Potential effects of Climate Change on Salmon and Steelhead in Streams of the Columbia River Gorge

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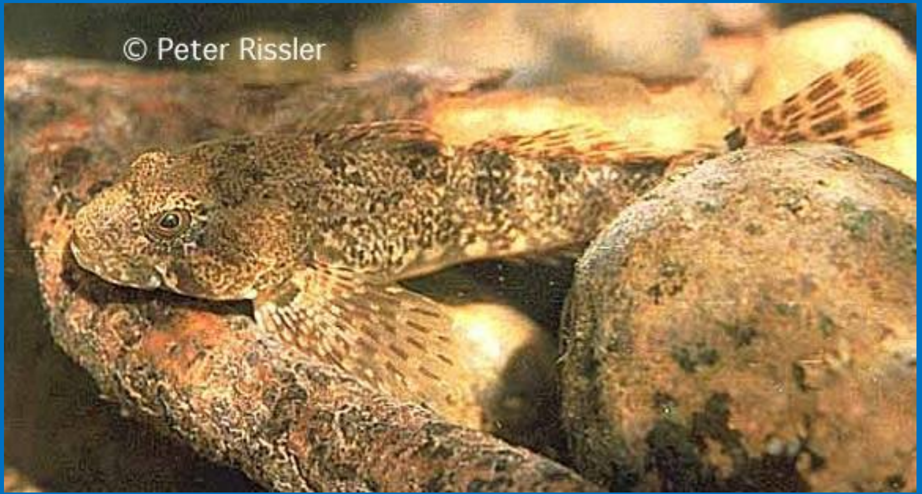
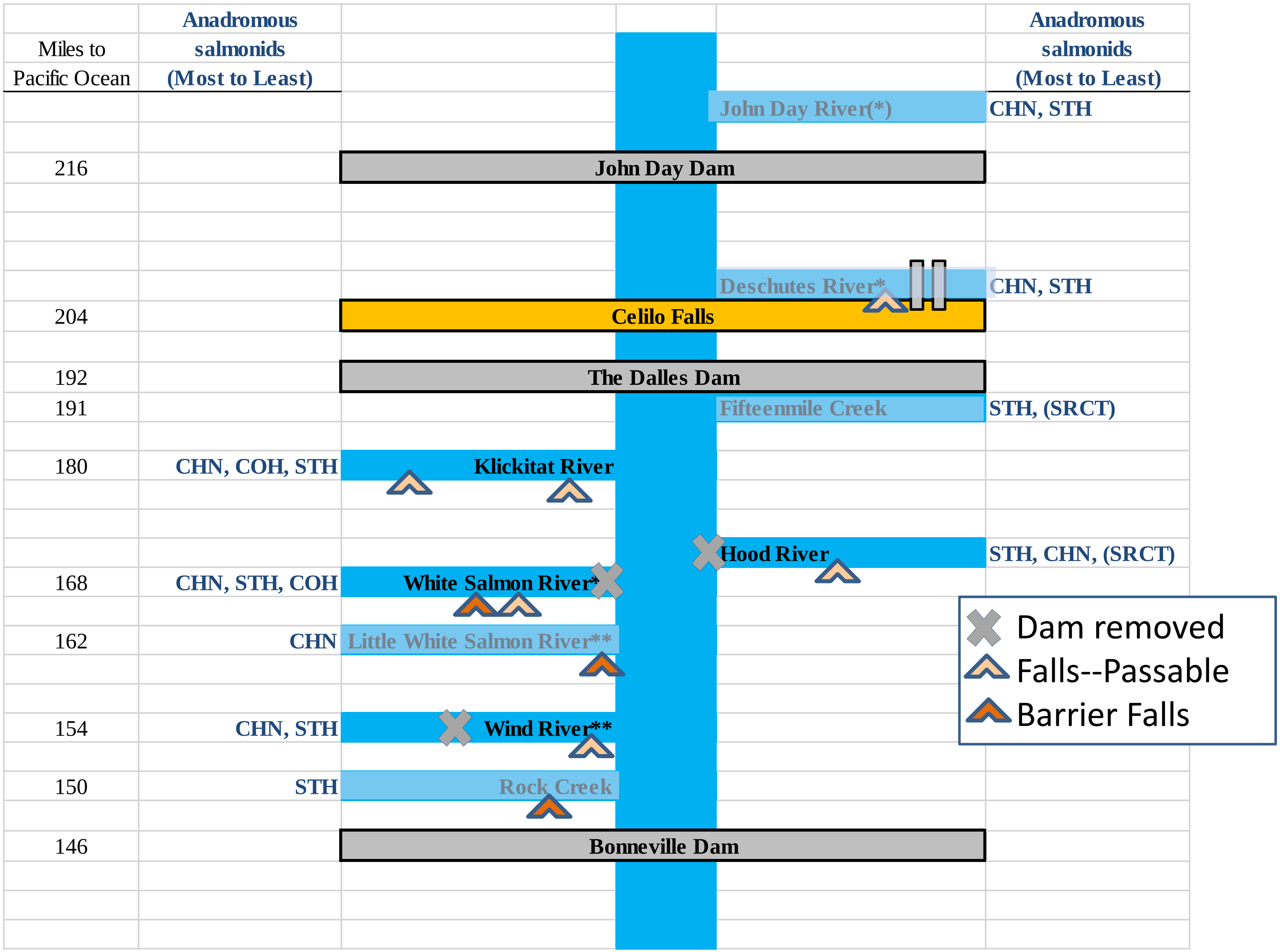
First: An Apology to the Rest of the Fish Assemblage



Rivers, Dams, and Falls



What and How Many Fish are Passing by our Backyard?

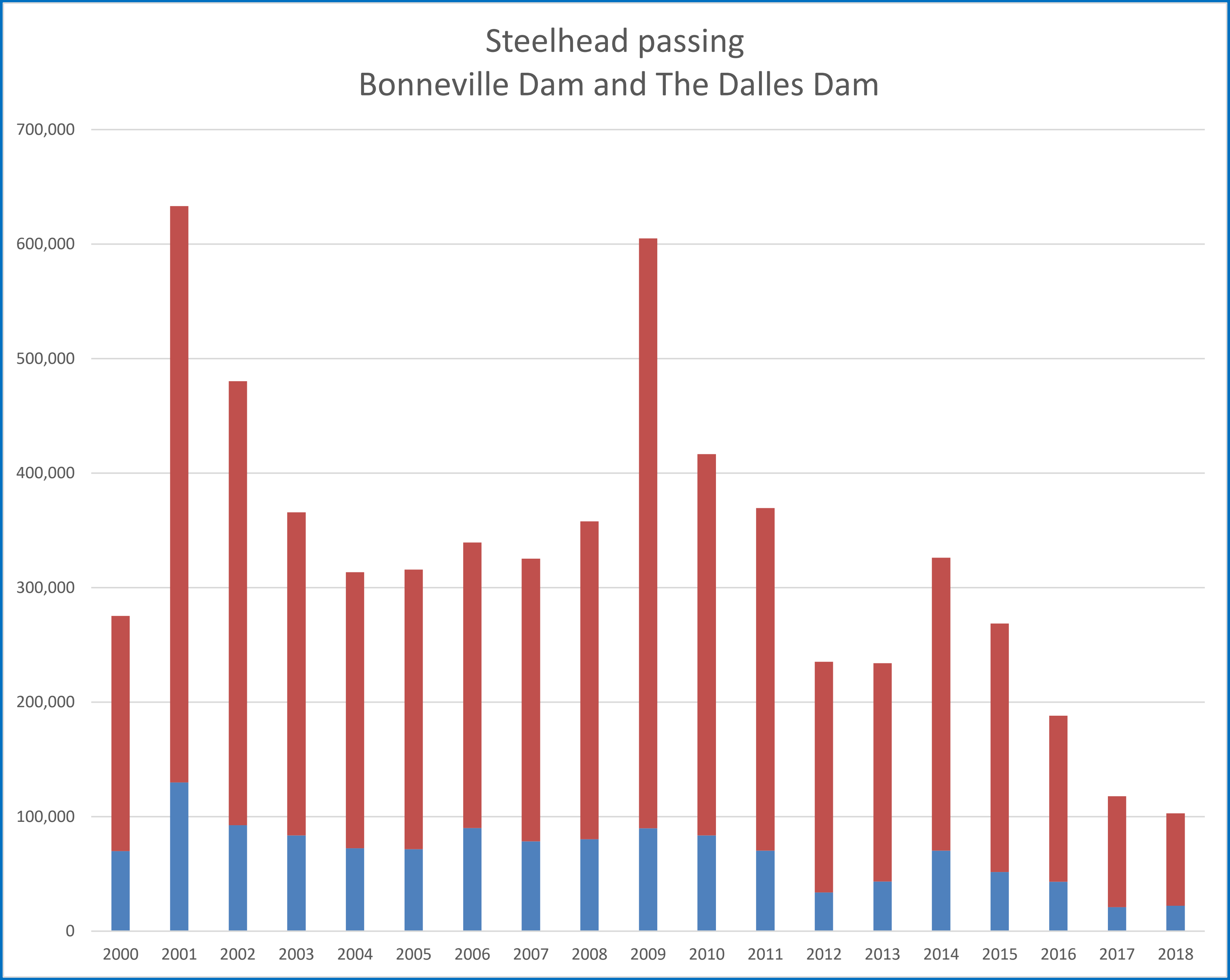
	Average number per year (2000-2018)	
	Bonneville Dam	The Dalles Dam
Anadromous salmonids		
Chinook salmon	708,707	470,740
Steelhead	329,986	261,729
Sockeye salmon	208,882	176,953
Coho salmon	114,366	41,436
Sea-run cutthroat trout	0-20	~0
Chum salmon	0-20	~0
Pink salmon	0-10	~0
Other fish		
American shad*	2,867,391	1,904,745
Pacific lamprey	40,055	11,115
White sturgeon	~50	~65
(most other fish species)	(One-way ticket downstream)	

* Non-native

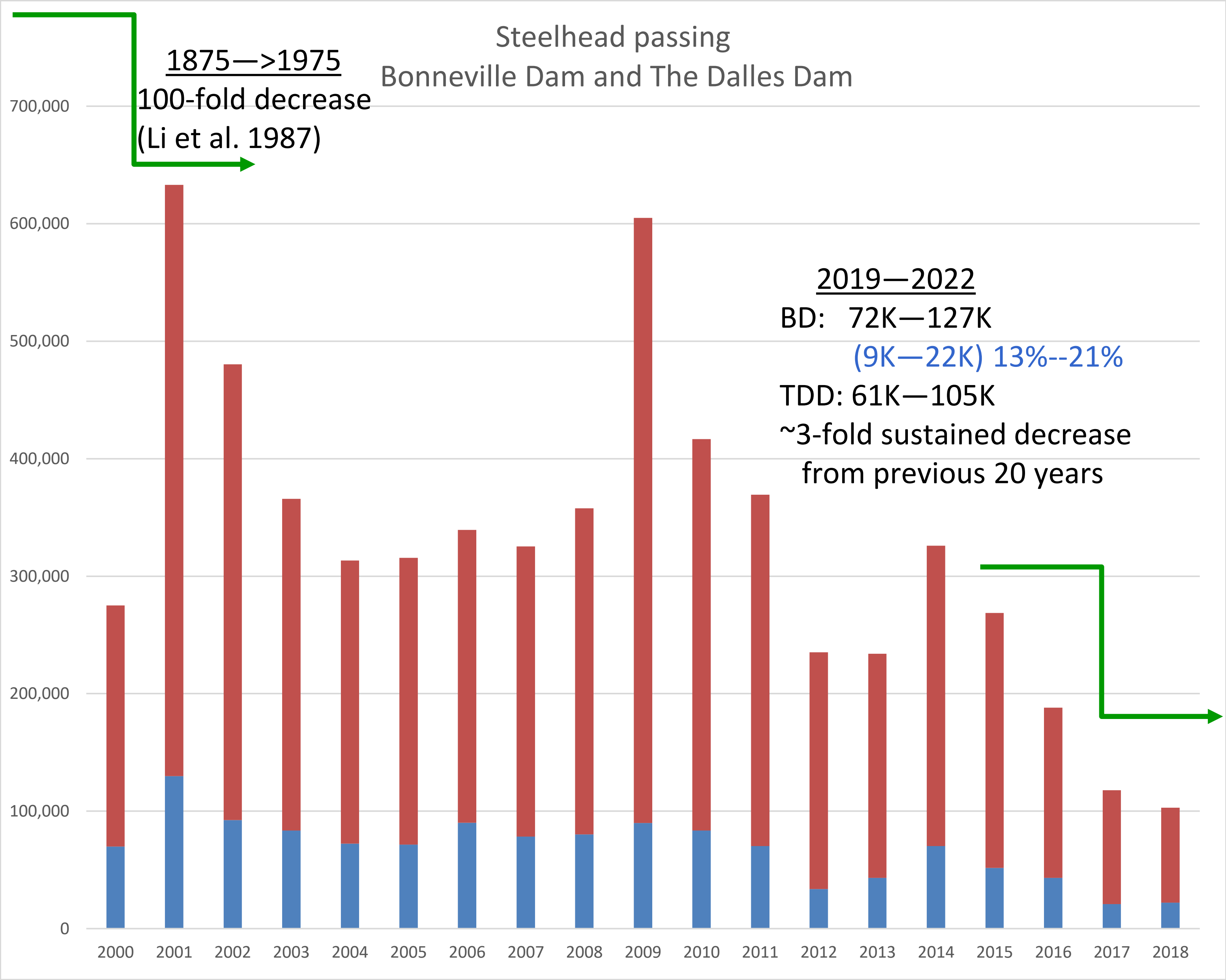
USGS

Status of Naturally Spawning Anadromous Salmonids in Gorge Streams

	1875	1975	2000	2023	Trend
SR Cutthroat Trout	M	L	LL	LL	↓
Steelhead	H	L	M	L	↓
Chinook	HH	ML	M	M	↗ (Fall run)
Coho	H	LL	LL	L	↗ (ReIntro.)
Sockeye	L	LL	LL	LL	→
Chum	M	LL	LL	LL	→
Pink	L	LL	LL	LL	→



Steelhead passing
Bonneville Dam and The Dalles Dam
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018


Steelhead passing
Bonneville Dam and The Dalles Dam
1875—>1975
100-fold decrease
(Li et al. 1987)
2019—2022
BD: 72K—127K
(9K—22K) 13%--21%
TDD: 61K—105K
~3-fold sustained decrease
from previous 20 years
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018

Past and Current Impacts to the Columbia River and Tributaries

Ghosts of Past Impacts
Fish harvest
Beaver harvest
Forest harvest
Channelization

Recent and Ongoing Impacts
Dams
Nonnative predators
Nonnative competitors
Contaminants
Water use

Nonnative fish
(WAL, SMB, Shad, Carp, ~N. Pike;
There and waiting to get in!)

Problems Created
Less fish habitat
Less productive habitat
Modified flows
Warmer waters
Fish disease increase
Change in food webs
Fewer salmon & steelhead

Add to This: Climate Change!

Dams
Nonnative fish
Urbanization
Agriculture
Forest Harvest

Fixes
Hatcheries
Harvest regulations
Minimum flows
Riparian buffers
Stream improvement
Nutrient & food enhancement
Removal of predator fish
--Bounties, Trapping, Rewards
Dam removals

Climate Change Doesn’t offer a Much Different Challenge Than What Salmon and Steelhead Have Been Through Before

Climate Change Doesn't offer a Much Different Challenge Than What Salmon and Steelhead Have Been Through Before

**It Just Promises to be Range-Wide
and the Fish Have
Fewer Options Available,**

**Now that We Humans have
Changed the Playing Field**

Important Concepts of Salmon and Steelhead Survival in the Age of Climate Change

Life History Diversity

Connectivity of Watershed Reaches

Resilience to Disturbance

Energy Needs: Trophic Inputs and Food Webs

Physiological and Genetic Constraints

Species Diversity in Anadromous Salmonids of the Columbia River

Increasing Life History Diversity:
1) Complexity,
2) Plasticity,
3) Resilience to episodic events

Sea-Run Cutthroat Trout

Steelhead

Chinook

Coho

Sockeye

Chum

Pink

Runs, Races, Stocks, and Other Delineations

Chinook Salmon

- Spring Chinook (stream-type)
- *Summer Chinook (ocean-type, stream type)*
- Fall Chinook (ocean-type)
  - Tules (below Celilo Falls)
  - Upriver Brights (human mix of upriver stocks)

Steelhead (anadromous Rainbow Trout)

- Coastal Rainbow Trout (below Celilo Falls)
  - Summer Steelhead
  - Winter Steelhead
- *Columbia Redband Trout (above Celilo Falls)*
  - *Summer Steelhead*
    - *Race A*
    - *Race B (Clearwater and Salmon rivers of Idaho)*

ESA & Management terms: Wild vs. Hatchery vs. Supplemented stocks
- Recovery Domains
- Evolutionarily Significant Units (ESUs)
- Distinct Population Segments (DPSs)
- Major Population Groups (MPGs)

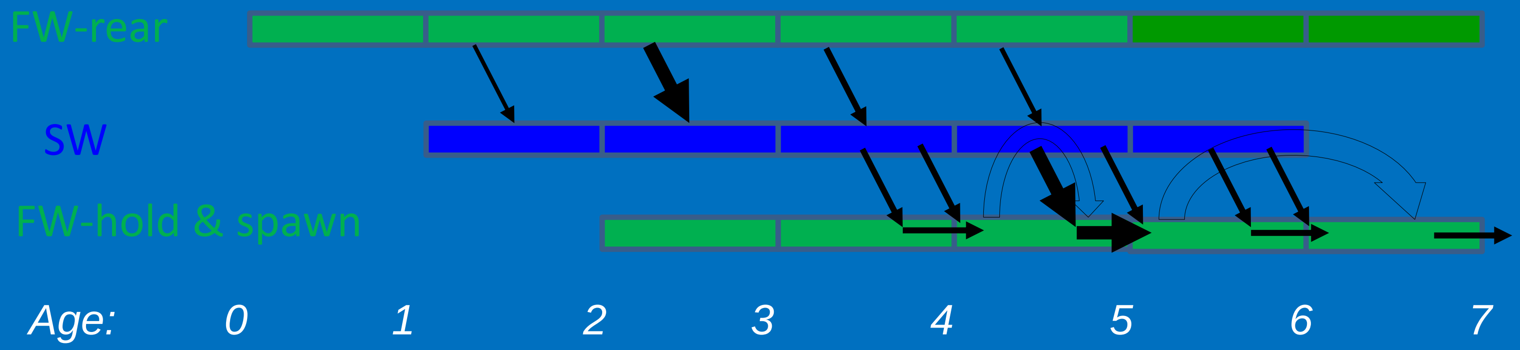
Life History Diversity of Steelhead

For example: Wind River Steelhead

Winter, Summer

FW 1-4+ : SW 2-4+

Plus residualization and repeat spawning



Lichatowich, Jim. 2001. Pacific Salmon Life Histories. *In*: Oregon Salmon: Essays on the State of the Fish at the Turn of the Millennium. Oregon Trout pp 59-63.

"Life-history diversity is how the salmon solved the problem of survival in fluctuating environments and changing habitats."

"Multiple life histories are how the salmon avoid "putting all their eggs in one basket."

"…if we are to restore abundant and sustainable salmon populations, we need to restore their life-history diversity, the multiple pathways through the watershed."

Expression of Genetic-Based Plasticity Depends on Food and Growth

Sloat, M. 2013.
Born to Run? Integrating Individual Behavior, Physiology, and Life Histories in Partially Migratory Steelhead and Rainbow trout (*Oncorhynchus mykiss*). Doctoral dissertation. Oregon State University.

"**Anadromous and resident forms are sympatric** and can produce offspring with a life history different from their own (i.e., steelhead parents can produce rainbow trout offspring and vice versa). "

"The expression of these **alternative life histories** is a **plastic response** to individual patterns of **energy acquisition**, **assimilation**, and **allocation** during juvenile life stages."

Sloat & Reeves (2014)

"**High standard metabolic rate** significantly decreased **rates of freshwater maturation** and increased **rates of smoltification** in females, but not males, after 1 year of rearing."

[A juvenile steelhead with a genetically determined high metabolic rate needs to eat more food than one with a low rate.]

A Steelhead Story: Methow River, Washington, USA

The Methow River is similar to our Gorge streams,
in that it is a cold-water system with lower productivity that would likely increase from having warmer water.

However, there is a The Flip Side to higher productivity.

A Steelhead Story: Methow River, Washington, USA

Modeling the Affects of Climate Change on Juvenile Steelhead

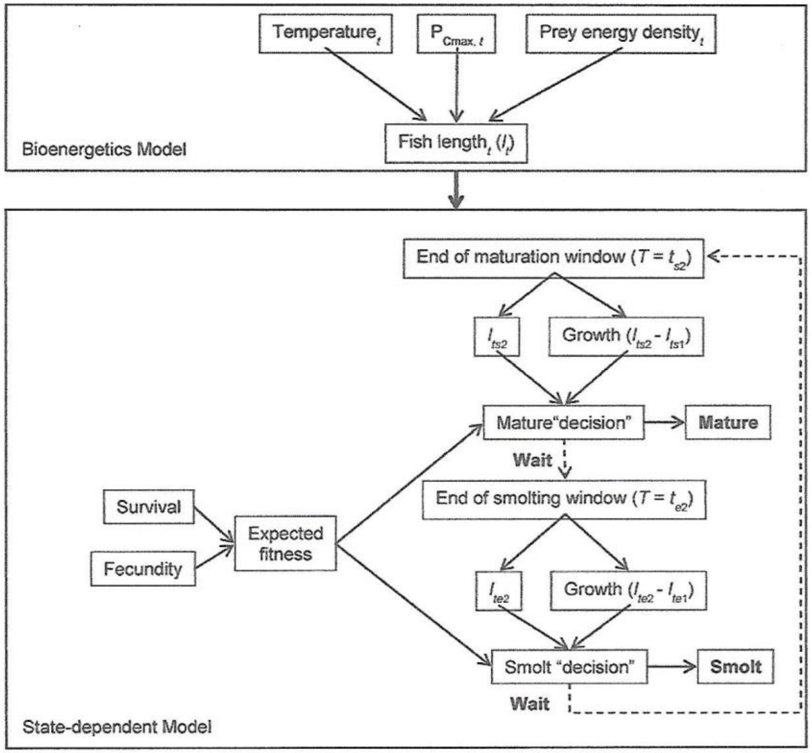


FIGURE 1. Conceptual diagram of the linkages between the climate change scenarios (i.e., temperature, P_{Cmax}, and prey energy density), the bioenergetics model, and the state-dependent life history model. The bioenergetics model simulates the length of each fish (l) at time t. The state-dependent model then predicts life history trajectories to either mature and spawn as a Rainbow Trout (s) or emigrate as a Steelhead smolt (e) as a function of expected fitness, growth over discrete time windows (t_{s1} to t_{s2} or t_{e1} to t_{e2}), and the length at the end of the window. The dashed line indicates no trajectory has been adopted and individual fish loop through the model until a trajectory is followed. See text for more details.

From: Benjamin , Connolly, Romine, & Perry. 2013. TAFS 142:208-220

A Steelhead Story: Methow River, Washington, USA

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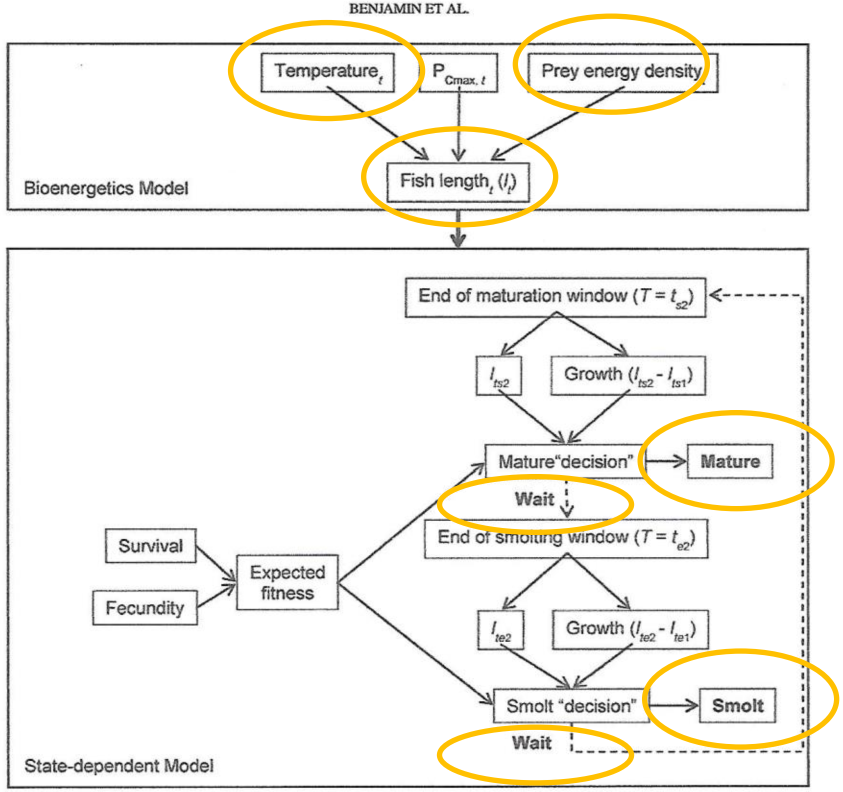

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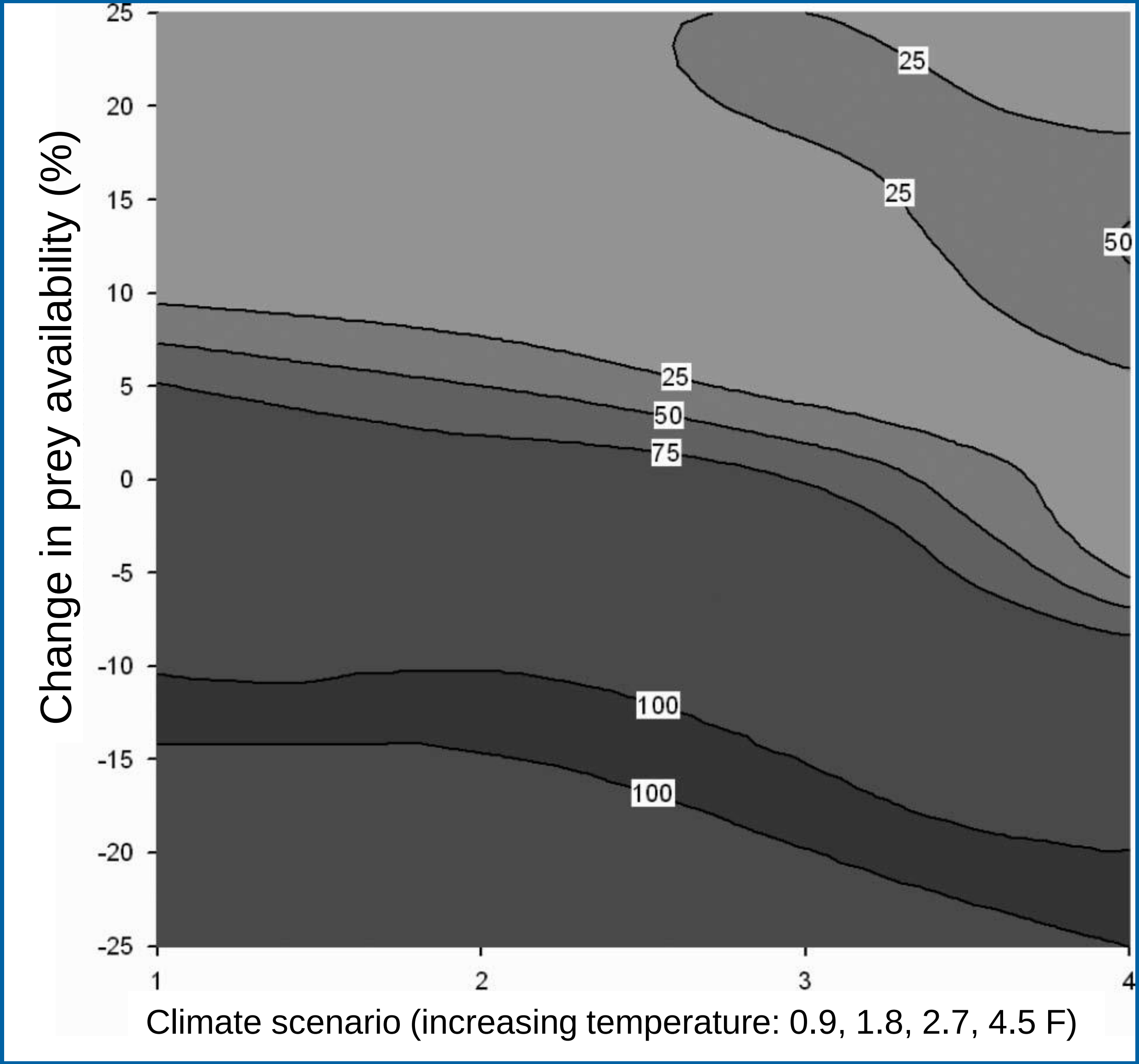
A Steelhead Story: Methow River, Washington, USA

Percentage of female *O. mykiss* that will smolt (vs. stay as resident)



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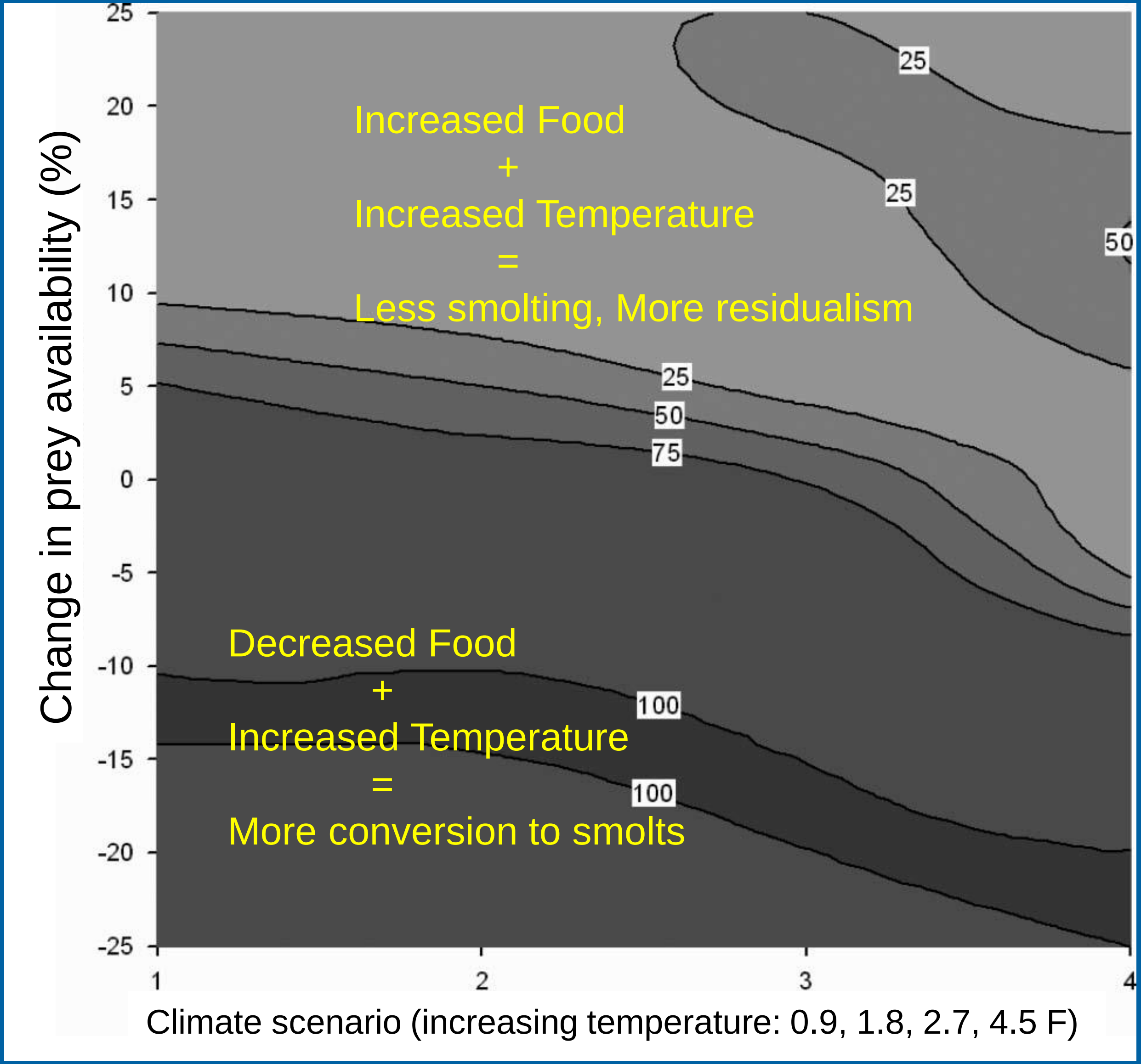

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According to Scotland-based (UG) Dr. John E. Thorpe (paraphrased):

"Smolting is the result of the freshwater system <u>not</u> being able to provide enough energy resources."

According to OSU's Dr. Carl Schreck (paraphrased):

"Fisheries ecology is not Rocket Science…"

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“Smolting is the result of the freshwater system not being able to provide enough energy resources.”

According to OSU’s Dr. Carl Schreck (paraphrased):

“Fisheries ecology is not Rocket Science,

it’s more complicated than that!”

Generalized Expected Results for Gorge Streams to Climate Change

Increased episodic disturbance
- Rain-on-snow, scour flows, landslides, fire, and drought
  - *Some is really good for fish habitat; Too much is really bad*
- Connectivity of watershed will likely decrease
  - Headwater contraction and more limited availability
  - Lower ends of large streams less hospitable
    - (high temperatures, increased non-native predators and competitors)

Change in trophic inputs and food webs
- Productivity of cool-water streams will likely increase
- Food resources will likely change (source, type, amount)
- Food webs could contract or expand, but certainly change

Change in life history diversity of salmon and steelhead
- Increased growth of fish in freshwater phase (if food is available)
- Increased early maturation (precociousness, residualism)
- Decreased age of smolts
- Younger age of return and smaller size for adults (jacks, 1-salts)

Relative Impact of Temperature to Survival of Salmon and Steelhead in Gorge Streams

How Can We Help Salmon and Steelhead Survive Climate Change in The Gorge?

I need to answer this question with a few questions:

1. Can we provide enough fixes or relax enough stressors on a large enough scale and fast enough?

2. Will changes in the Pacific Ocean simply be too large and overwhelming to what we can change in our watersheds?

3. Are we All In or All Out: Do we do something, or Do we wait and see?

Life History Diversity (FW : SW years)

Increasing:
1) complexity,
2) plasticity,
3) adaptability, and
4) resilience
to episodic
temperature
stress

↑

Sea-Run Coastal Cutthroat Trout
2-4+ : 2-6+; with repeat spawning, residualization

Steelhead (Winter, Summer)
1-4+ : 2-6+; with repeat spawning, residualization

Chinook (Spring, Summer, Fall)
0.8/1.8 : 2-5

Coho (Early, Late)
1.5 /2.5 : 3-6

Sockeye (Kokanee)
1.8/2.8 : 3-6, with residualization

Chum // Pink
0.8 : 2-5 // 0.8 : 2

A Coho Story: Carnation Creek, B.C.

(Holtby, L.B. 1988. CJFAS 45: 502-515)

Intensive hillslope and riparian logging in watershed, 1976-77

Caused increased solar exposure.

Resulting in mean stream temperature all months of the year and increases up to 5 C in summer.

Effect on Coho Salmon

Earlier emergence of fry

Lengthening of the growing season by up to 6 weeks

Fingerlings much larger by fall

Improved winter survival

Number of yearling smolts doubled, although 2-yr-old smolts decreased

Overall large increase (47%) in number of smolts.

End of story. Great. Logging helped. Right?

USGS

The Rest of A Coho Story: Carnation Creek, B.C.

(Holtby, L.B. 1988. CJFAS 45: 502-515)

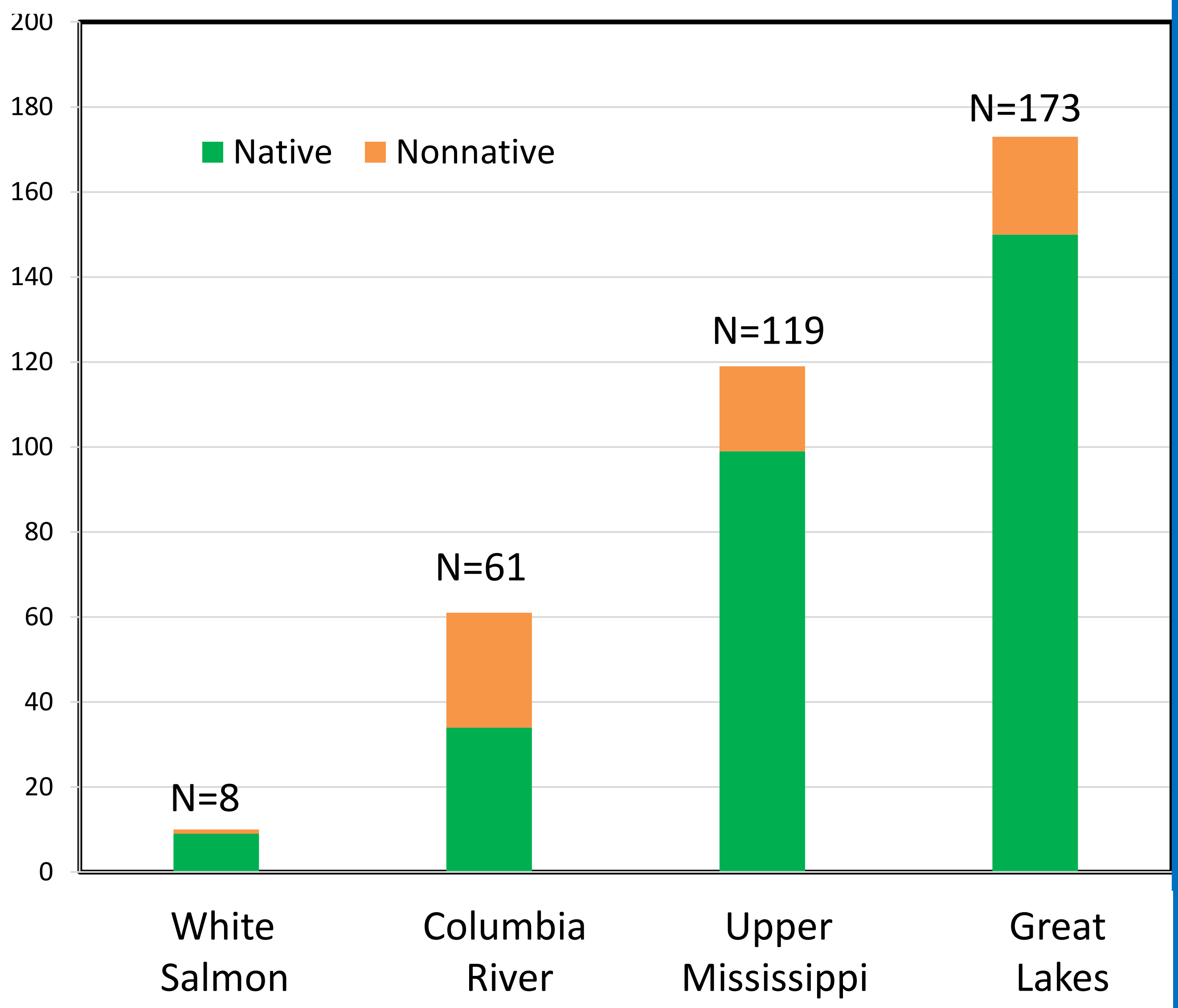
More smolts, <u>but</u> of younger age (age 1)
and they were smaller than the average age-2 smolt.

Resulted in <u>decreased</u> Smolt-to-Adult survival.

Resulted in smaller than expected increase (9%) in adults.

My add:
Resulted in less life history diversity, and therefore less resilience to a potential additional disturbance like climate change.

Number of Fish Species



USGS

Self-sustaining Fish Species in the White Salmon River
(abv Condit Dam site)
N=11

Native

1. *Chinook salmon (Spring, Fall [Tules, Upriver brights])
2. *Coho salmon
3. Coastal rainbow trout (and it's *steelhead form)
4. Coastal cutthroat trout (and possibly it's *sea-run form)

5.* Pacific lamprey
6. Western brook lamprey
7. Long-nosed dace
8. Shorthead sculpin

Others possible in very low numbers

9. *Bull trout

Non-native

10. Brook trout
11. Brown trout

* New kids on the block

USGS