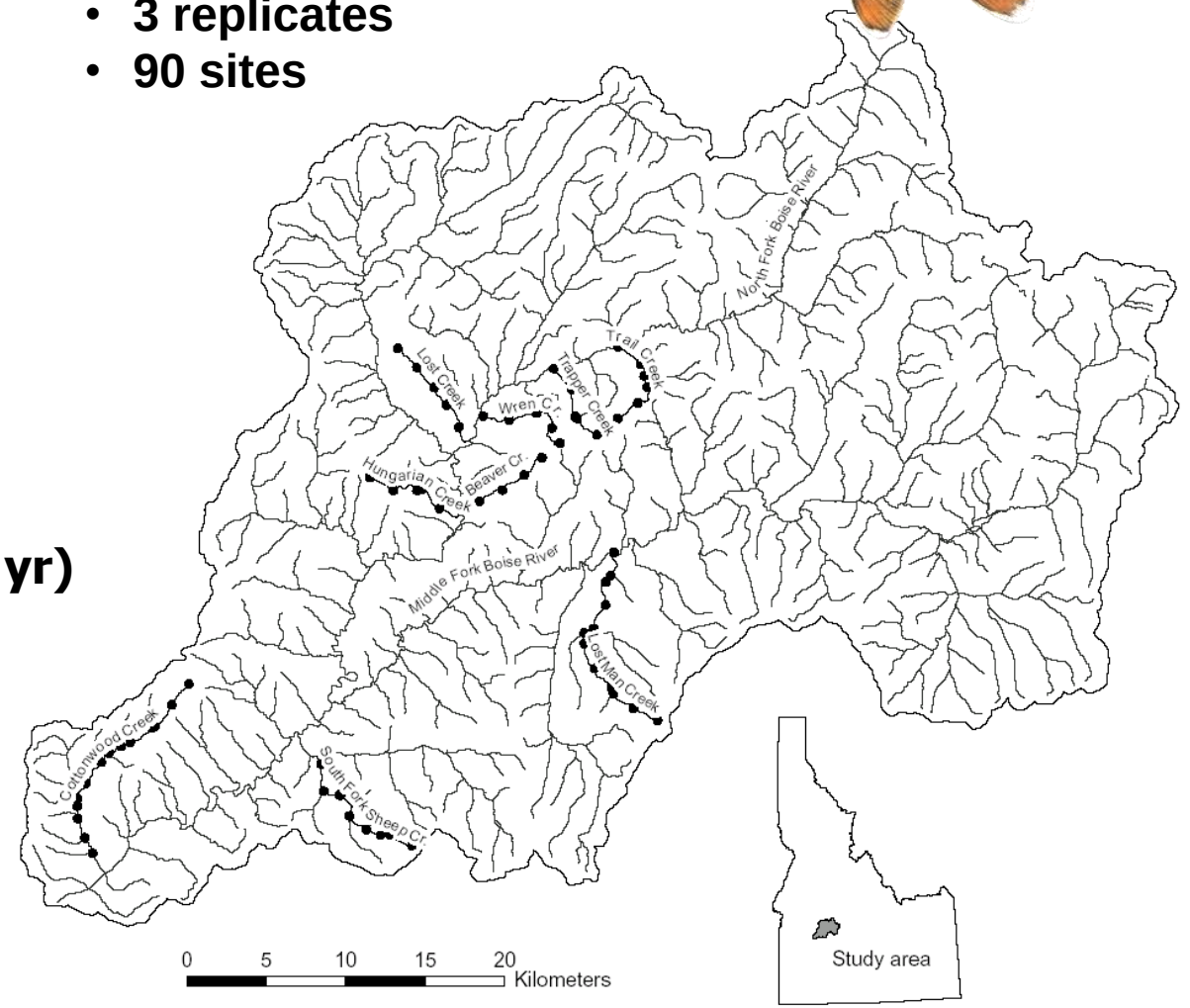
burned (9 years)

burned & reorganized (9-11 yr)

2-3 rd order streams

3 Stream types

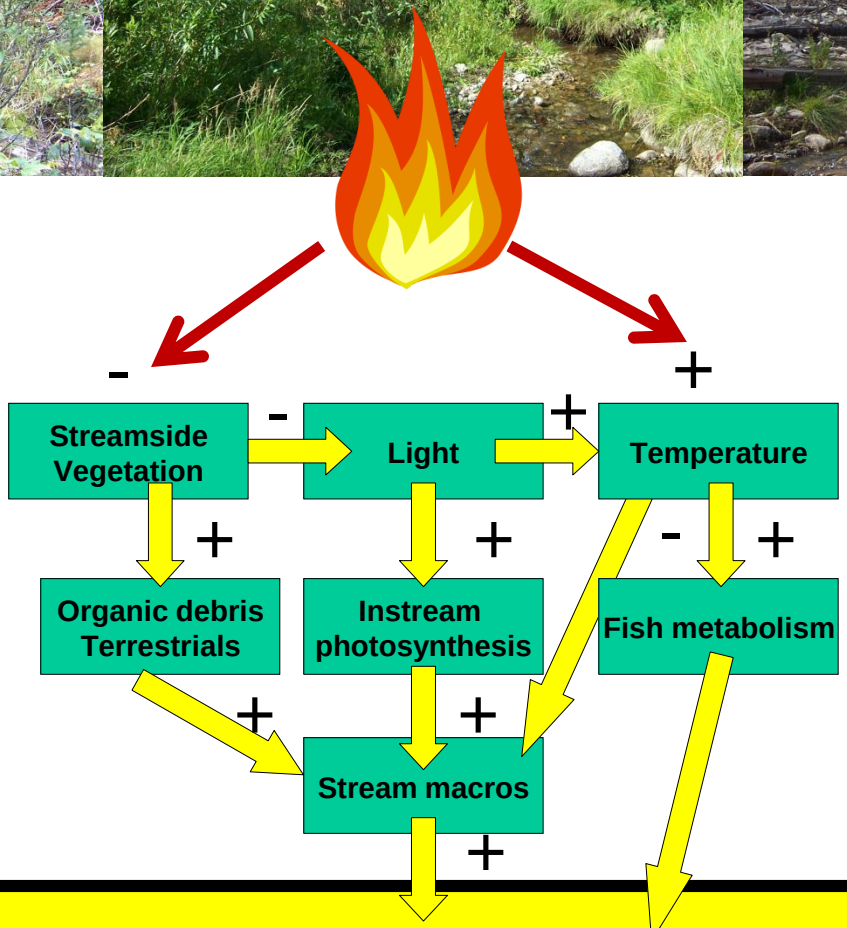
- **3 replicates**
- **90 sites**



“Unburned” – without severe fire in last century

“Burned” – focus on stand-replacing wildfire 9 years postfire

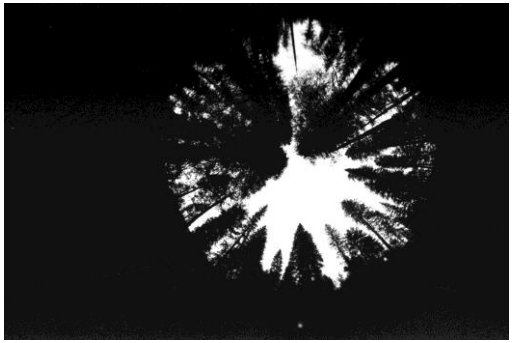
“Burned & Reorganized”



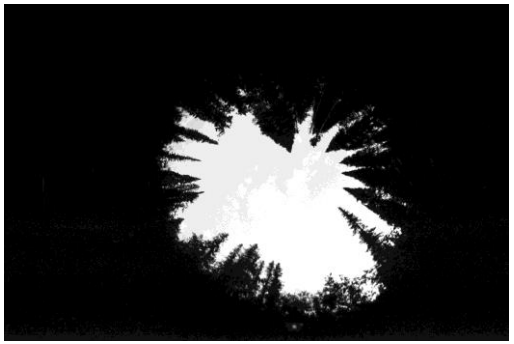
FISH

Individual **condition, growth, maturity, diet**

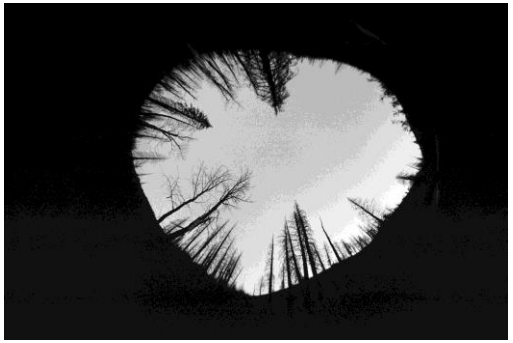
Population density



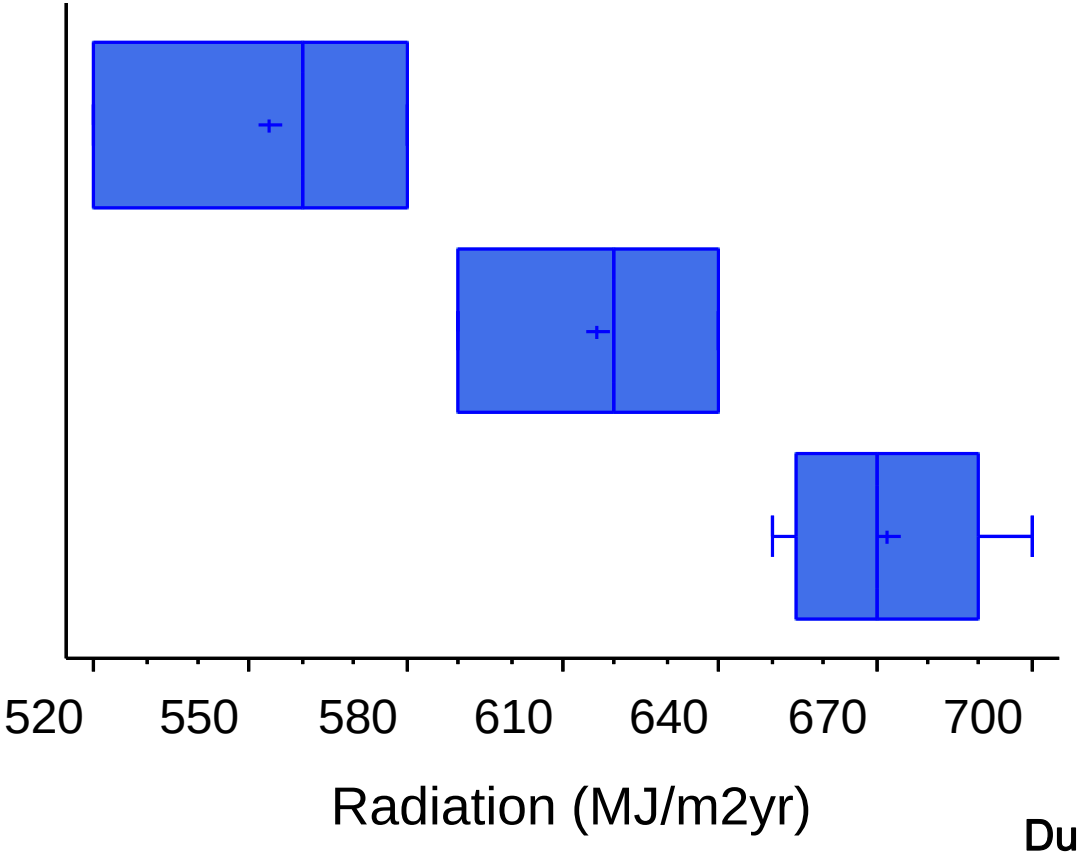
Unburned



Burned

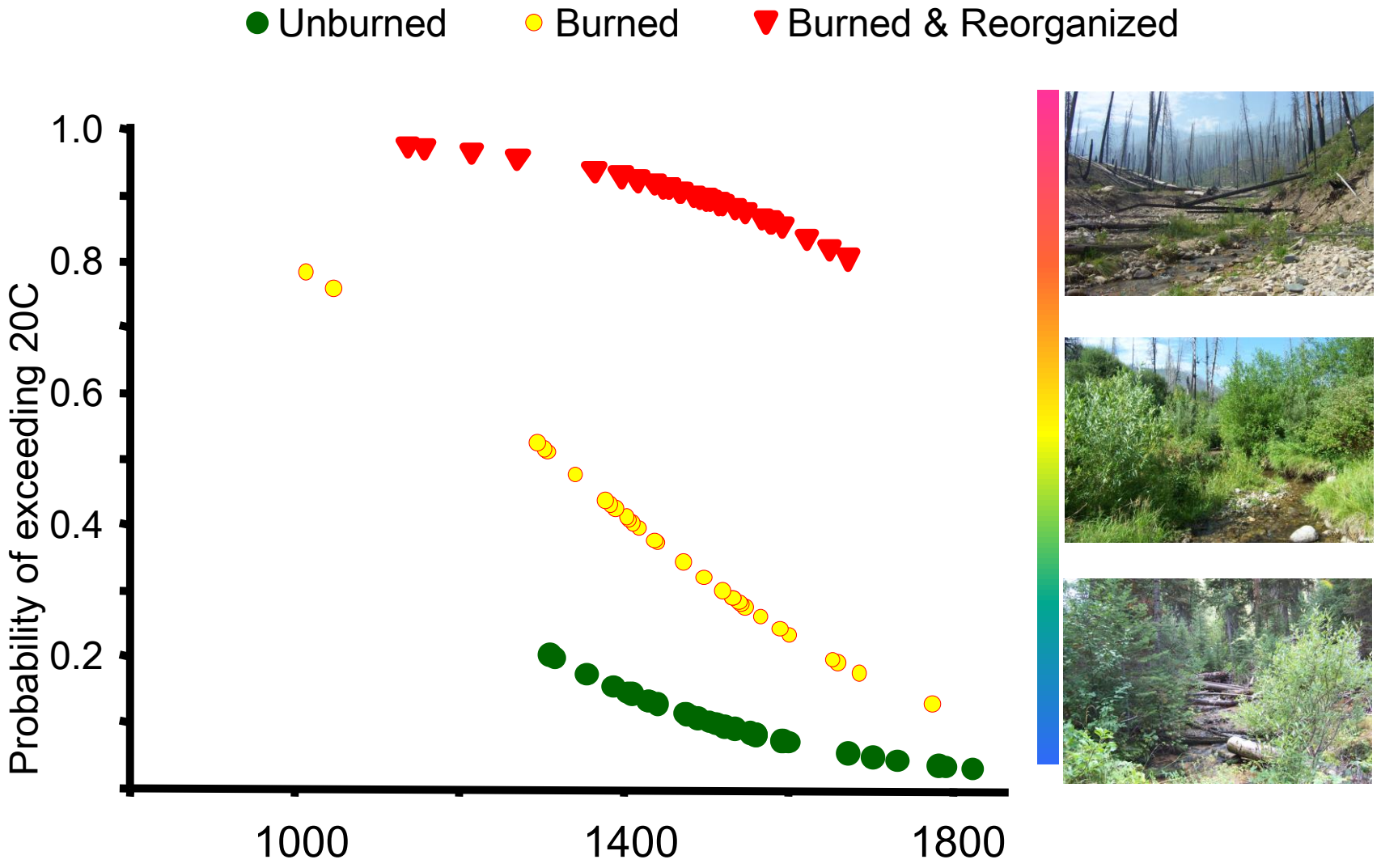


Burned &
Reorganized



Dunham *et al.* 2007

Stream Temperature: 9-11 years post-disturbance

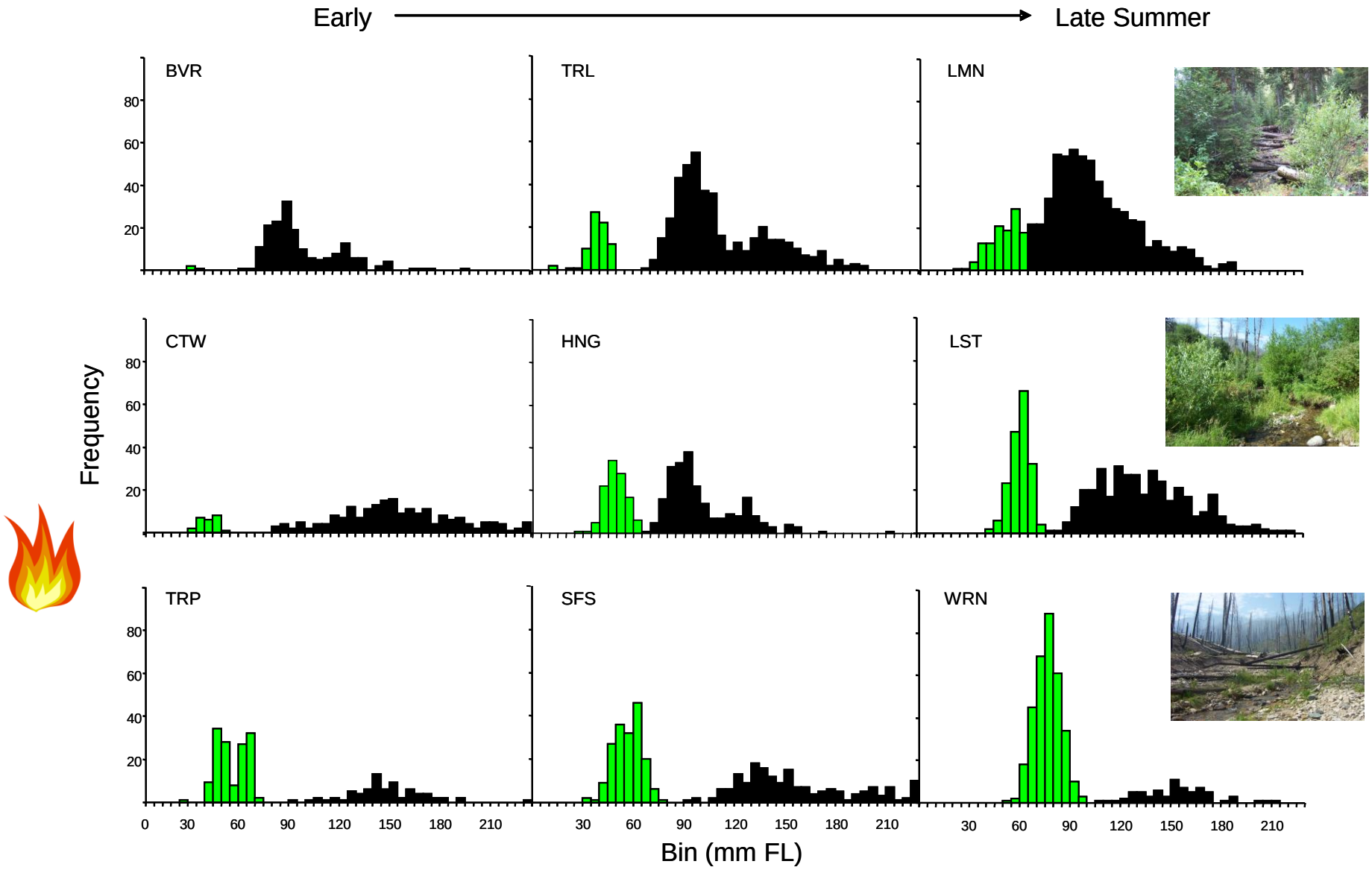


Dunham *et al.* 2007

Resilience – young of year and older fish in all 90 sites

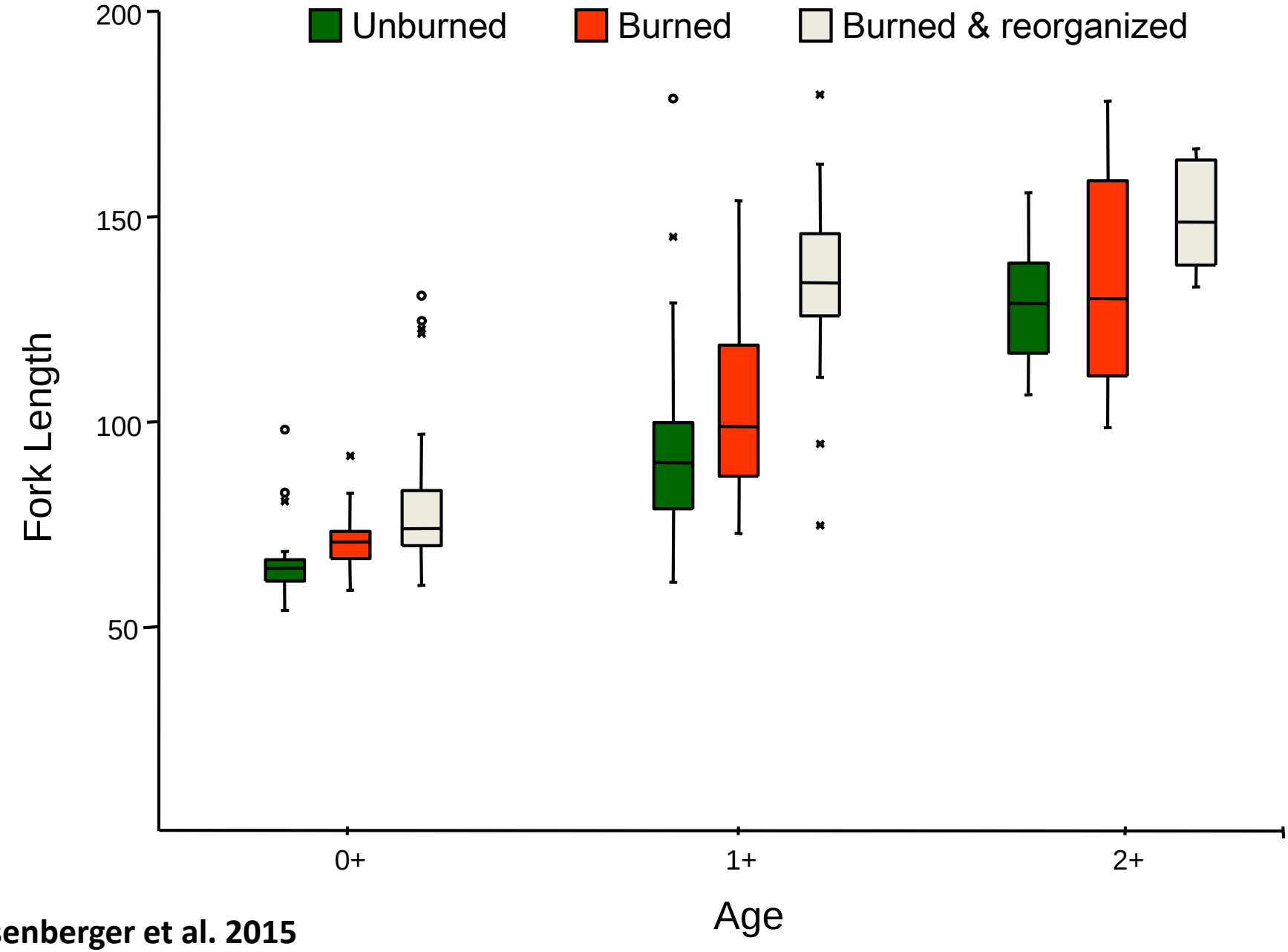
Burton et al. 2005
Dunham *et al.* 2007

Age class structure, emergence phenology, and population density



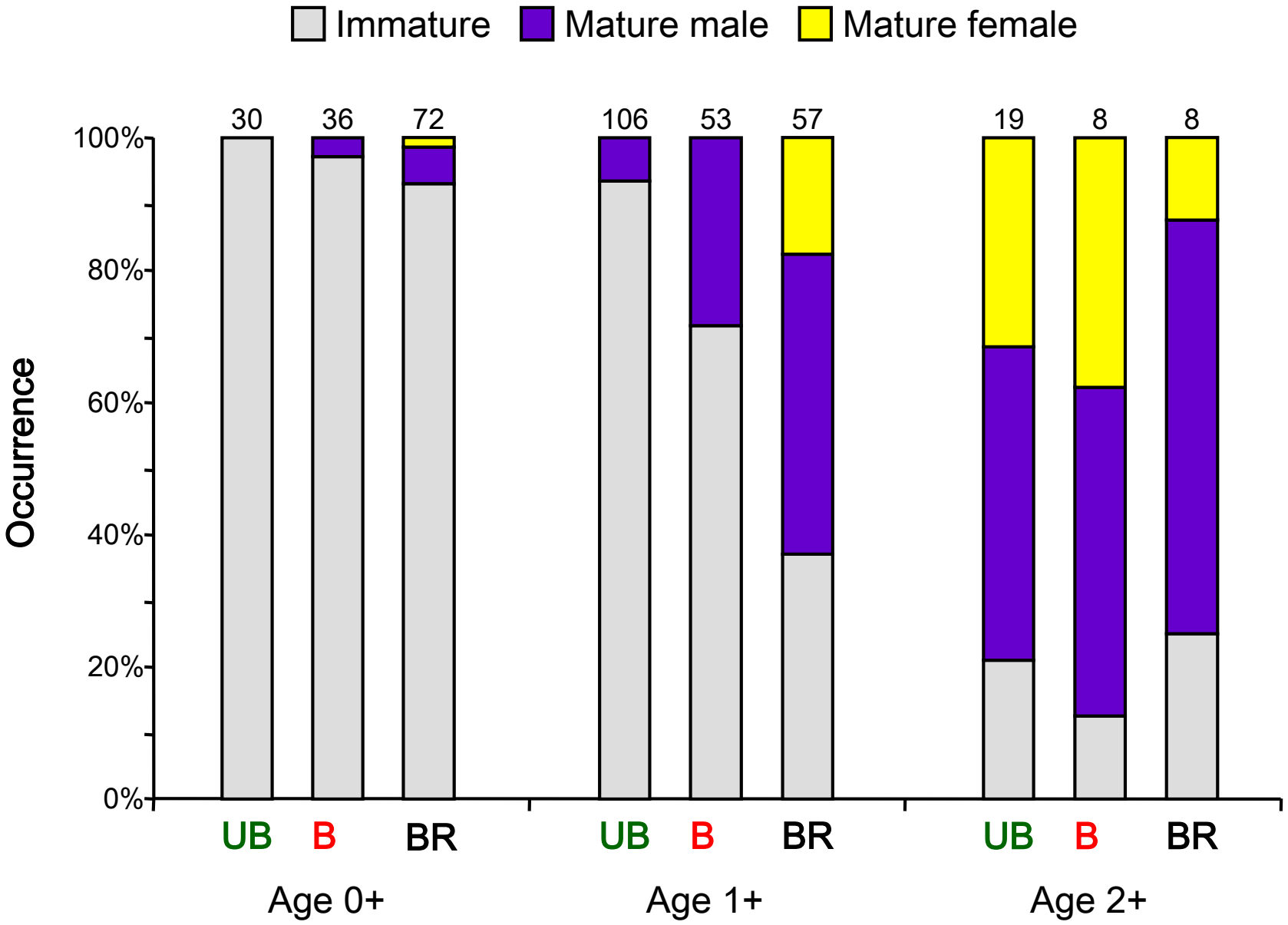
Rosenberger et al. 2015

Faster growth in warmer streams



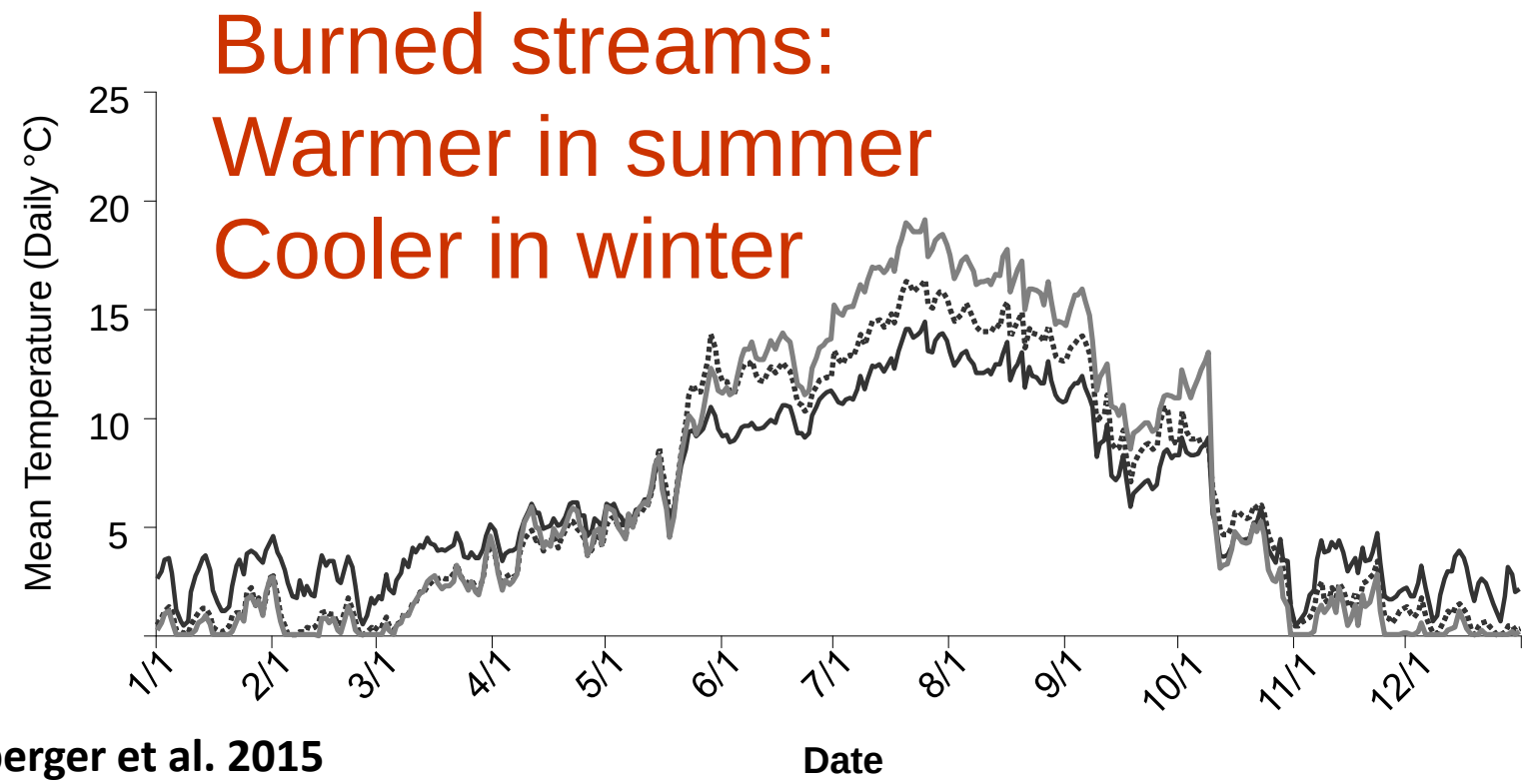
Rosenberger et al. 2015

Fire = “Live fast – die young”



Rosenberger et al. 2015

- **Why do fish grow faster after fire?**
  - Earlier emergence of young
  - Longer growing season (sublethal max temps)
  - Lower population density
  - **Net effect = faster growth, early maturity**



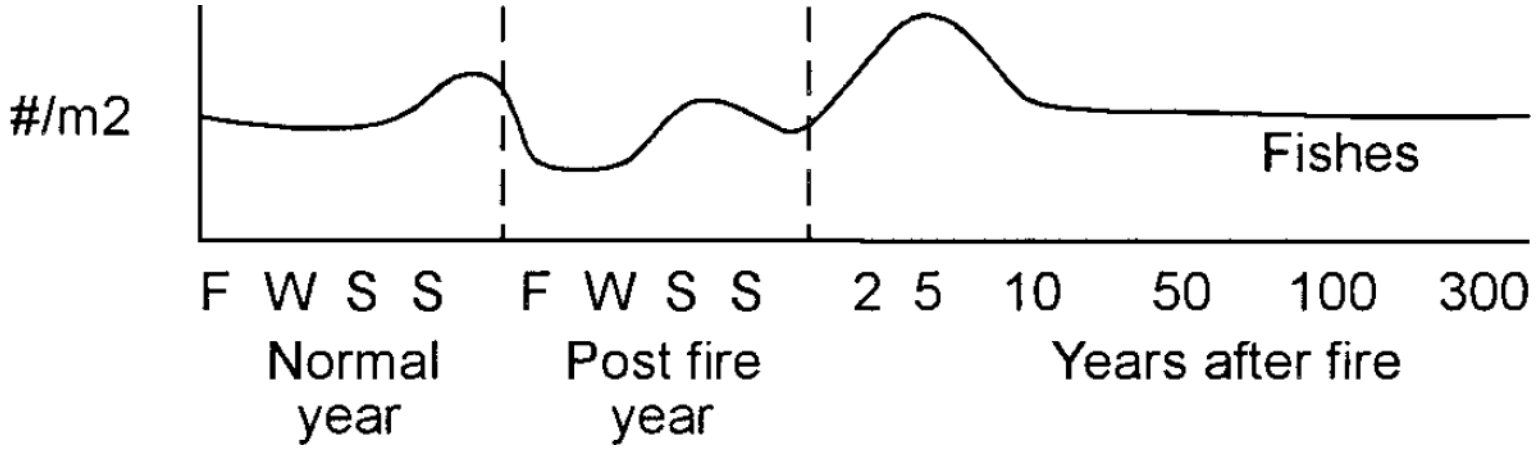
Rosenberger et al. 2015

Implications

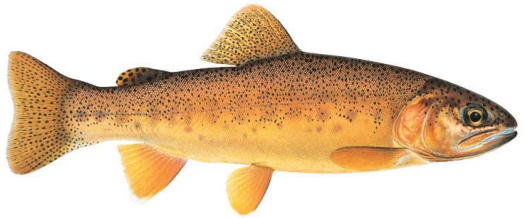
- **Long-term influences on light and temperature**
- **Both fish *and* ecosystems change**
- **Single biological responses misleading**
- **Fire not a problem when fish have options**

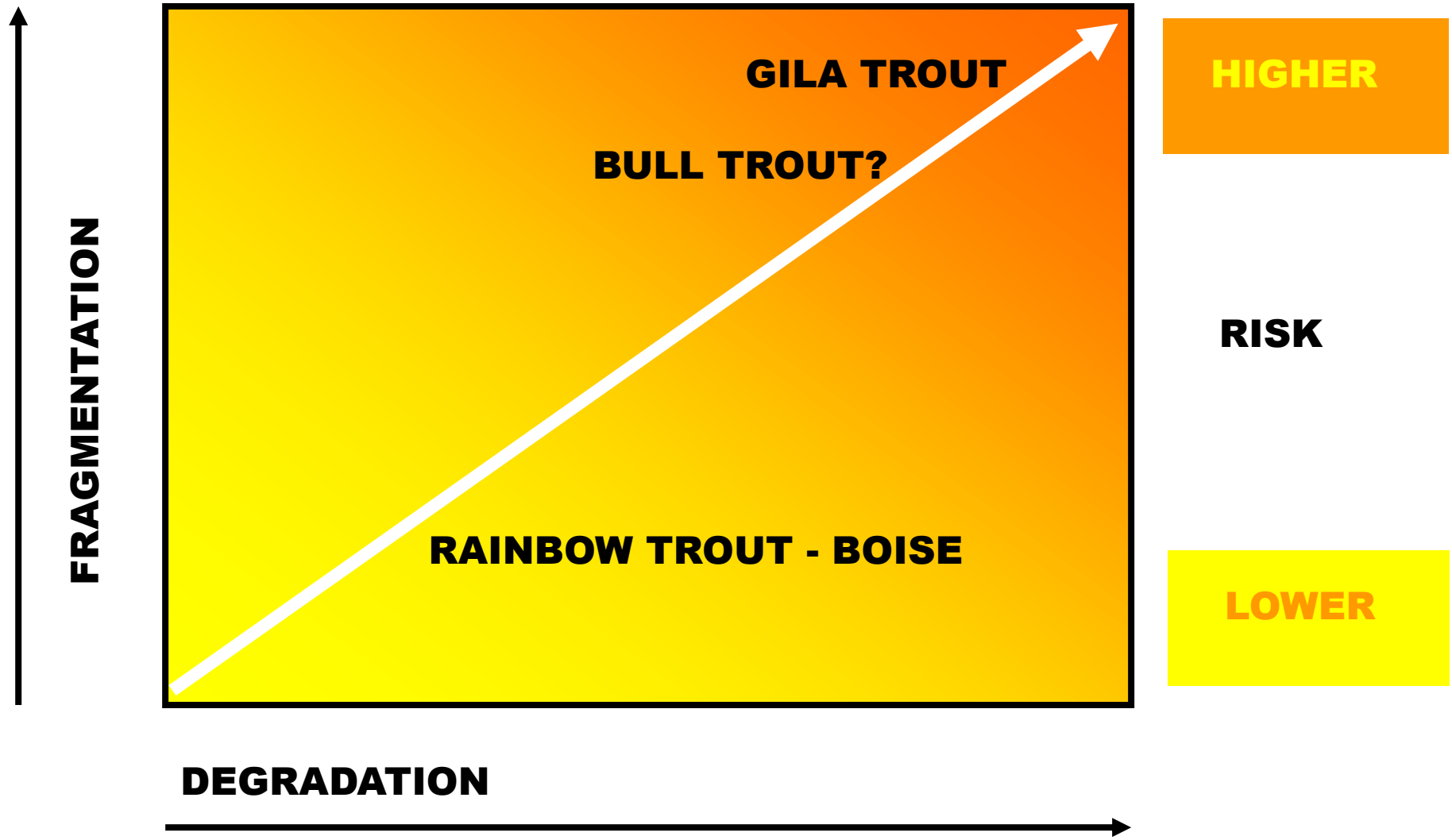
Was Bob right?

- **Kind of! (if we change the Y axis to growth)**



Is *wildfire* a threat?

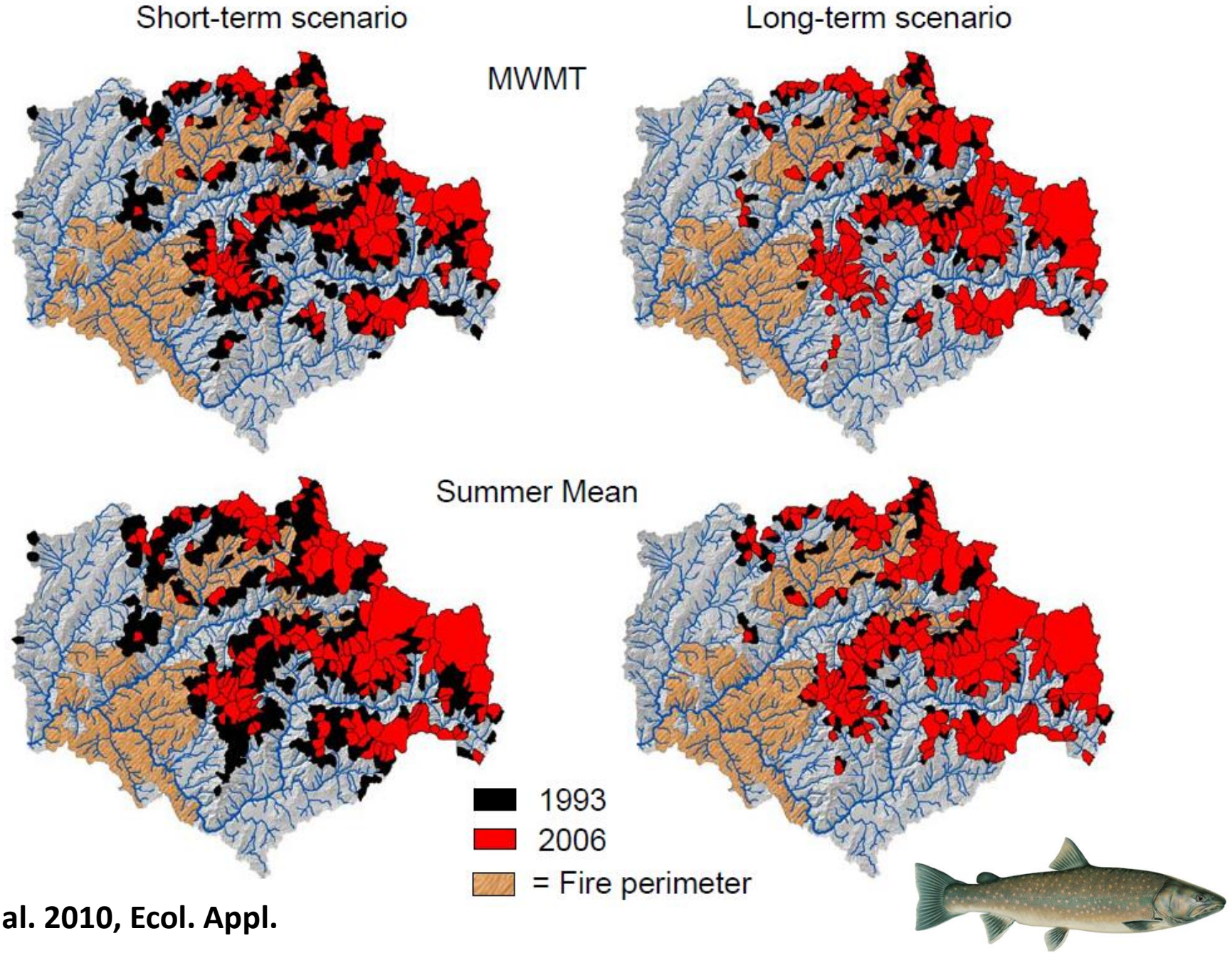




Dunham et al. (2003)

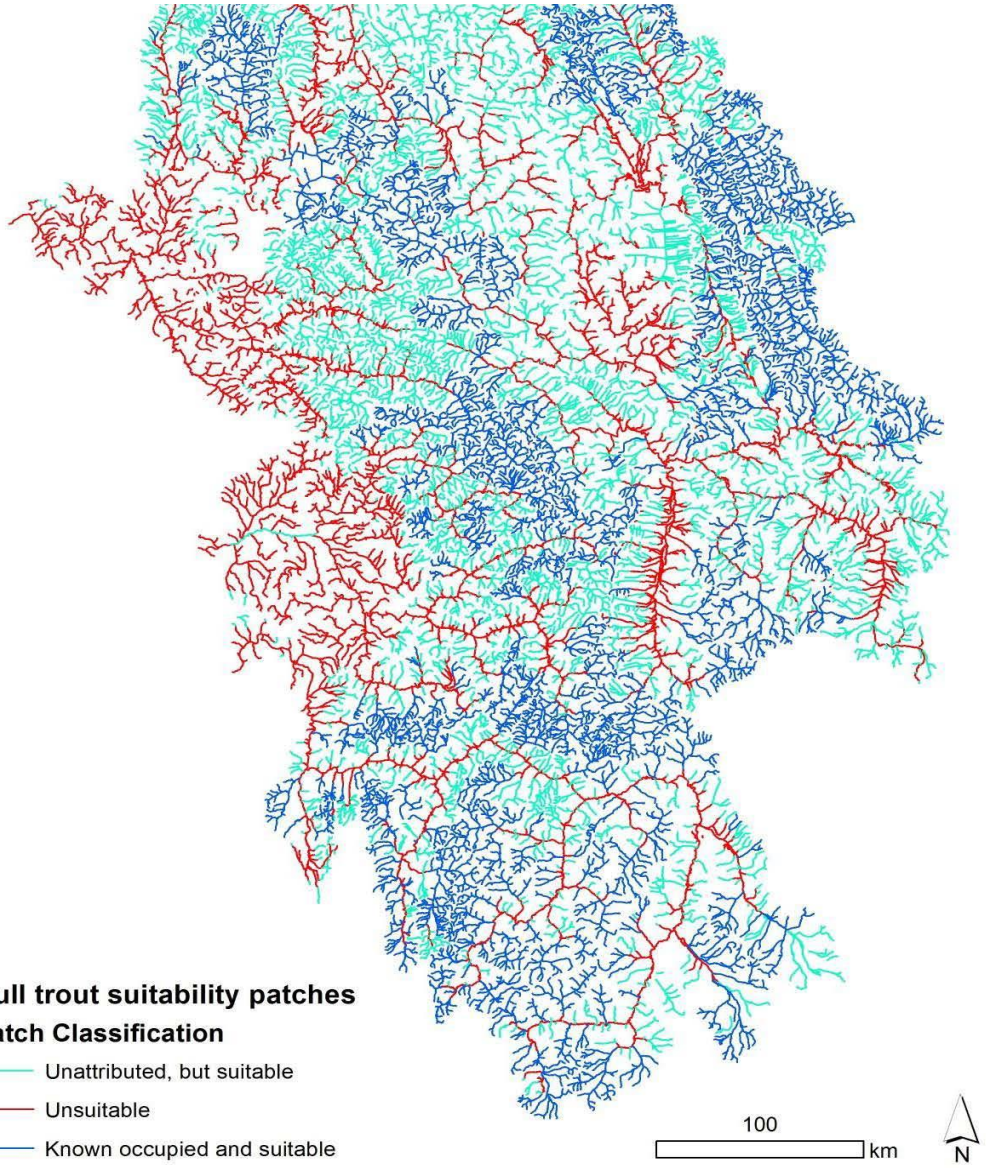
The threatened bull trout

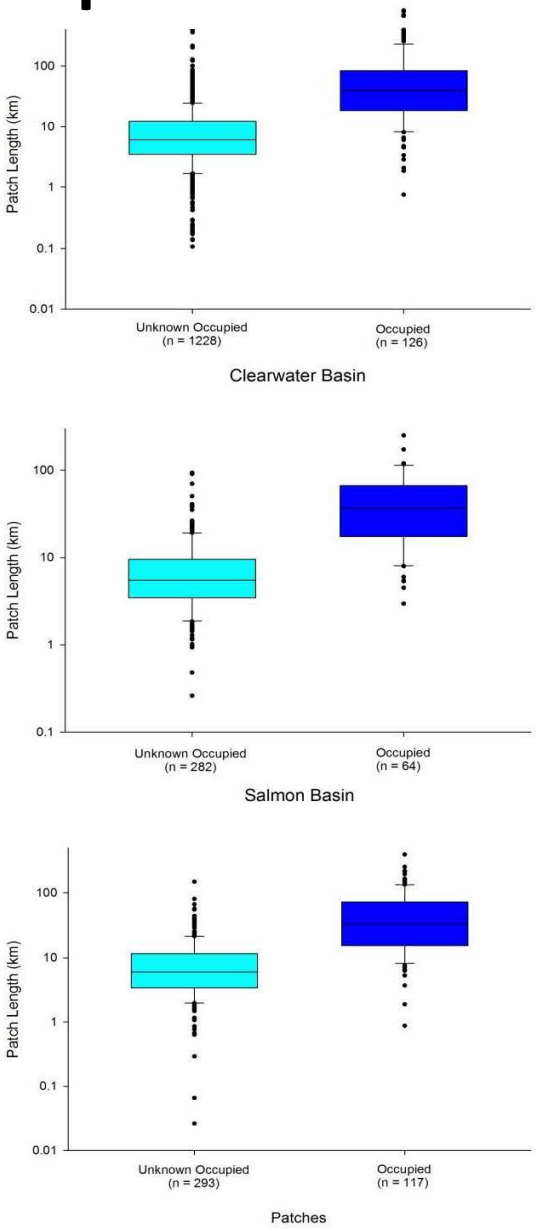
- A “high maintenance salmonid”
  - Coldwater specialist
  - Highly fragmented
  - Often found in fire-prone environments



Isaak et al. 2010, Ecol. Appl.

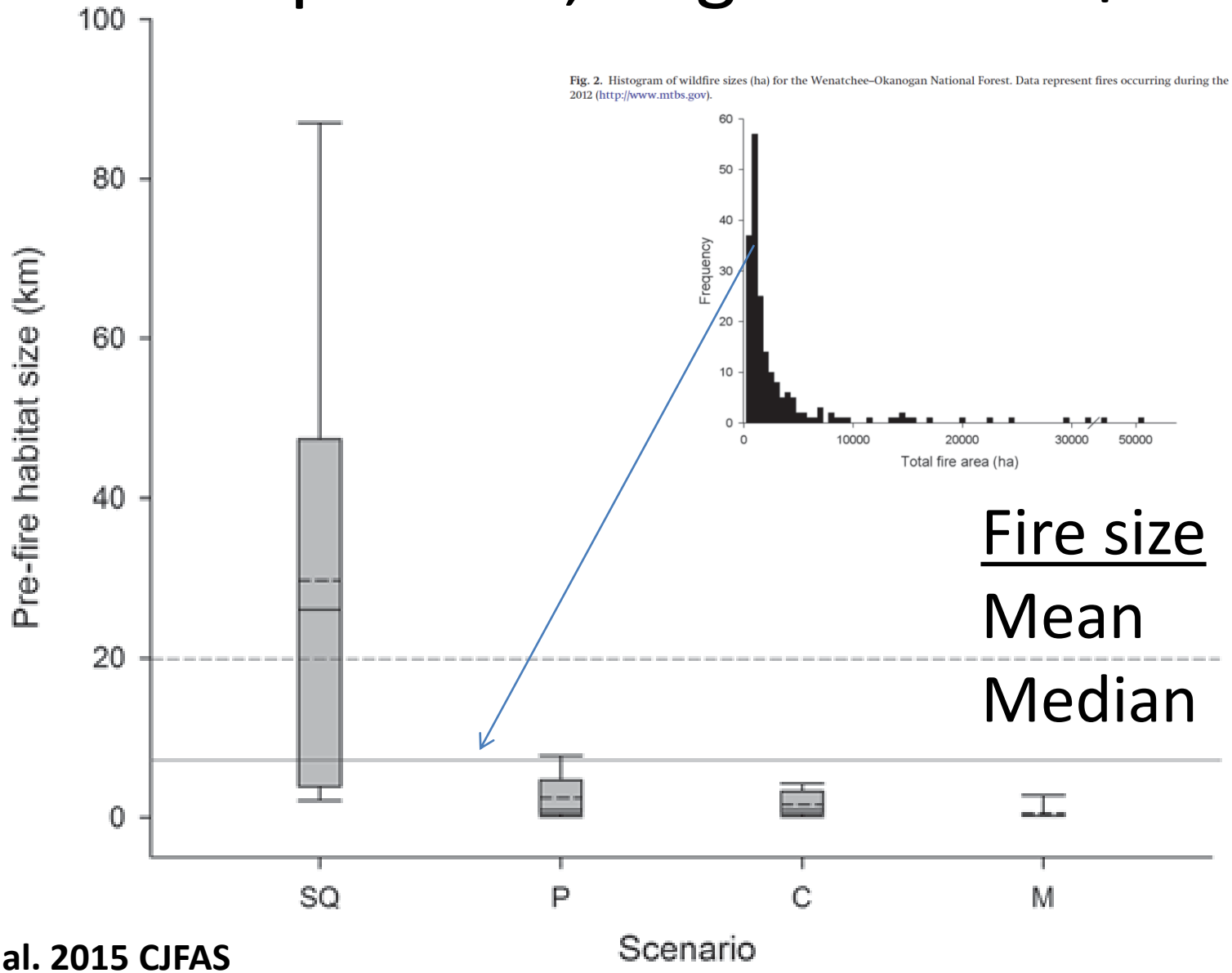
Rangewide perspective:
Fire in the past 20 years does not influence presence





Dunham et al. 2015

Future climate effects = Smaller patches, larger fires = ↑risk



Falke et al. 2015 CJFAS

AGU Geophysical Research Letters 10.1002/2014GL059576

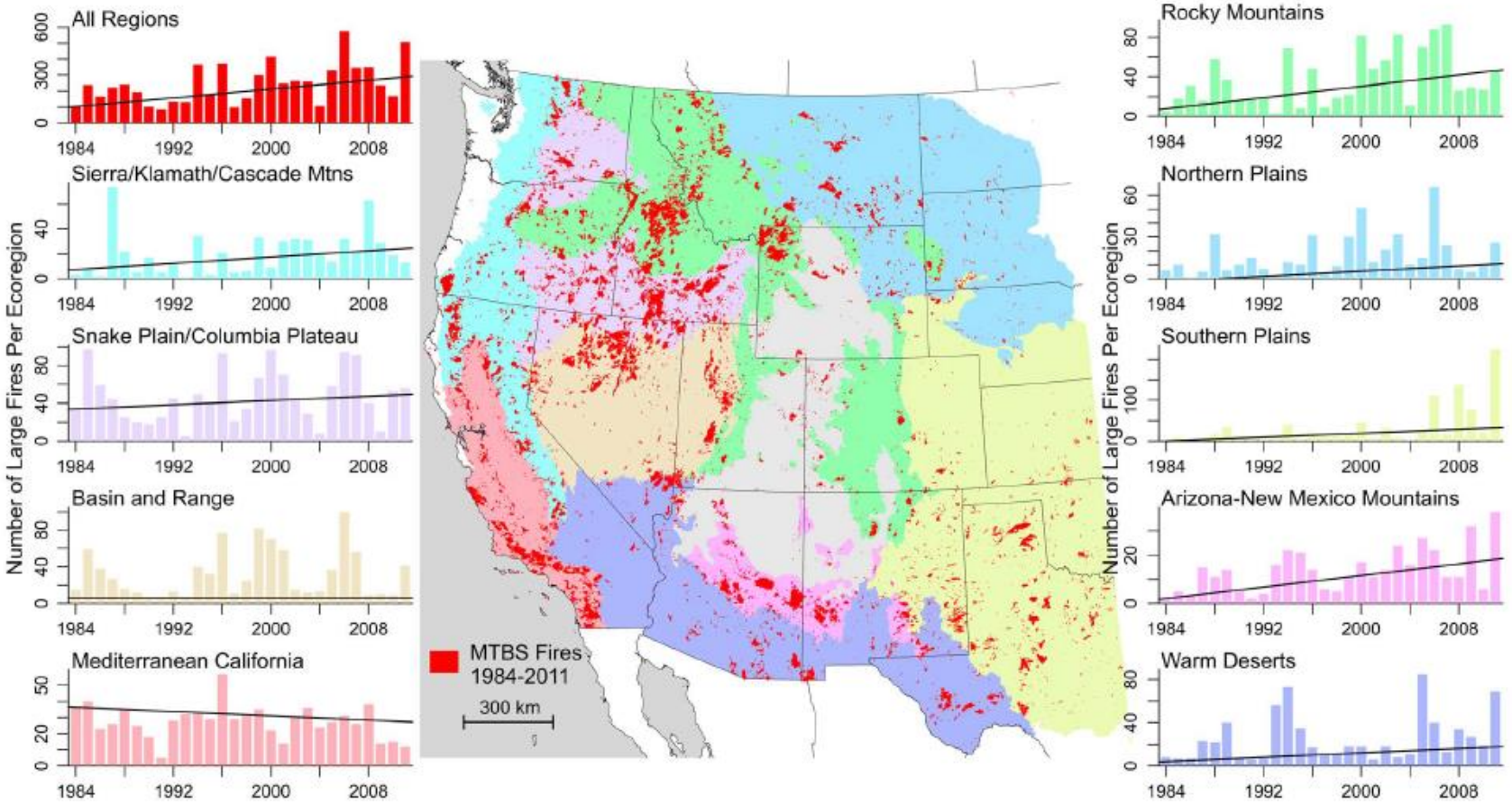
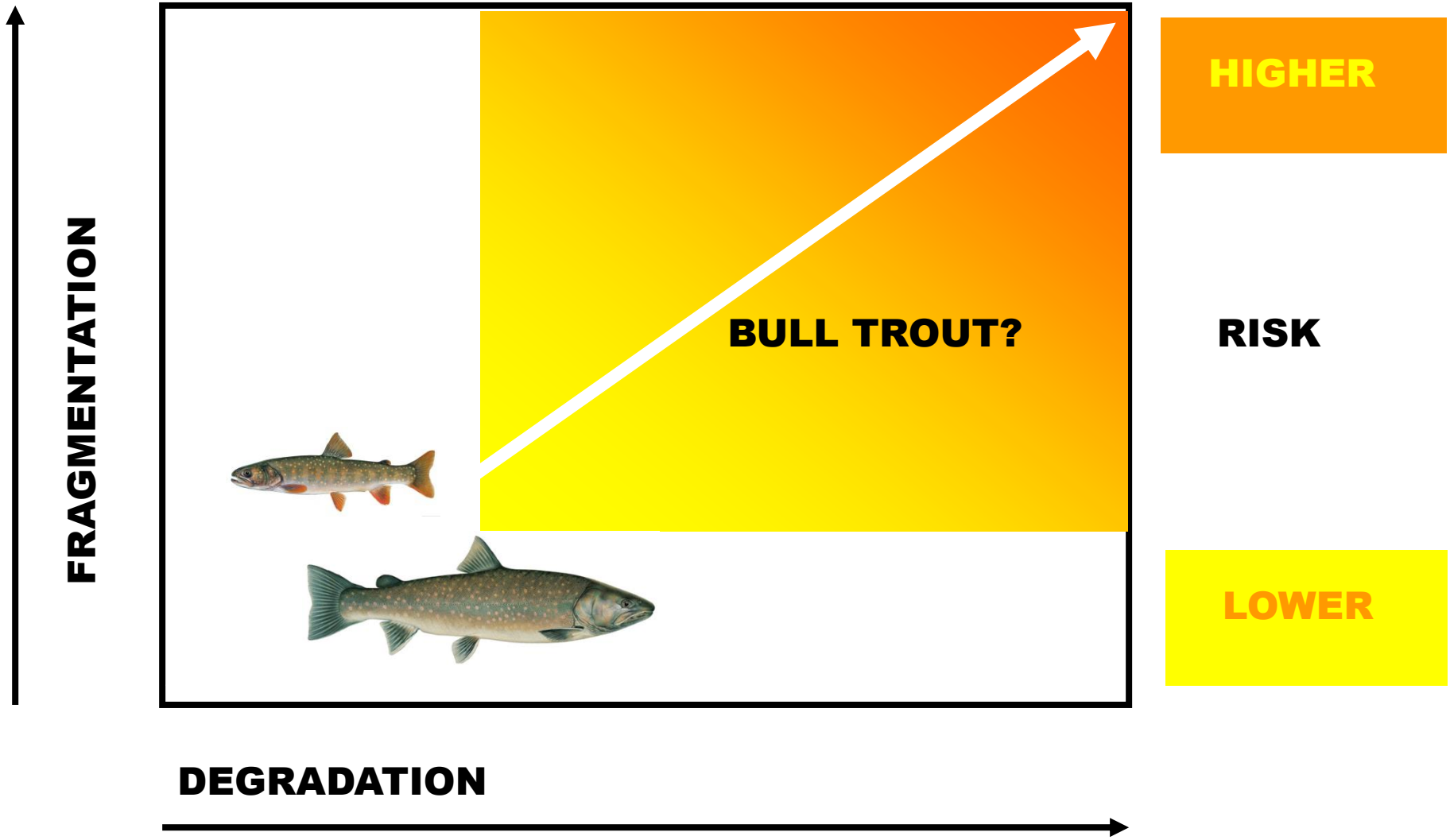


Figure 1. Western U.S. trends for number of large fires in each ecoregion per year. The center map illustrates ecoregions based on Levels II and III of the Omernik ecoregion system. The Wyoming Basin and Colorado Plateau ecoregions had too few large fires for trend analysis at the ecoregion level, and are shown in gray. MTBS-mapped fires are shown in red. The surrounding bar plots display the number of large fires in each ecoregion over the 1984–2011 study period. The black line on each plot indicates the Theil-Sen estimated slope for each ecoregion, with slope values and significance shown in Figure 2a.

Dennison et al. 2014 GRL

Loss of resilience: painted into a corner?



Dunham et al. (2003)

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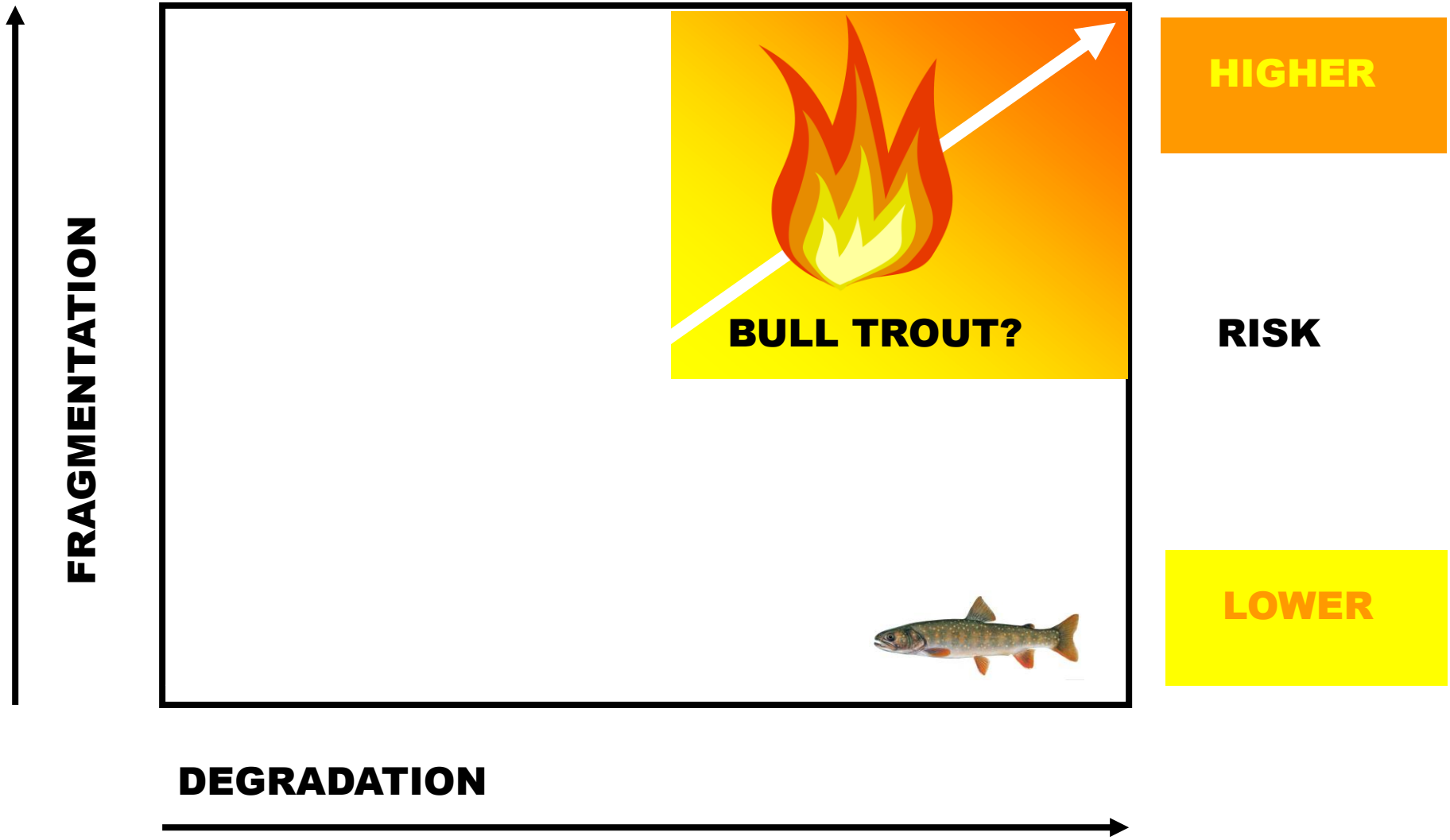
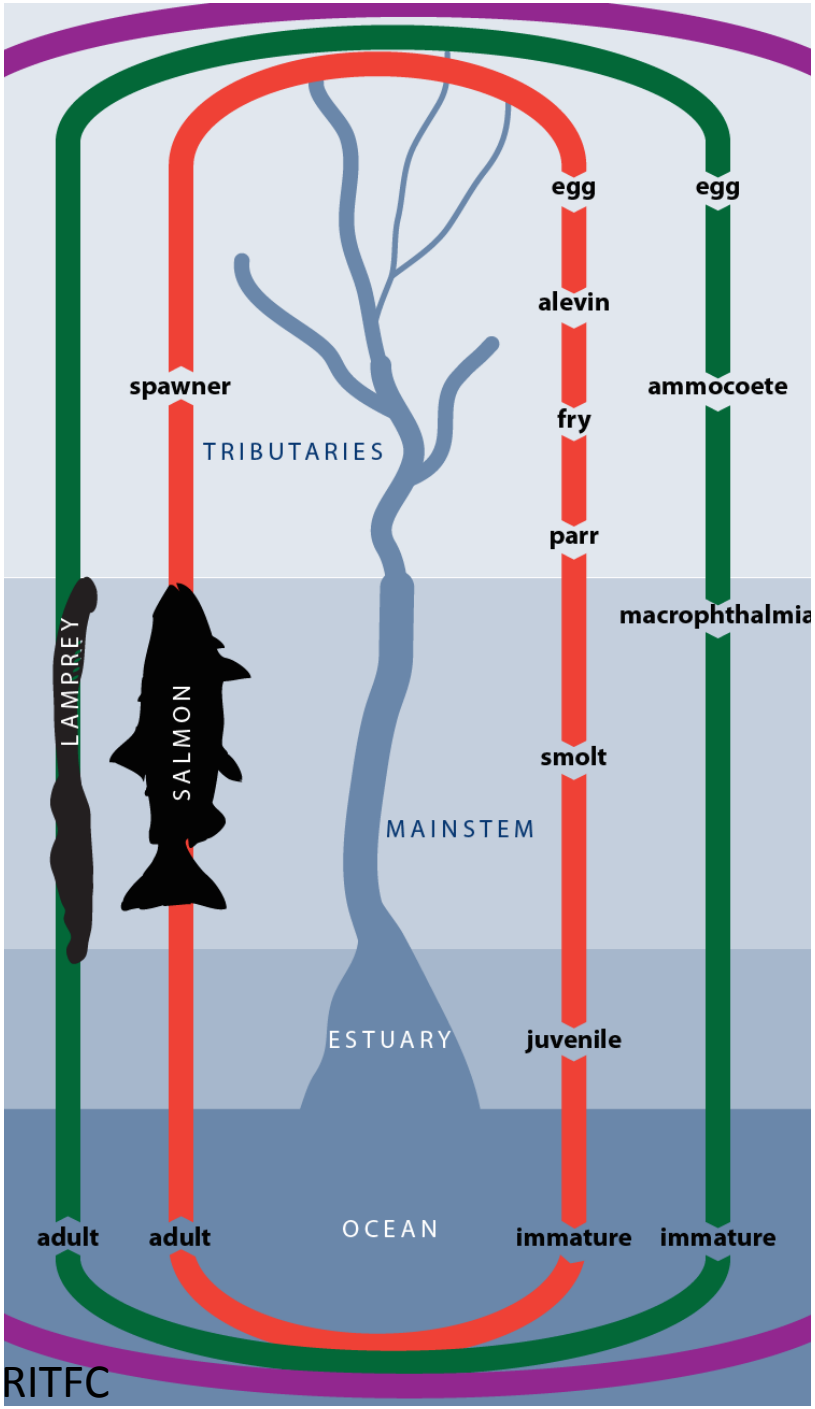


Dunham et al. (2003)

Why didn’t I talk about lamprey, anadromous salmonids?

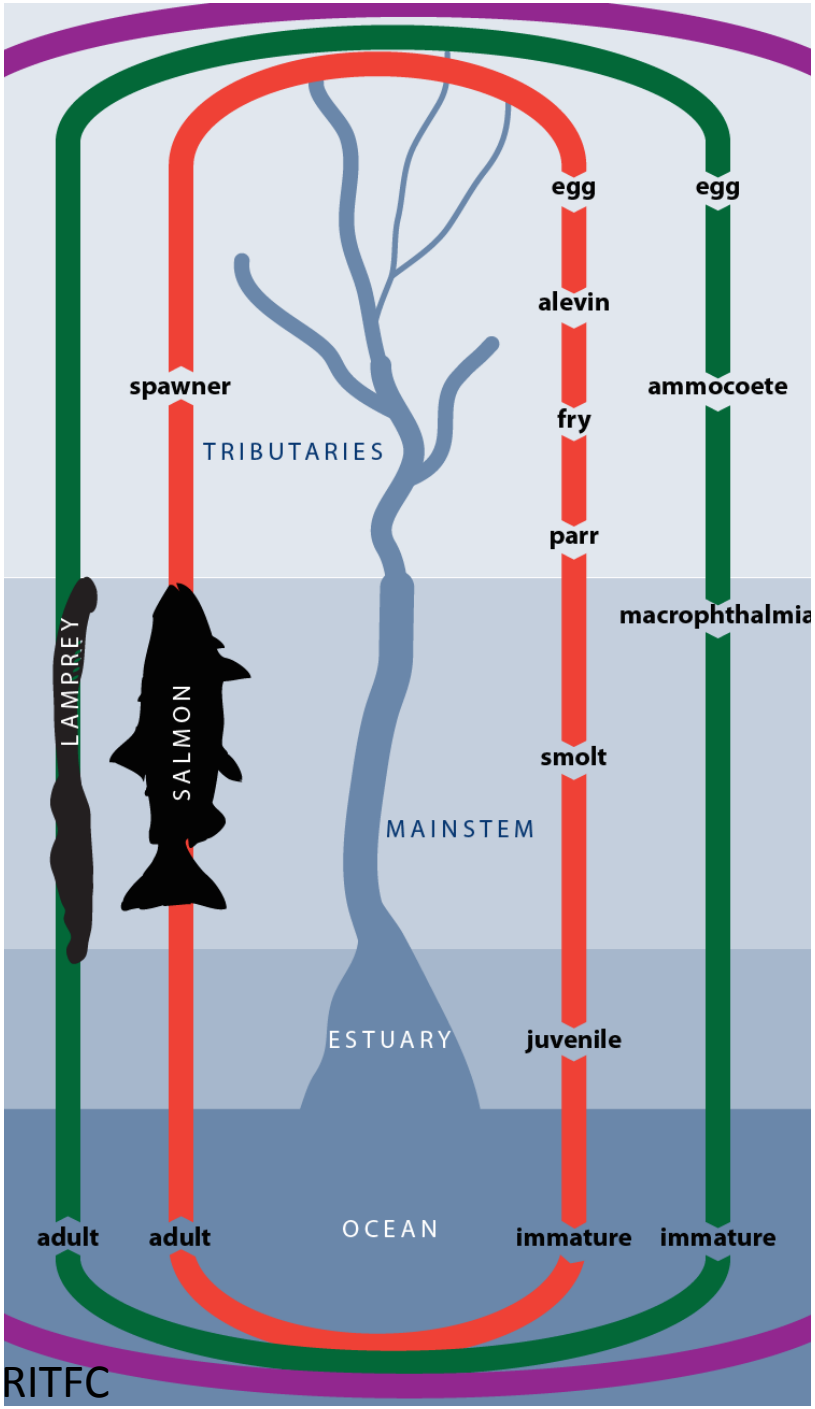
Oregonlive.com



Pacific lamprey

- Tied to fine sediment
- Long residence in FW
- Links to salmon host
- Temperature sensitive
- Year-long adult residency

One lamprey generation = 2-3 salmon generations!



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Anadromous salmon

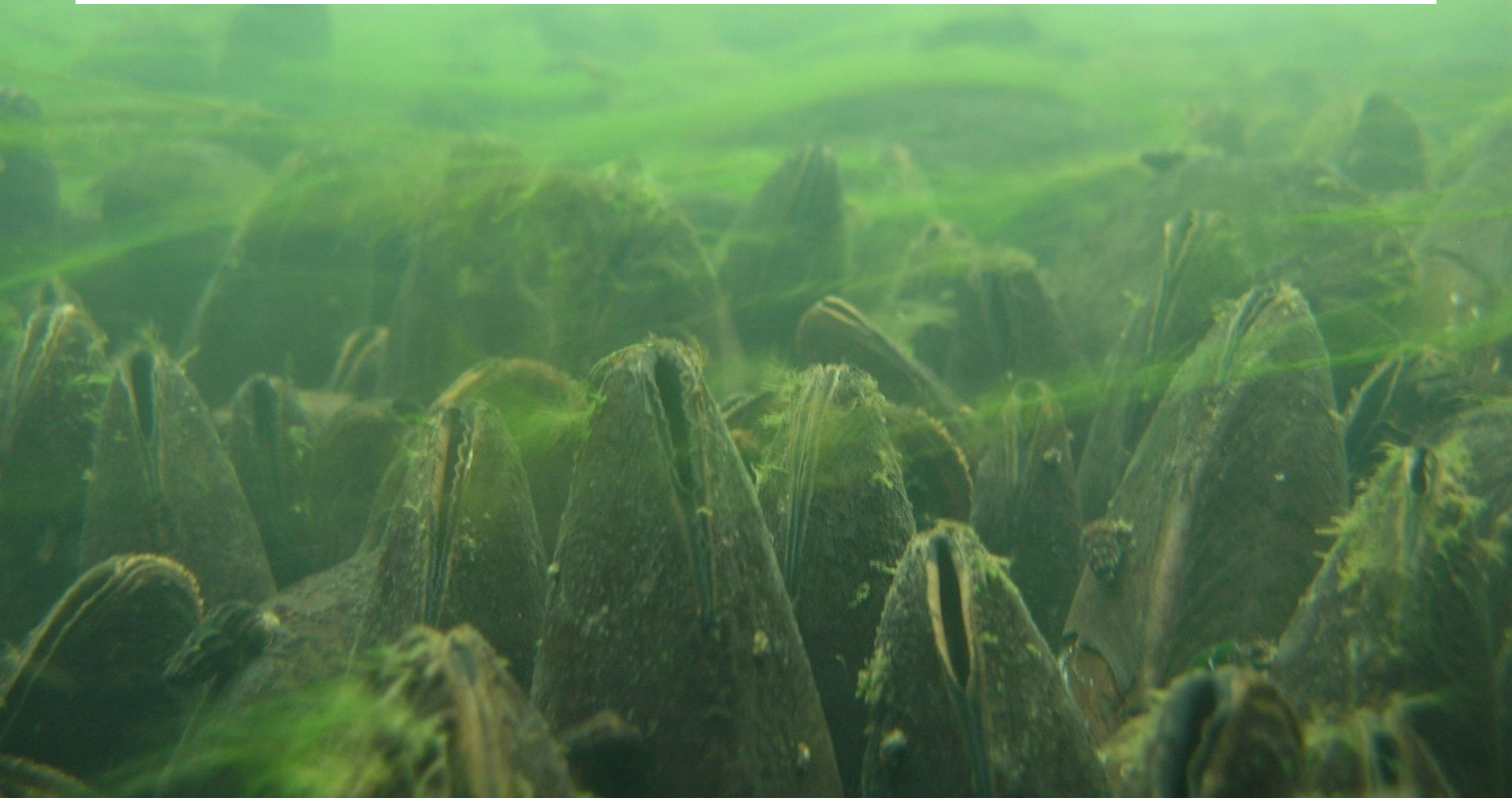
- Similar to trout – but…
- Tied to marine
- Migratory corridors
- Partial migration
- ***More resilient than trout: If we stay out of their way***

CRITFC

Freshwater mussels

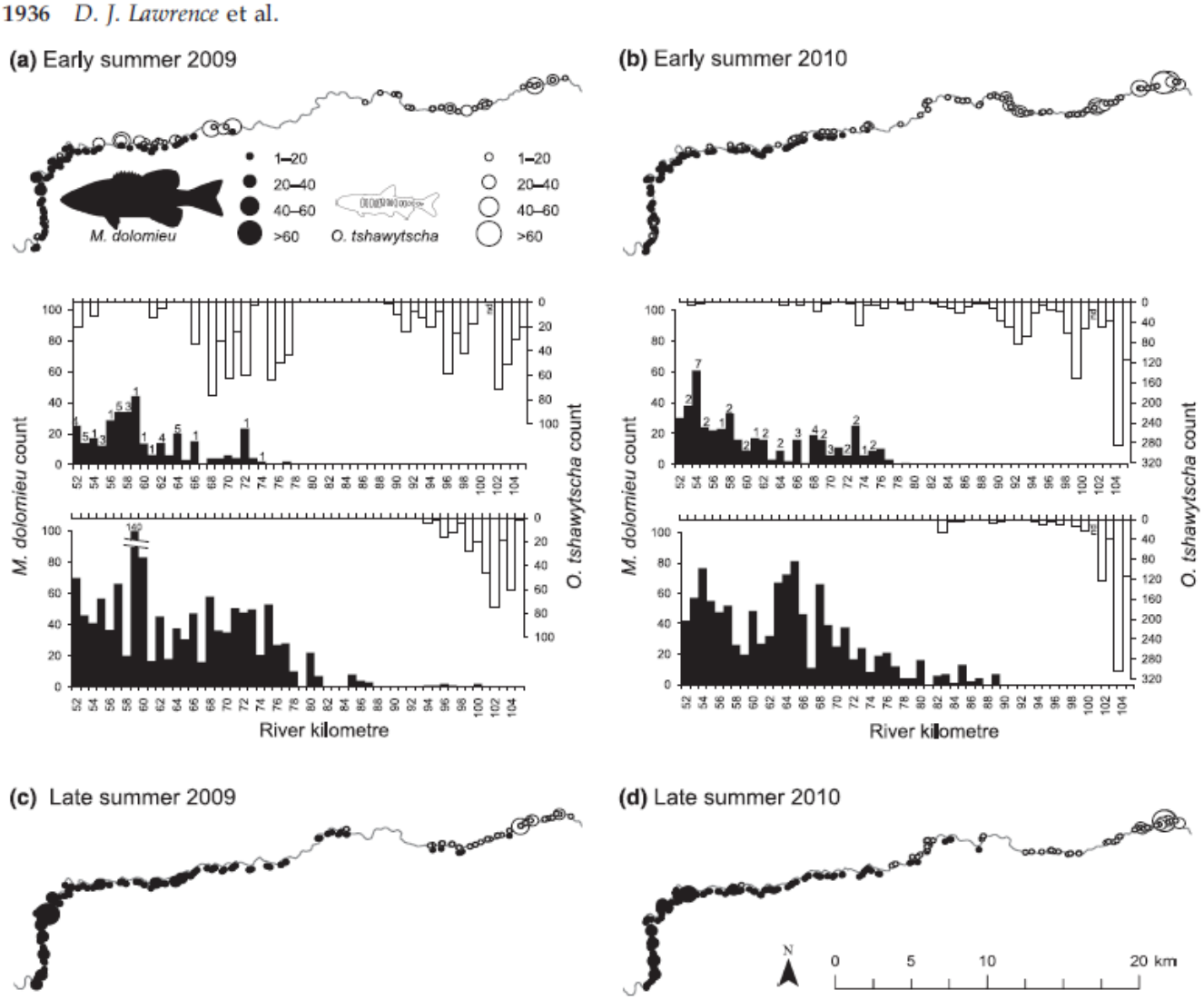
>100 years!, obligate fish parasites

Sensitive to scour, sediment, hot water

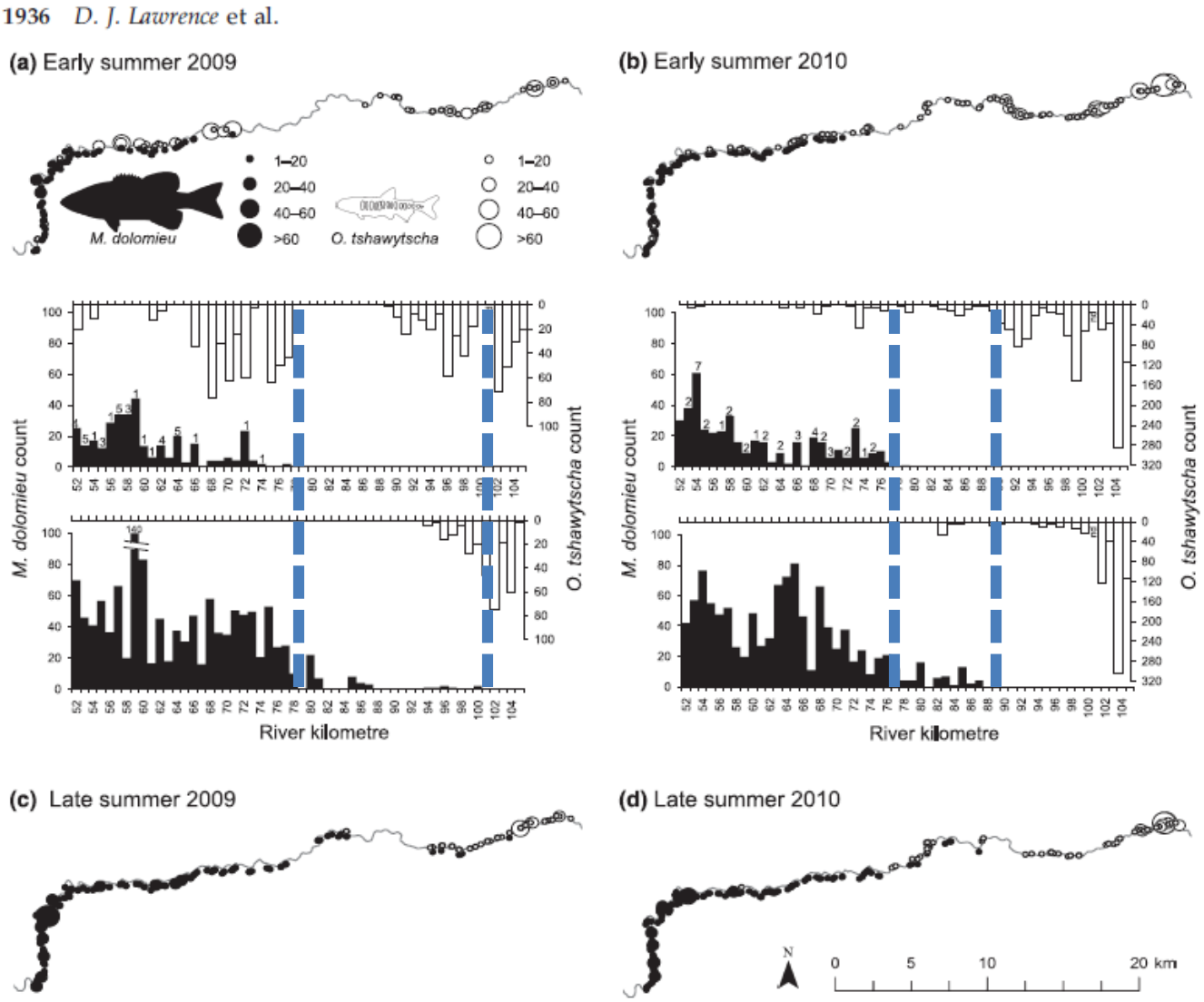


Non-salmonids: warmwater invaders

(North Fork John Day River – Lawrence et al. 2012)



15-20 km seasonal invasion



Bottom lines for resilience

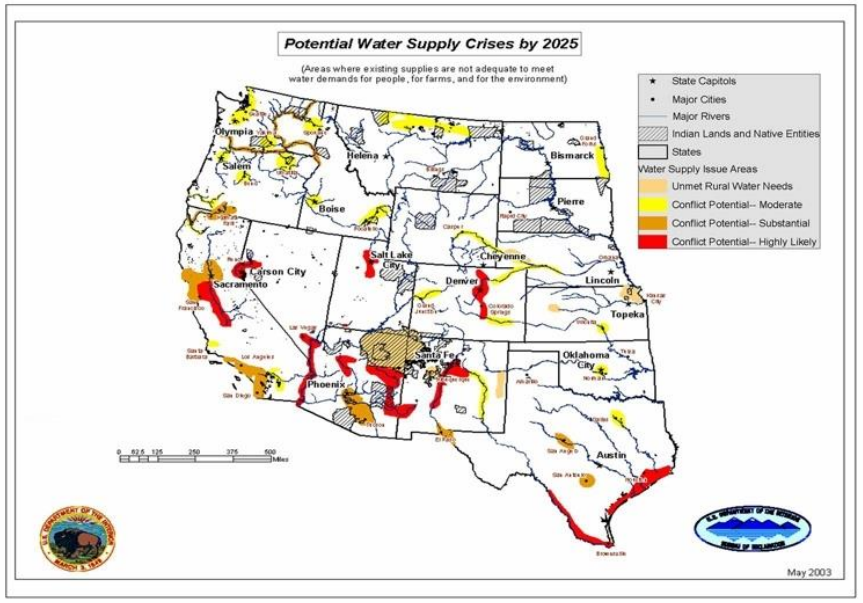
- Fire is a natural process that is important for natural functioning of streams

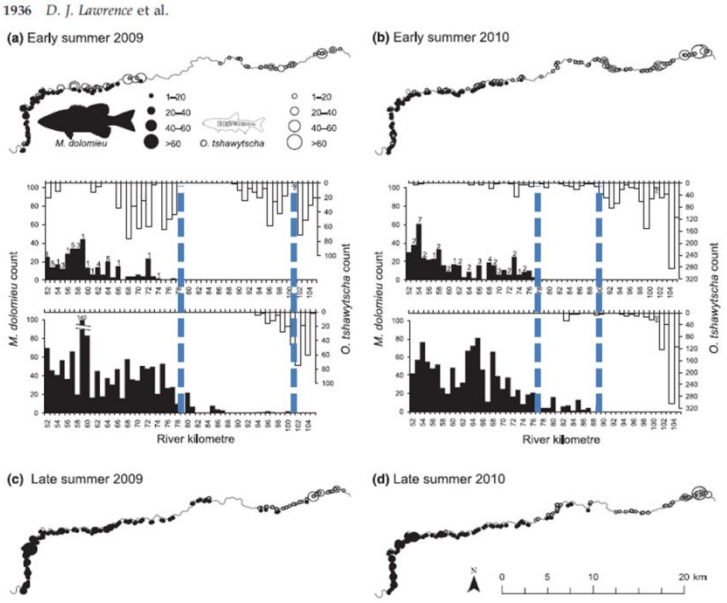
Bottom lines for resilience

- Fire is only a threat when we cut off options for fish to be resilient
- Climate change may constrain resilience
- Manage to support natural resilience

Bottom lines for resilience

- Natural isn't enough…
- "No-analog" conditions pose new constraints
  - Warmwater invasion
  - Other human-related influences





What's next?

- Very little published on effects of wildfire or fire management on anadromous fishes

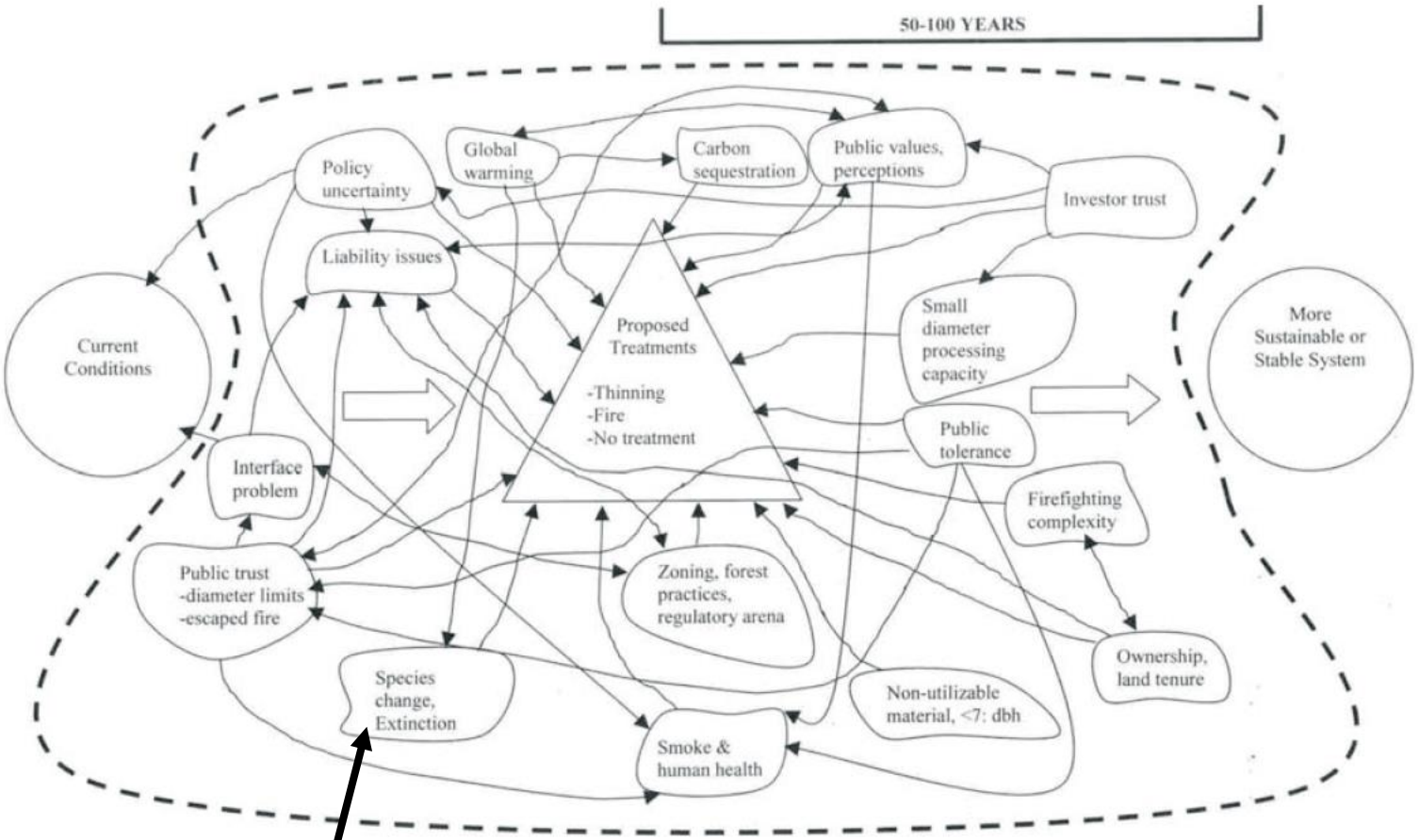
2001

FIRE & AQUATIC ecosystems

2015

What's next?

Holistic assessments – real adaptive management



You are here

Carroll et al. 2007

http://www.fs.fed.us/psw/publications/documents/psw_gtr208en/psw_gtr208en_253-264_carroll.pdf


FIN
(the end)

Wildfire Management Alternatives

Alternative	Assessment
Pre-fire management **•Population resilience** **•Fuels management**	**Proactive – general improvement in ecosystem integrity**
Manage during the fire	**Reactive – does not address ecosystem, only fire**
Post fire management	**Reactive – may be too late to deal with post fire disturbance**
Fire monitoring and research	**Great in theory, and hopefully getting better in practice**

Dunham et al. (2003)

Fish, fire, and management
What have we learned since 2001?

Wildfire Management Alternatives

Alternative

Pre-fire management

Manage during the fire

Post fire management

Fire monitoring and research

Dunham et al. (2003)

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Dunham et al. (2003)

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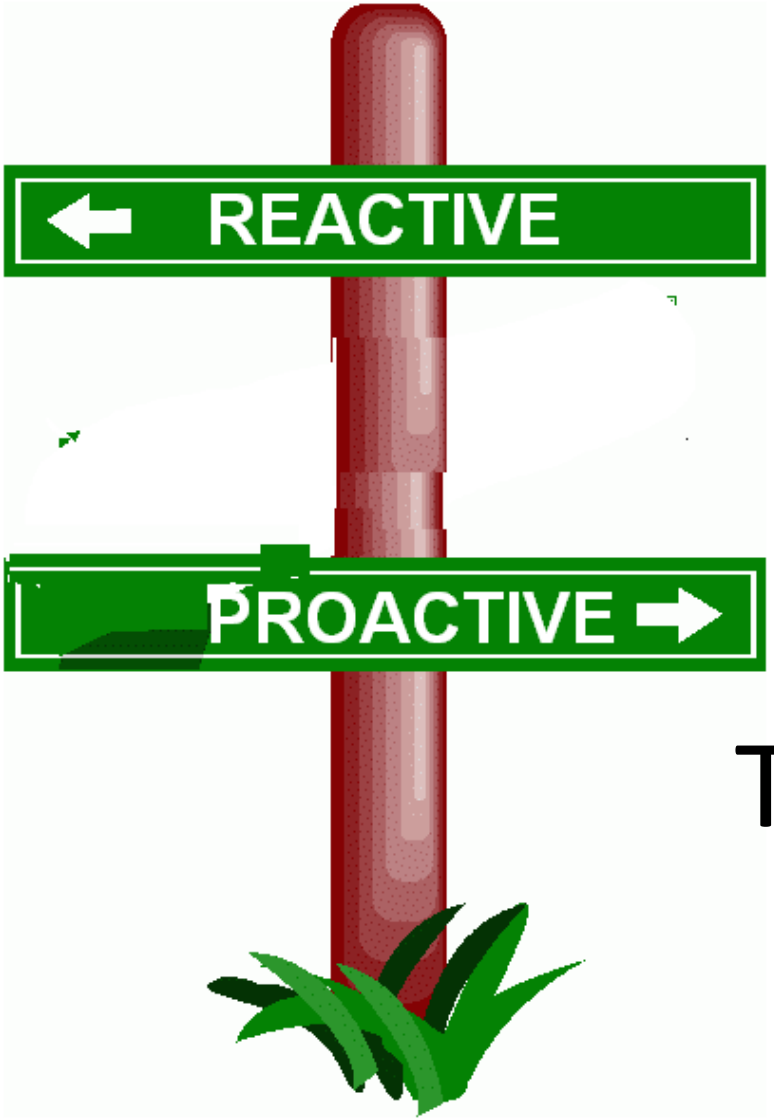
Dunham et al. (2003)

Let’s be *proactive*

Oh crap!



Told you so!

Roni et al. 2001 NAJFM – prioritizing stream restoration: *Should* we start with reconnecting???

Photo by Meegan M. Reid, KITSAP SUN

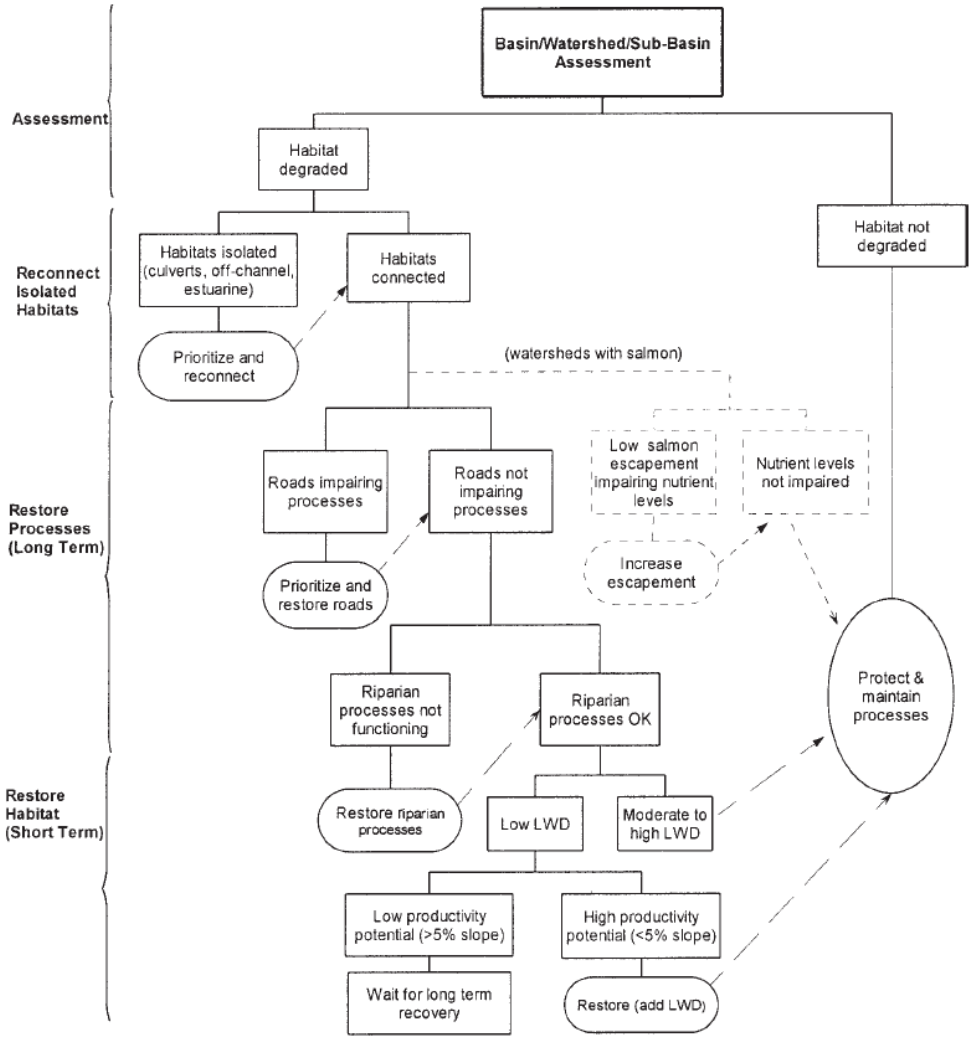
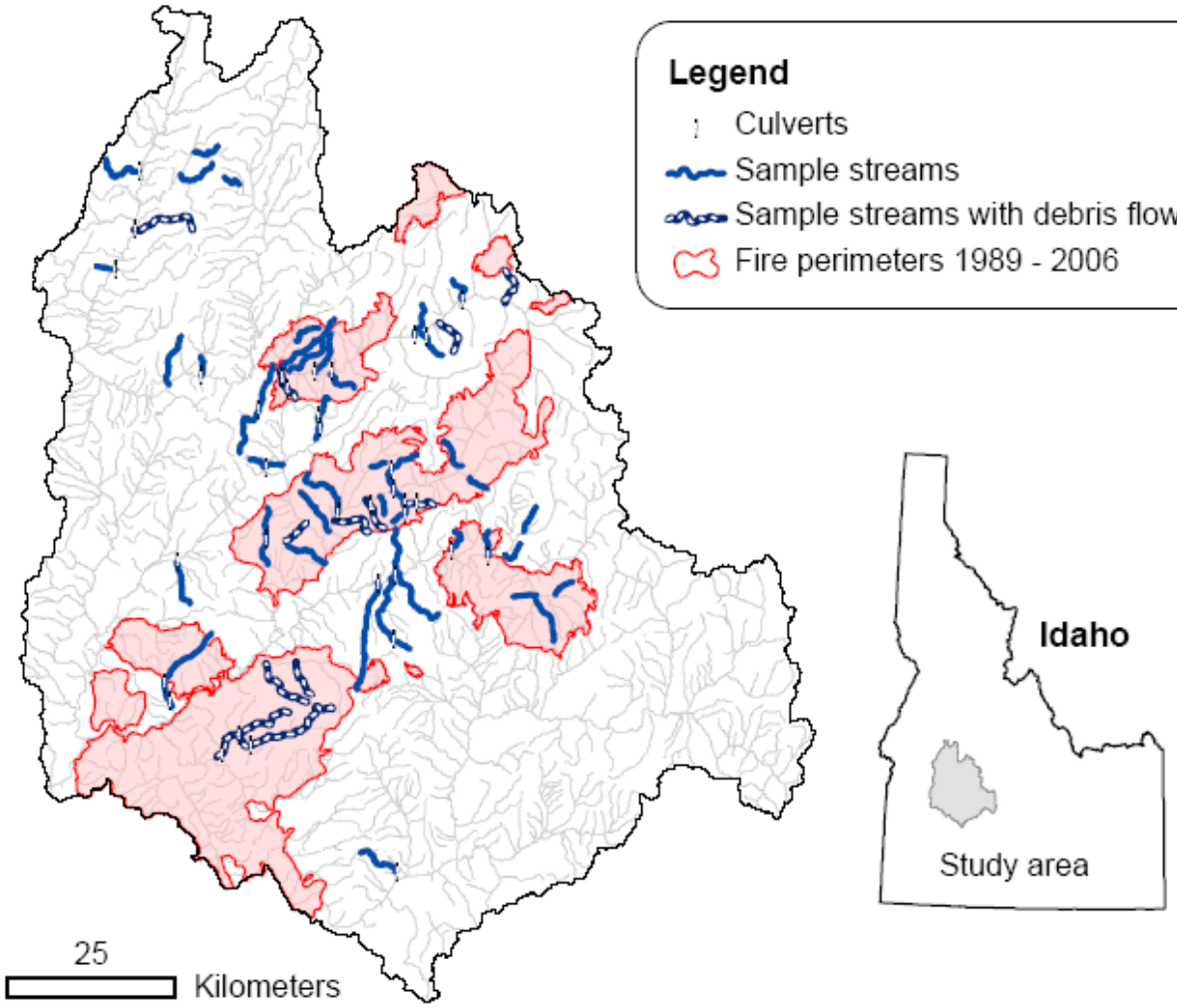


FIGURE 2.—Flow chart depicting hierarchical strategy for prioritizing specific restoration activities. Ovals indicate where restoration actions should take place. Addition of salmon carcasses or nutrients (small dashed lines) may be appropriate at various stages following reconnection of isolated habitats.

http://www.crab.wa.gov/LibraryData/RESEARCH_and_REFERENCE_MATERIAL/Environmental/020923StreamRestoreTechPNW.pdf

Within-population genetic variation in rainbow trout

n = 55 streams, 1974 fish

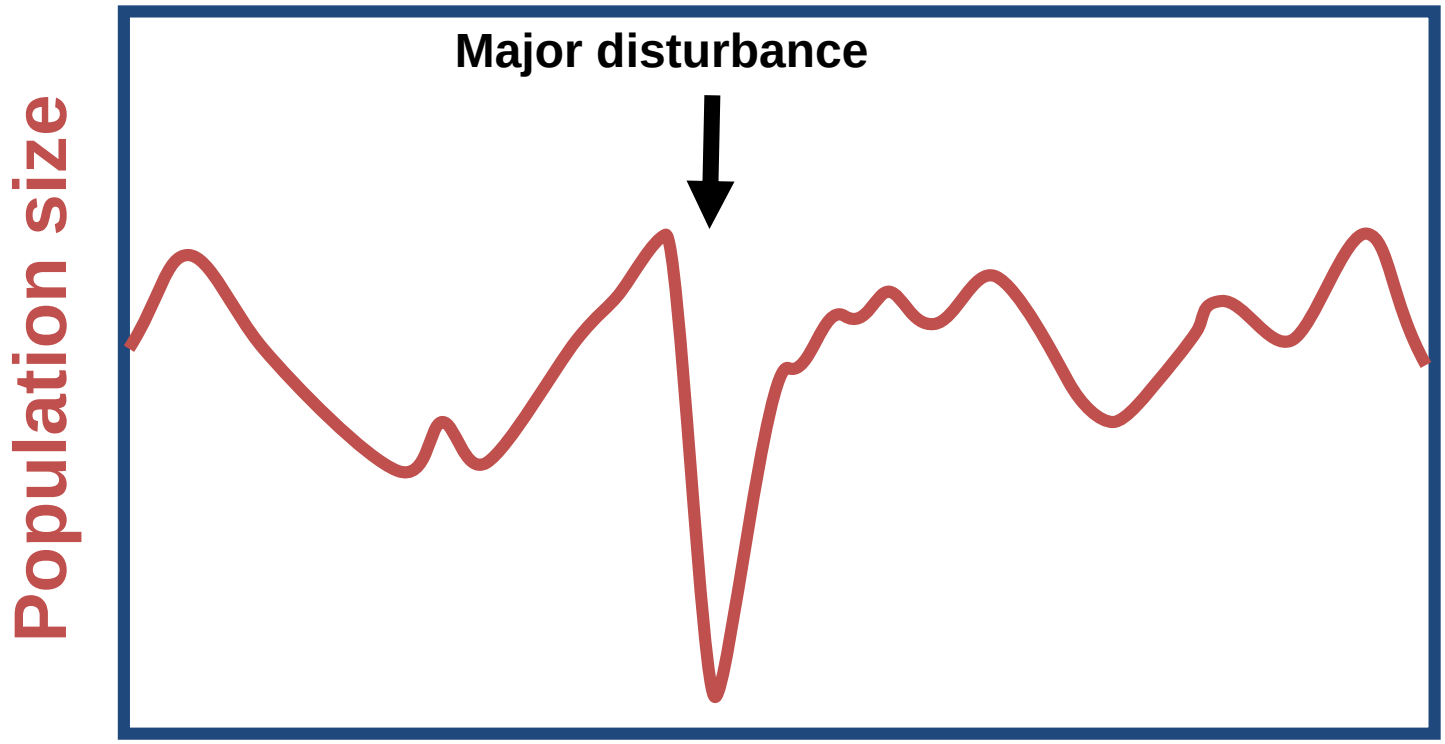


Key factors

Disturbance

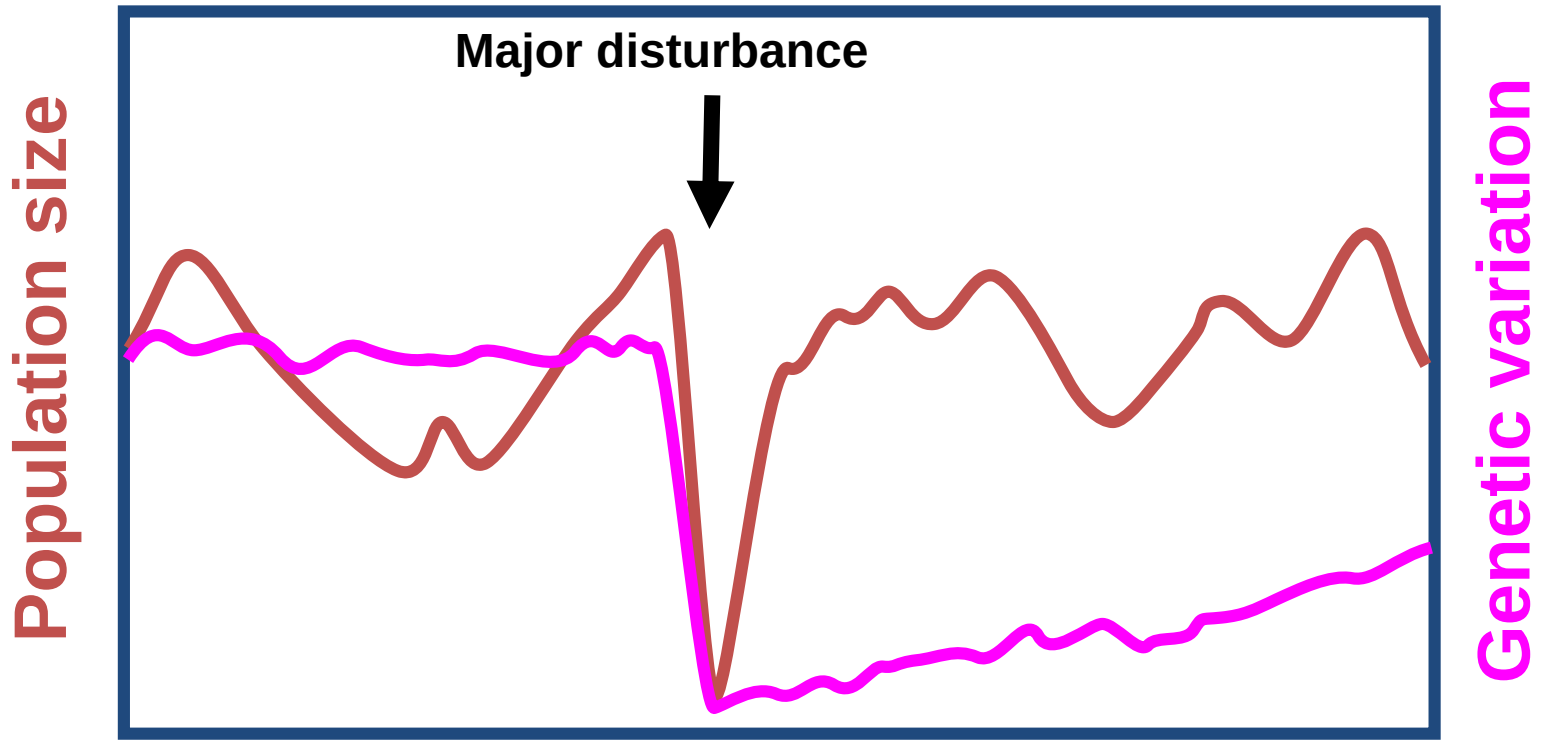
Isolation

Disturbance and resilience

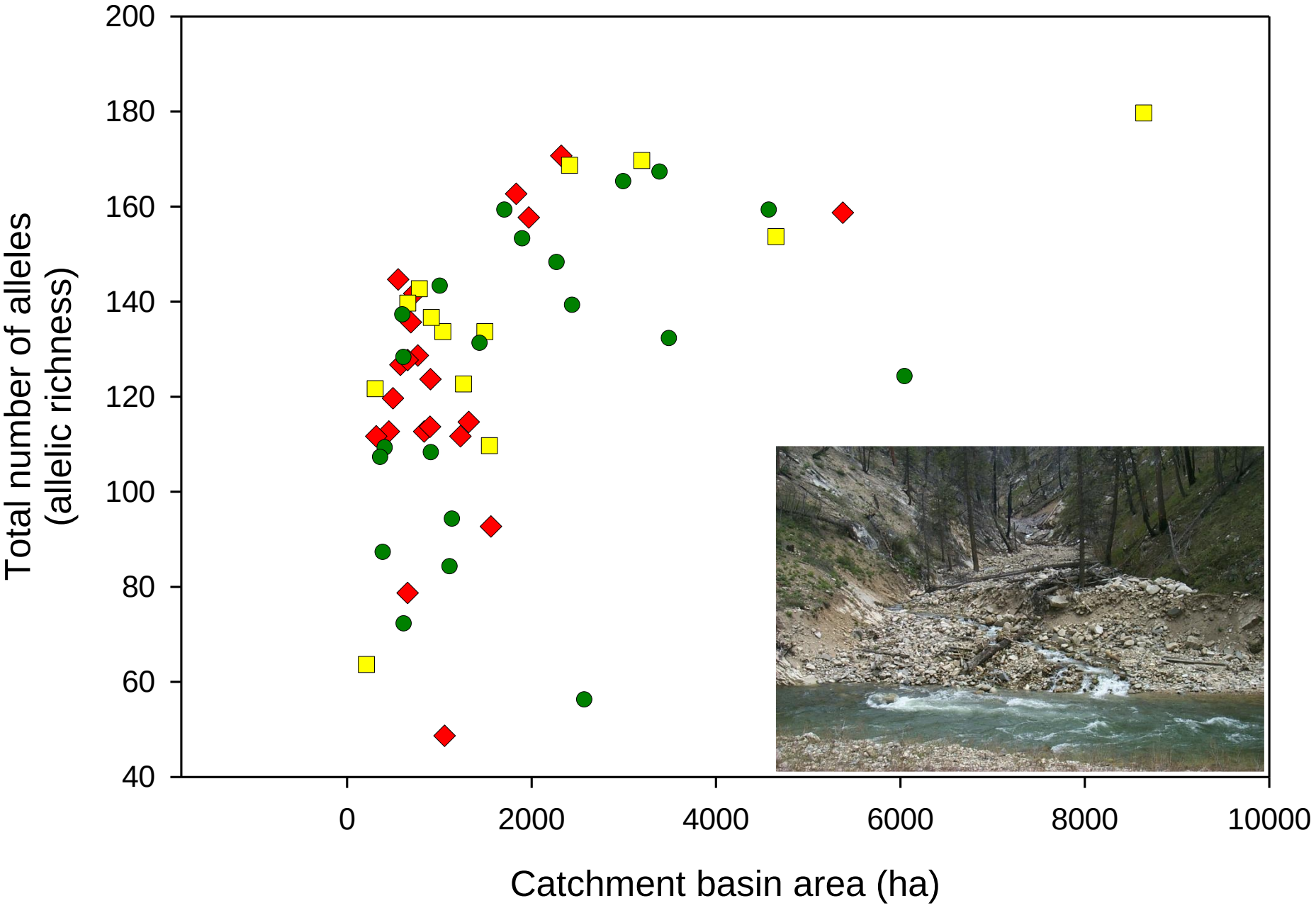


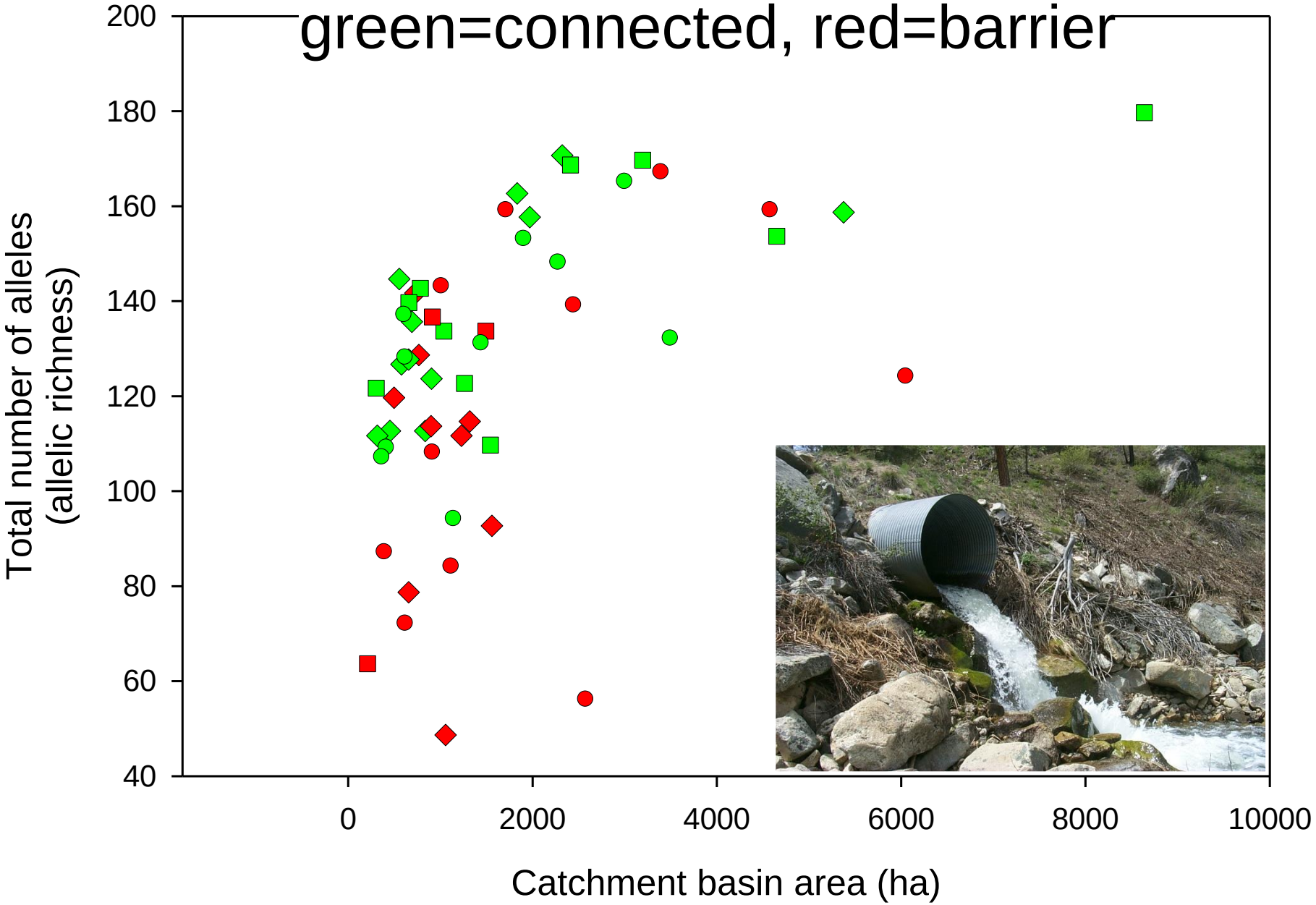
Dunham et al. (1999)

Disturbance and resilience

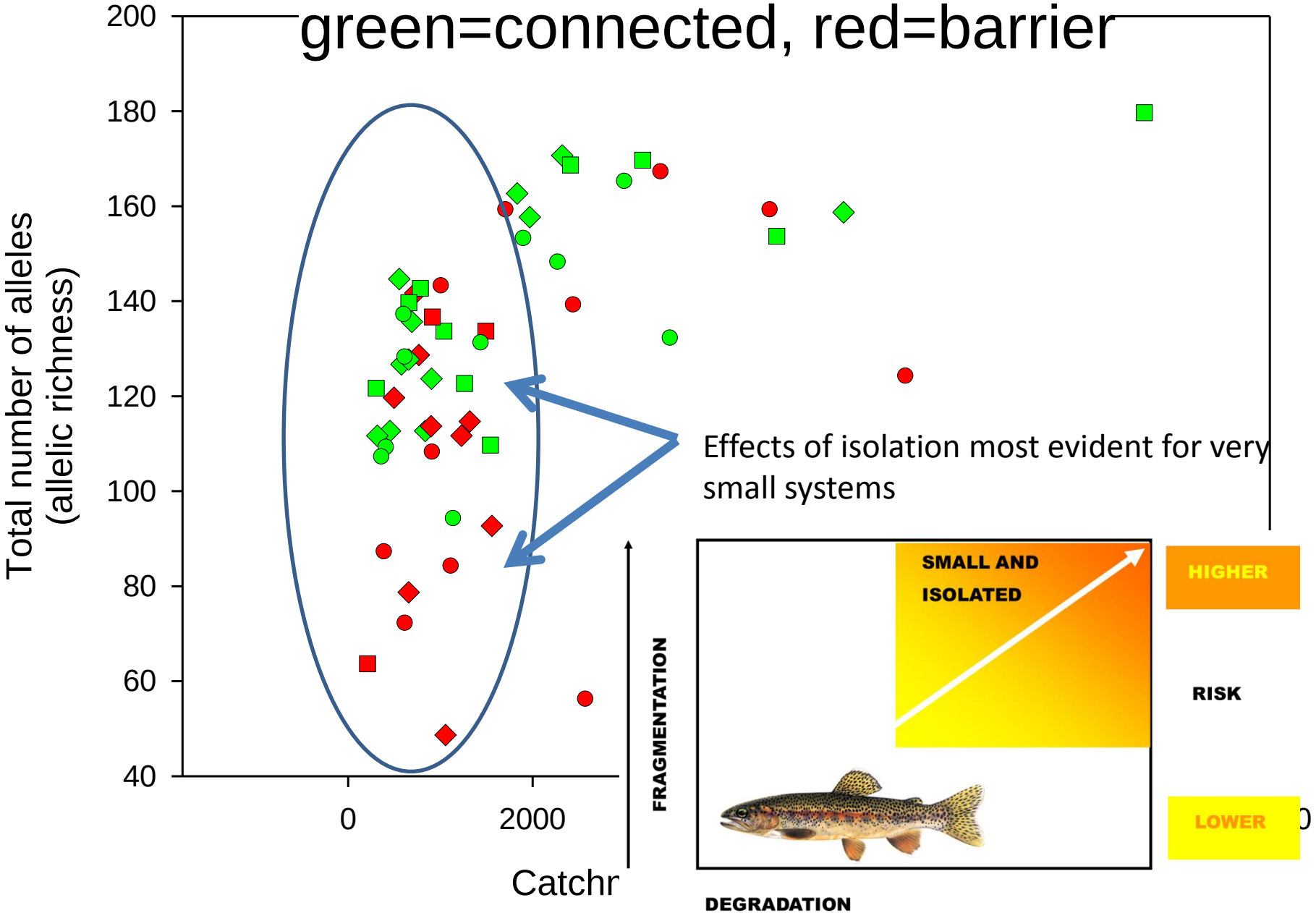


Total number of alleles across all loci




green=connected, red=barrier
Total number of alleles
(allelic richness)
200
180
160
140
120
100
80
60
40
0
2000
4000
6000
8000
10000
Catchment basin area (ha)

green=connected, red=barrier



Cutthroat*Rainbow trout hybrids in 15 of 55 pops

Management Implications

- **Small barriers trump big disturbance**
  - **Isolation only a problem in the smallest of streams**
  - **Hybridization – reversible?**

Fuels treatment

- Expensive up-front costs
- Can it save cost of long-term fire suppression?
- Do we risk expensive or irreversible biological impacts?

MOKELUMNE WATERSHED AVOIDED COST ANALYSIS:

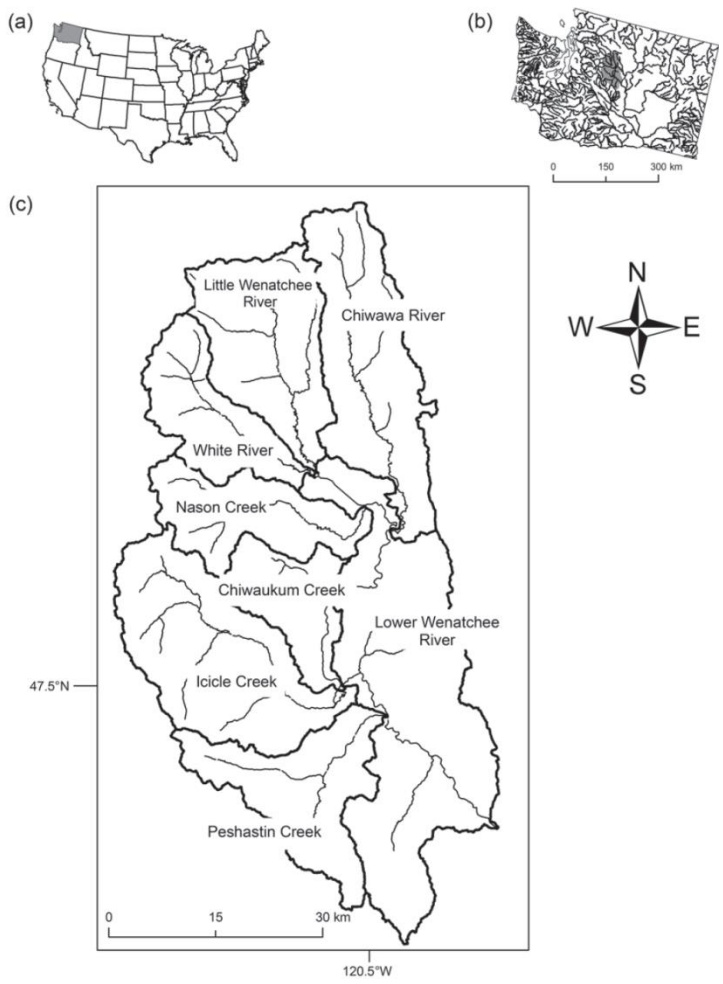
Why Sierra Fuel Treatments Make Economic Sense

The Nature Conservancy
Protecting nature. Preserving life.

SIERRA NEVADA CONSERVANCY

Firescience.gov

Case study: Wenatchee basin bull trout



In a nutshell:

- Effects of temperature on bull trout distribution
- Effects of fire on stream temperature
- Simulated fire regimes
- Fire * climate interaction
- Contrast vs. improved connectivity

1

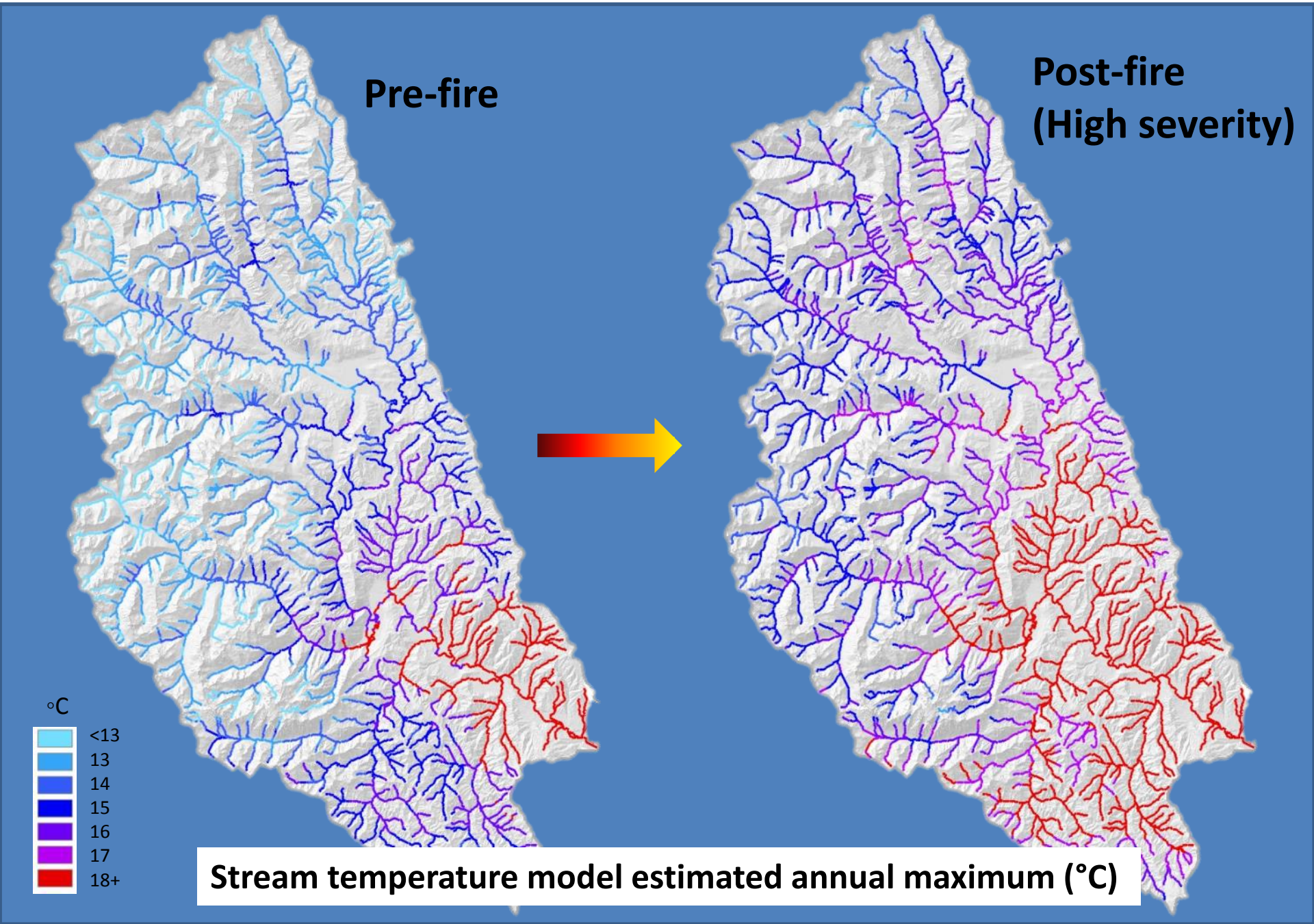
NRC Research Press

ARTICLE

Climate change and vulnerability of bull trout (*Salvelinus confluentus*) in a fire-prone landscape

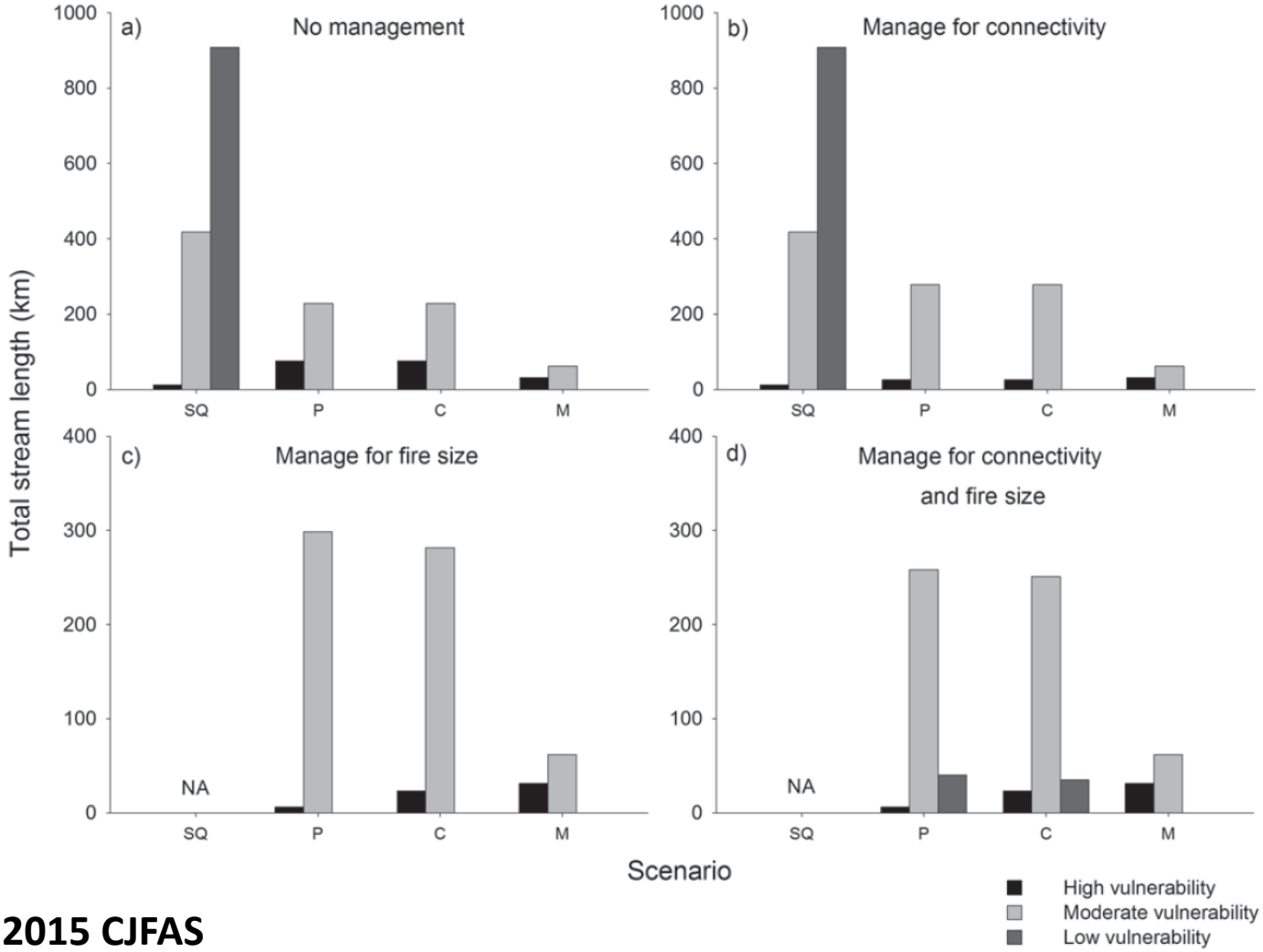
Jeffrey A. Falke, Rebecca L. Flitcroft, Jason B. Dunham, Kristina M. McNyset, Paul F. Hessburg, and Gordon H. Reeves

Effects of wildfire on temperatures (basinwide)



Managing fire, not connectivity is the best way to protect bull trout in the face of climate change

Fig. 7. Total stream length classified to three states of bull trout population vulnerability to wildfire under a status quo (SQ) and three climate change scenarios: P, low warming; C, moderate warming; M, high warming. Four management options are presented: no management (*a*), manage for connectivity (*b*), manage for fire size (*c*), and manage for both connectivity and fire size (*d*). See text for description of management options and scenarios.



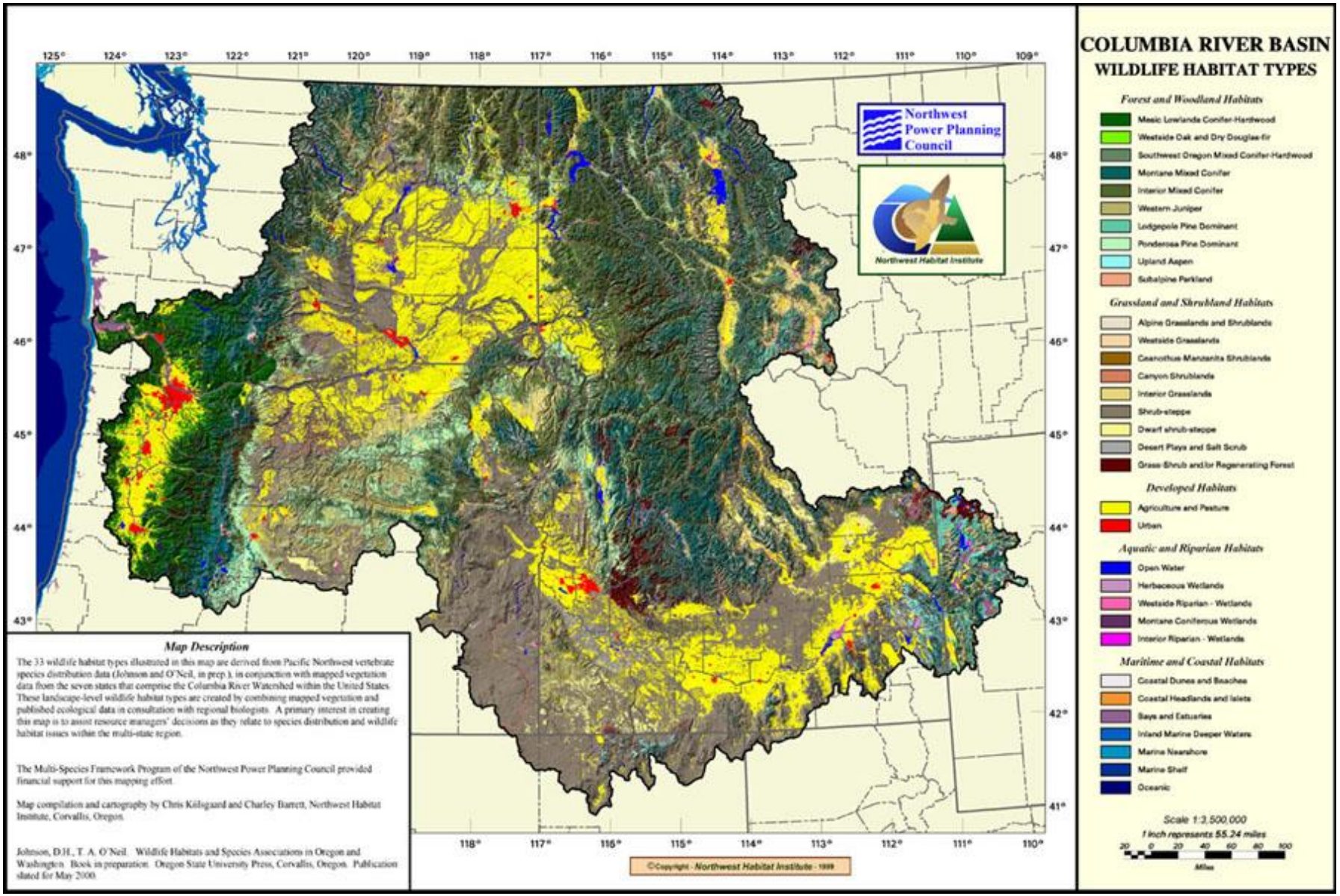
Falke et al. 2015 CJFAS

Management Implications

- **Fuels treatments trump connectivity in Wenatchee**
- **Extreme climate effects trump everything (see also Wenger et al. 2014)**
- **Outcomes likely context dependent**

Beyond forests: shrublands, grazing and fire

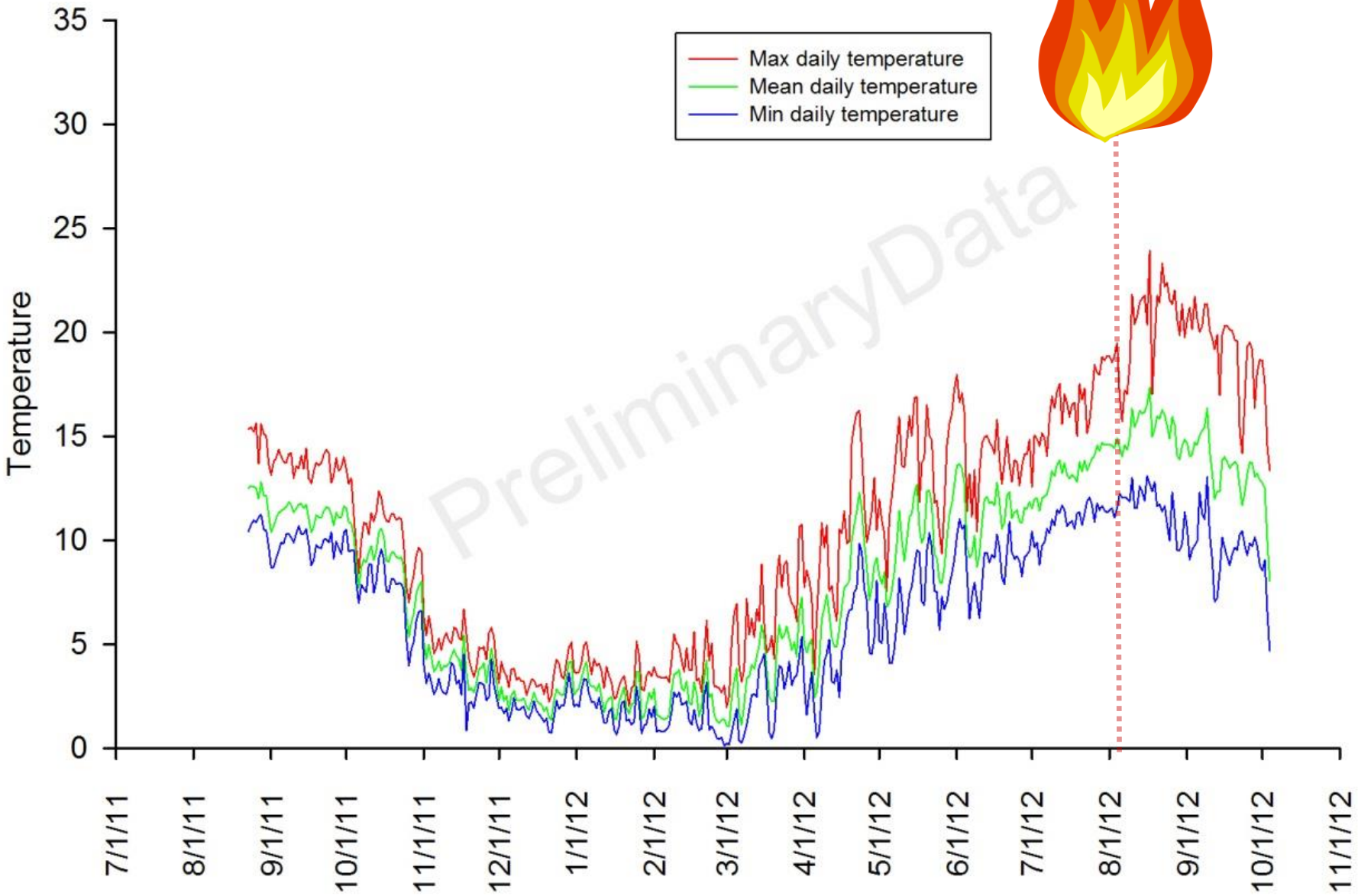
Shrublands are big in the Columbia

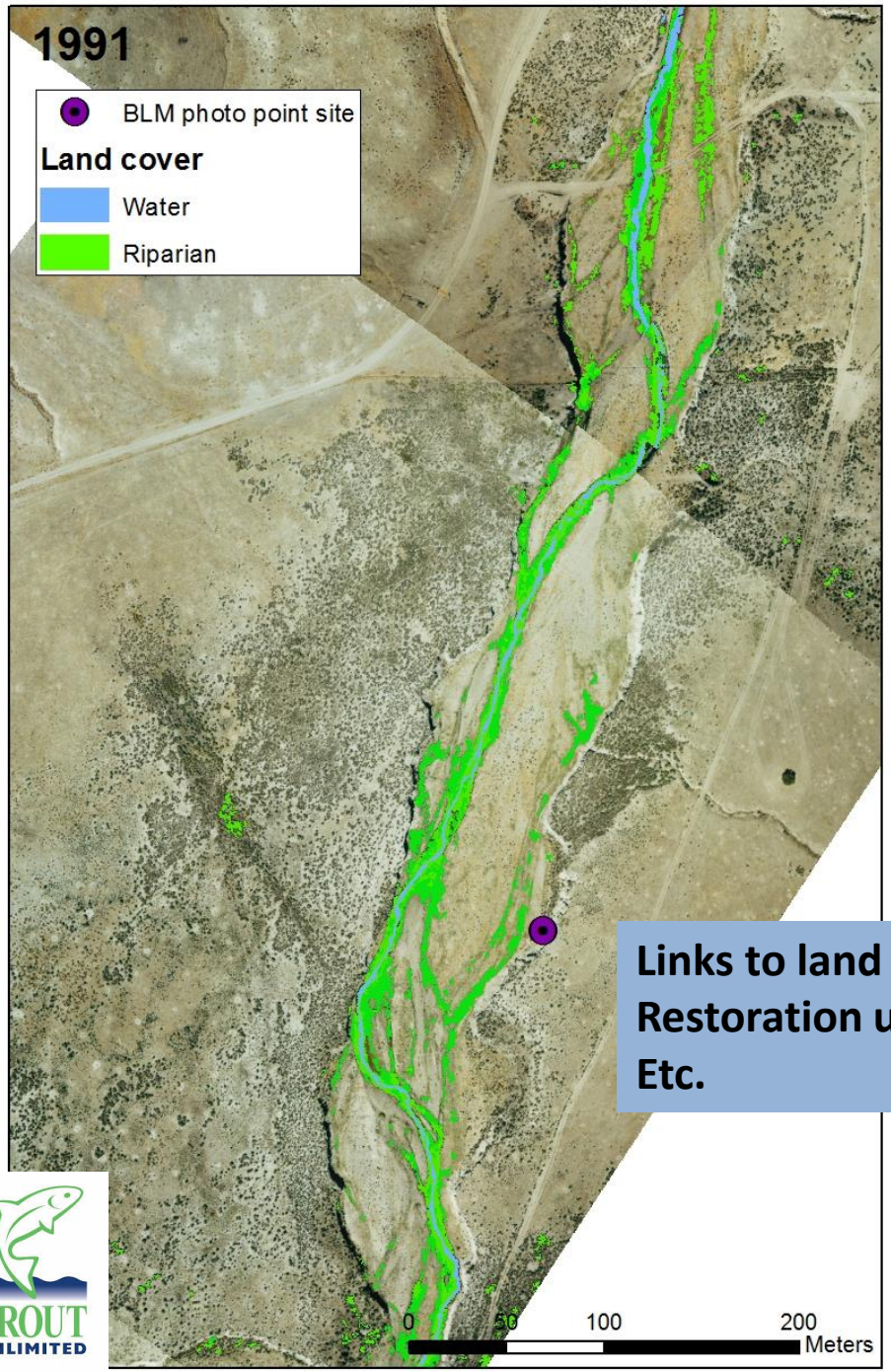


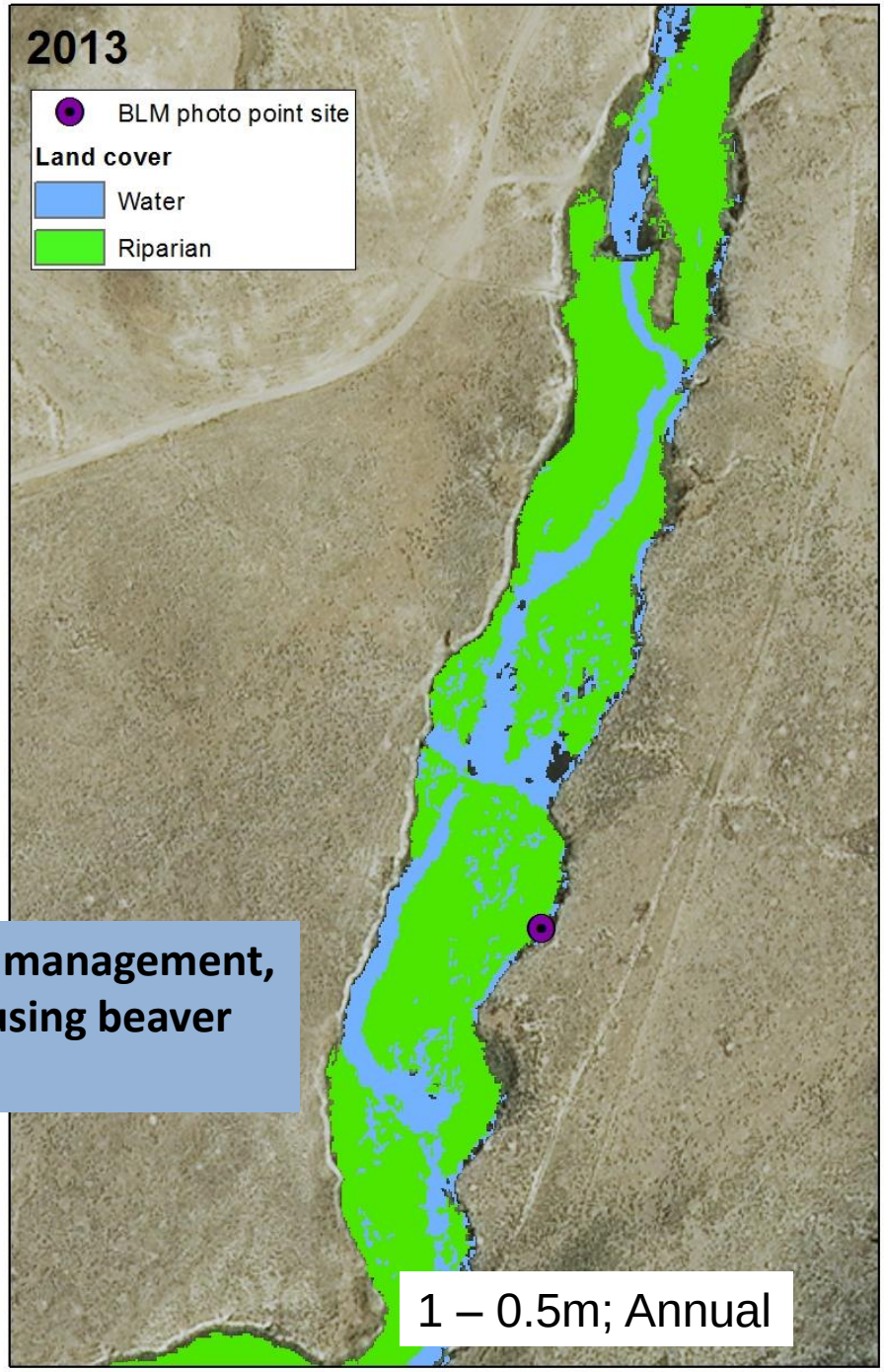
Wildfires in shrublands =strong impacts

TROUT UNLIMITED

Increase in max and min temps (where it's wet!)







Links to land management, Restoration using beaver Etc.

1 – 0.5m; Annual

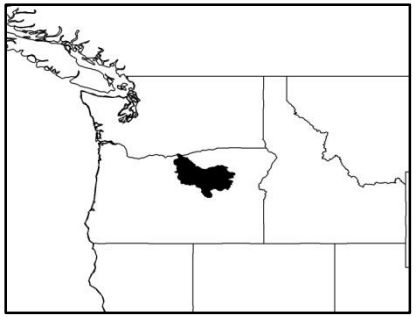
TROUT UNLIMITED

Management Implications

- **Shrublands are understudied with respect to aquatic responses to wildfire**
- **Dominant ecosystem in the CRB**
  - **All migratory fish at least swim through them**
- **Unique management issues**

Let's finish in a (partially) anadromous note…

John Day River, OR



- **Large (~20,000 km^2)**
- **Diverse**
  - **Elevation**
  - **Climate**
  - **Geology**
- **Wild**
  - **No large dams**
  - **No hatcheries**

PNW Natural Features Classification (T. Whittier, OSU)

Should I stay or should I go…?
O. mykiss life history diversity

John McMIllan photos

Sex and migration costs/benefits

Costs / benefits of migration	Males	Females
Decreased age-specific survival	X	X
Avoid poor freshwater conditions	X	X
Increased body size	X	X
Fitness strongly size dependent	o	**X**

J. McMillan photos

Life history diversity…why care?

Long-term viability and life history diversity

- **Ability to exploit many habitat types**
- **“Spread the risk”**
- **Buffer periods of low FW or marine survival**
- **More resilient to long term change**
  - **Why does that “r” word keep coming up?**

Anadromy and residency

(McMillan et al. 2012, Mills et al. 2012, Falke et al. 2013)

- **Stream flow**
  - Female anadromy positively related to stream size
  - Residency more likely in smaller streams
  - Lower flows = rainbows
- **Thermal regime**
  - Cold water = increased lipid = increased residency
  - Climate warming/**fire** = steelhead

Anadromy and residency

(McMillan et al. 2012, Mills et al. 2012, Falke et al. 2013)

- **Stream flow vs. temperature**
  - **Antagonistic effects of climate**
    - Warmer water vs. smaller streams
    - Will proportions change?
- **What if we increase fish numbers…**
  - We might get more of both!

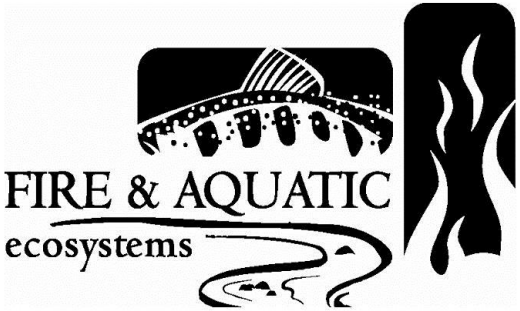
Management Implications

- **No explicit link to fire, but fire and other factors influence flows and temperatures and thus life history expression**

- **Spatial variation in life histories is predictable and can be used to guide priorities**

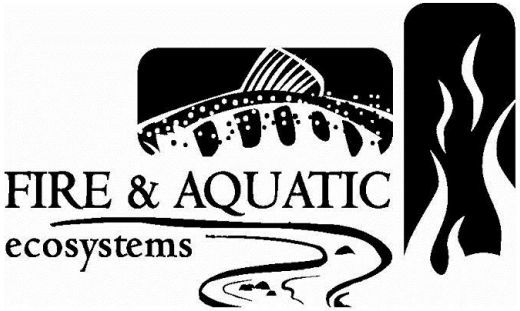
- **How does this play out in other basins?**

What have we learned since 2001?



- Loads about responses of streams and trout in forested ecosystems in the interior
- Influences of changing flows and temperatures on warmwater invaders
- Not nearly as much about anadromous species, including salmon and lamprey
- Nothing about emerging species of concern
  - Freshwater mussels (>100 year lifespan!)

What have we not learned since 2001?



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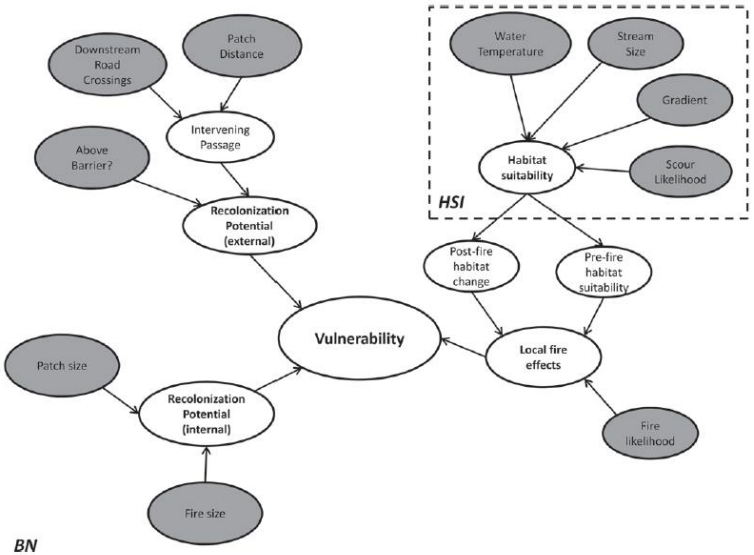
Acting adaptively
When will we make it real?

FIRE & AQUATIC ecosystems

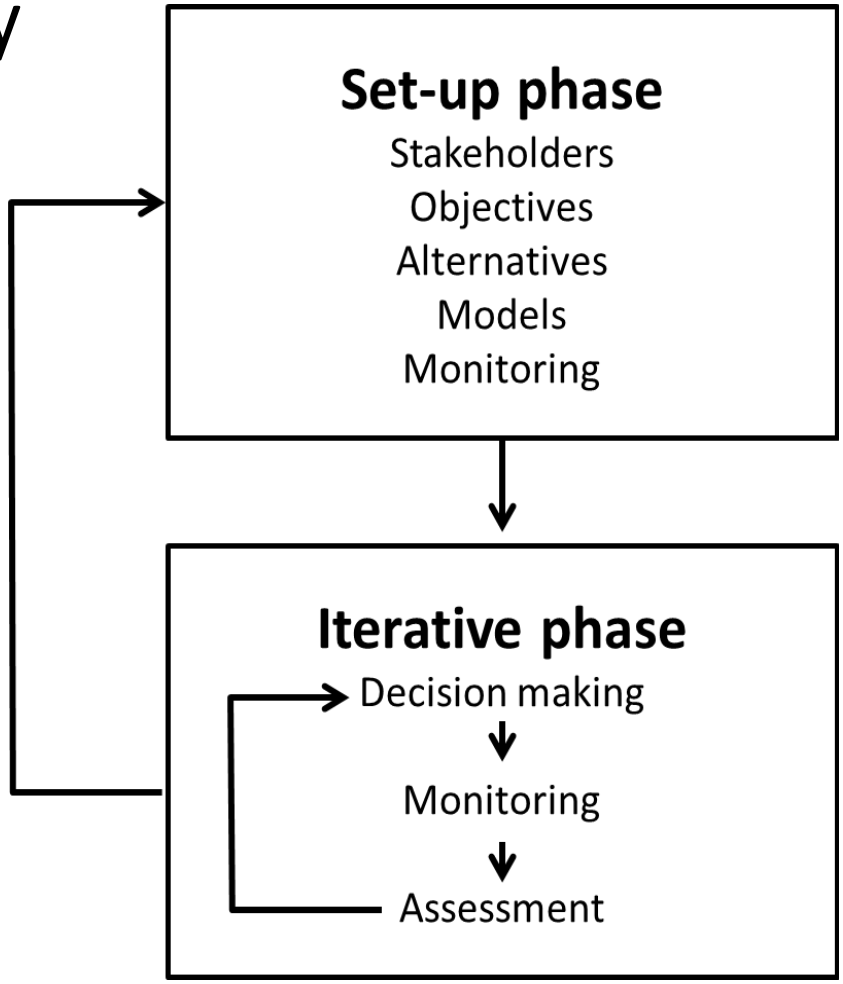
Prioritization + uncertainty

=

adaptive management

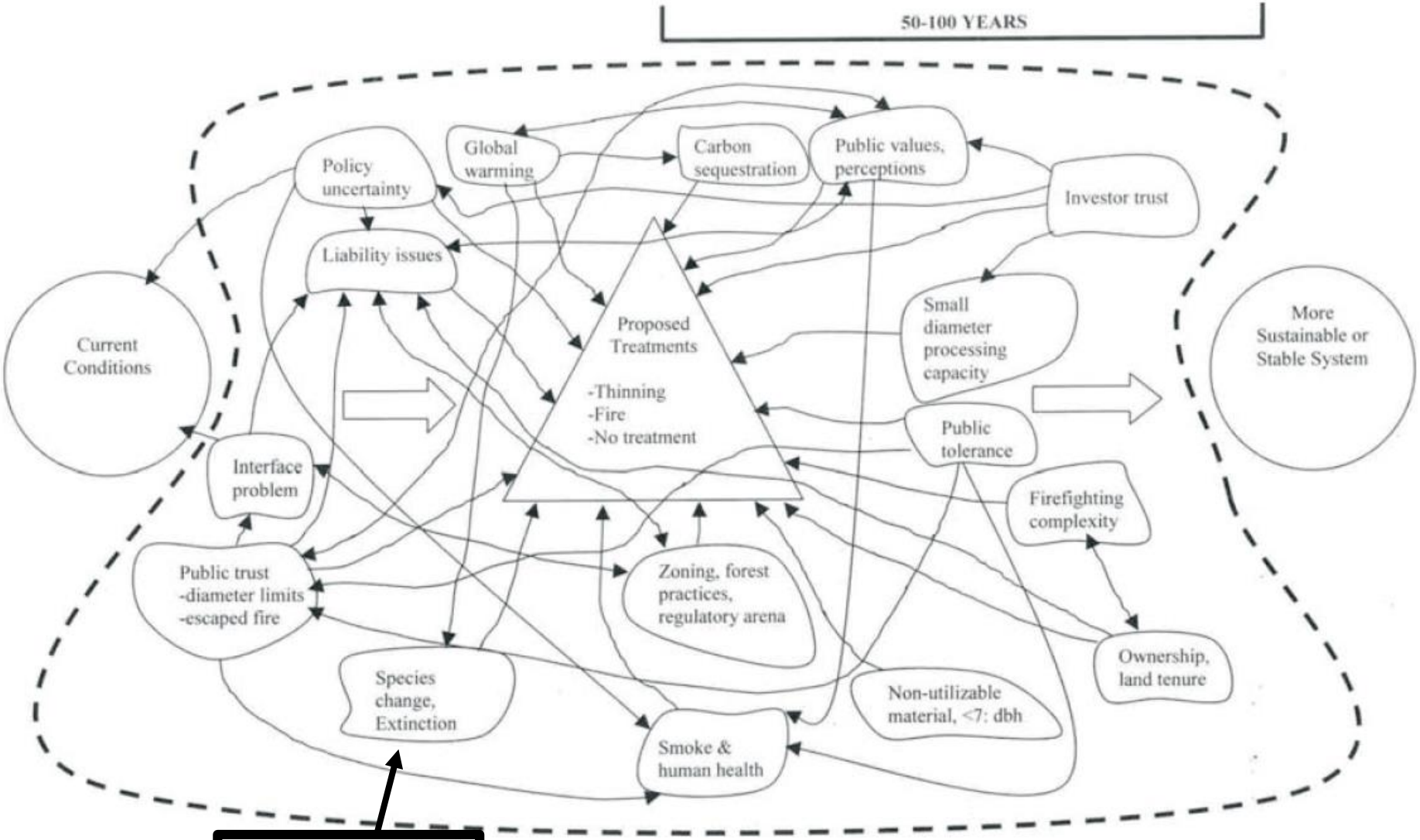


Falke et al. 2015 CJFAS



Williams and Brown (2012)

We need to play in the big leagues



FIRE & AQUATIC ecosystems

Carroll et al. 2007

http://www.fs.fed.us/psw/publications/documents/psw_gtr208en/psw_gtr208en_253-264_carroll.pdf

Minshall et al. 1989

Gresswell 1999

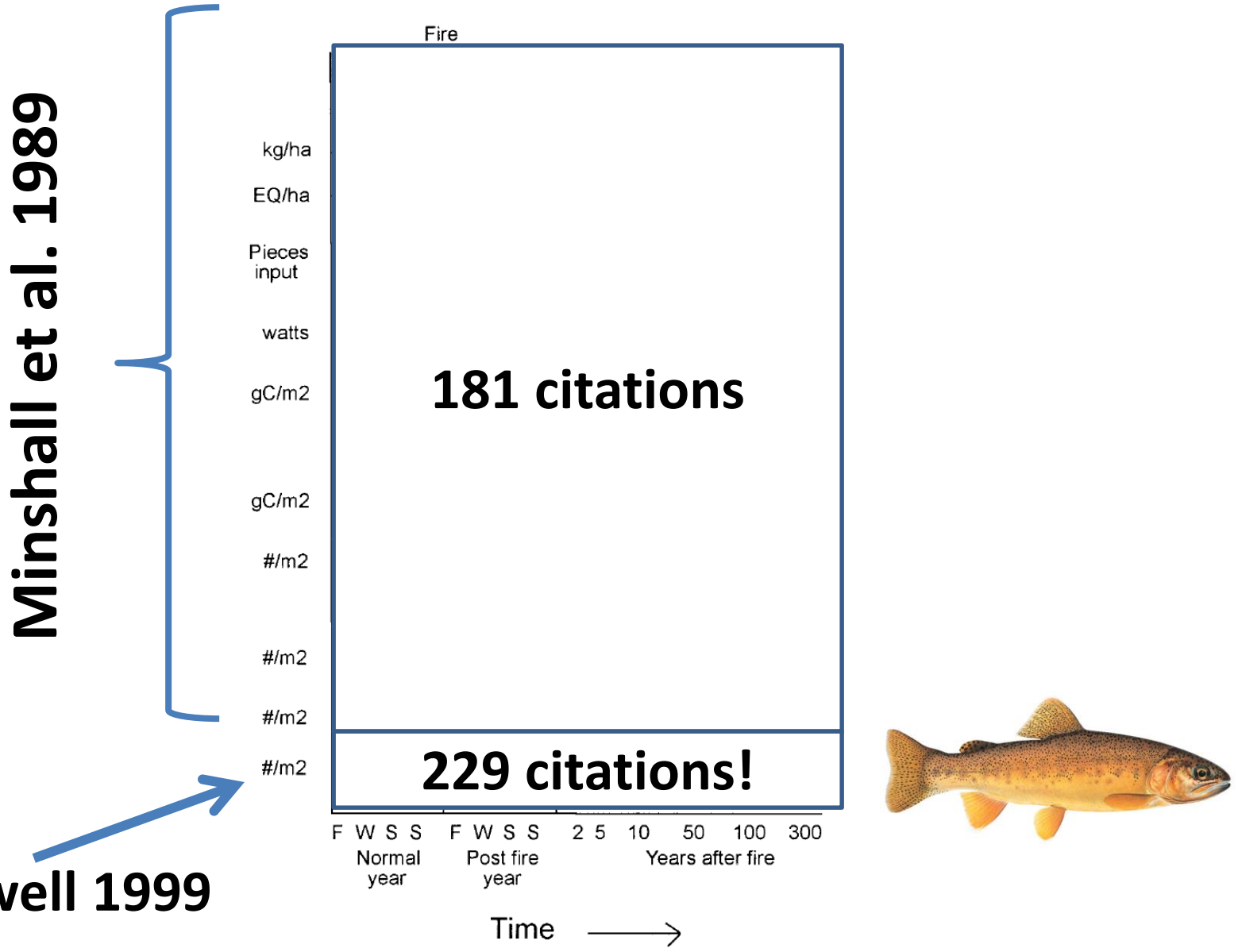


FIGURE 3.—Hypothetical changes in physical, chemical, and biological characteristics of fluvial systems following fire. The letters F, W, S, and S, indicate fall, winter, spring and summer, respectively. (Adapted from G. W. Minshall et al. 1989.)