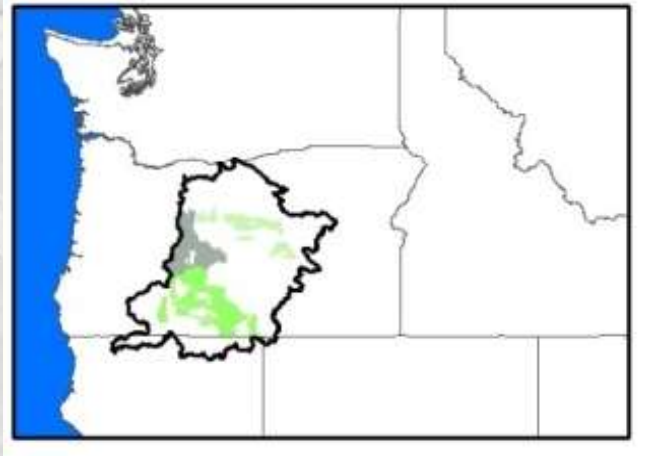
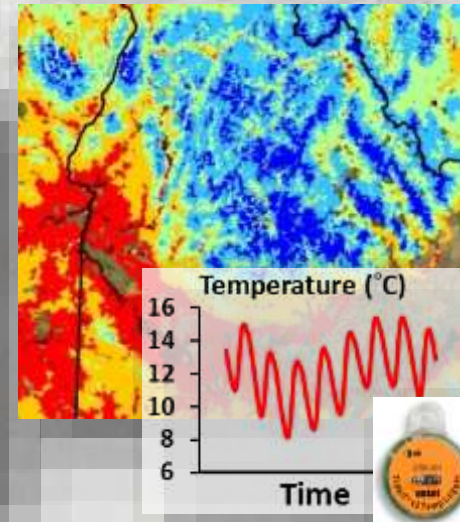
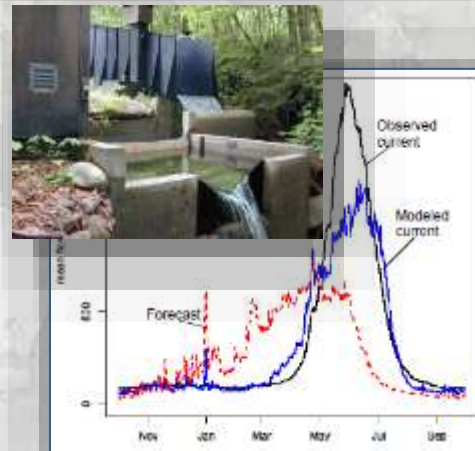
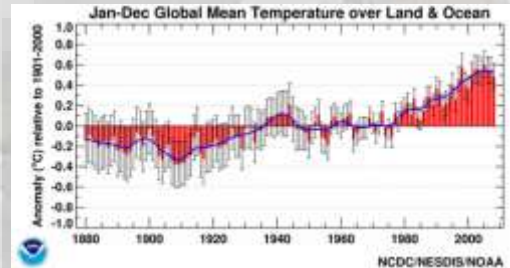
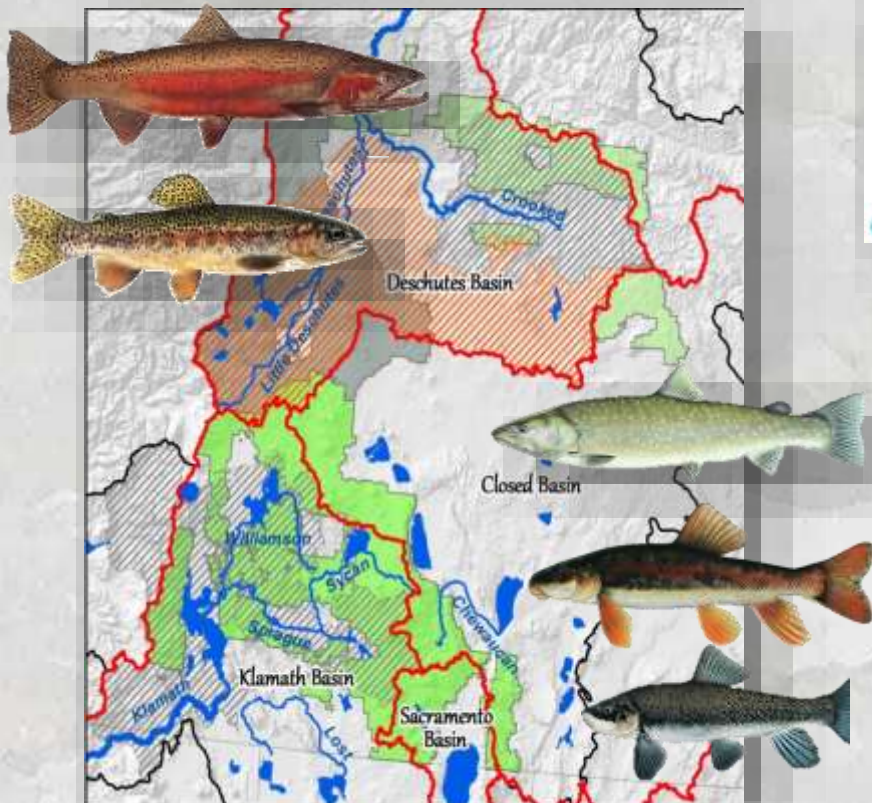


South Central Oregon Adaptation Partnership: Effects of Climate Change on Fisheries



John Chatel, Jennifer Mickelson, Phillip Gaines, Terry Smith,
Dona Horan, Dan Isaak

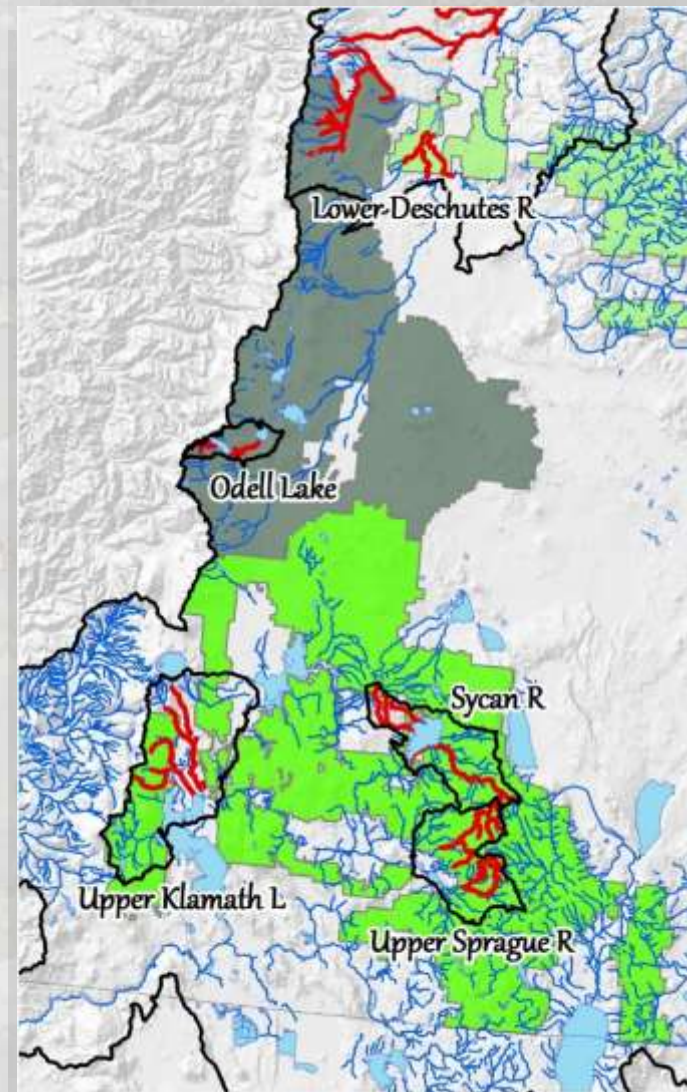


Species of Concern... Bull trout



Critical habitat

- ESA listed as threatened
- Cold thermal niche constrains populations to high-elevation refugia
- Habitats & populations are fragmented & isolated
- Occurs in small streams that are susceptible to disturbance
- Spawns in fall & eggs incubate overwinter

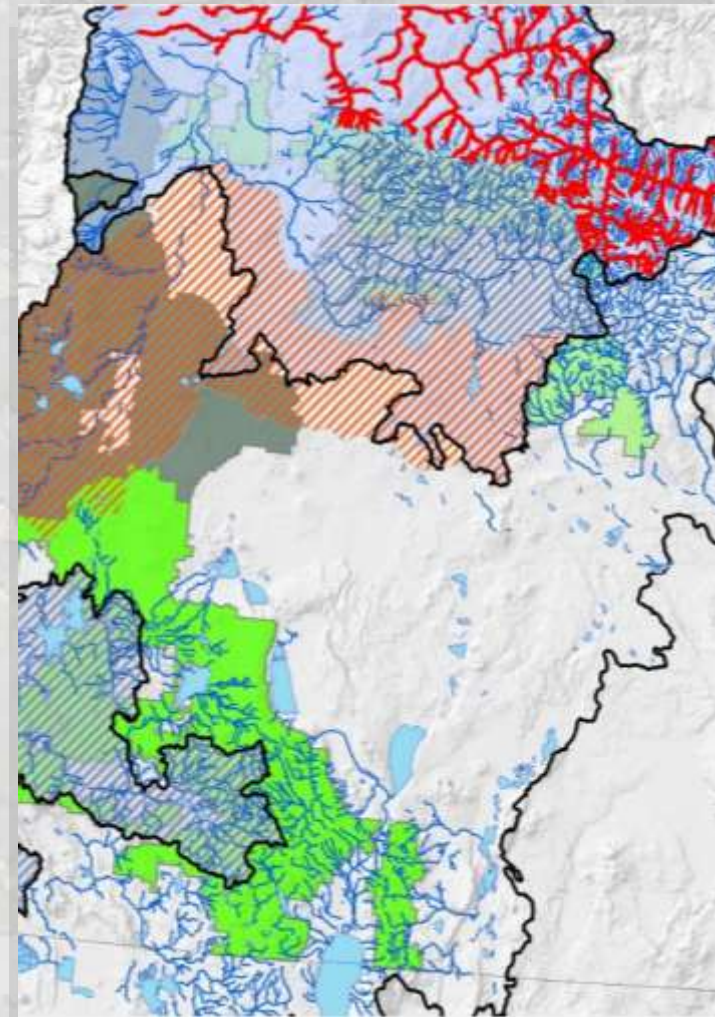


Species of Concern... Steelhead



- ESA listed as threatened
- Populations require fluvial connectivity to ocean
- Ocean cycles strongly affect freshwater abundance
- Relatively warm thermal niche – unsuitably cold upstream areas could serve as refugia
- Spring spawner after peak flows
- Natal habitats occur in small streams susceptible to disturbance

Critical habitat



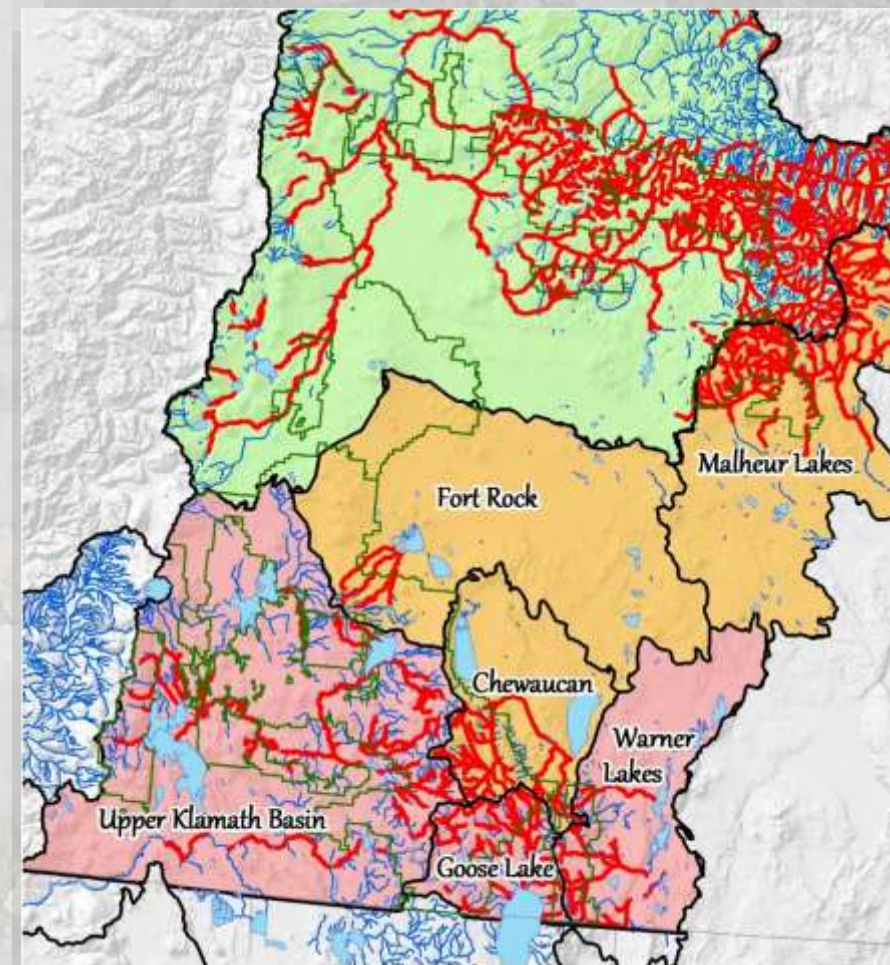
Species of Concern...

- Not ESA listed, but Regional Forester considers to be “sensitive species”
- Non-anadromous version of steelhead
- Relatively warm thermal niche – unsuitably cold upstream areas could serve as refugia
- Spring spawner after peak flows
- Natal habitats occur in small streams susceptible to disturbance

Redband trout



Stream Habitats



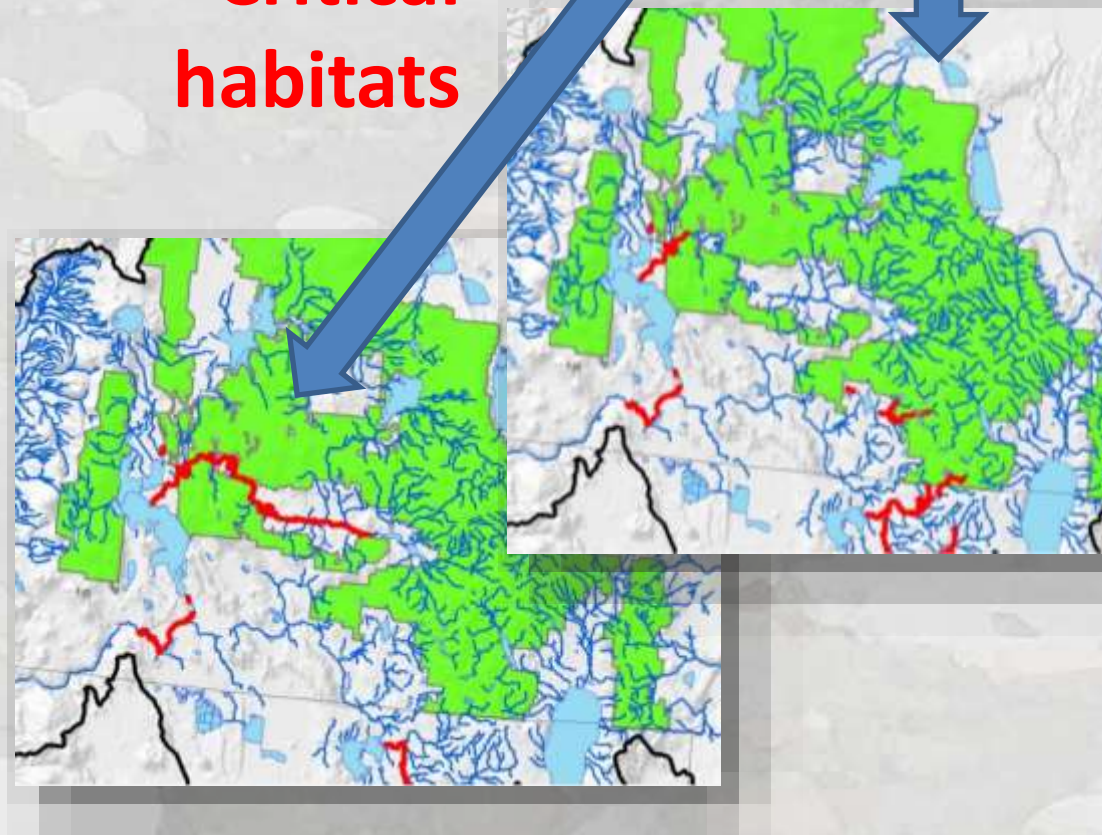
Species of Concern...

Lost River Sucker Shortnose Sucker

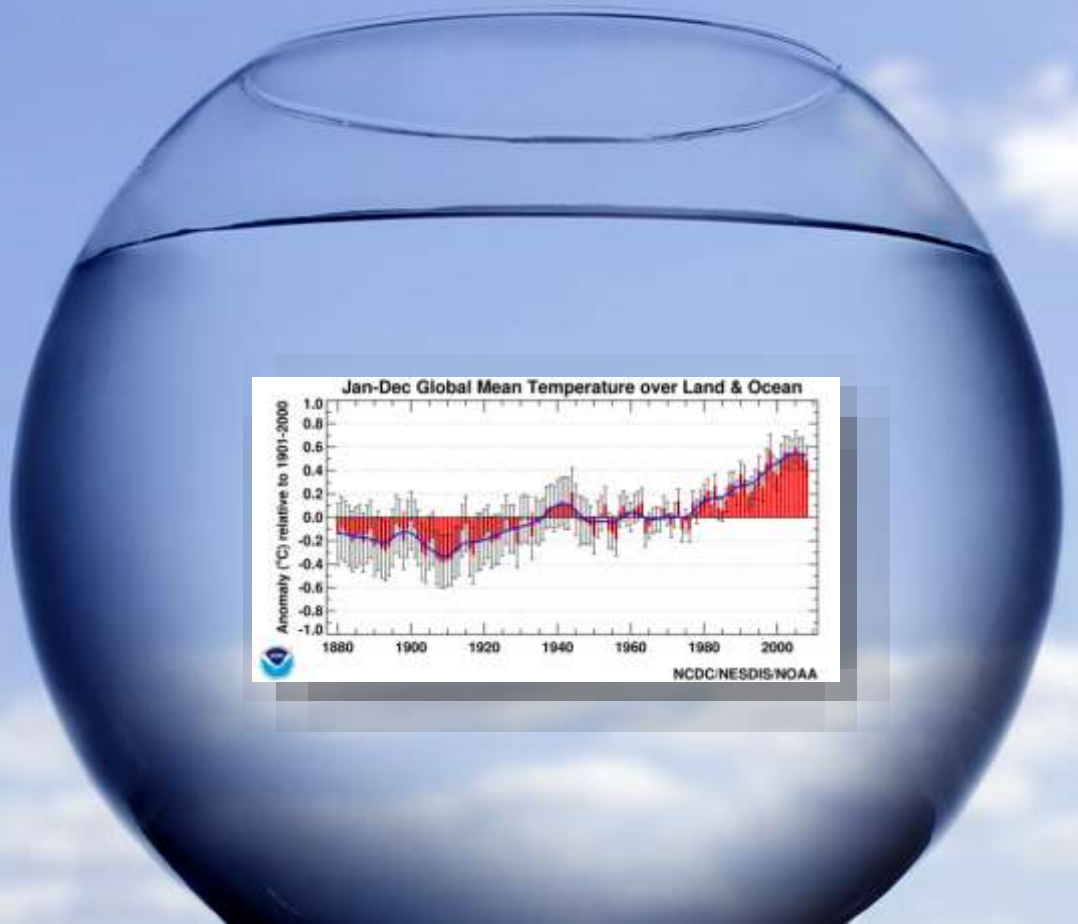


- ESA listed as endangered
- Endemic species
- Main habitats are lakes but use inflowing streams for spawning
- Distribution on FS lands limited to ~40 kilometers of stream on the Fremont-Winema NF

**Critical
habitats**

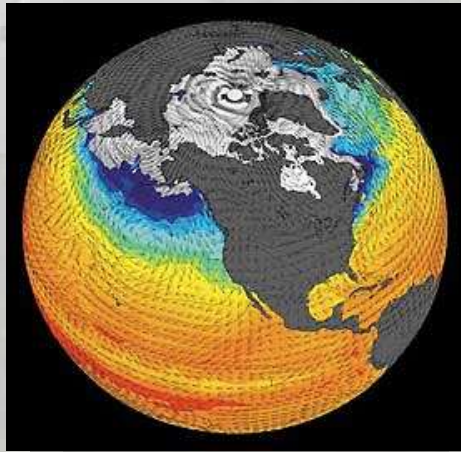


Taking Climate into the Water Where Fish Live...

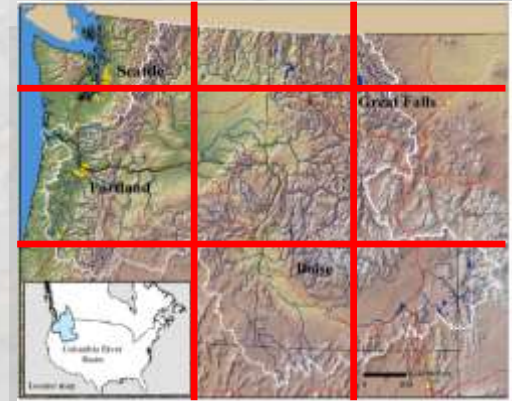


Taking Climate into the Water Where Fish Live...

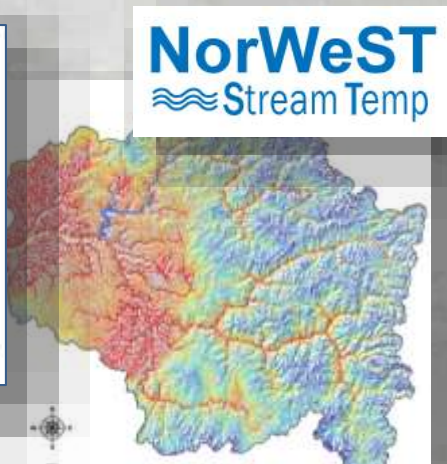
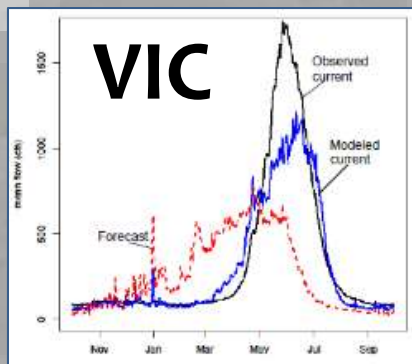
Climate model (air temp & precip)



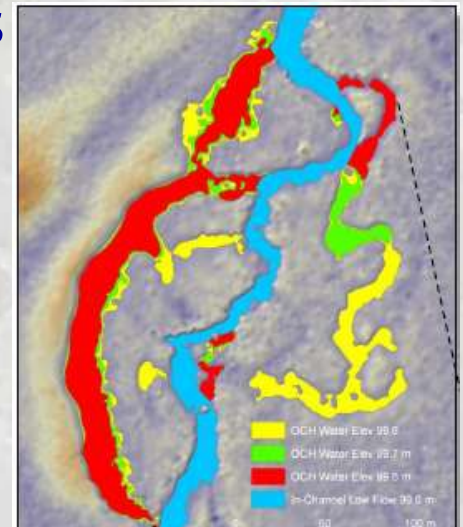
Regional patterns



Stream temperatures & flow

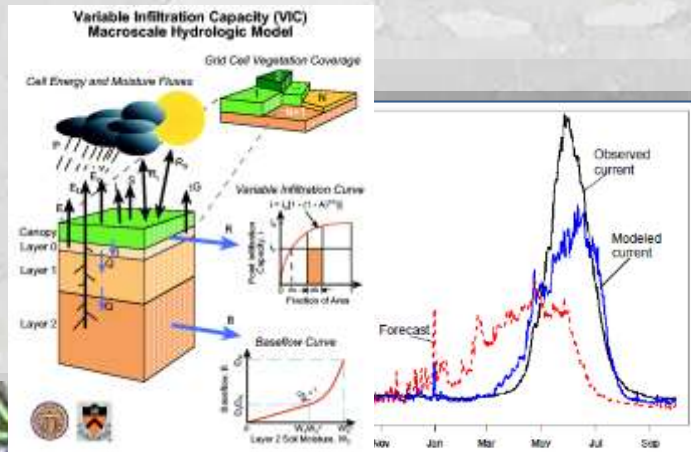


Stream reach patterns



GIS Data for Stream Flow & Temperature Scenarios Downloaded from Websites

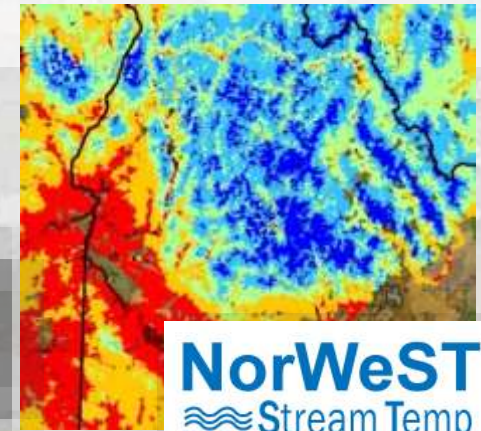
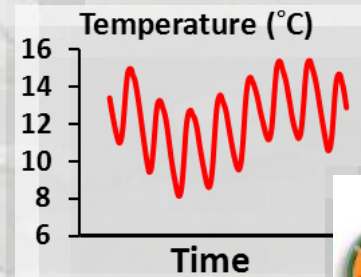
VIC Streamflow Scenarios



Google “Stream flow Metrics”



Google “NorWeST stream temp”



Isaak et al. 2010. *Ecol. Apps.* **20**:1350-1371

Isaak et al. 2012. *Climatic Change* **113**:499-524.

Luce et al. 2014. *Wat Res Res* DOI: 10.1002/2013WR014329

Ver Hoef et al. 2006. *Environ Ecol Stat* **13**:449-464.

Ver Hoef & Peterson. 2010. *Journal Am Stat Ass* **105**:6-18.

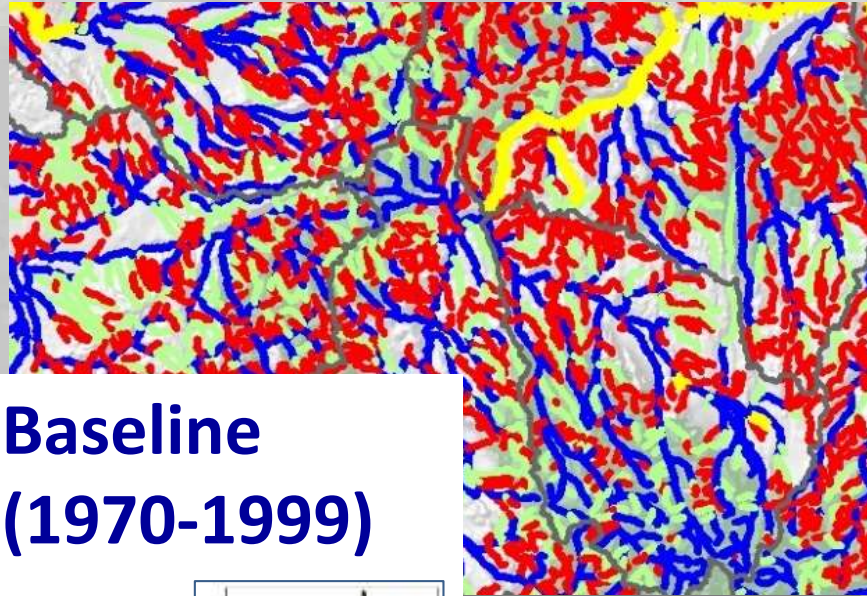
Liang et al. 1994. *J. Geophys Res* **99**:14415-14428.

Wenger et al. 2010. *Water Res Res* **46**:W09513.

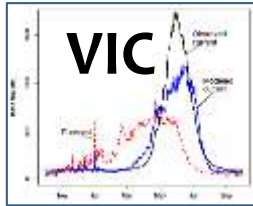
Safeeq et al. 2014. *Hydrology and Earth System Sciences* **11**:3315-3357.

Stream Hydrography Baseline for Fish

1:100,000 NHDPlus



Baseline
(1970-1999)

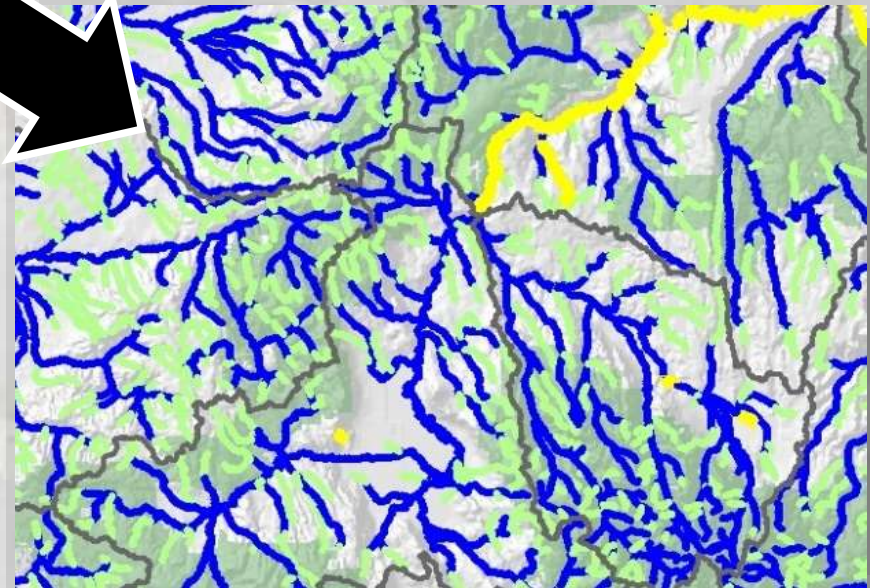


>0.2 cfs summer flow

<15% slope

Deleted intermittent channels

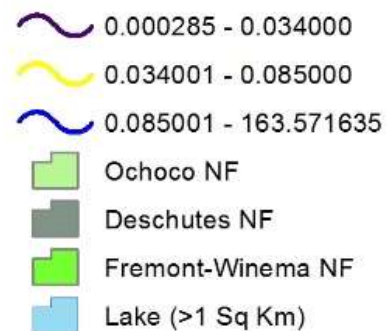
~65% network
reduction



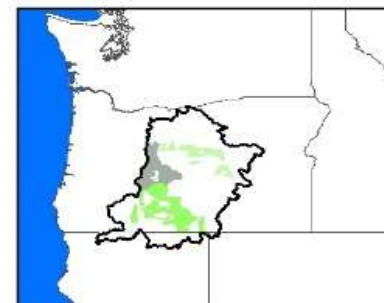
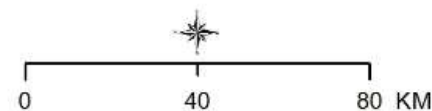
**Baseline
(1970-1999)**

Stream Fish Hydrography

Mean Summer Flow (cms)

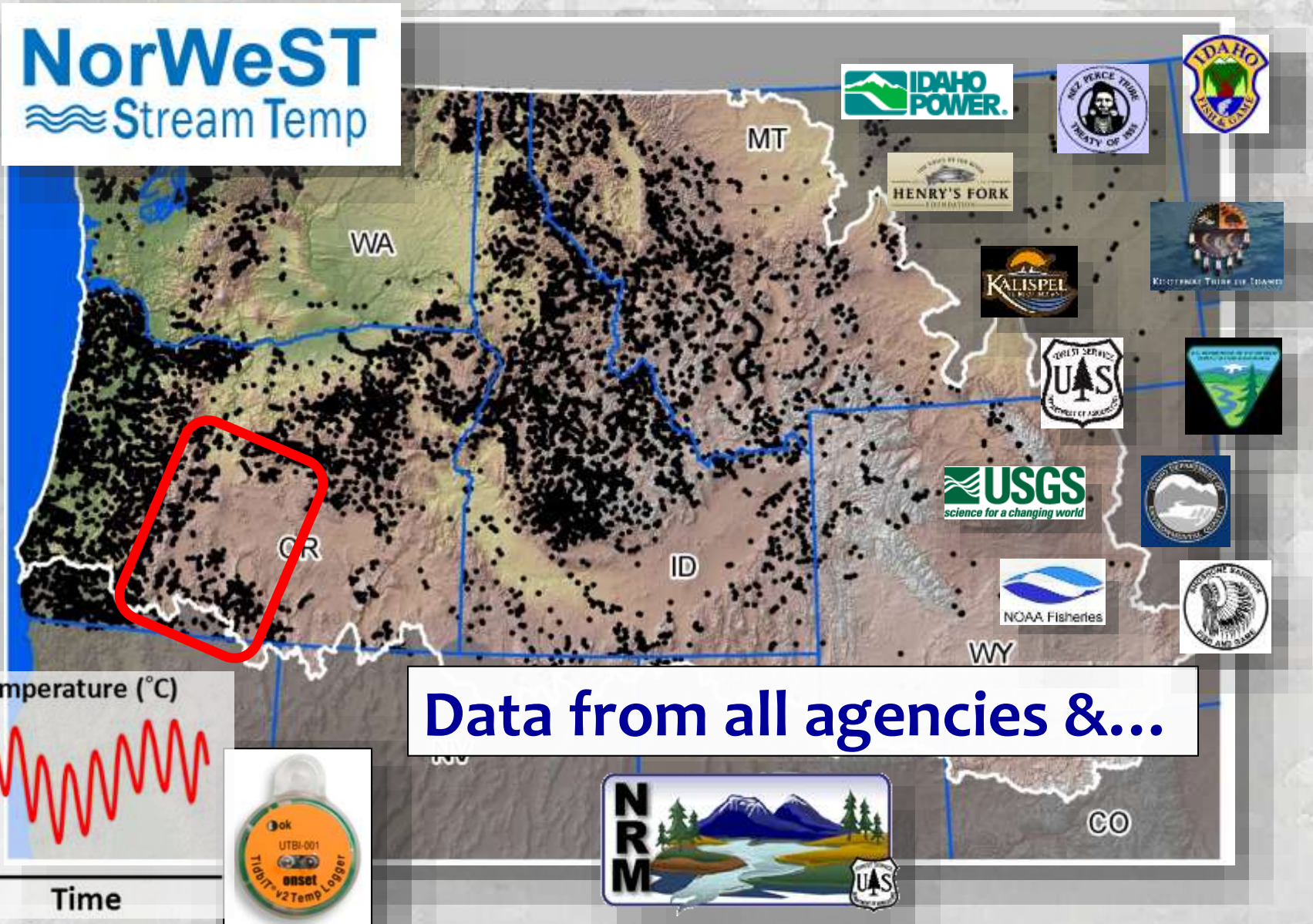


	All Streams	USFS Streams
Historic	19,161 km	4,968 km

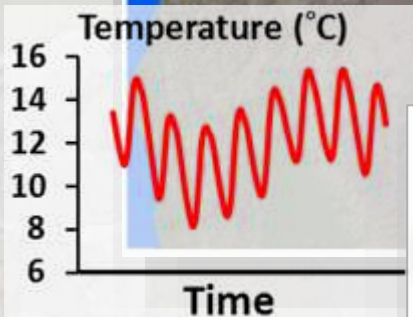


Stream Temperature Database

NorWeST
Stream Temp

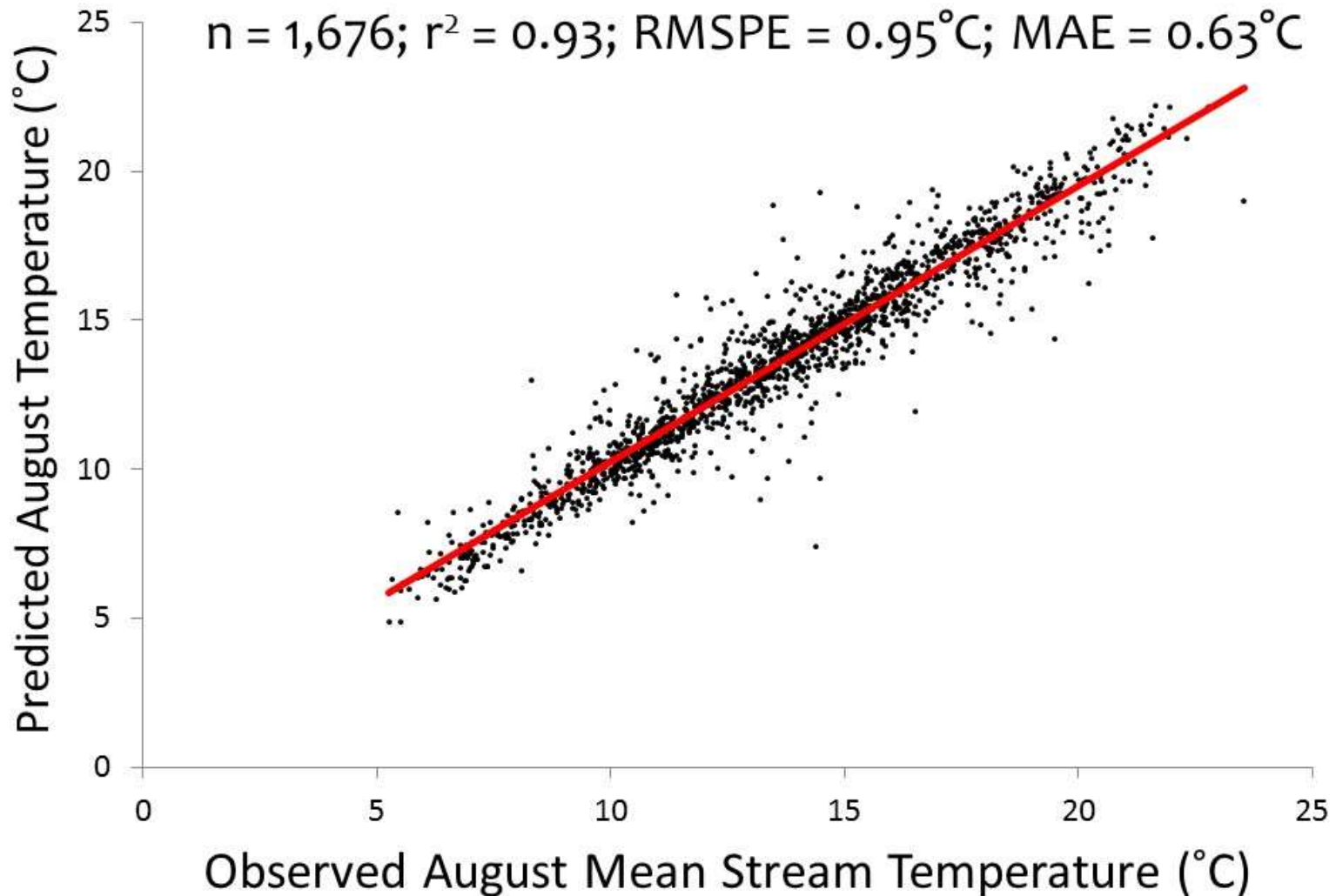


Data from all agencies &...



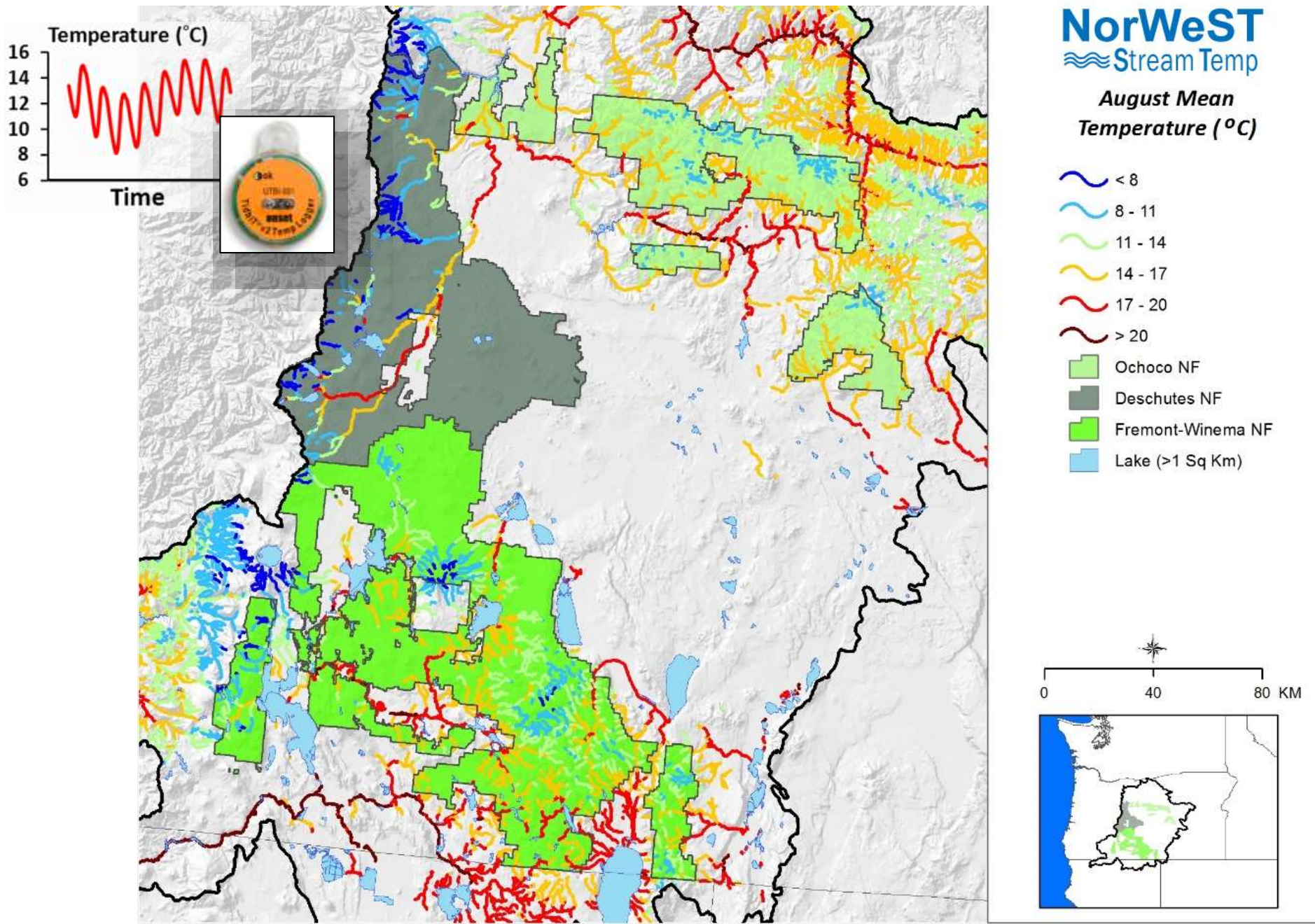
NorWeST Temperature Model Accuracy

Central Oregon NorWeST Stream Temperature Model



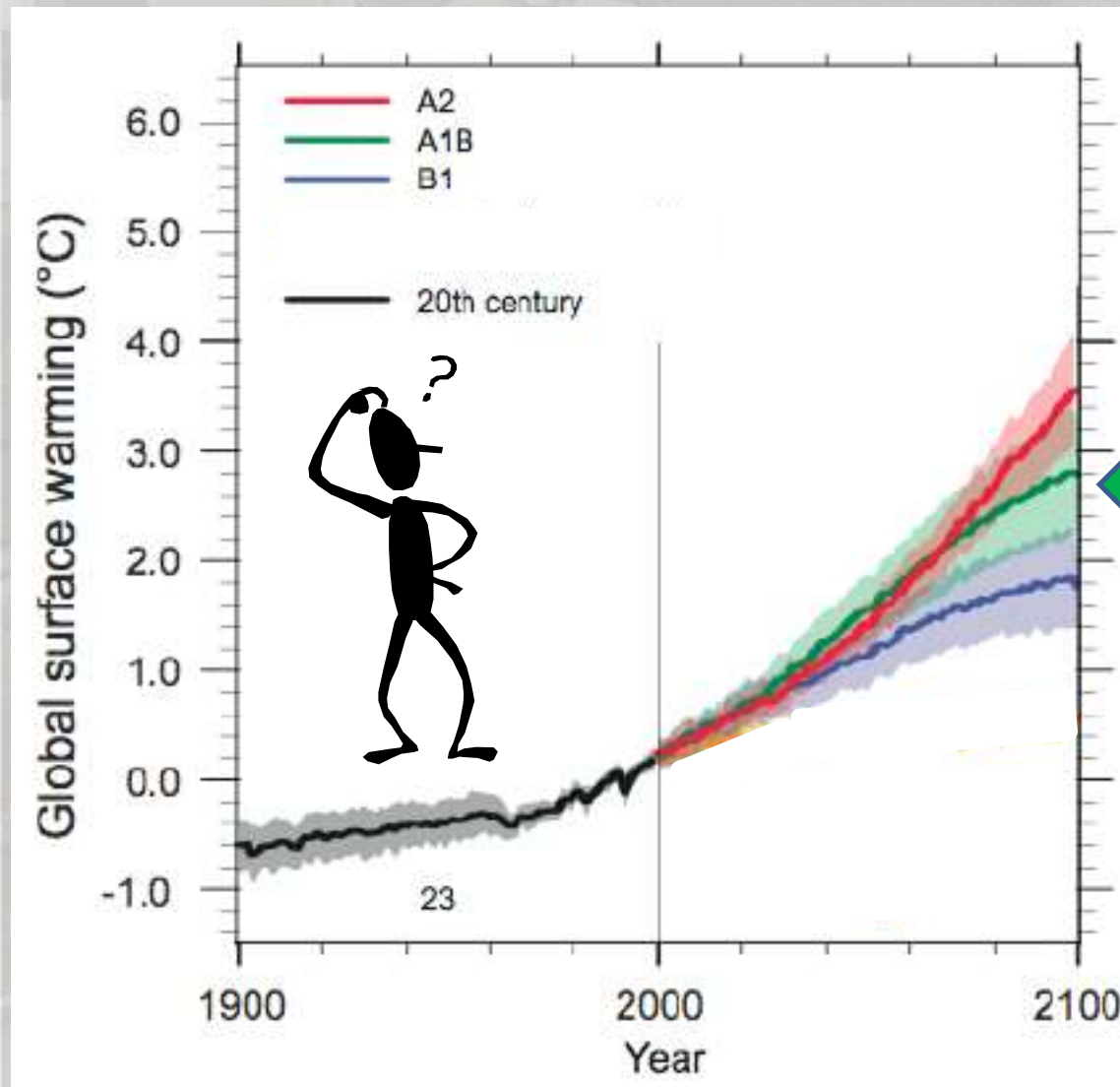
Stream Temperature Baseline

Baseline (1970-1999)



Future Climate Scenarios

A1B 10 GCM Ensemble from CIG



A1B

~RCP 6.0

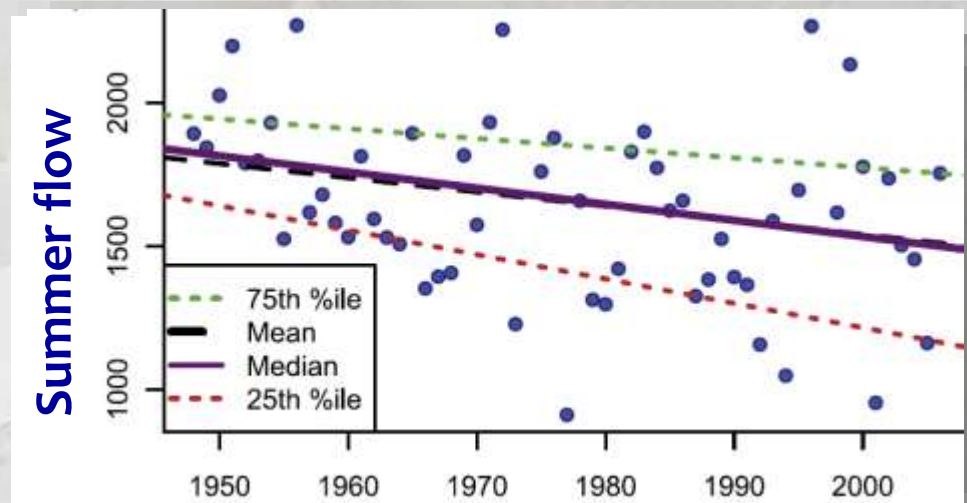
- Historic baseline (1970-1999)
- 2040s (2030-2059)
- 2080s (2070-2099)

Changes in Mean Summer Flows - Summary



	<u>All lands</u>	<u>USFS lands</u>
Baseline (1970-1999)	-	-
2040s (2030-2059)	-20.0%	-31.3%
2080s (2070-2099)	-29.5%	-47.1%

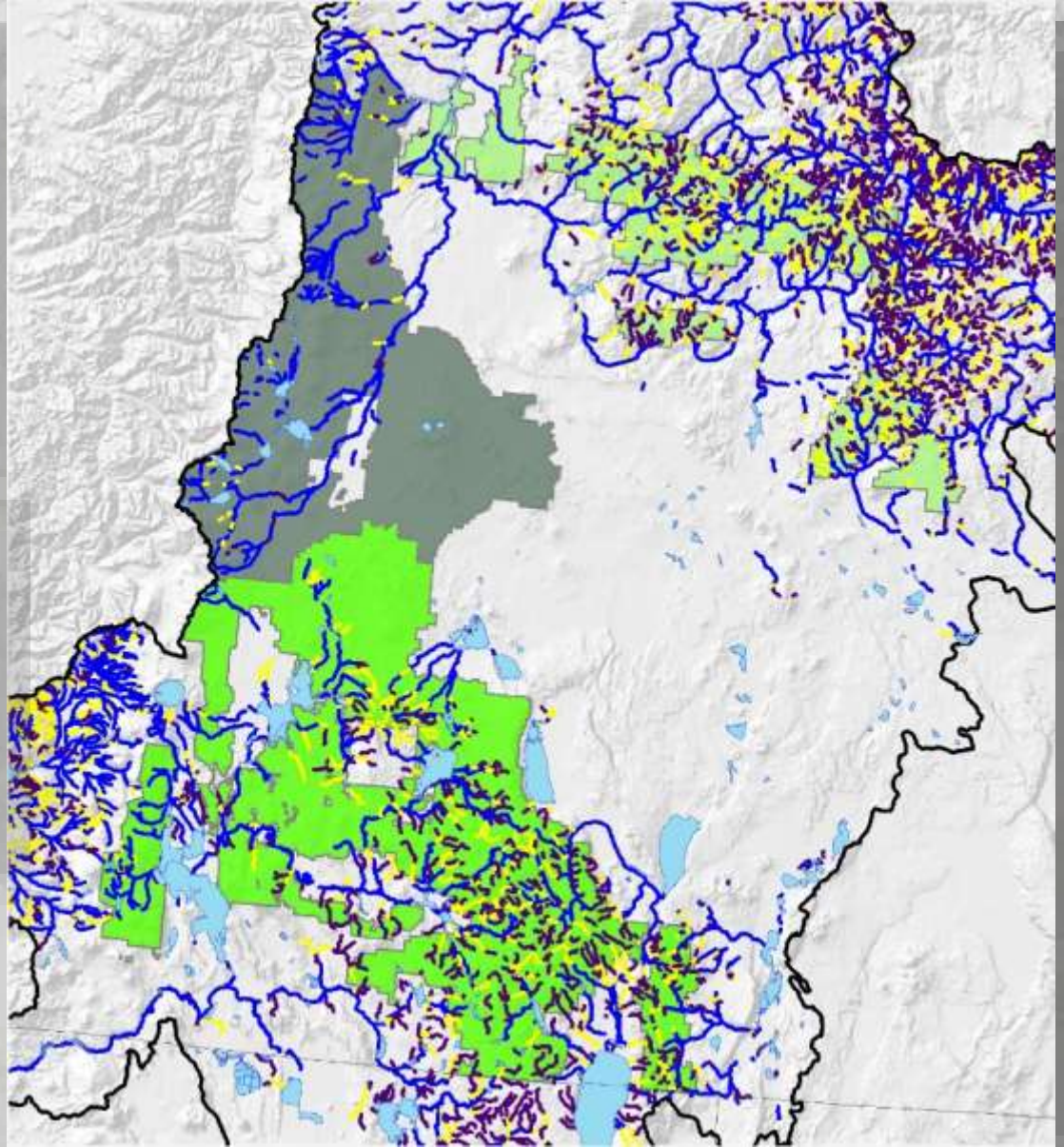
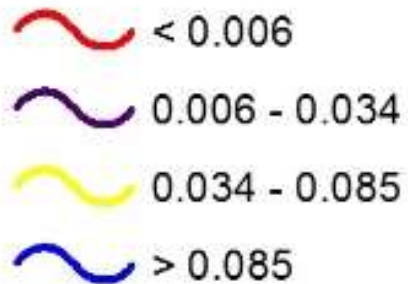
*VIC projections as modified by Safeeq et al. (2014)



Mean Summer Flows – 1980s



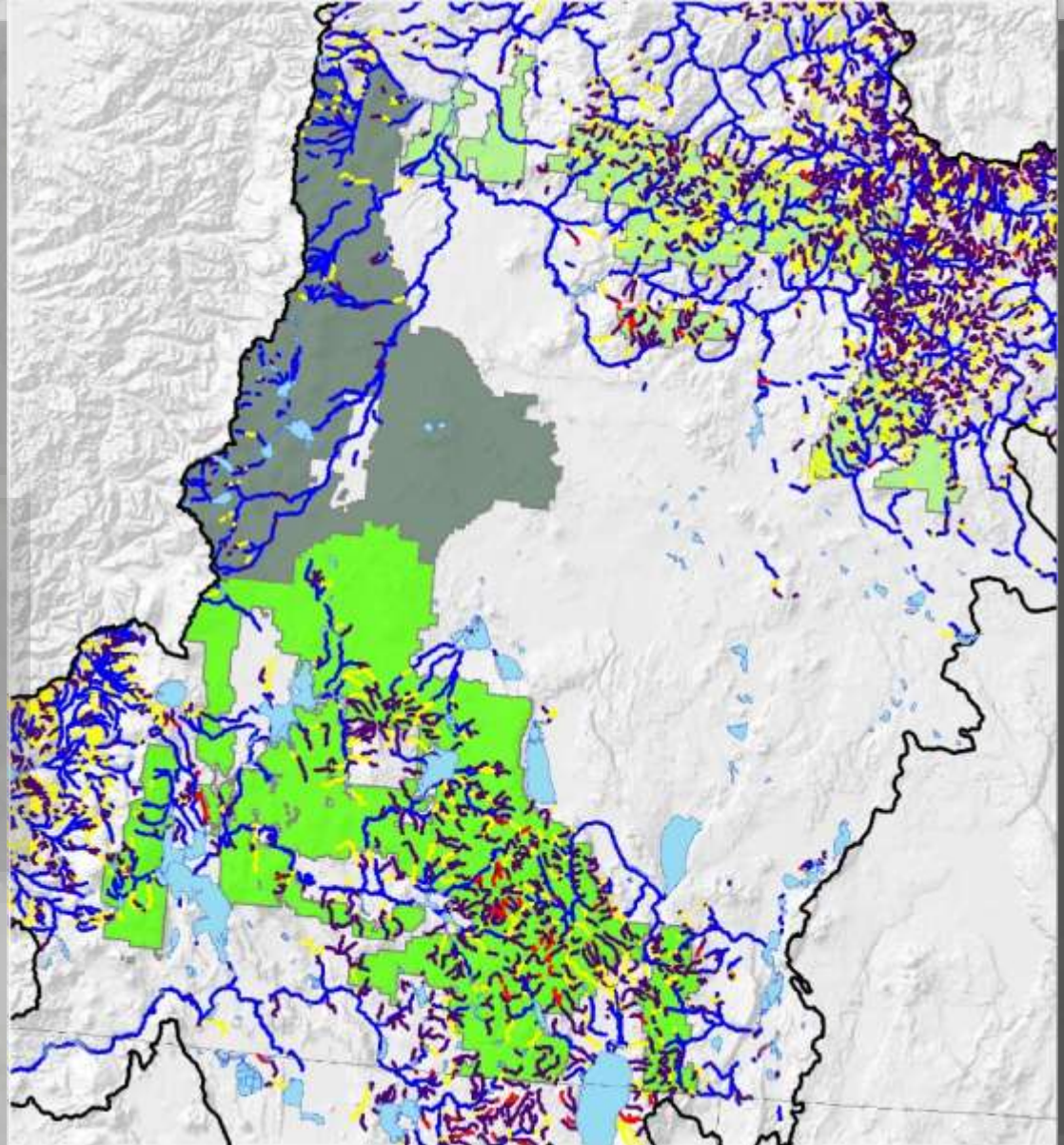
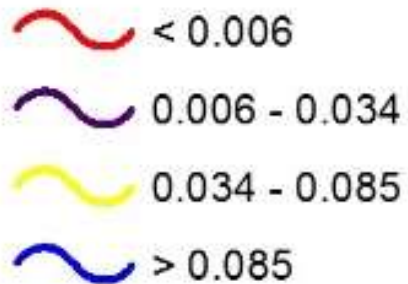
Mean Summer Flow (cms)



Mean Summer Flows – 2080s



Mean Summer Flow (cms)

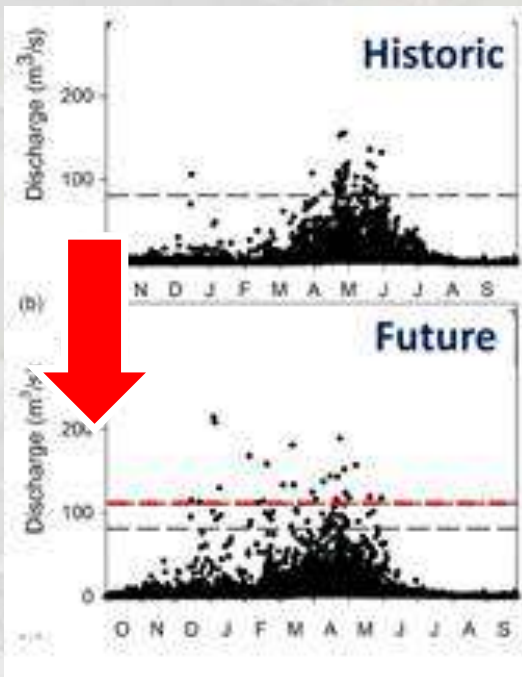


Changes in Winter High Flows - Summary

Winter95 flow metric



Winter95 flow metric	All lands		USFS lands	
	<u>Number of Days</u>	<u>Days Increase</u>	<u>Number of Days</u>	<u>Days Increase</u>
Baseline (1970-1999)	10.5	-	9.8	-
2040s (2030-2059)	12.4	1.9	12.6	2.8
2080s (2070-2099)	13.2	2.7	13.8	4

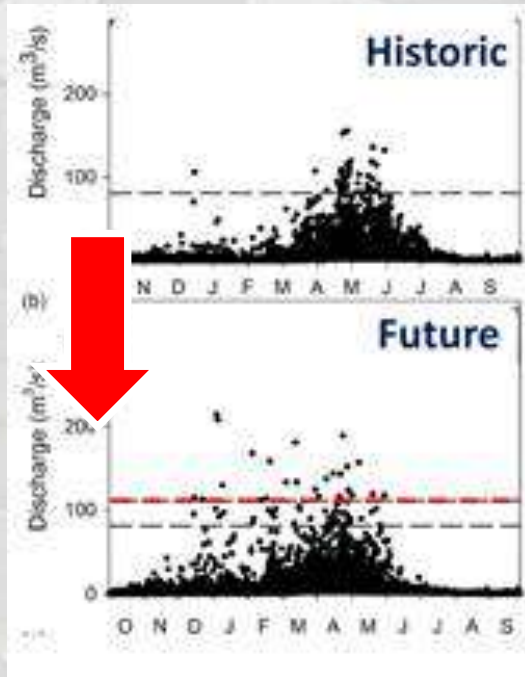


Infrastructure impacts

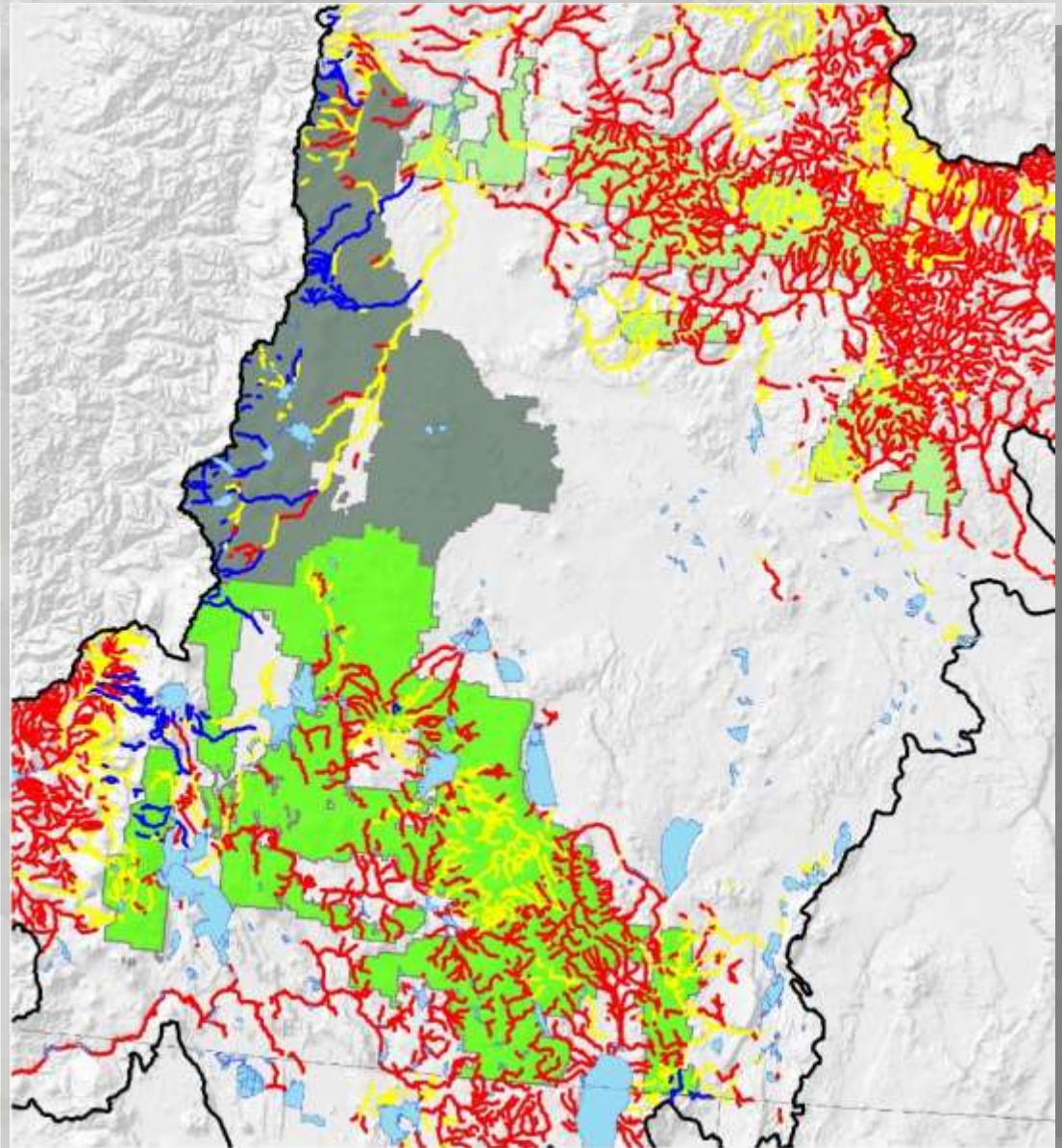
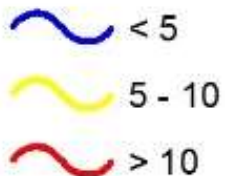


Fall spawner egg & juvenile mortality

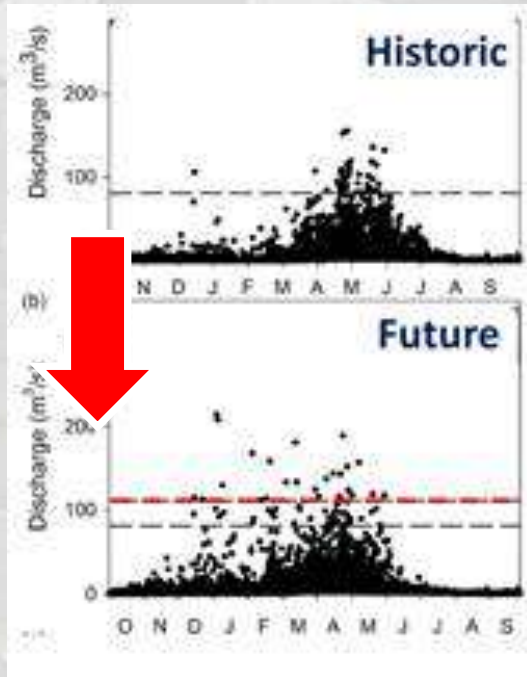
Winter High Flow Days – 1980s



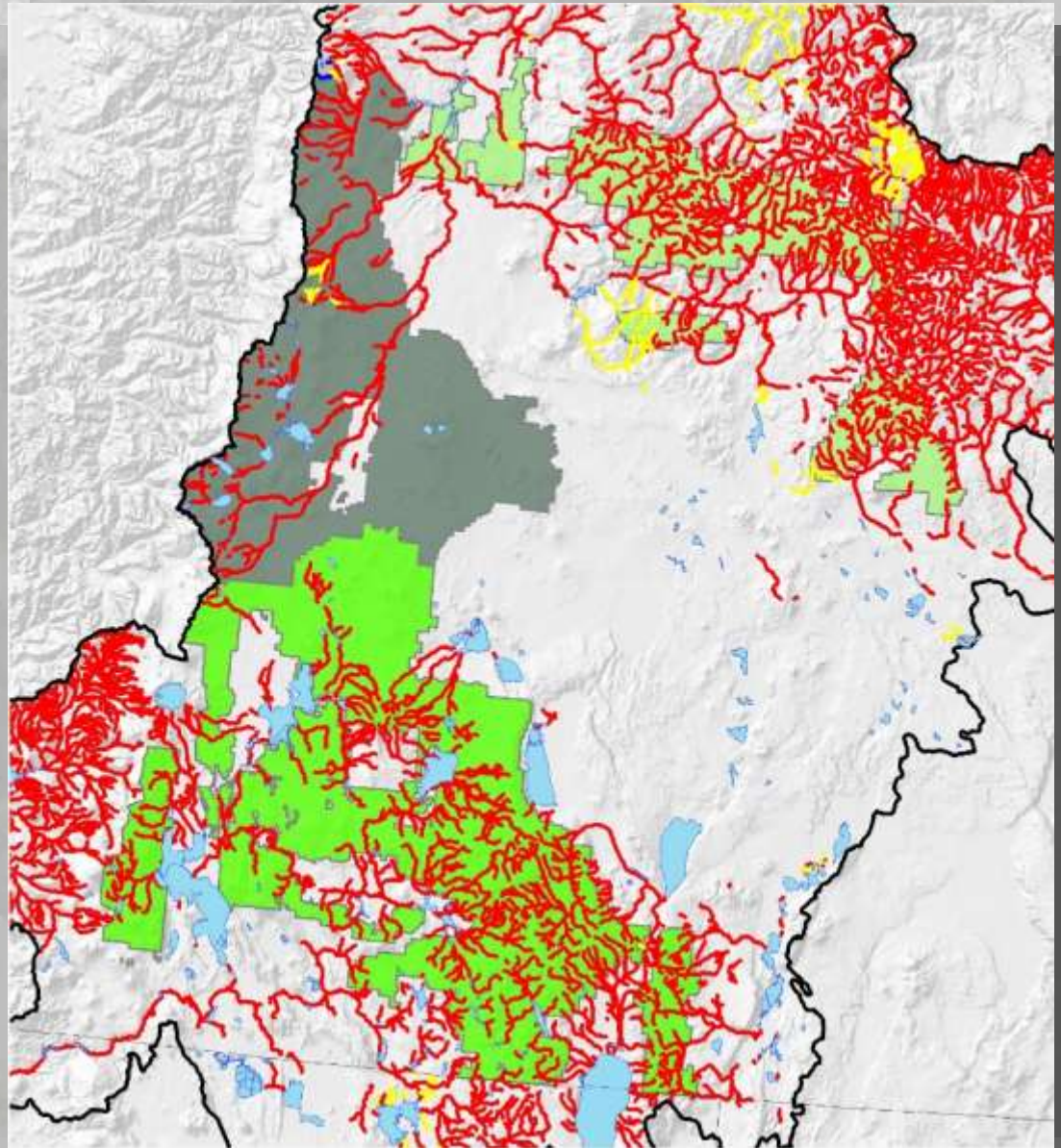
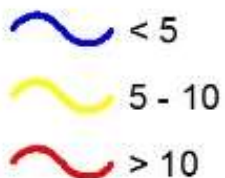
*Number of days that
winter flow is among
highest 5% for the year*



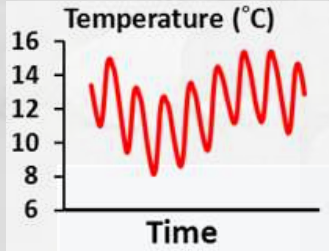
Winter High Flow Days – 2080s



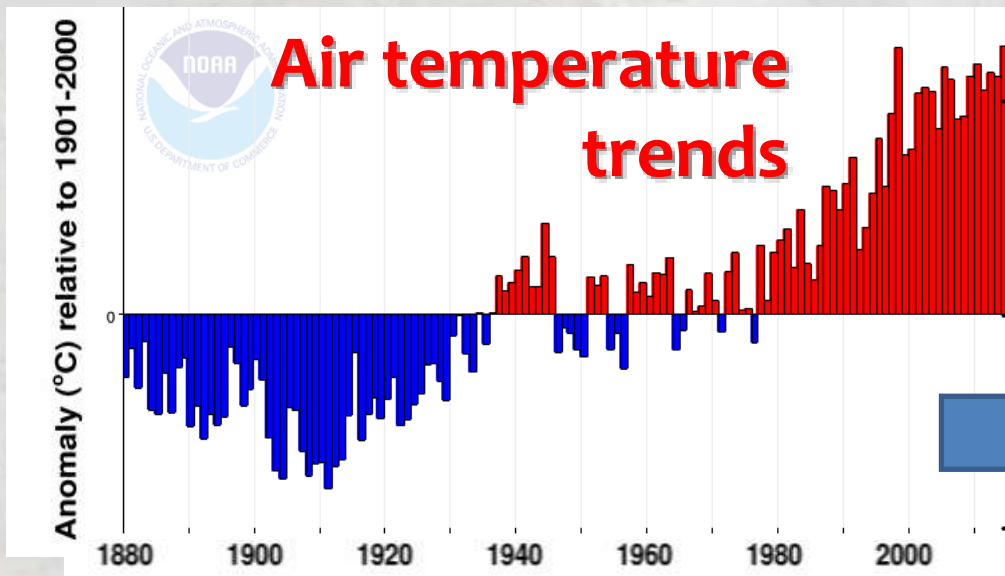
*Number of days that
winter flow is among
highest 5% for the year*



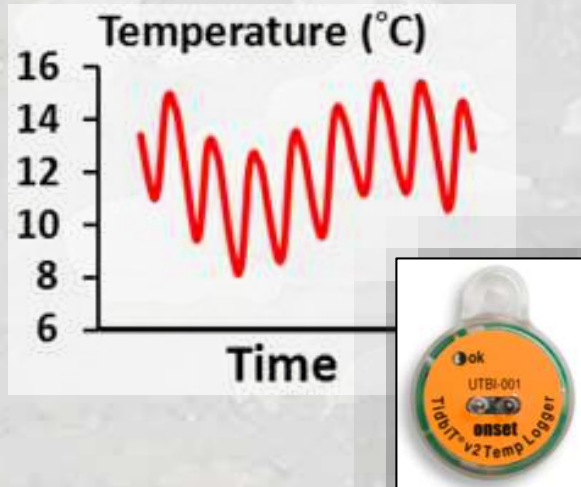
Changes in Summer Stream Temperature



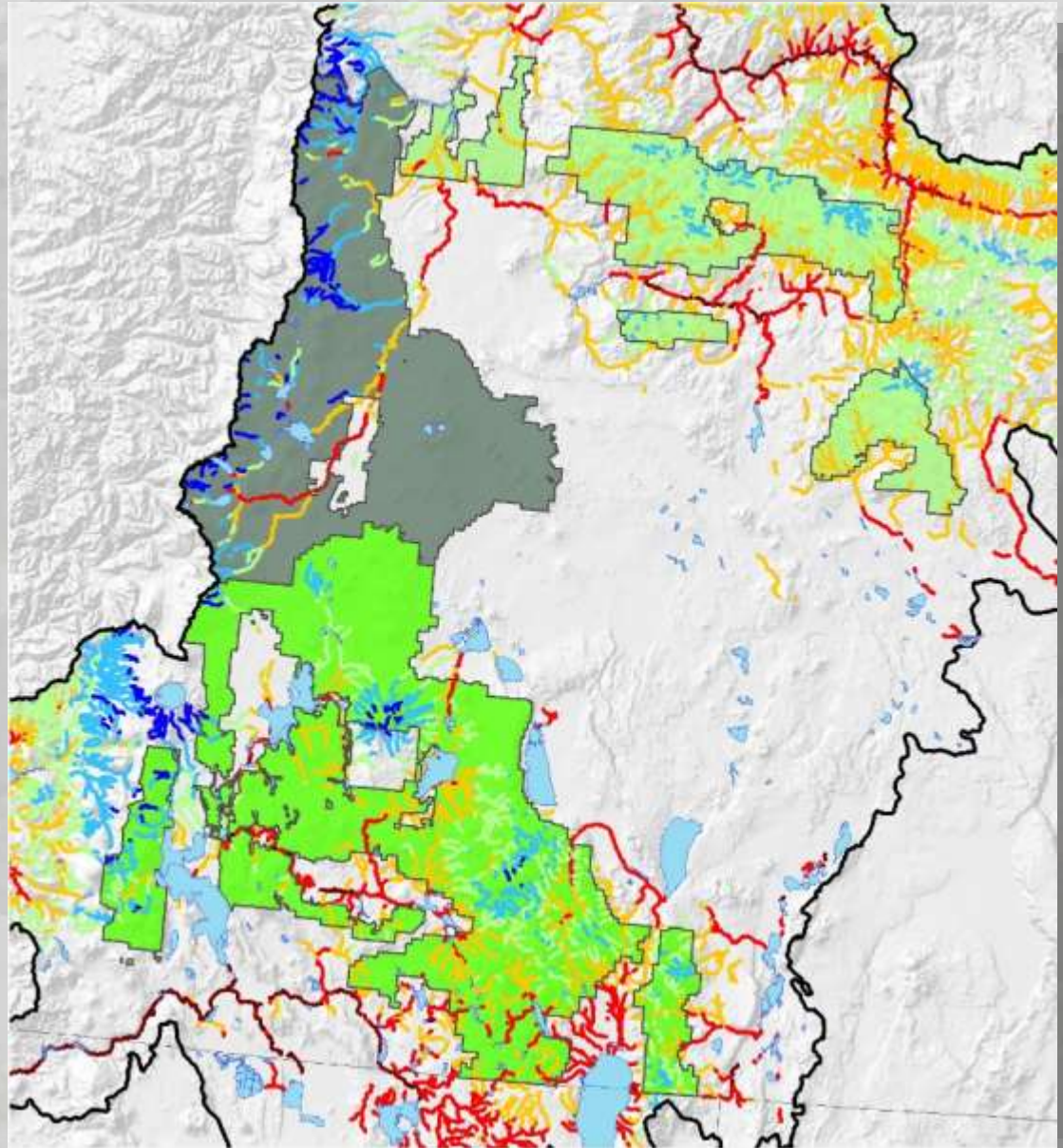
	<u>All lands</u>	<u>USFS lands</u>
Baseline (1970-1999)	-	-
2040s (2030-2059)	1.3°C	1.2°C
2080s (2070-2099)	2.2°C	2.0°C



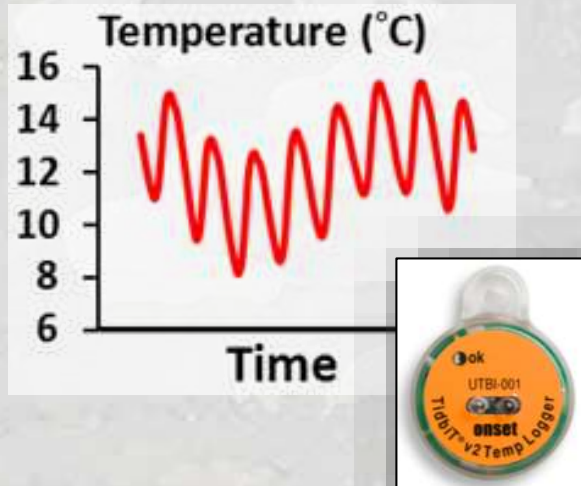
Summer Stream Temperature – 1980s



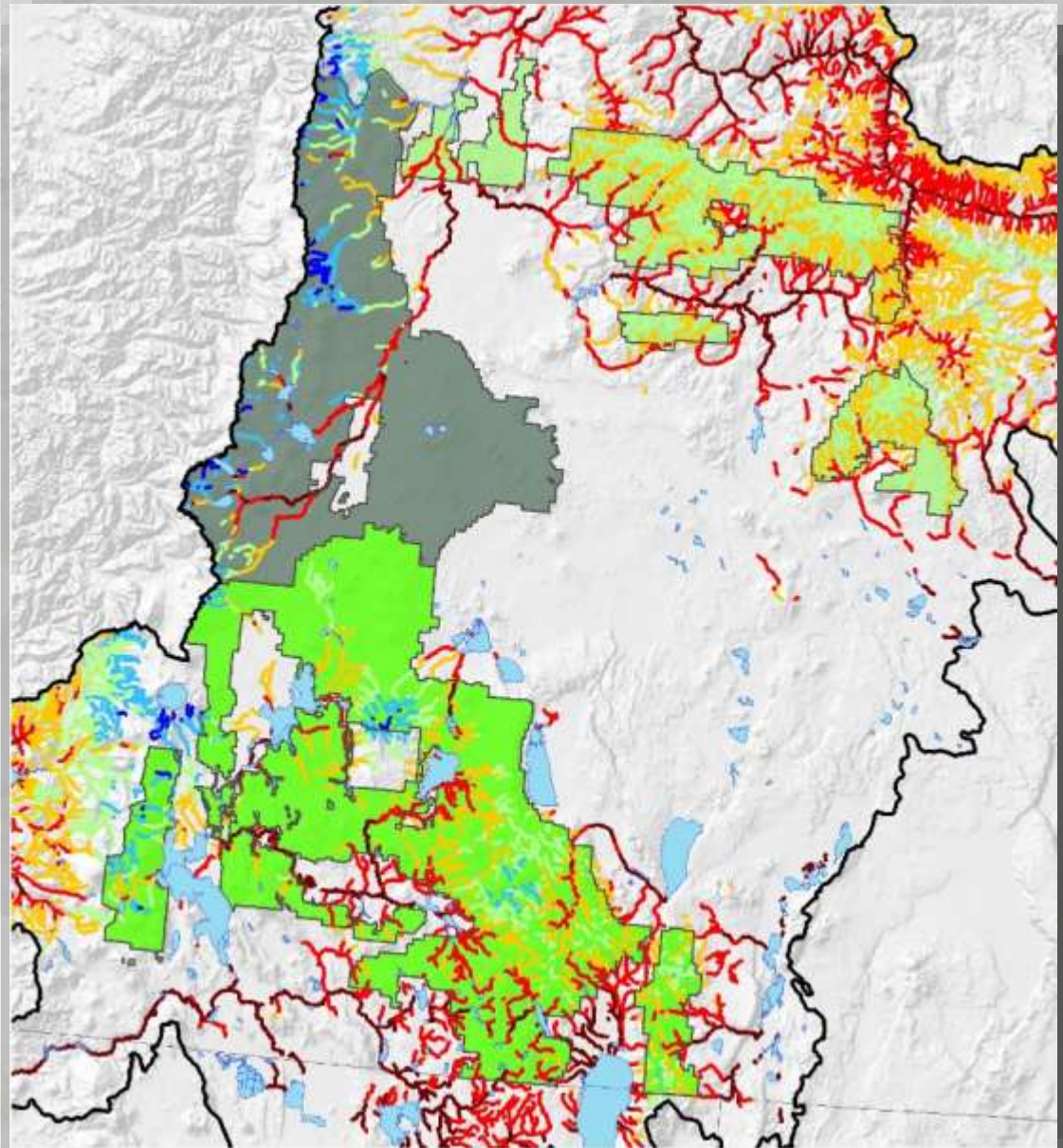
August Mean Temperature (°C)



Summer Stream Temperature – 2080s



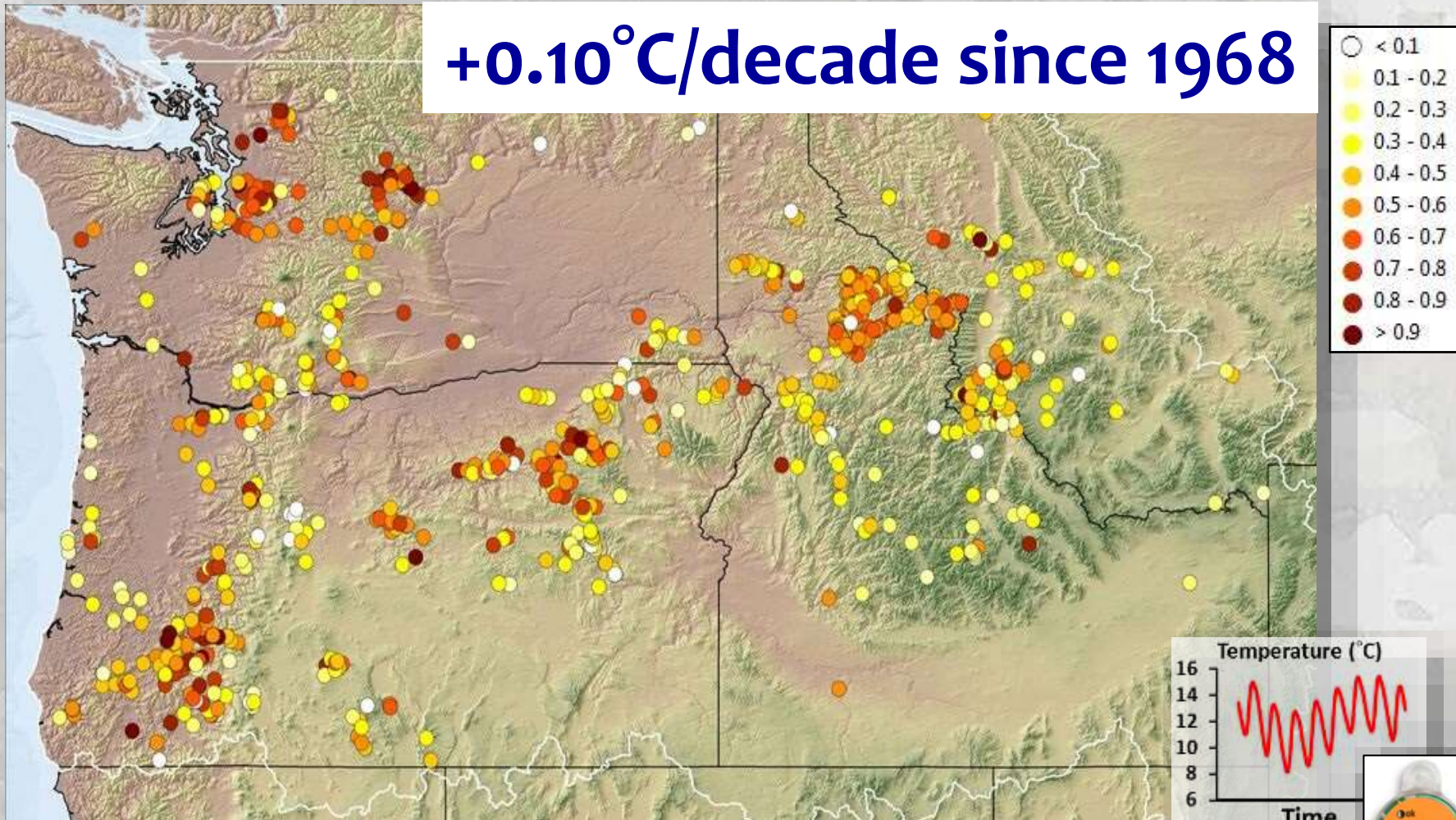
August Mean Temperature (°C)



Heterogeneity in Stream Warming Rates

923 sites in NorWeST database with >10 year records

+0.10°C/decade since 1968



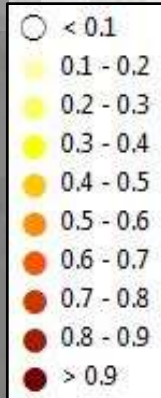
Isaak et al. 2016. Slow climate velocities of mountain streams portend their role as refugia for cold-water biodiversity. *Proc Nat Acad Sci*

Heterogeneity in Stream Warming Rates

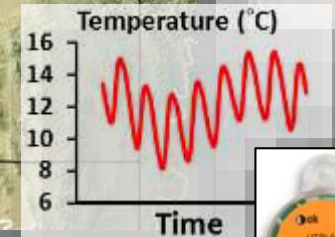
923 sites in NorWeST database with >10 year records

+0.10°C/decade since 1968

Weather Stations



**Air trend =
0.21°C/decade**





...the velocities of mountain streams portend their re
...perugia for cold water biodiversity. *Proc Nat Acad Sci*

Effects to Mid-Columbia River Steelhead

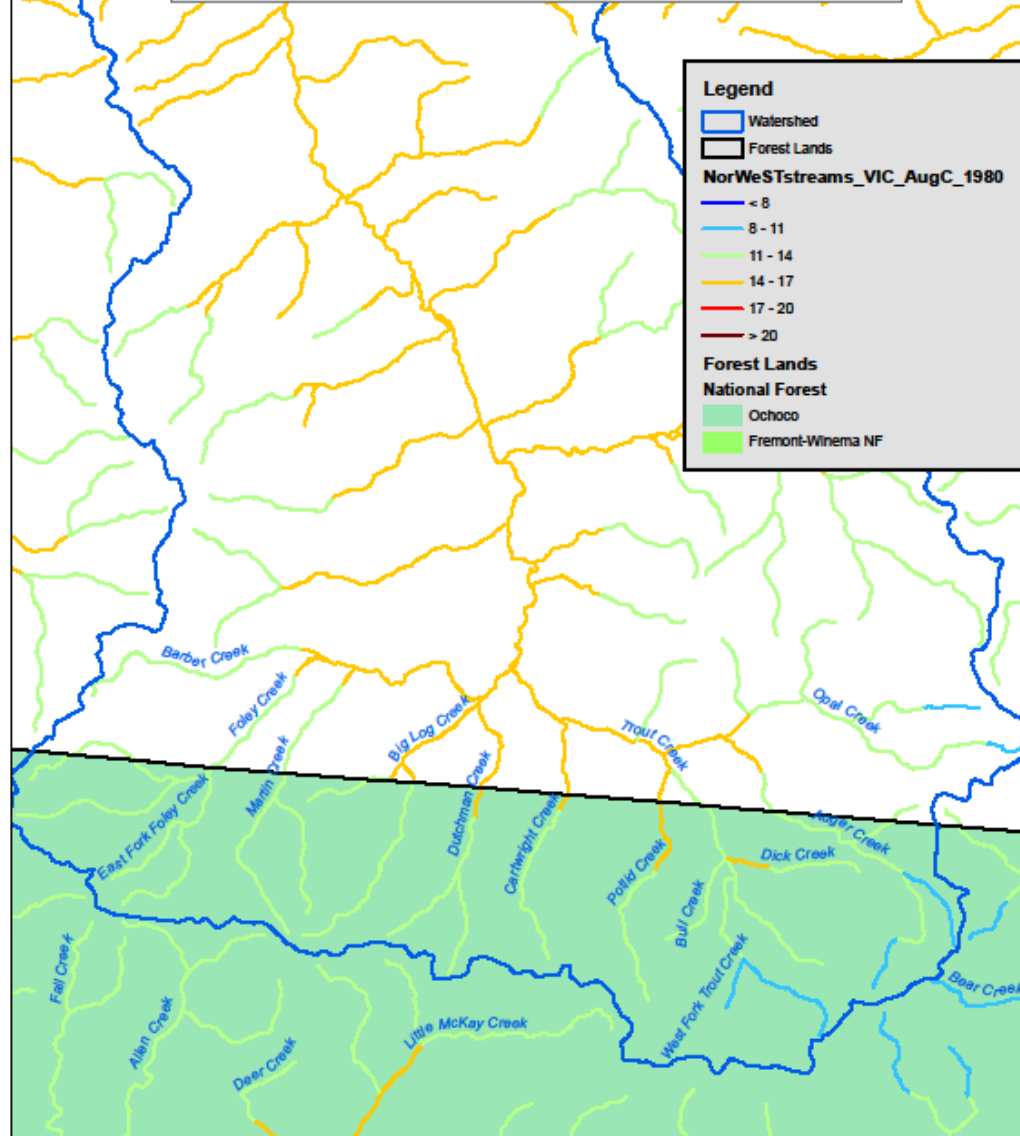
Cascades Eastern Slope Tributaries & John Day River

- Largest Risk - Increases in summer stream temperature
- Models predict stream temperatures outside optimal range – increase of 37% and 33% respectively
- Reduction in available habitat, some of which is already in a degraded condition
- Winter peak flows & summer flow mostly maintained

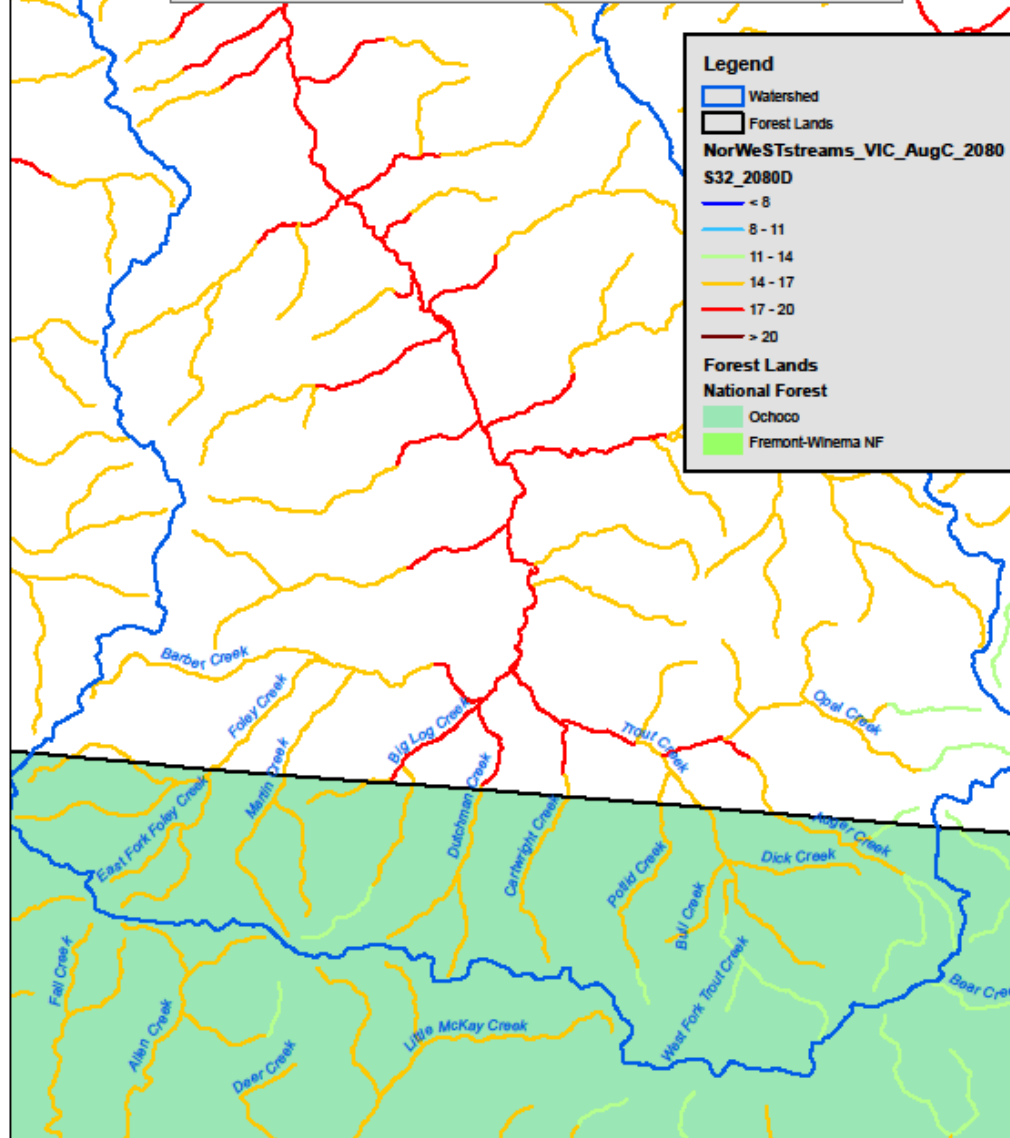
		Number of high flow days					
Stream metric	Period	<5	5-10	>10			
Winter 95% flow	1980s	0.1%	24%	76%			
	2040s	0	12%	88%			
	2080s	0	9%	91%			
		m³/s					
		<0.034	0.034-0.085	>0.085			
Summer flow	1980s	9%	14%	77%			
	2040s	10%	14%	76%			
	2080s	11%	14%	75%			
		Stream kilometers					
		<8	8-11	11-14	14-17	17-20	>20
August temp	1980s	0.4%	6%	19%	38%	26%	11%
	2040s	0.1%	2%	12%	29%	39%	18%
	2080s	0	1%	8%	23%	39%	29%



NorWeST August Stream Temperatures Using the VIC Model - 1980




NorWeST August Stream Temperatures Using the VIC Model - 2080



Effects to Redband Trout

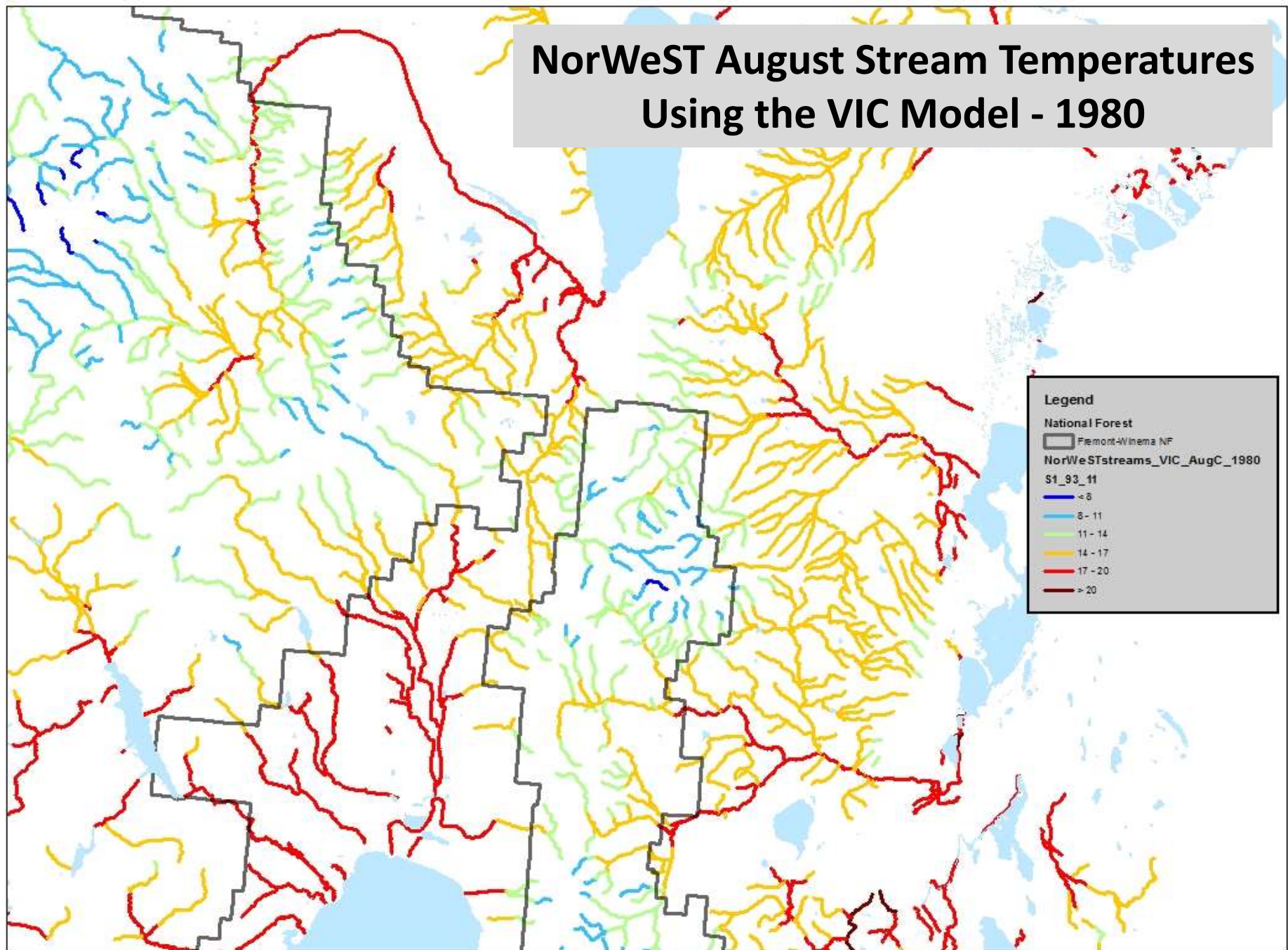
Throughout Analysis Area

- **Largest Risk - Increases in summer stream temperature**
- **Summer base flows mostly maintained**
- **Models predict that by 2040 the majority of the redband occupied streams will experience more than 10 days with the highest 5% winter peak flows**

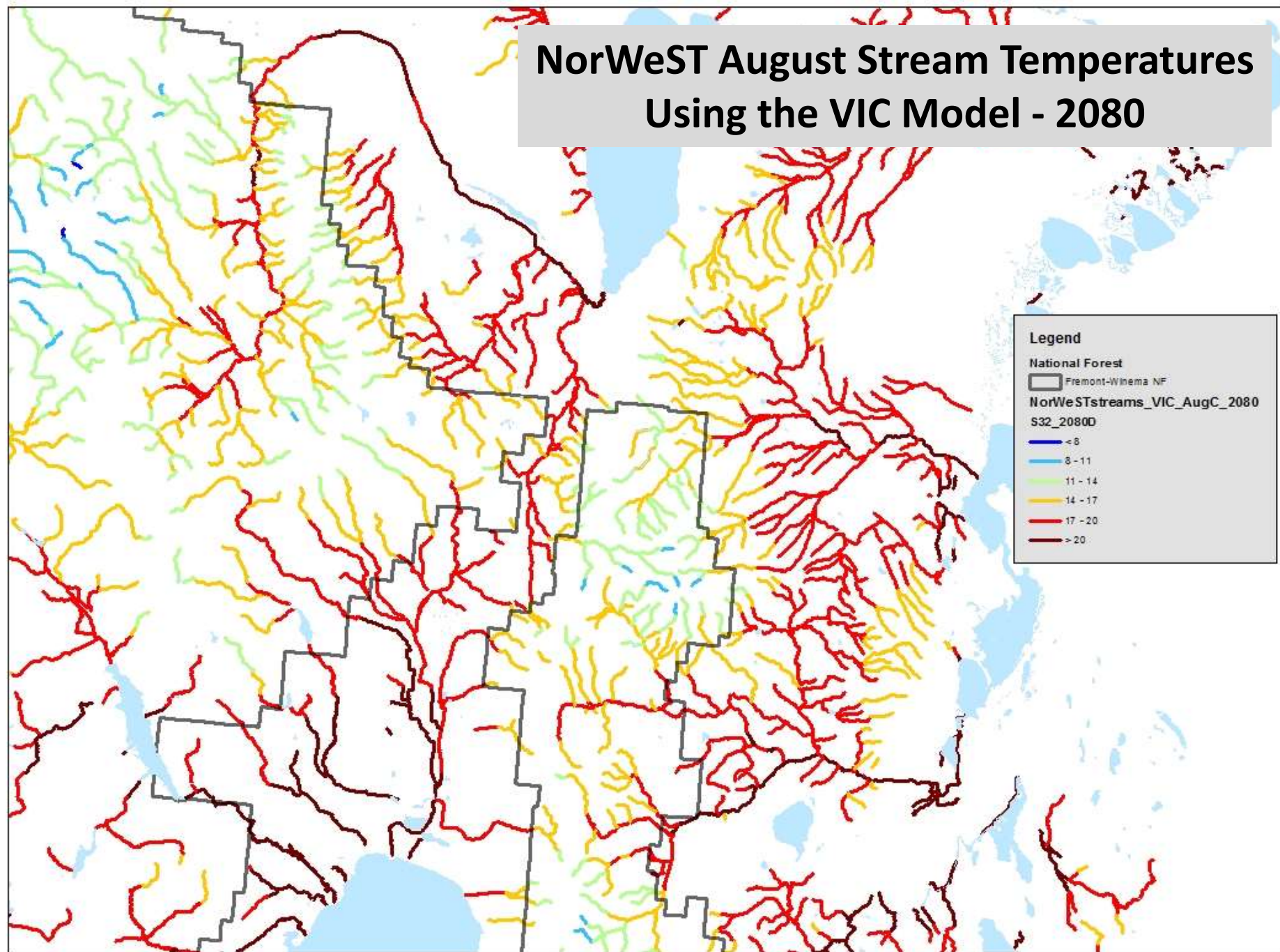
		Number of high flow days					
Stream metric	Period	<5	5-10	>10			
Winter 95% flow	1980s	0.1%	26%	73%			
	2040s	0	2%	98%			
	2080s	0	1%	99%			
		m³/s					
		<0.034	0.034-0.085	>0.085			
Summer flow	1980s	17%	20%	63%			
	2040s	21%	20%	59%			
	2080s	23%	20%	56%			
		Stream kilometers					
		<8	8-11	11-14	14-17	17-20	>20
August temp	1980s	1%	8%	29%	38%	21%	4%
	2040s	1%	4%	19%	38%	29%	9%
	2080s	1%	5%	15%	35%	28%	16%



NorWeST August Stream Temperatures Using the VIC Model - 1980



NorWeST August Stream Temperatures Using the VIC Model - 2080




Effects to Lost River Sucker and Shortnose Sucker

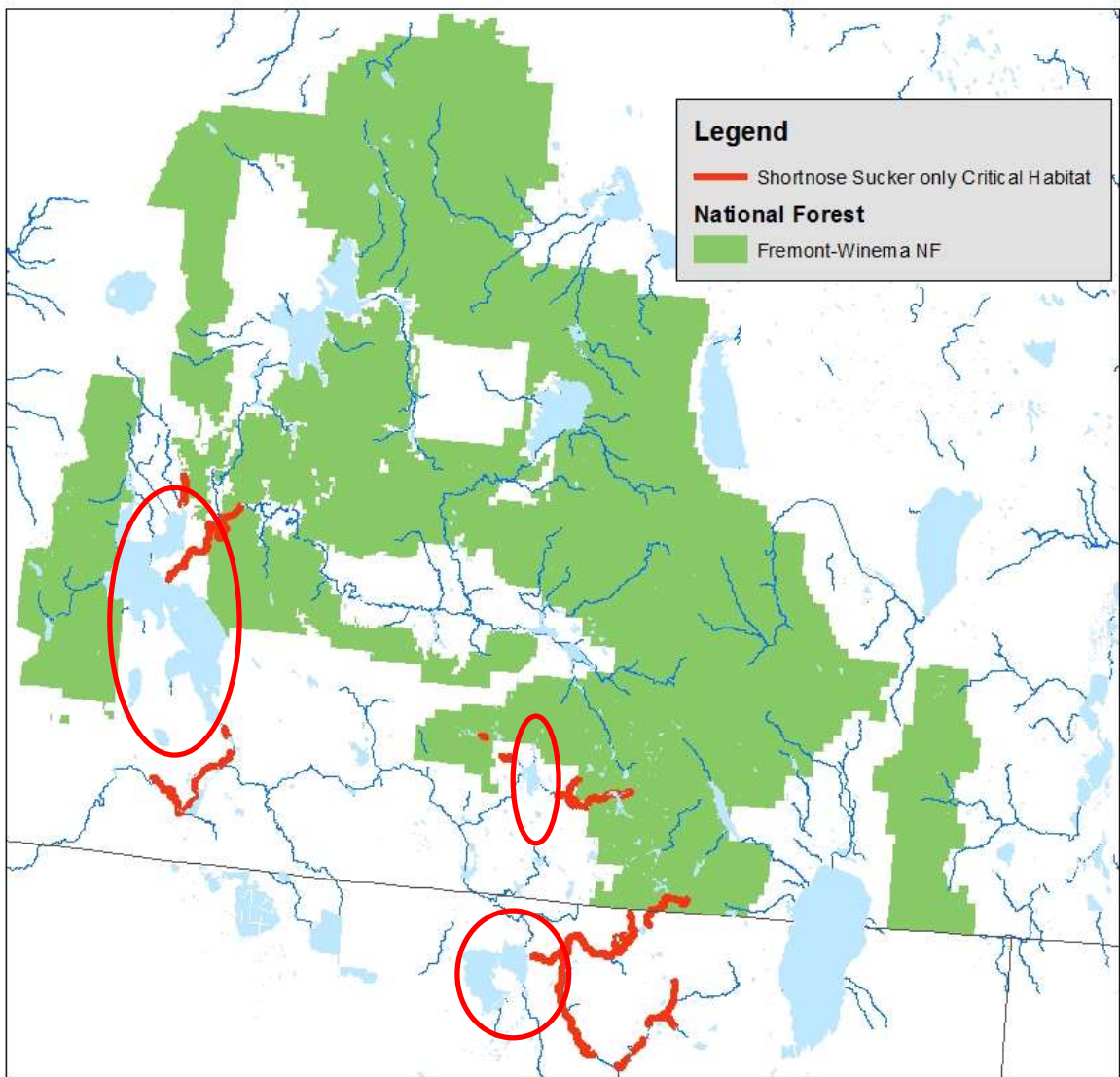
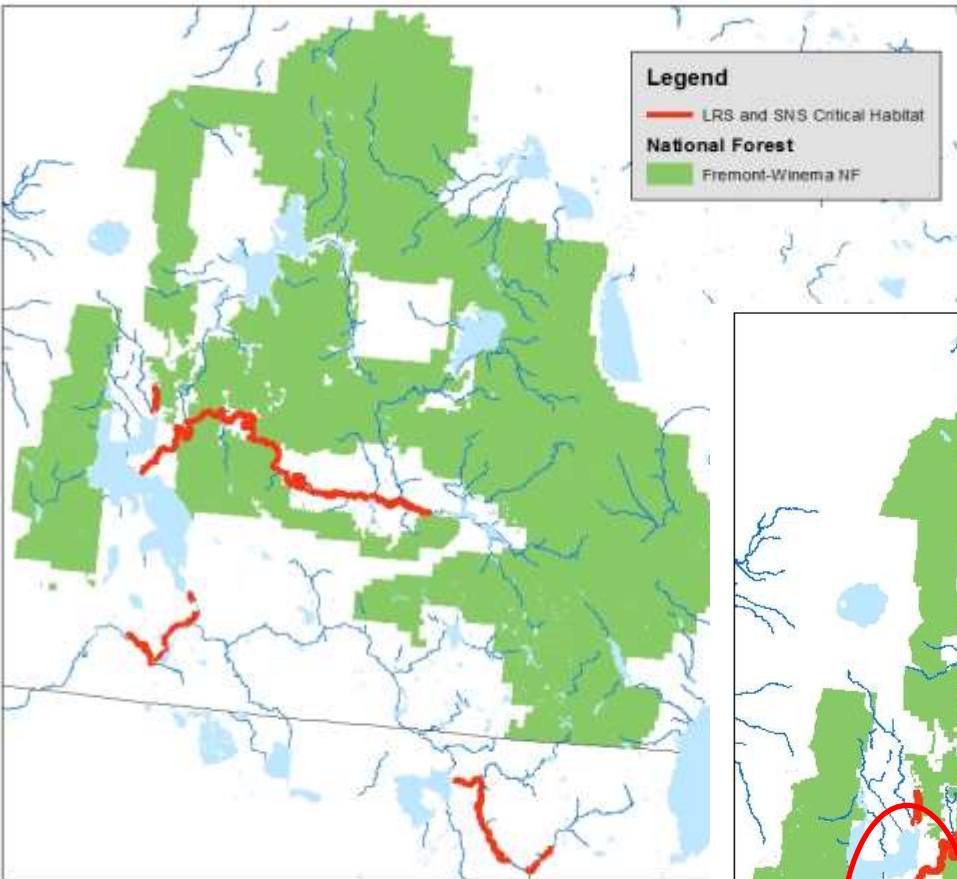
Upper Klamath Lake and Lost River Basin Recovery Units

- Largest Risk on National Forest streams – Loss of stream flow
- Winter peak flows and summer flow remain similar to current modeled conditions
- Extensive modification of historic habitat, intermittent flows, isolation and increasingly limited access between lake habitats and stream spawning habitats.

		Number of high flow days					
Stream metric	Period	<5	5-10	>10			
Winter 95% flow	1980s		5%	95%			
	2040s			100%			
	2080s			100%			
		m³/s					
		<0.034	0.034-0.085	>0.085			
Summer flow	1980s	8.5%	8.5%	83%			
	2040s	11%	8%	82%			
	2080s	13%	7%	80%			
		Stream kilometers					
		<8	8-11	11-14	14-17	17-20	>20
August temp	1980s			3%	8%	66%	23%
	2040s			1%	5%	45%	49%
	2080s				4%	18%	78%







Legend

2080s cfs < 1.2 cfs

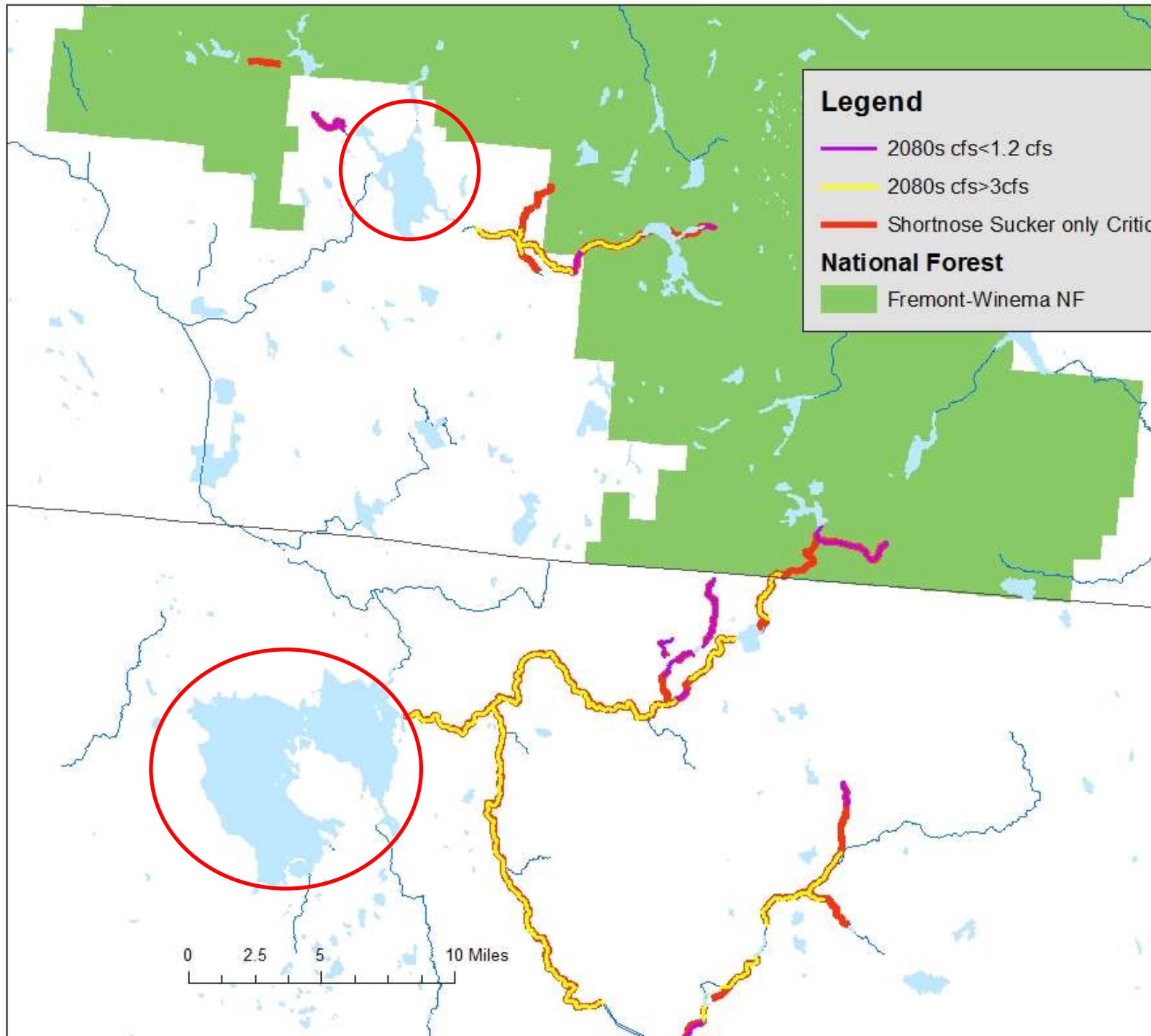
2080s cfs > 3 cfs

Shortnose Sucker only Critical Habitat

National Forest

Fremont-Winema NF

0 2.5 5 10 Miles


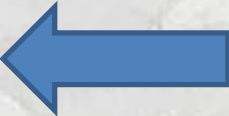


Effects to Bull Trout

Odell Lake

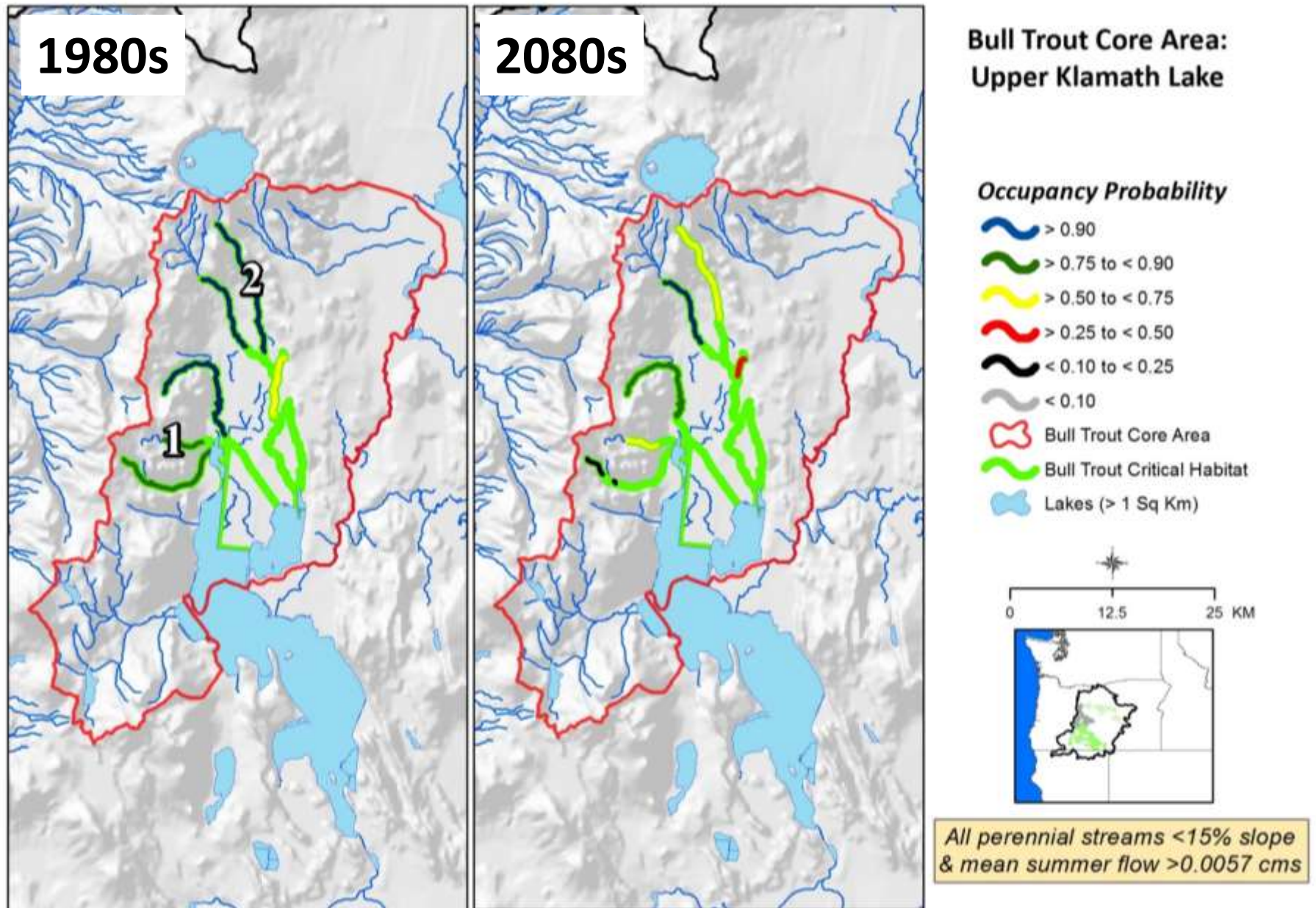
- Largest Risk – Increase in winter peak flows
- Models predict the highest 5% winter peak flows are expected to increase by 100% by 2080
- Summer stream temperatures not expected to increase significantly, but 10% estimated reduction in headwater summer bull trout habitat
- Core area already has a small population, fragmented habitat and limited spawning habitat
- Changes put population at high risk – reduction in available habitat, direct redd effects, reduced headwater habitat availability

		Number of high flow days					
Stream metric	Period	<5	5-10	>10			
Winter 95% flow	1980s	100%	0	0			
	2040s	11%	67%	22%			
	2080s	0	0	100%			
		m³/s					
		<0.034	0.034-0.085	>0.085			
Summer flow	1980s	0	12%	88%			
	2040s	12%	10%	78%			
	2080s	12%	10%	78%			
		Stream kilometers					
		<8	8-11	11-14	14-17	17-20	>20
August temperature	1980s	85%	0	15%			
	2040s	85%	0	0	15%		
	2080s	85%	0	0	15%		





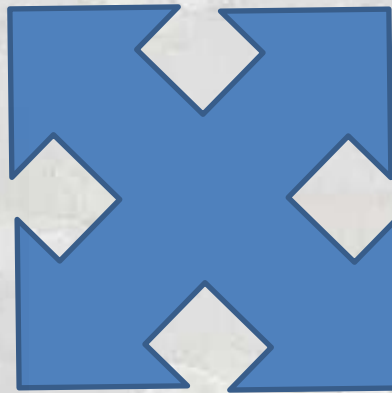
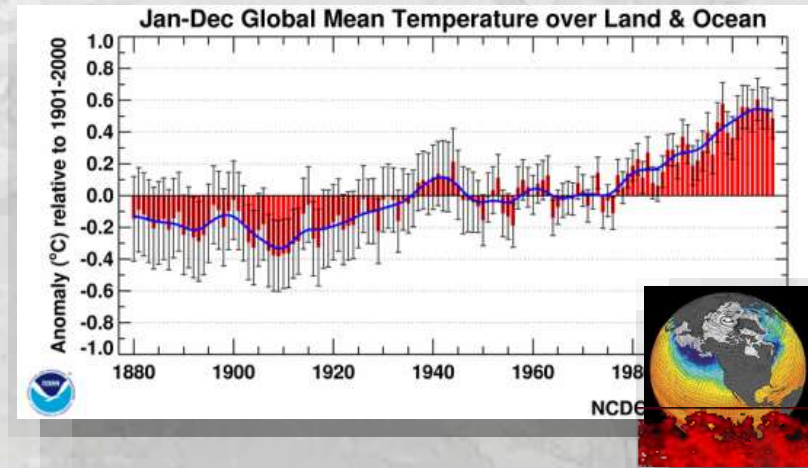
Bull Trout Habitat



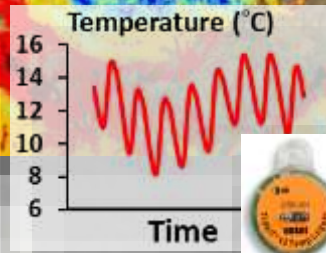
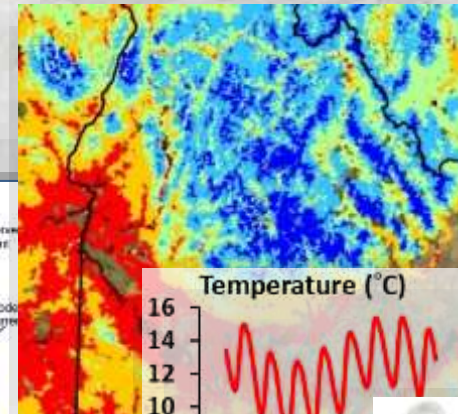
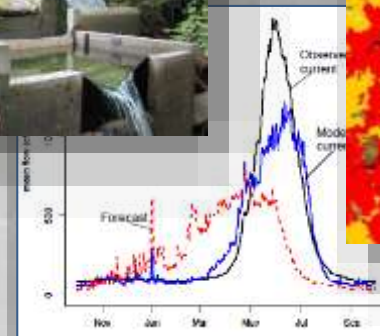
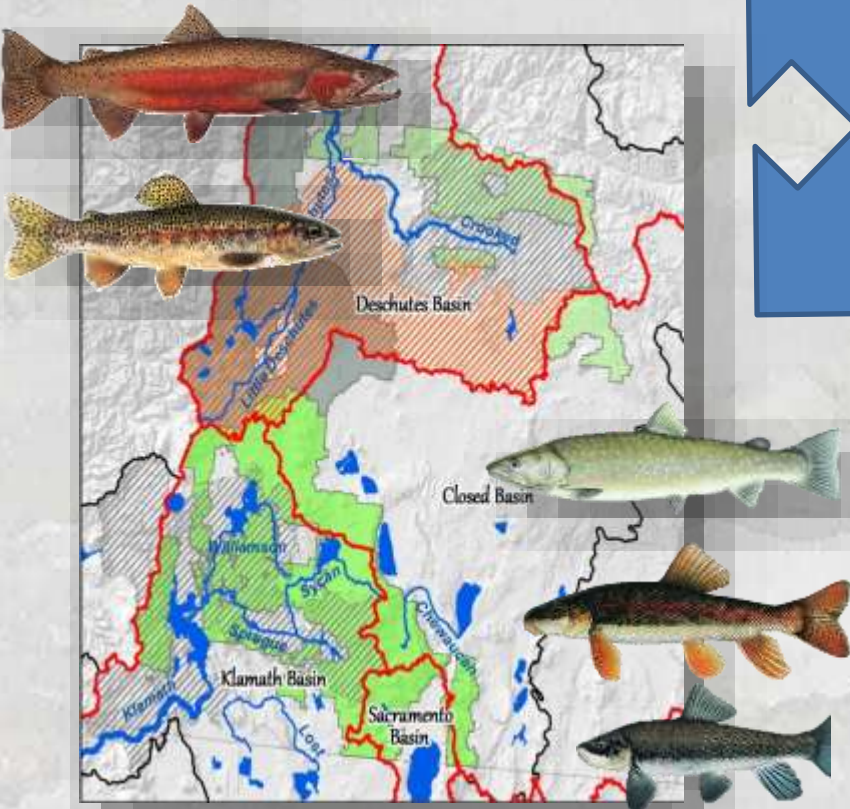
Fish Climate Vulnerability

What matters?

- 1) species considered
- 2) stream location
- 3) climate factor



Where do
vulnerabilities meet
“on-the-ground”
opportunities?



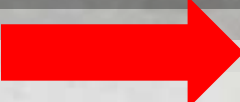
Climate Vulnerability Could Provide a Context for Prioritizing Stream Restoration Efforts...

2013 Aquatic and Riparian Restoration Annual Report
USDA Forest Service Pacific Northwest Region



- Modifying road culverts...
- Maintaining/restoring flow...
- Maintaining/restoring riparian...
- Restoring channel form/function...
- Non-native species control...
- Large woody debris...



Before  After



Forest Datasets Were Key to The Quality of This Assessment...



**& Will Be Key to Improving
Assessments in *Future* Decades...**



The End