Integrating future climate change and riparian land-use to forecast the effects of stream warming on species invasions and their impacts on native salmonids

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Research Team

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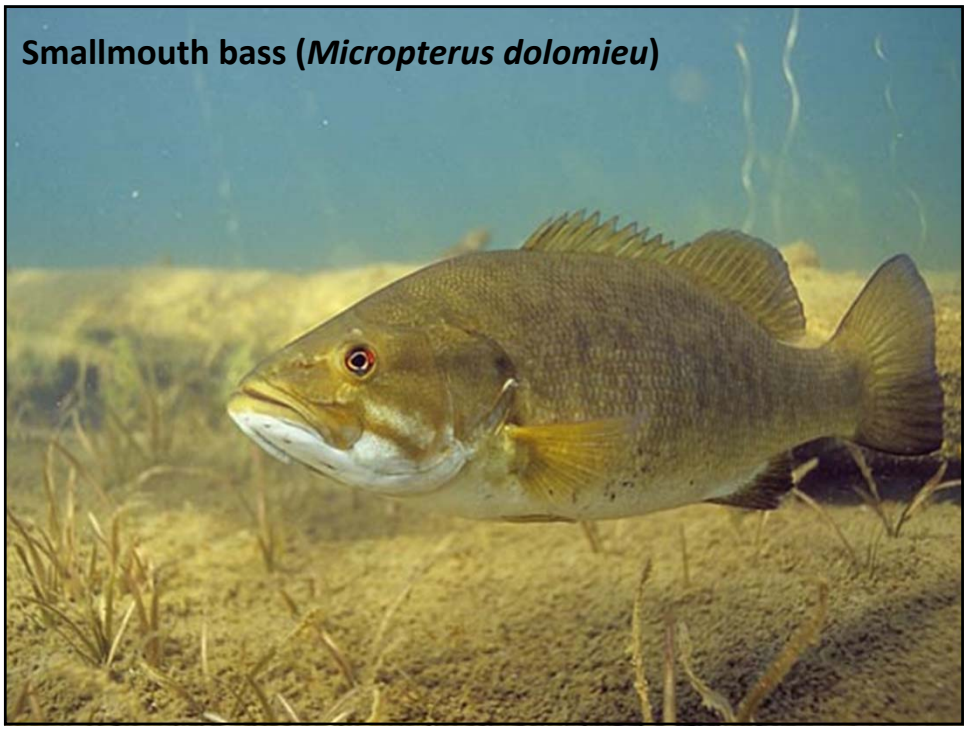
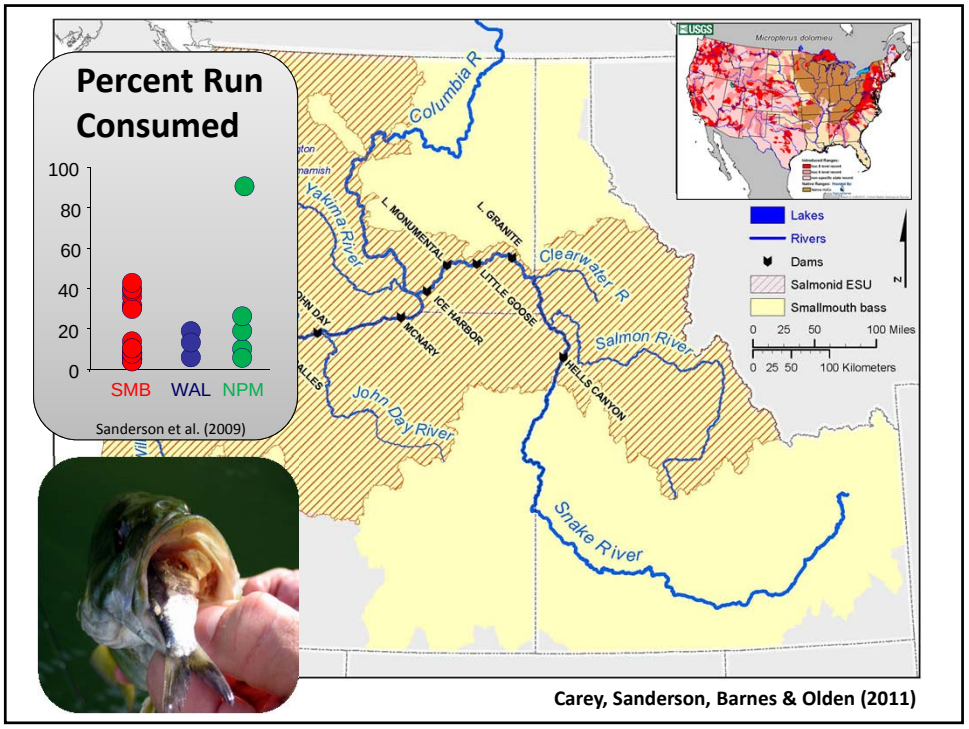
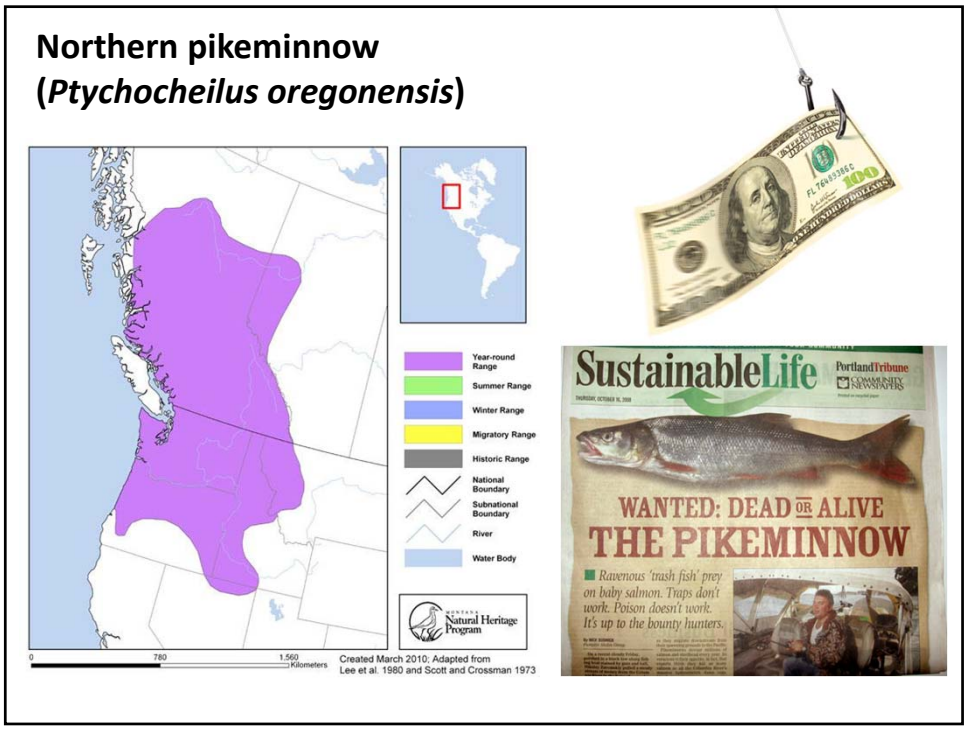
Challenge Synopsis

- The prospect of dramatic climate change over the next century underscores the need for innovative science and new decision-support tools for efficiently managing freshwater ecosystems
- Elevated stream temperature is one of the most pervasive water quality issues threatening freshwater ecosystems in the Pacific Northwest
- Cumulative effects and complex interactions among multiple agents of environmental change are unknown

Smallmouth bass (*Micropterus dolomieu*)

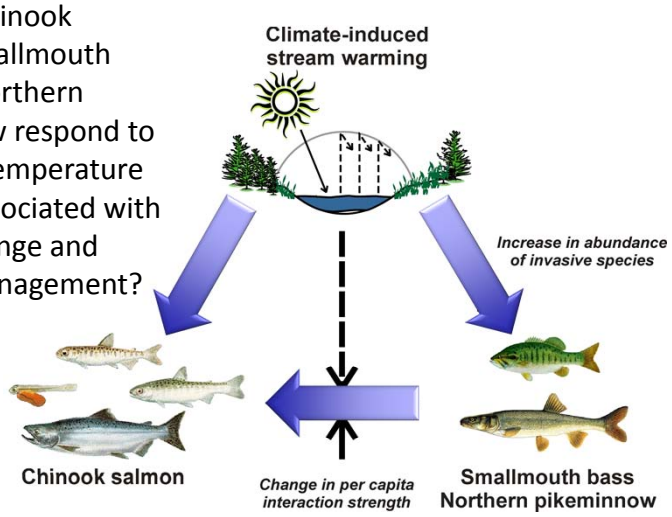



Percent Run Consumed
100
80
60
40
20
0
SMB
WAL
NPM
Sanderson et al. (2009)
Columbia R.
Yakima River
L. MONUMENTAL
L. GRANITE
LITTLE GOOSE
ICE HARBOR
MCNARY
Clearwater R.
Salmon River
HELLS CANYON
John Day River
Snake River
Lakes
Rivers
Dams
Salmonid ESU
Smallmouth bass
0 25 50 100 Miles
0 25 50 100 Kilometers
Carey, Sanderson, Barnes & Olden (2011)


Northern pikeminnow
(Ptychocheilus oregonensis)
Year-round Range
Summer Range
Winter Range
Migratory Range
Historic Range
National Boundary
Subnational Boundary
River
Water Body
Natural Heritage Program
Created March 2010; Adapted from Lee et al. 1980 and Scott and Crossman 1973
SustainableLife
Portland Tribune
WANTED: DEAD OR ALIVE
THE PIKEMINNOW
Ravenous 'trash fish' prey on baby salmon. Traps don't work. Poison doesn't work. It's up to the bounty hunters.

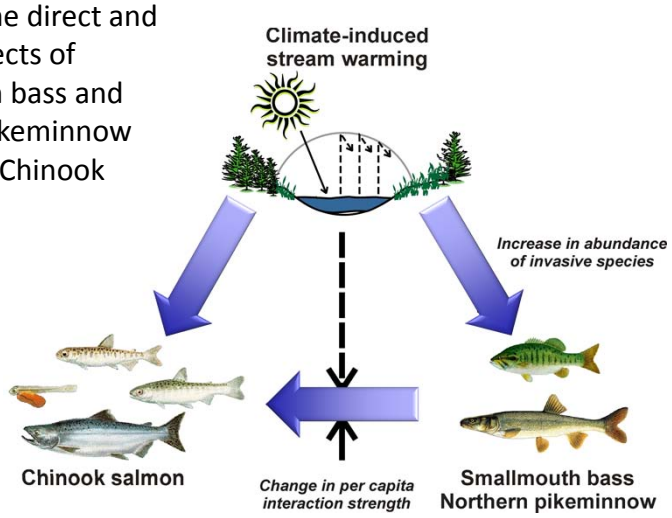
Project Goals

1. How will Chinook salmon, smallmouth bass and northern pikeminnow respond to projected temperature changes associated with climate change and riparian management?



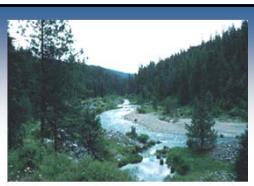
Project Goals

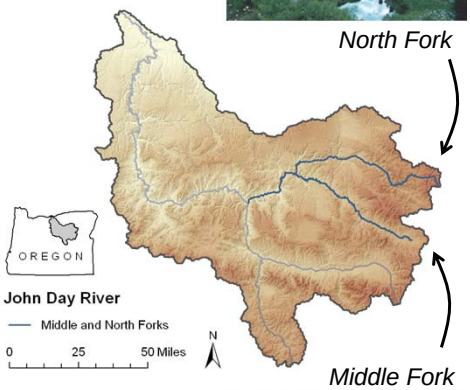
2. What are the direct and <u>indirect</u> effects of smallmouth bass and northern pikeminnow on juvenile Chinook salmon?



Ecological Setting

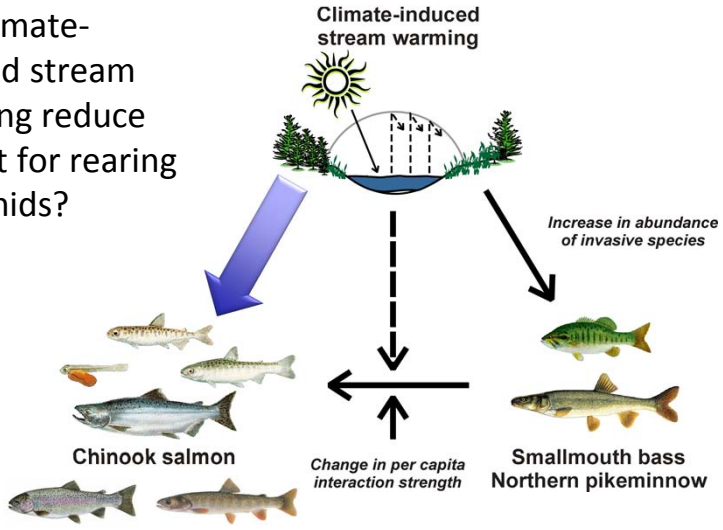
- Land use vary longitudinally
- Unregulated and one of the few remaining wild spring Chinook salmon runs in the Columbia River Basin
- Upstream invasion front of smallmouth bass (and northern pikeminnow)

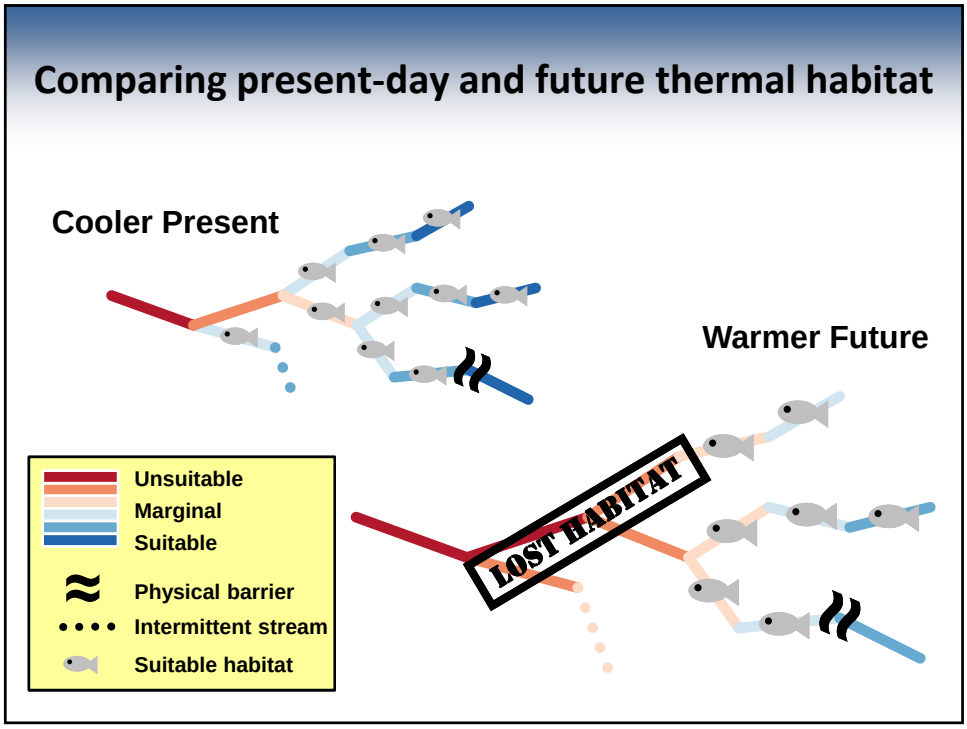


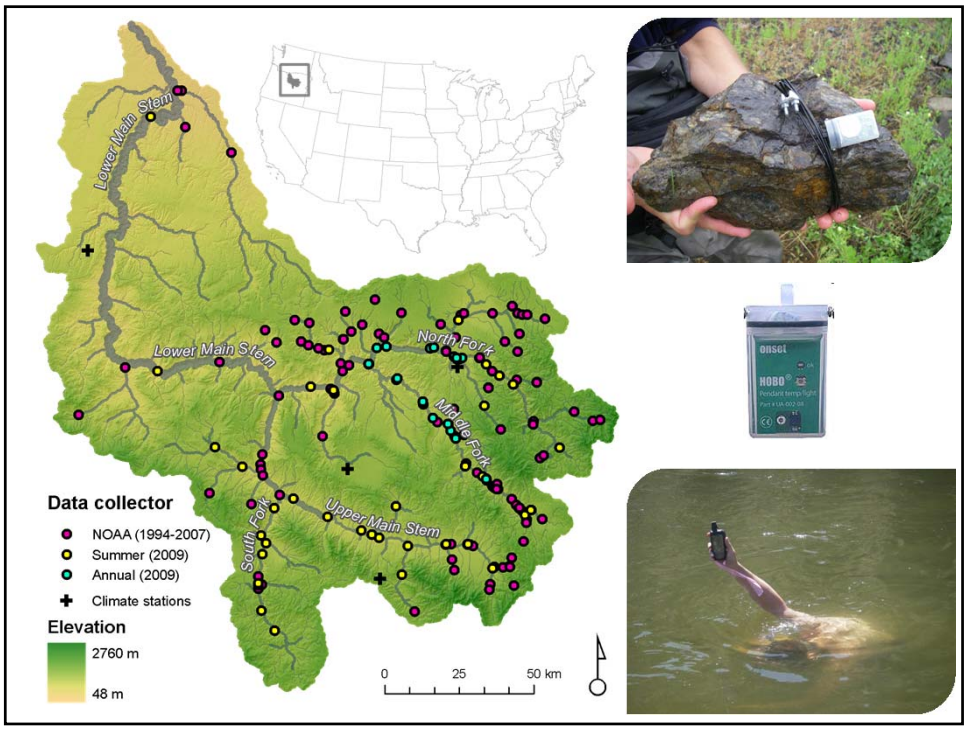


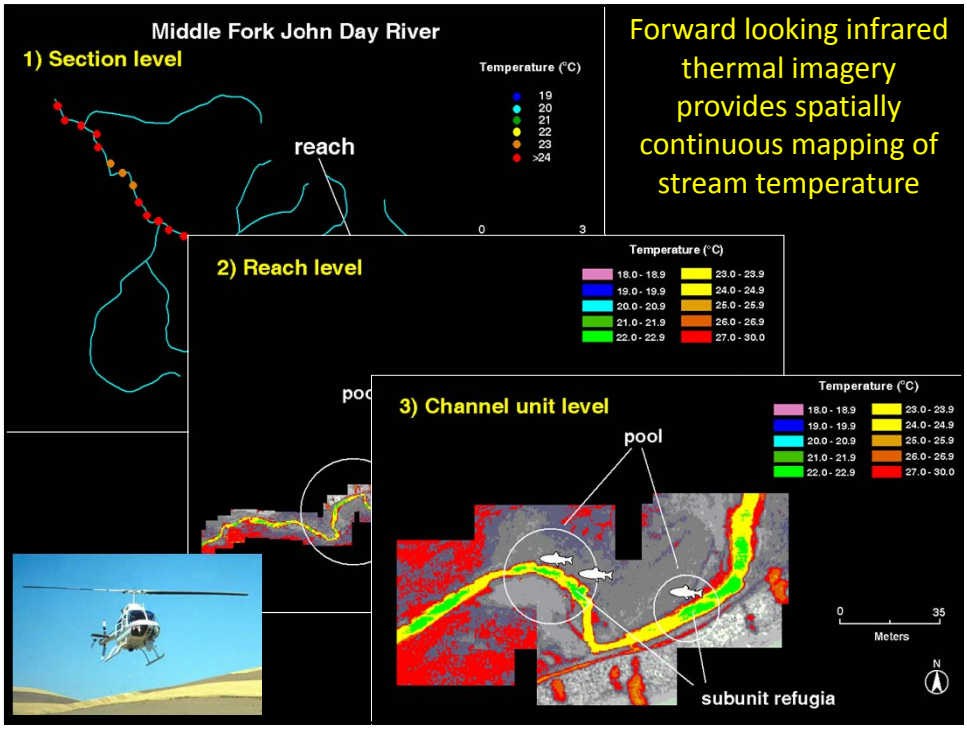
Objective #1

- Will climate-induced stream warming reduce habitat for rearing salmonids?



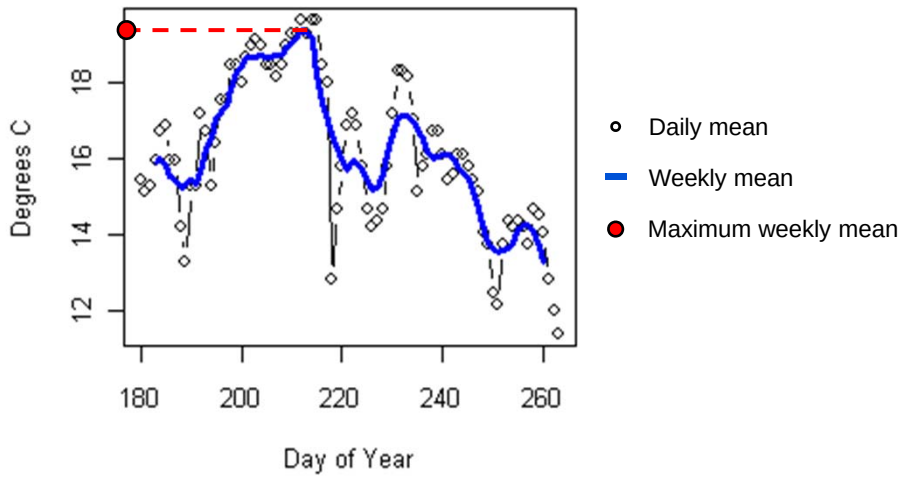

Comparing present-day and future thermal habitat
Cooler Present
Warmer Future
Unsuitable
Marginal
Suitable
Physical barrier
Intermittent stream
Suitable habitat
LOST HABITAT


Lower Main Stem
Lower Main Stem
North Fork
Middle Fork
South Fork
Upper Main Stem
Data collector
NOAA (1994-2007)
Summer (2009)
Annual (2009)
Climate stations
Elevation
2760 m
48 m
0
25
50 km
onset
HOBO



Measure of stream temperature

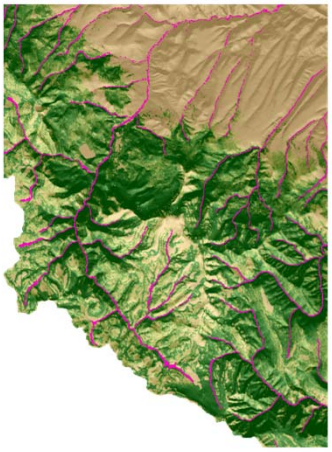
Maximum **W**eekly **M**ean **S**tream **T**emperature (**MWMST**)



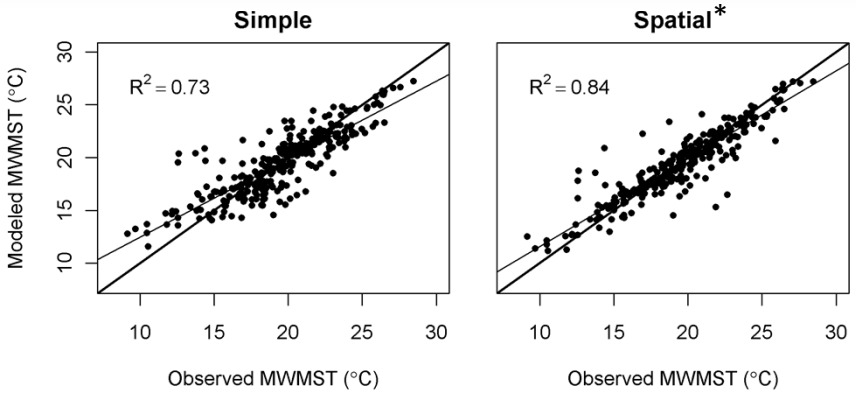
Modeling MWMST

MWMST = ƒ (…

- Mean Elevation
- Maximum 7-day average daily maximum air temperature
- Cumulative Riparian Solar Penetration
  - Amount of annual solar radiation that passes through canopy in riparian areas

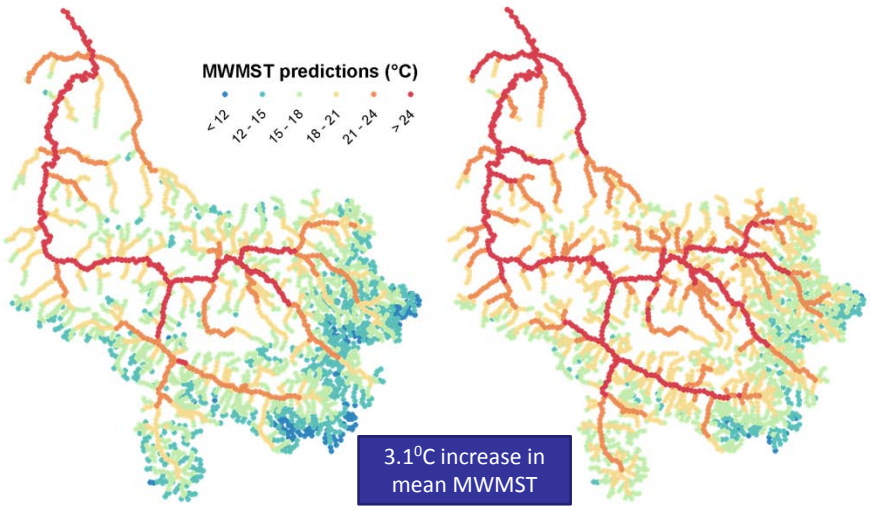


Model performance



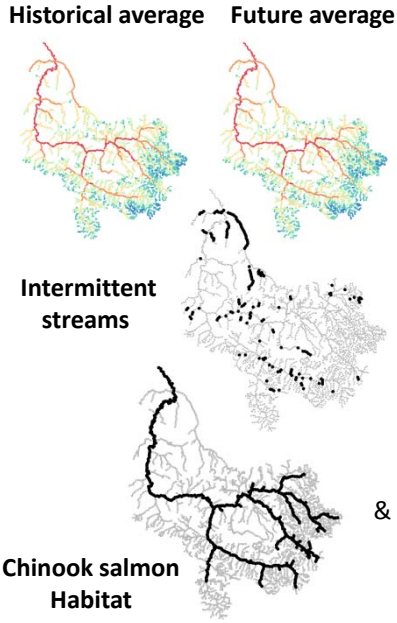
- 1 degree Celsius increase in air temperature results in an 0.6^0C increase in stream temperature

* Geographically-weighted regression for stream networks (Peterson and Ver Hoef 2010)



* Three GCMs (ECHAM5/MPI-O, CNRM-CM3, UKMO-HadCM3) for a mid-range (A1B) greenhouse-gas emissions scenario. Spatially downscaled daily time-step climate projections to a 1/16th degree resolution (Mote and Salathe 2010), and temporally downscaled from one month to daily temporal resolution using a "Hybrid Delta Approach" (Hamlet et al. 2010).

Ruesch et al. (in review)



Calculating habitat loss due to climate change

→ Which sites were < 24⁰C historically, but predicted ≥ 24⁰C in the future (Eaton et al. 1995) …

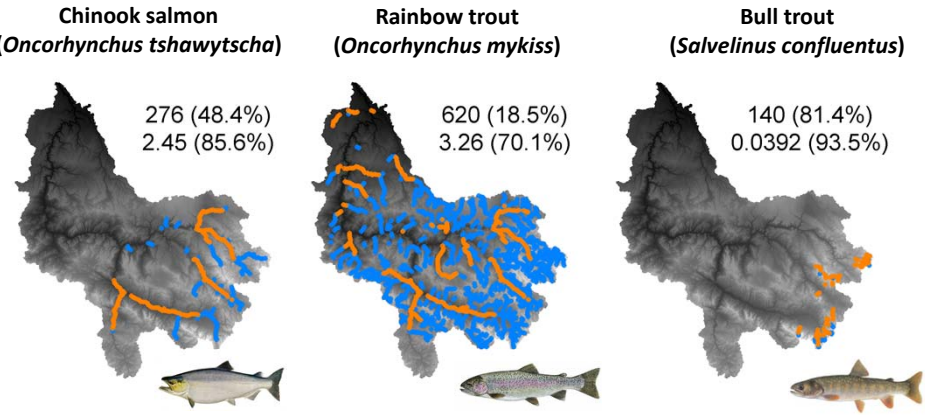
& do not occur on intermittent streams*…

& overlap favorable habitat**.

*Oregon Department of Forestry and National Hydrography Dataset

**Compilation of observations and expert opinion (Oregon Department of Environmental Quality). Not thermally dependent.

Projected loss of thermally suitable habitat

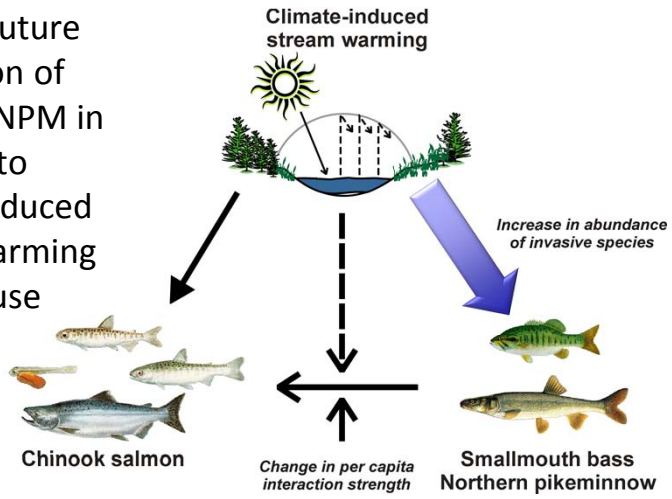


Loss length in km (percent of formerly suitable)
Loss volume in M m^3 (percent of formerly suitable)

Ruesch et al. (in review)

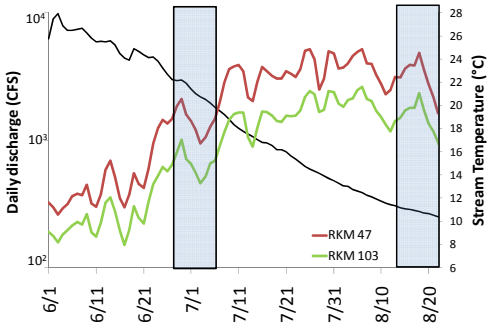
Objective #2

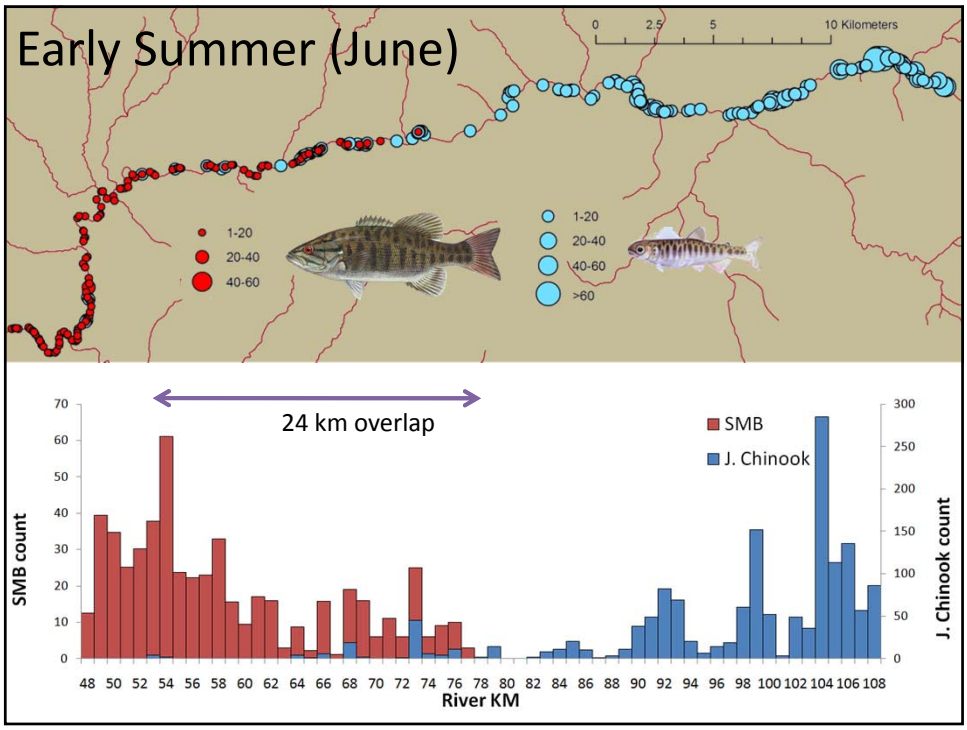
- Forecast future distribution of SMB and NPM in response to climate-induced stream warming and land use change

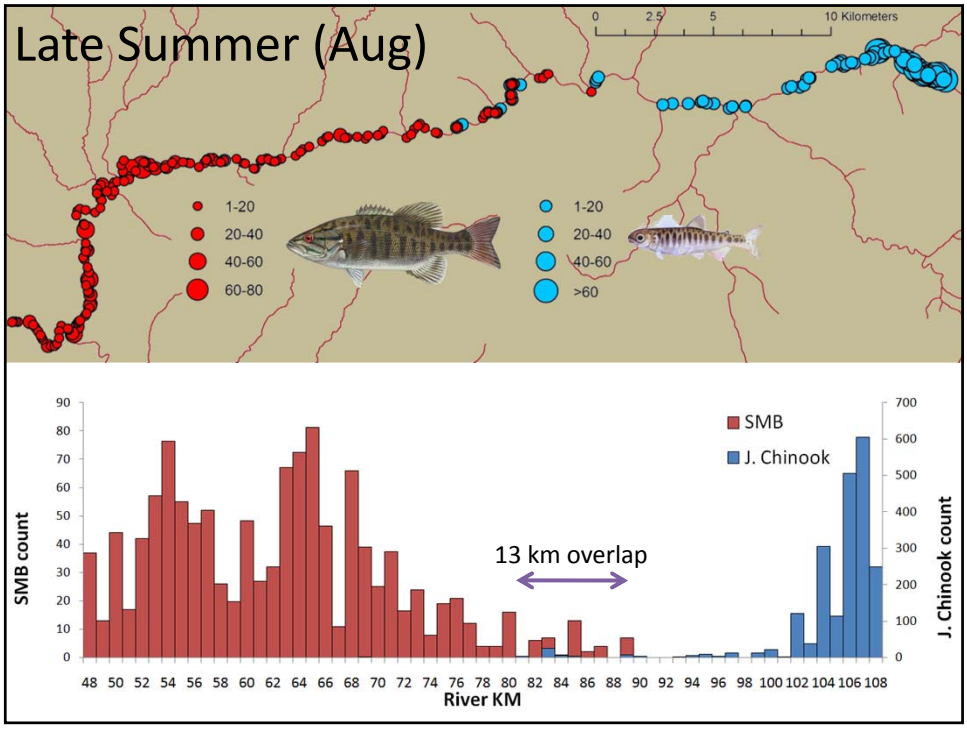


Riverscape Surveys

- Spatially extensive snorkel survey of the NF (55km) and MF (50 km)
- Two sampling periods over two years (2009, 2010)
  - Early summer (June)
  - Late summer (August)
- Fish counts, habitat assessment, bass nest distribution
- Temperature monitoring







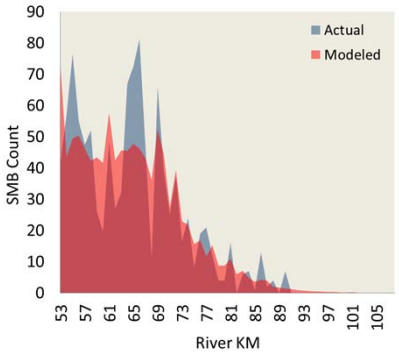
Model results

Generalized Additive Models

	Estim.	St. Err.	t-value	P
June				
β_0	-29.23	3.13	-9.32	<0.001
Temp	1.85	0.18	10.22	<0.001
Deviance explained = 78%, R-sq = 0.727, P<0.001				
August				
β_0	1.13	0.34	3.33	0.002
Temp*			4.98	<0.001
M.Depth	0.22	0.08	2.67	0.011
Deviance explained = 87%, R-sq = 0.766, P<0.001				

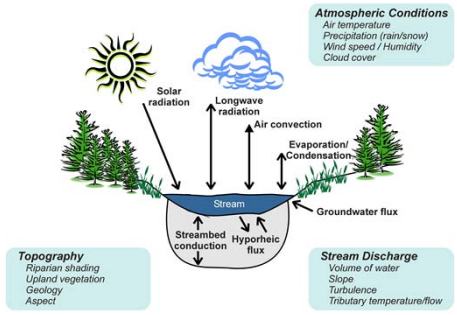
* Approximate significance of smooth term

Model performance - August

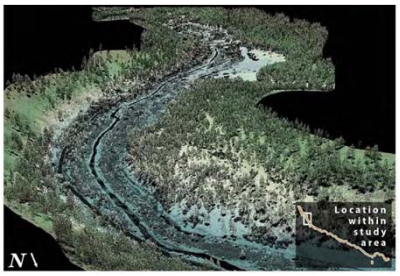


Forecasting species responses

- Applied a mechanistic temperature model (Heat Source) that allows for the simulation of water temperature at the reach scale using high resolution spatially continuous data
- Predicted future thermal regimes according to climate and management scenarios



Olden & Naiman (2010)



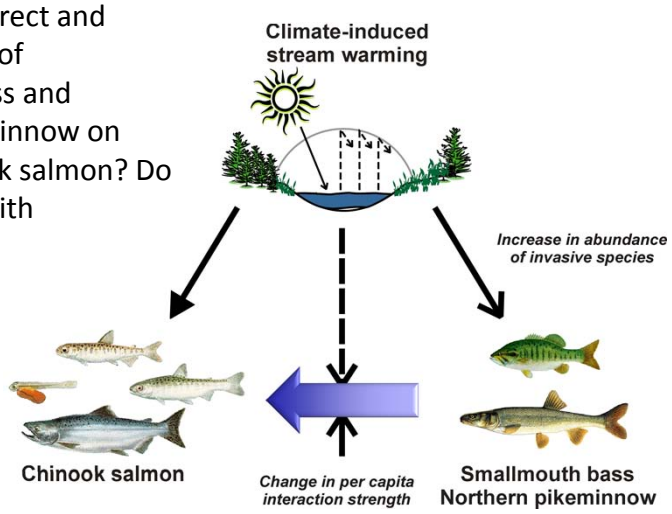
LiDAR from Watershed Sciences Inc. (2006)

Climate and management scenarios

Scenario	Description
Future climate	Scenarios of projected water temperature
Future vegetation	Scenarios of projected land development
Restored vegetation	Complete restoration to estimated potential vegetation (mature species composition)
	John Day Fish Habitat Enhancement Program
	Conservation and acquisition priorities (TNC, TFT)
Potential flow	Estimated volume of water in the absence of human-related influences
Thermal potential	Natural thermal potential associated with vegetation, flow and geomorphic restoration
Ecological targets	Scenarios targeting specific ecological outcomes

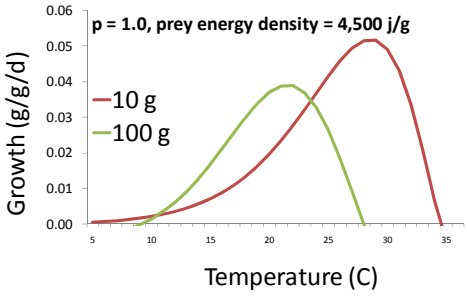
Objective #3

What are the direct and indirect effects of smallmouth bass and northern pikeminnow on juvenile Chinook salmon? Do these change with temperature?



- Fatty acid analysis will provide an integrated measure of predation on juvenile salmon and degree of dietary overlap of SMB and NPM

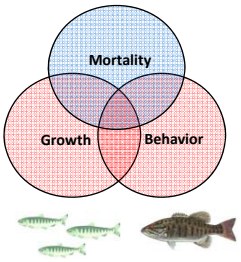
- Bioenergetics modeling will provide insight into smallmouth bass and pikeminnow growth and consumption for different life stages in relation to temperature



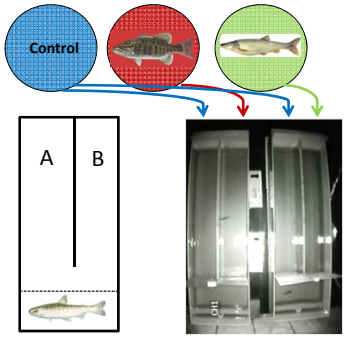
Direct and indirect effects of temperature and predation on juvenile Chinook salmon

Response variables :

1. **Consumption** (direct)
2. **Behavior** (indirect)
3. **Growth** (indirect)
4. **Stress response** (indirect)



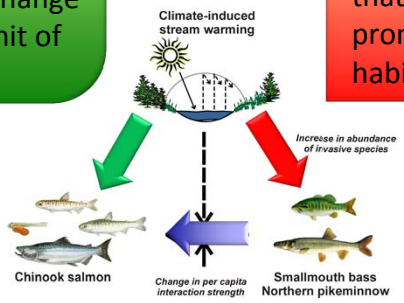
Differences in innate recognition of juvenile Chinook salmon to native and non-native predators



- Standard **Y-maze** experiment to test innate recognition of northern pikeminnow (native) and smallmouth bass (non-native)
- Replicated in field setting

Projected losses of thermally suitable habitat for salmonids ranged from 12 to 100% depending on the species, climate-change projection, and unit of measurement

Climate-induced range expansion of SMB is imminent and can be mitigated through restoration activities that create and promote coolwater habitats



Juvenile Chinook salmon showed minimal response to SMB odor and lacked the panic or fright response which existed for a co-evolved predator, NPM

Implications

- Robust management and policy strategies for freshwater ecosystems depend on understanding the interactive effects of multiple drivers of change
- Coupled correlative-mechanistic models will help identify opportunities for co-benefits arising from management actions that aim to minimize the future range expansion of invasive species and produce thermally-suitable habitat for coolwater salmonids
- Management portfolios based on different ecological endpoints will be distributed to local and regional agencies

Acknowledgements

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- USGS: Jeff Duda, David Powell, Audrey Taylor, Ethan Welty
- North Fork John Day Ranger Station
- North Fork John Day Watershed Council
- TNC: Jerry Ebeltoft
- BLM: Jimmy Eisner, Anna Smith
- Pentec Environmental: Michelle Havey
- Watershed Sciences: Russell Faux
- >80 landowners that allowed access to their land

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