Effects of Recent Climate and Fire on Thermal Habitats within a Mountain Stream Network: An Example with a Native Char Species

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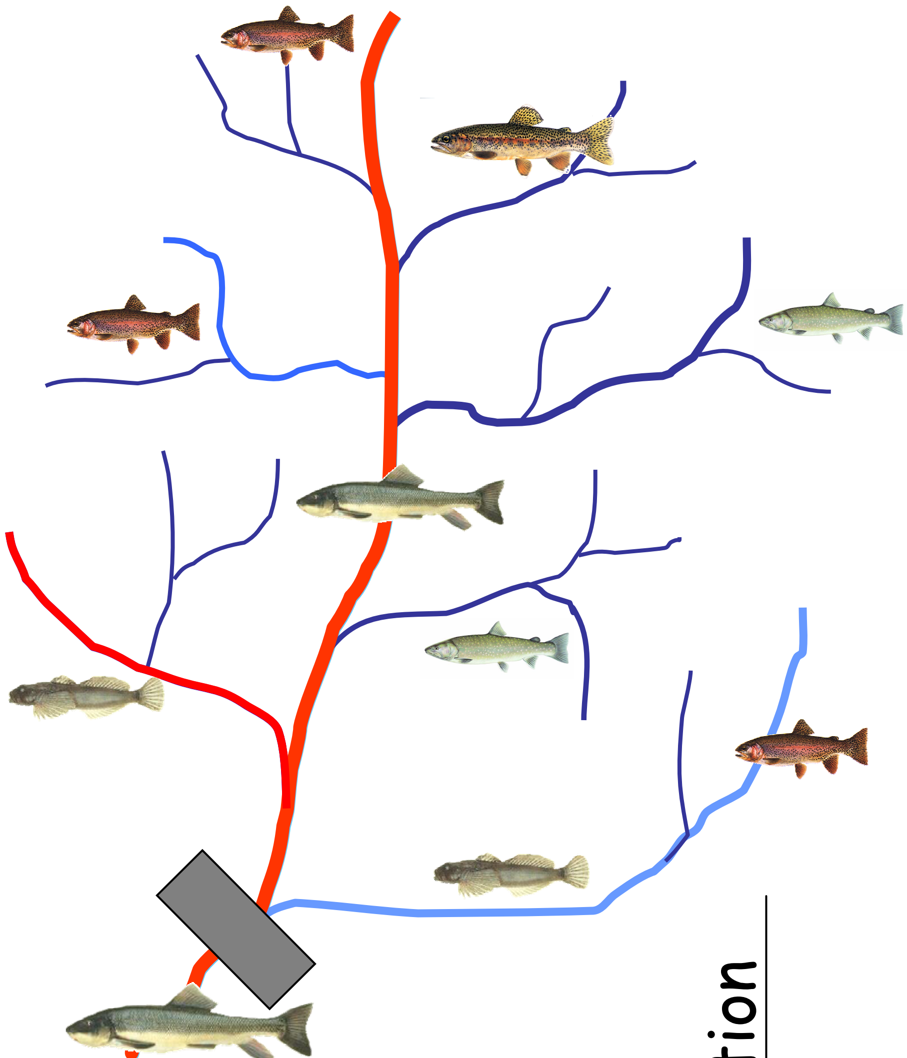
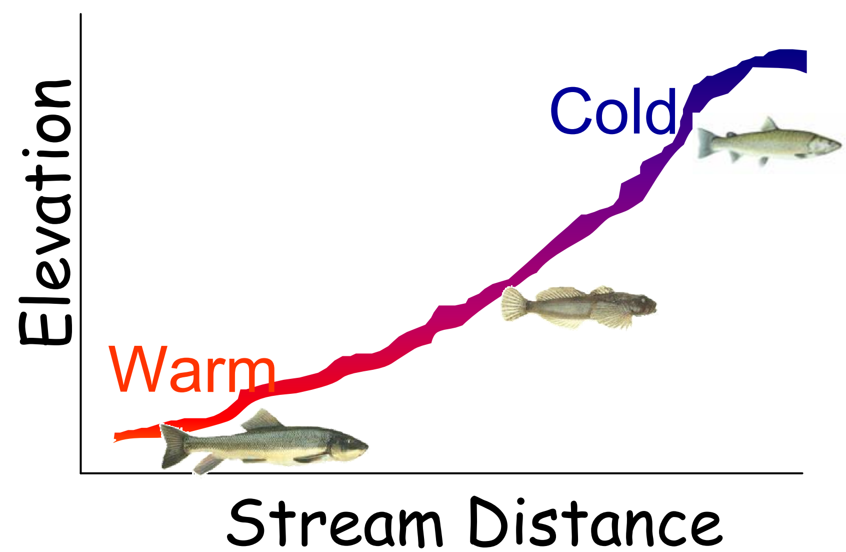
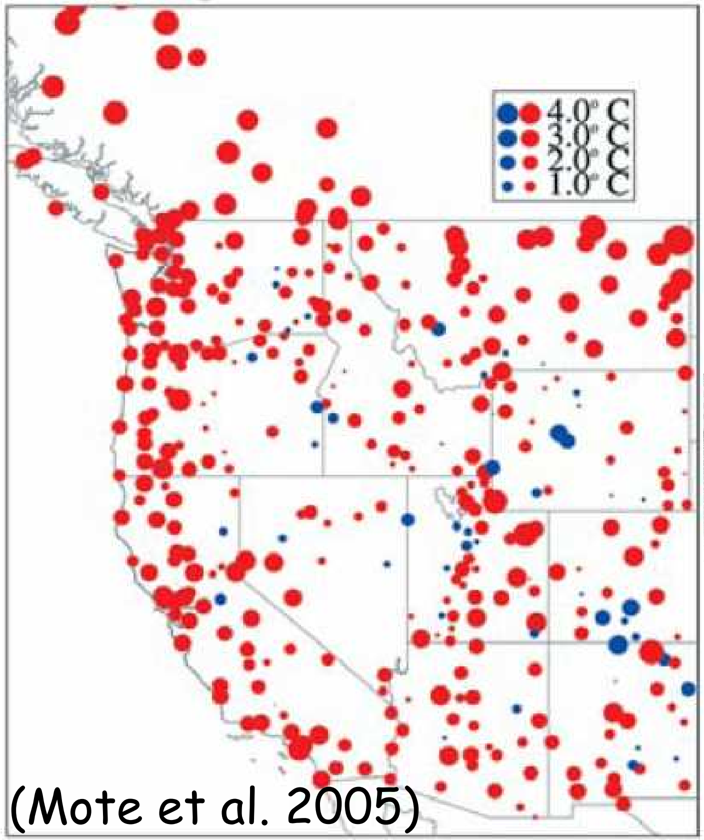
Fish Art Courtesy of Joe Tomelleri




Cold
Warm
Elevation
Stream Distance

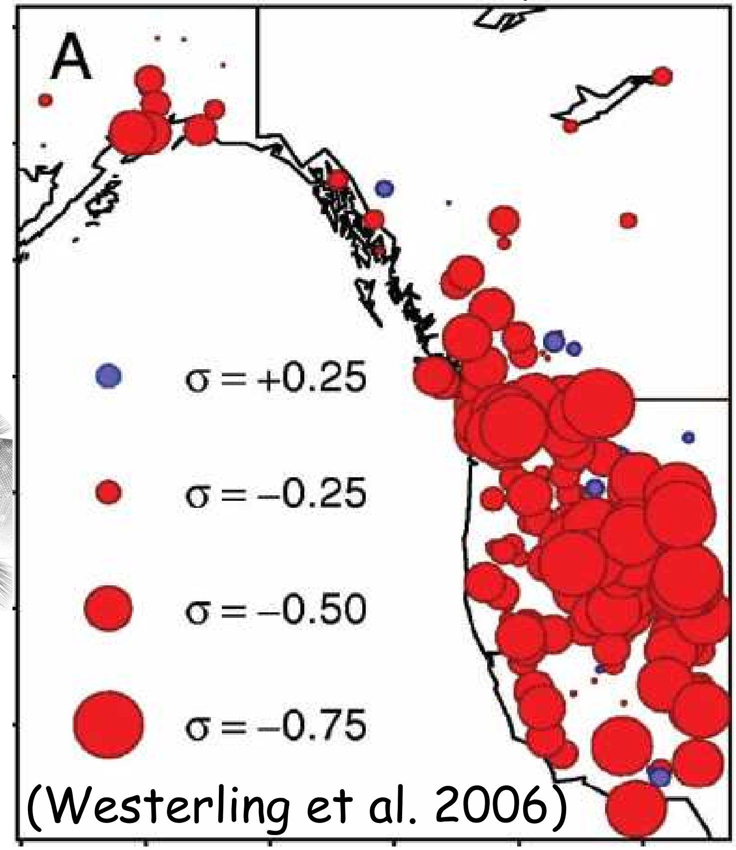
Western US – Environmental Trends

Warmer Air Temperatures



(Mote et al. 2005)

Increasing Fire Severity

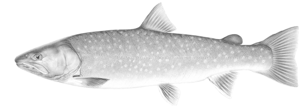


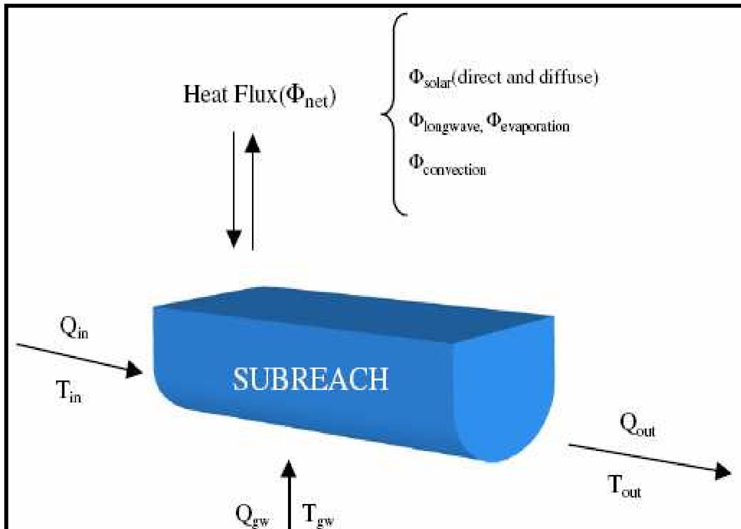
(Westerling et al. 2006)

-Decreasing summer flows

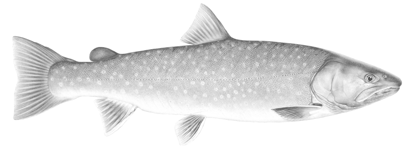
-Vegetation conversion

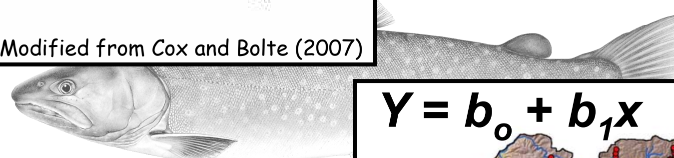
Statistical vs Mechanistic Stream Temperature Models

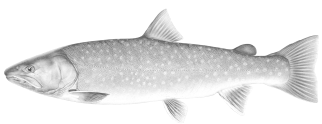


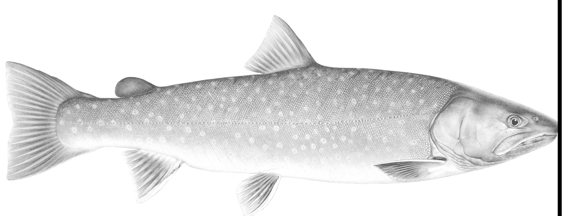


Modified from Cox and Bolte (2007)

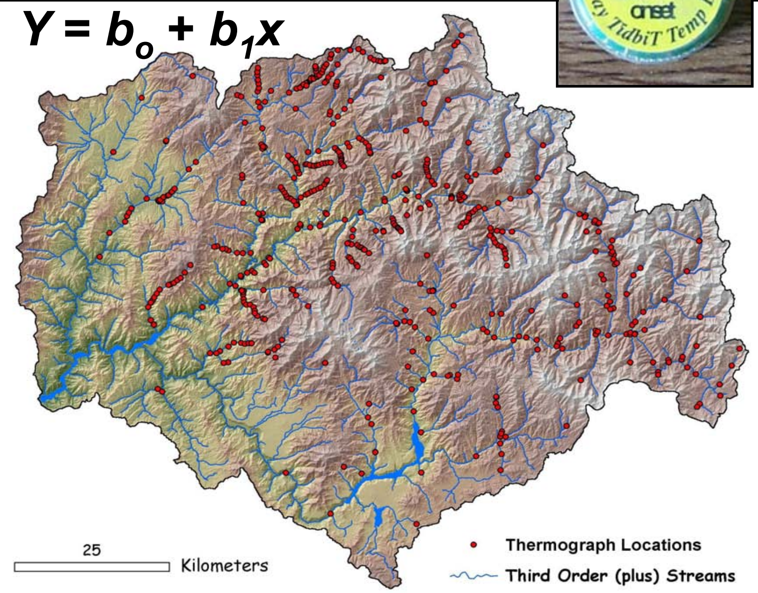




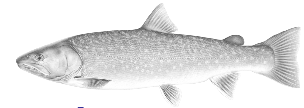


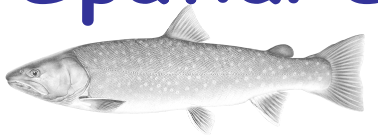


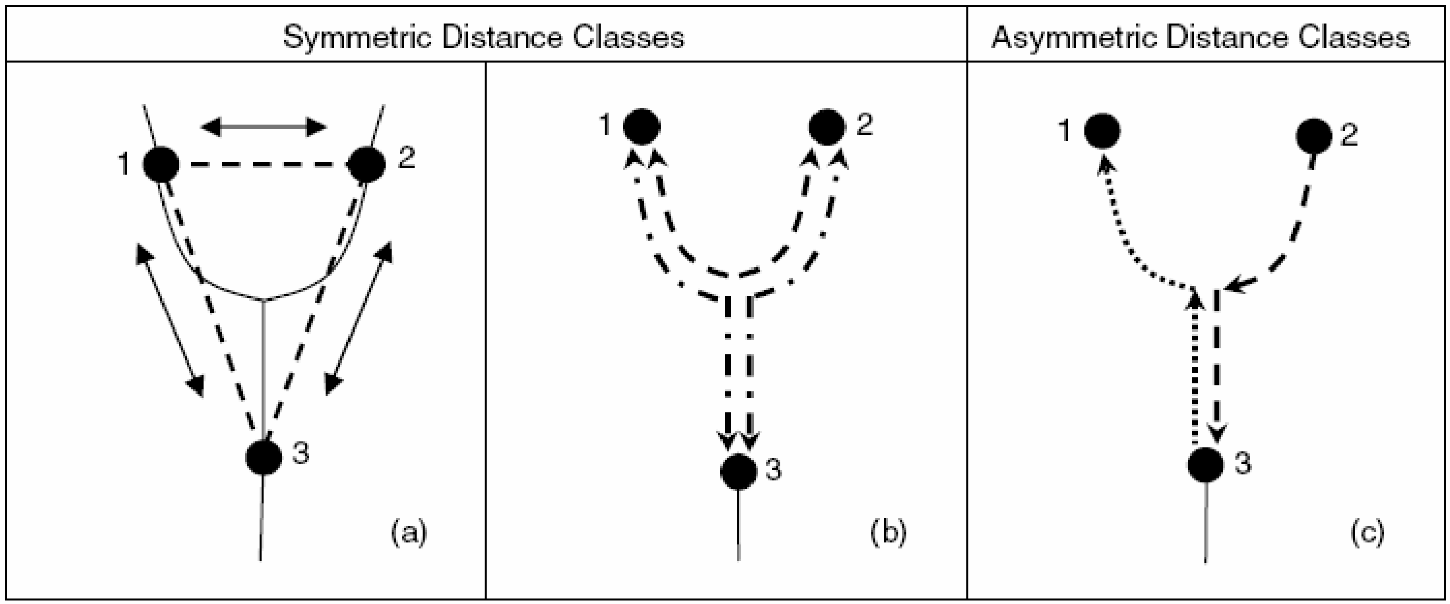
$Y = b_o + b_1x$



Spatial Statistical Models for Stream Networks





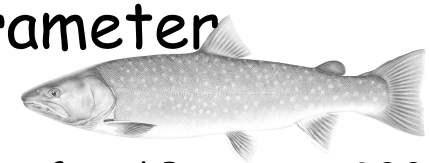


Advantages:

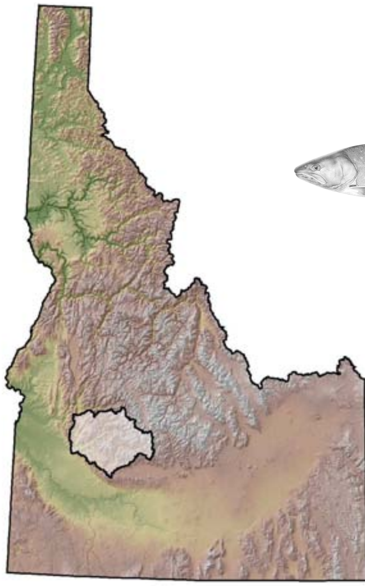
-flexible covariance structures account for different spatial autocorrelations

-weighting by stream size

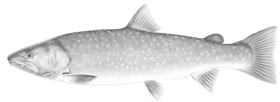
-improved predictive ability & parameter estimates relative to OLS



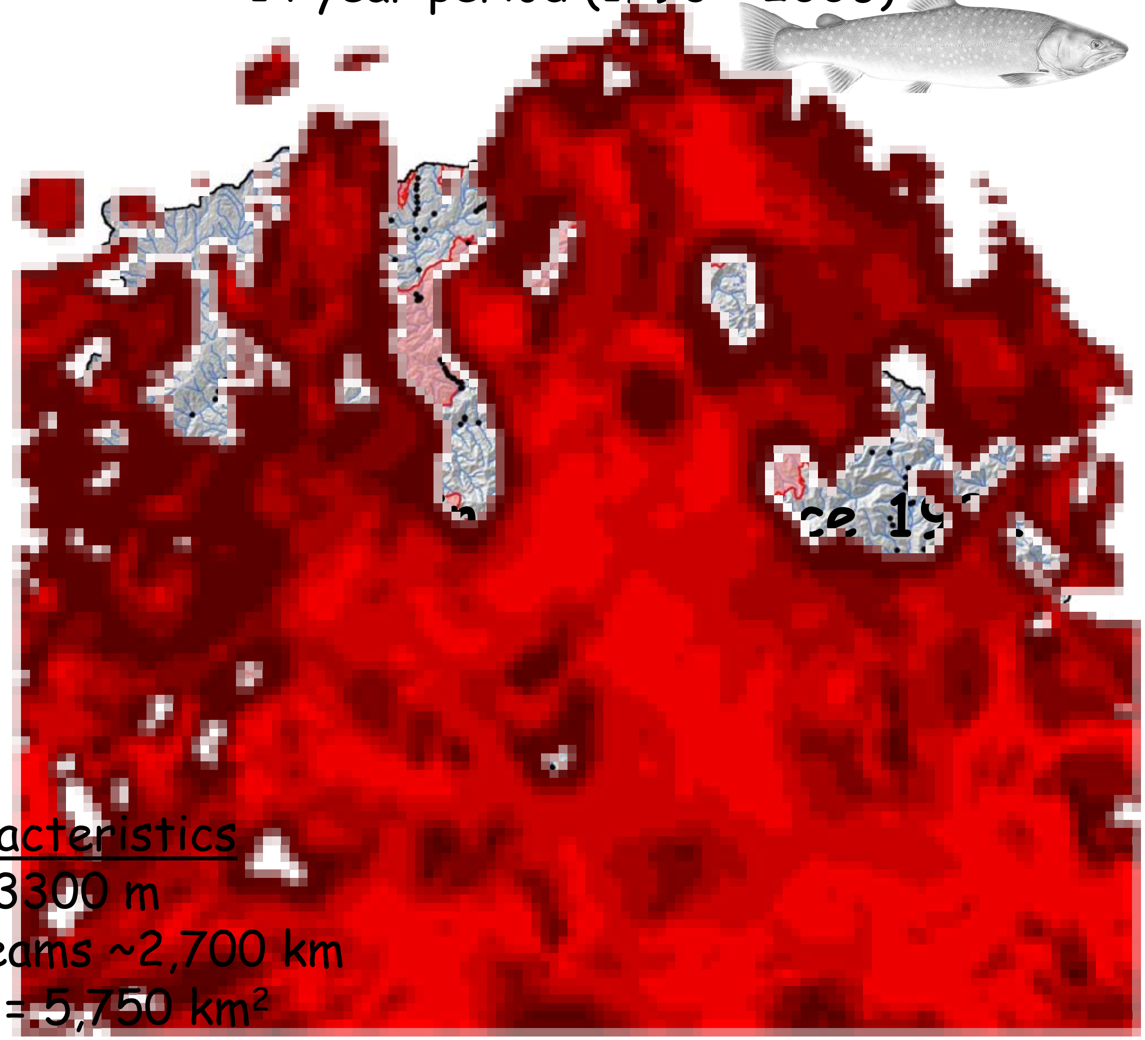
Peterson et al. 2006; Ver Hoef and Peterson 2007

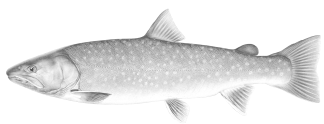


Boise River Watershed

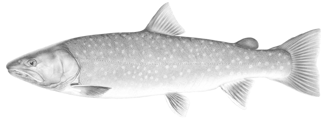


Stream Temperature Database
787 observations
518 unique locations
14 year period (1993 – 2006)





Watershed Characteristics
Ele Range 900 – 3300 m
Fish bearing streams ~2,700 km
Watershed area = 5,750 km²



Response Variable

Stream MWMT (highest 7-day moving average of the maximum daily temperatures)

Predictor Variables

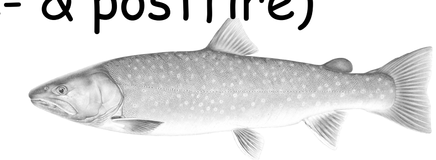
Geomorphic attributes (DEM derived)

- -basin elevation
- -basin size
- -reach slope
- -glaciated valley extent
- -alluviated/flat valley extent

Climate attributes (3 weather & 2 flow stations)

- -annual summer discharge
- -annual air MWMT

Solar radiation (TM satellite imagery pre- & postfire)



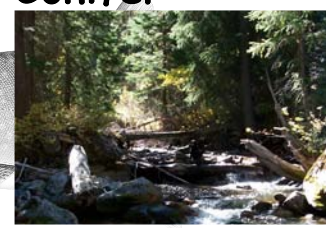
Solar Radiation Estimation

TM satellite imagery classifies riparian vegetation pre- & postfire into (open, shrub, conifer)

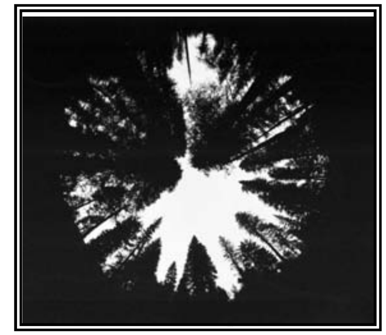
Open

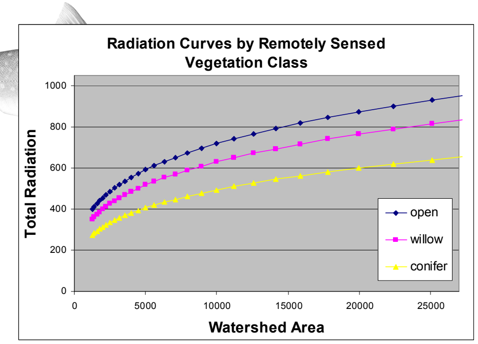
Willow

Conifer



Canopy Photography estimates site-level radiation for each class (181 sites)



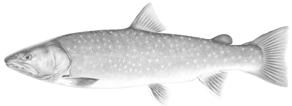


Radiation curves by vegetation class

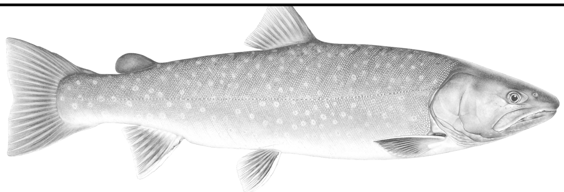
Predicted radiation across stream network

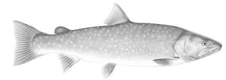
Luce et al., manuscript in preparation

Model Selection Results



Model Type	Model Predictors	R^2	ΔAIC_c	AIC_c weight	RMSPE
Spatial	Elev, Glacial, Vall_bot, Rad, Air_MWMT, Summ_flow	0.85	0.00	0.92	1.575
Spatial	Elev, Glacial, Vall_bot, Rad, Air_MWMT, Summ_flow, Slope, DS_area	0.85	5.03	0.07	1.588
Spatial	Elev, Rad, Air_MWMT, Summ_flow	0.85	15.85	0.00	1.597
Spatial	Elev, Air_MWMT, Summ_flow, Slope, DS_area	0.84	61.66	0.00	1.639
Spatial	Elev, Glacial, Vall_bot, Lake, Drain_dens, Slope, DS_area	0.83	152.35	0.00	1.697
OLS	Elev, Glacial, Vall_bot, Rad, Air_MWMT, Summ_flow	0.55	770.65	0.00	2.750
OLS	Elev, Glacial, Vall_bot, Rad, Air_MWMT, Summ_flow, Slope, DS_area	0.54	777.95	0.00	2.760
OLS	Elev, Rad, Air_MWMT, Summ_flow	0.53	800.15	0.00	2.800
OLS	Elev, Air_MWMT, Summ_flow, Slope, DS_area	0.45	921.25	0.00	3.028
OLS	Elev, Glacial, Vall_bot, Lake, Drain_dens, Slope, DS_area	0.45	927.15	0.00	3.040



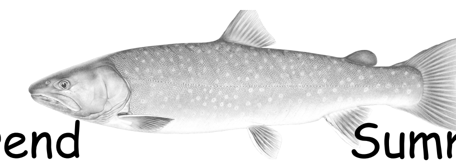


Scenarios

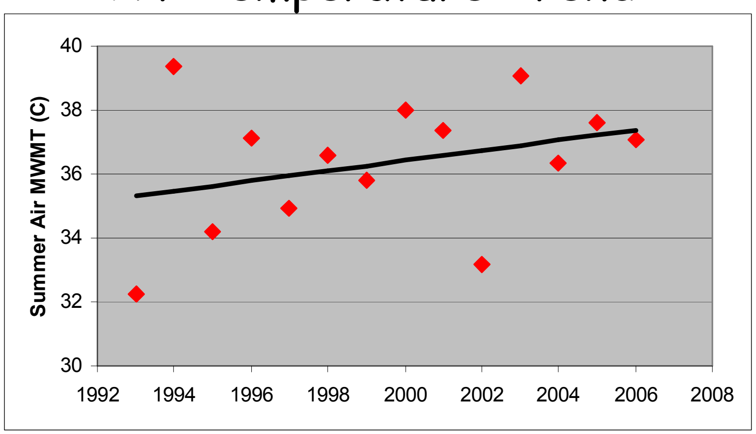
1) Baseline conditions (1993) – prefire radiation,
-high summer flows,
-cool air temperatures

2) Current conditions (2006) – postfire radiation (23% burn),
-low summer flows (decrease by 42%),
-warm air temperatures (MWMT increased by 2°C)

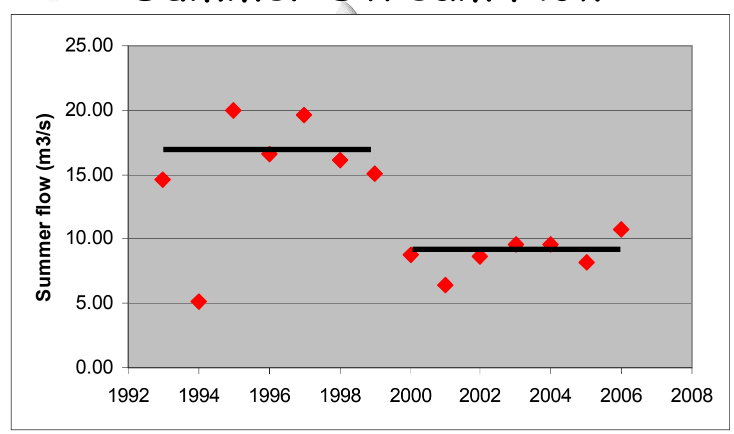
3) Current conditions (no fire) – prefire radiation,
-low summer flows (decreased by 42 %),
-warm air temperatures (MWMT increased by 2°C)



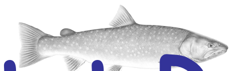
Air Temperature Trend

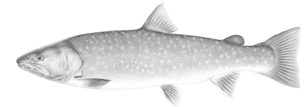


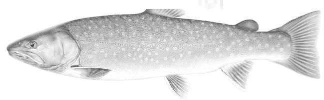
Summer Stream Flow

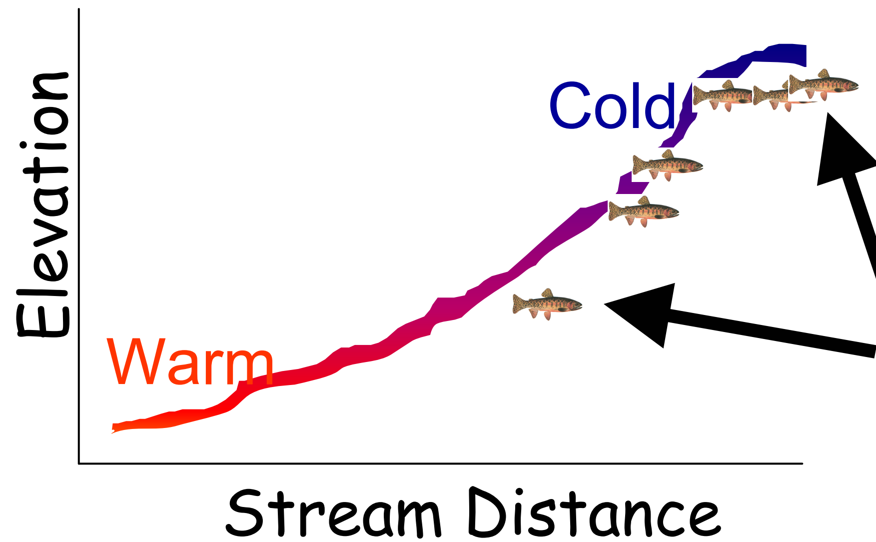


Bull Trout Habitat Requirements

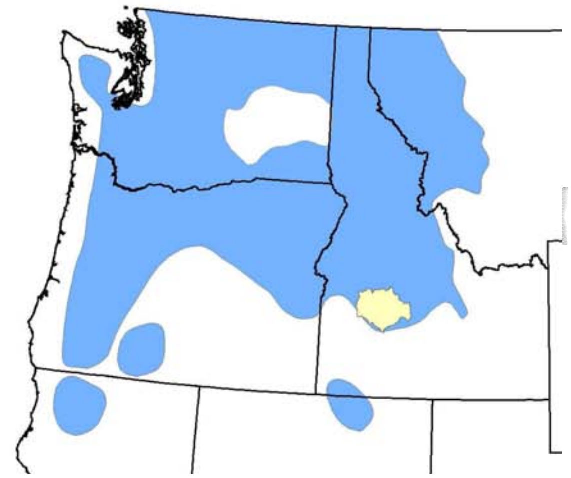


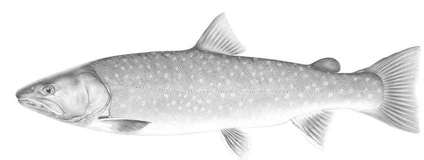






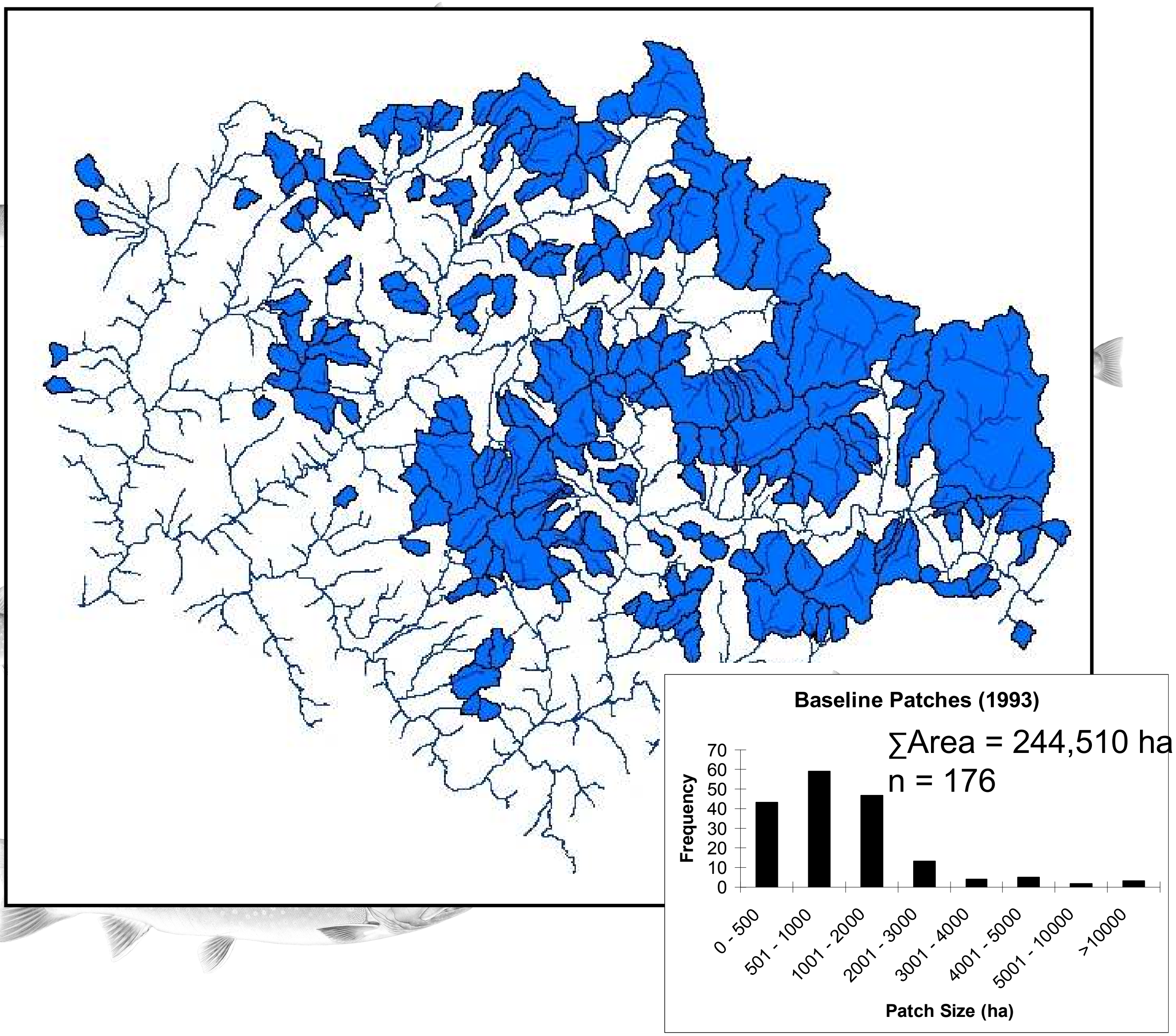
Suitable habitat = MWMT < 15.5°C





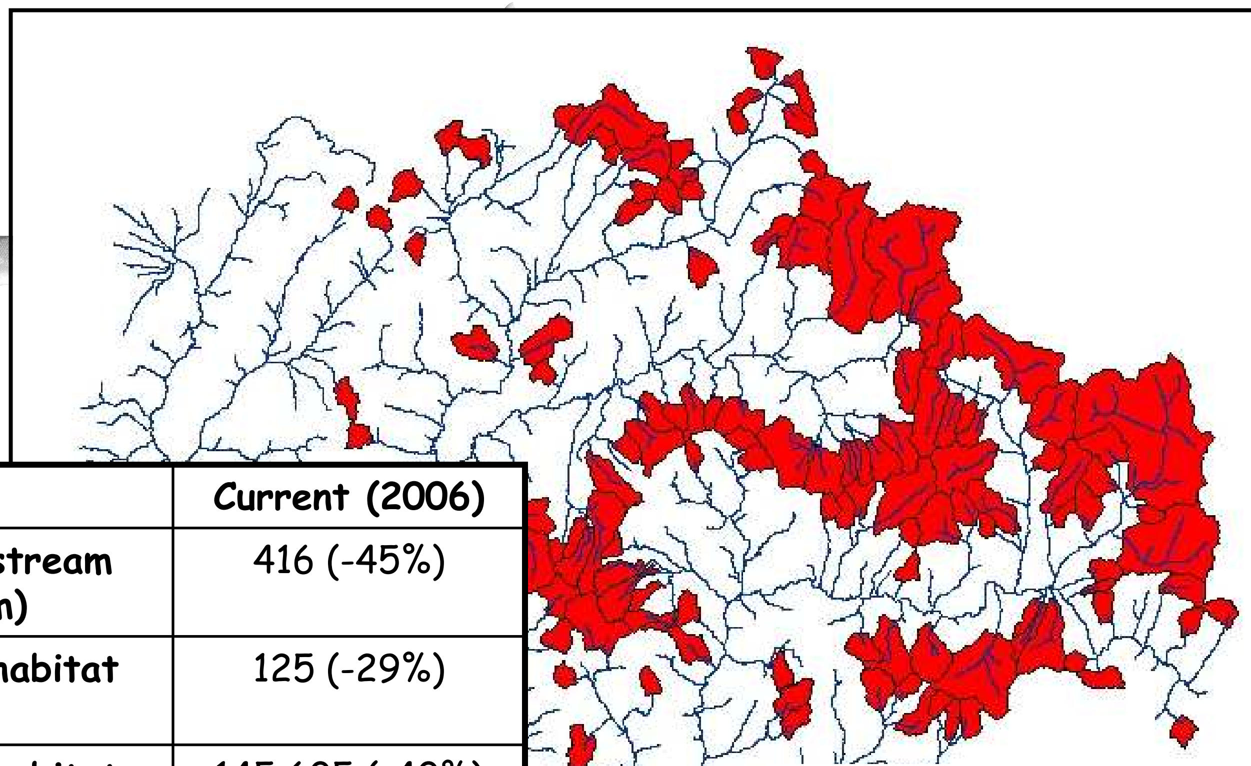
Bull Trout Temperature Patches

Baseline Conditions (1993)

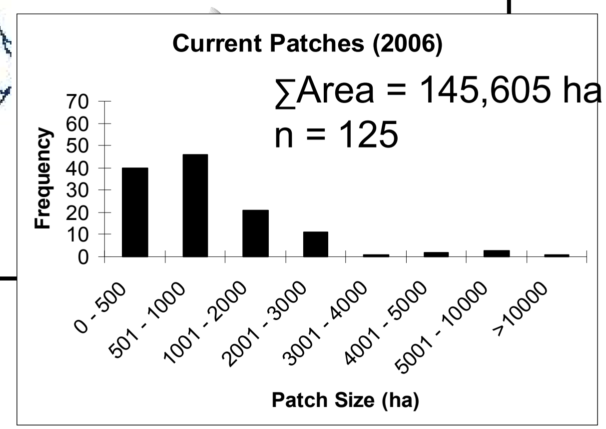


Bull Trout Temperature Patches

Current Conditions (2006)

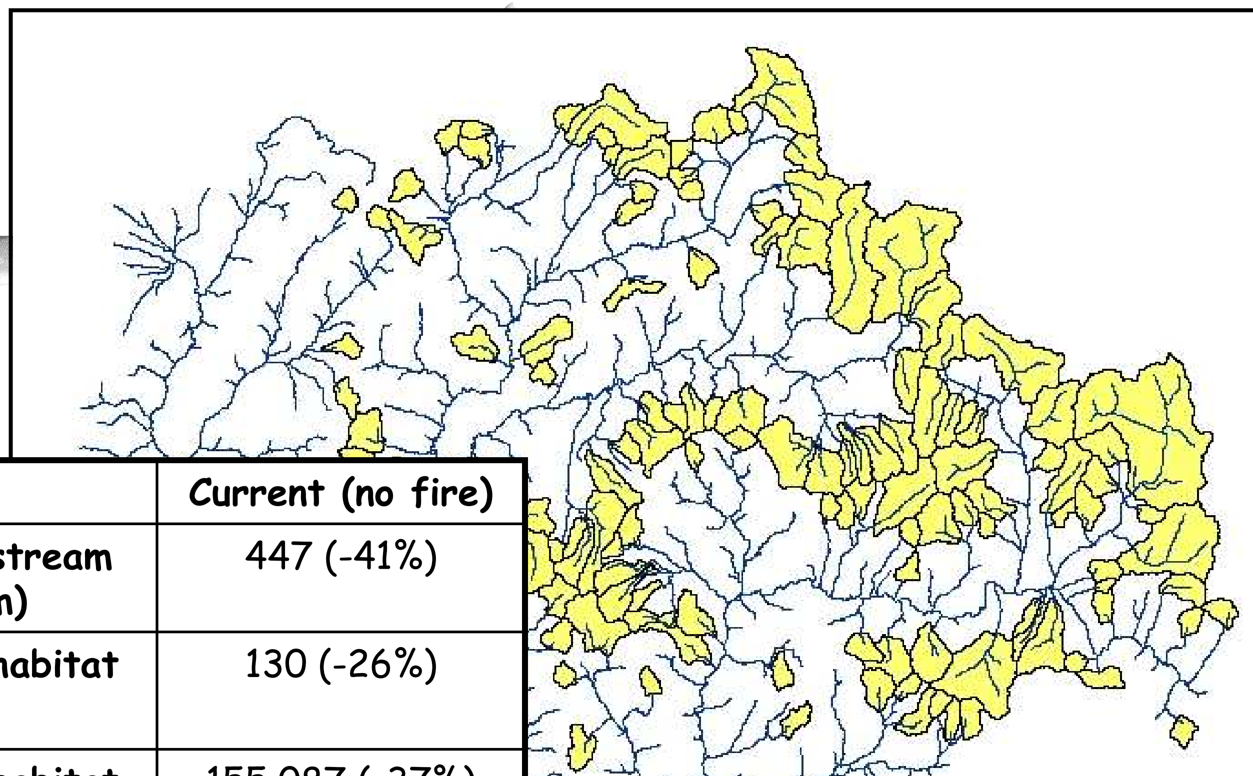


	Current (2006)
Suitable stream length (km)	416 (-45%)
Suitable habitat patches*	125 (-29%)
Suitable habitat patch area (ha)	145,605 (-40%)
Mean patch size (ha)	1165 (-16%)
Median patch size (ha)	682 (-8%)
Maximum patch size (ha)	12433 (-49%)

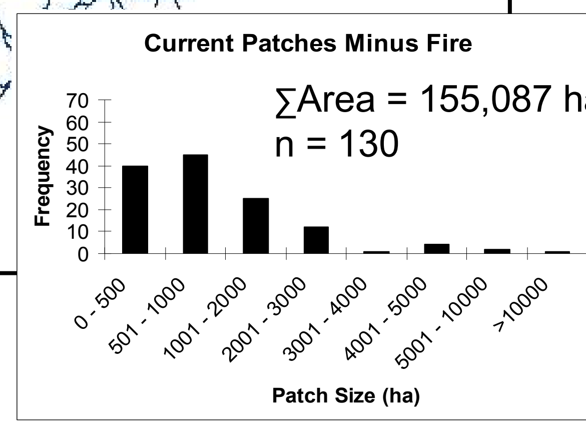


Bull Trout Temperature Patches

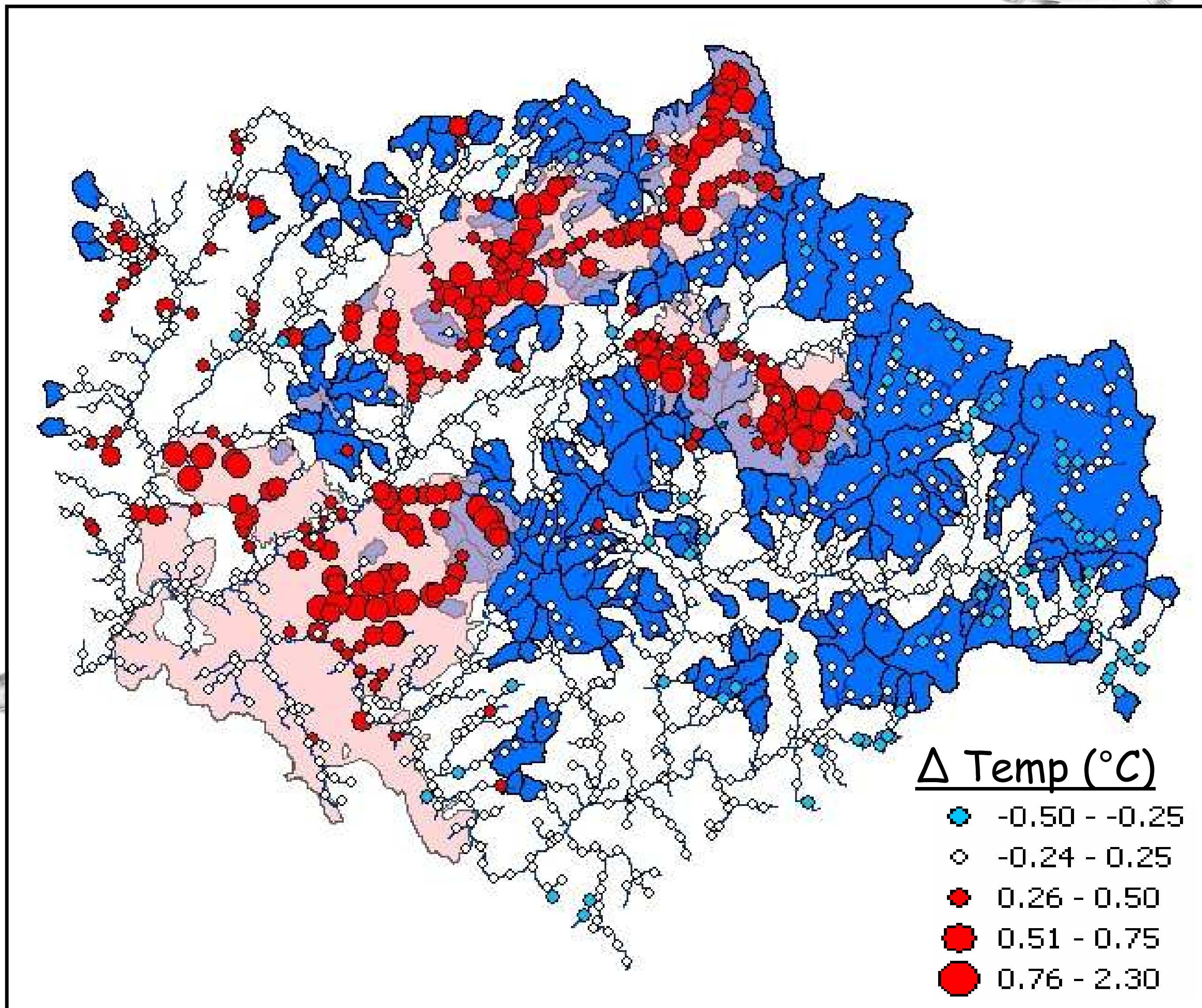
Current Conditions (No Fire)



	Current (no fire)
Suitable stream length (km)	447 (-41%)
Suitable habitat patches*	130 (-26%)
Suitable habitat patch area (ha)	155,087 (-37%)
Mean patch size (ha)	1193 (-14%)
Median patch size (ha)	716 (-4%)
Maximum patch size (ha)	12433 (-49%)



Fire Effect on Stream Temperature



Conclusions…

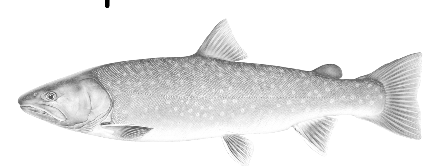
-Recent losses of suitable thermal habitat may be substantial. Most losses were related to air temperature & flow regime. Fire effects were small at the watershed scale, but important locally & could become more important depending on the distribution of future fires

-Hydrologic regimes trending towards lower annual yields and summer baseflows, which could exacerbate stream warming, but also decrease habitat extent in headwater streams

-Biological assessments needed to determine whether populations respond immediately or lag environmental shifts?

-Continuation of current trends suggest difficult choices for management agencies. Current federal recovery planning efforts for bull trout do little to acknowledge climate threats.

-Future efforts to conserve species will require proactive management & models capable of translating global patterns to habitat networks at landscape scales



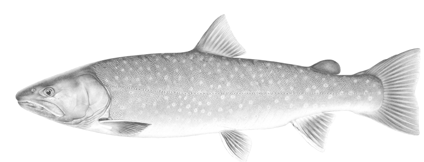
Future work…

-Describe changes in thermal habitats for other species (winners / losers), in different areas of a species' range (core / margins), or relative to other modeling approaches (broad- / finescale)

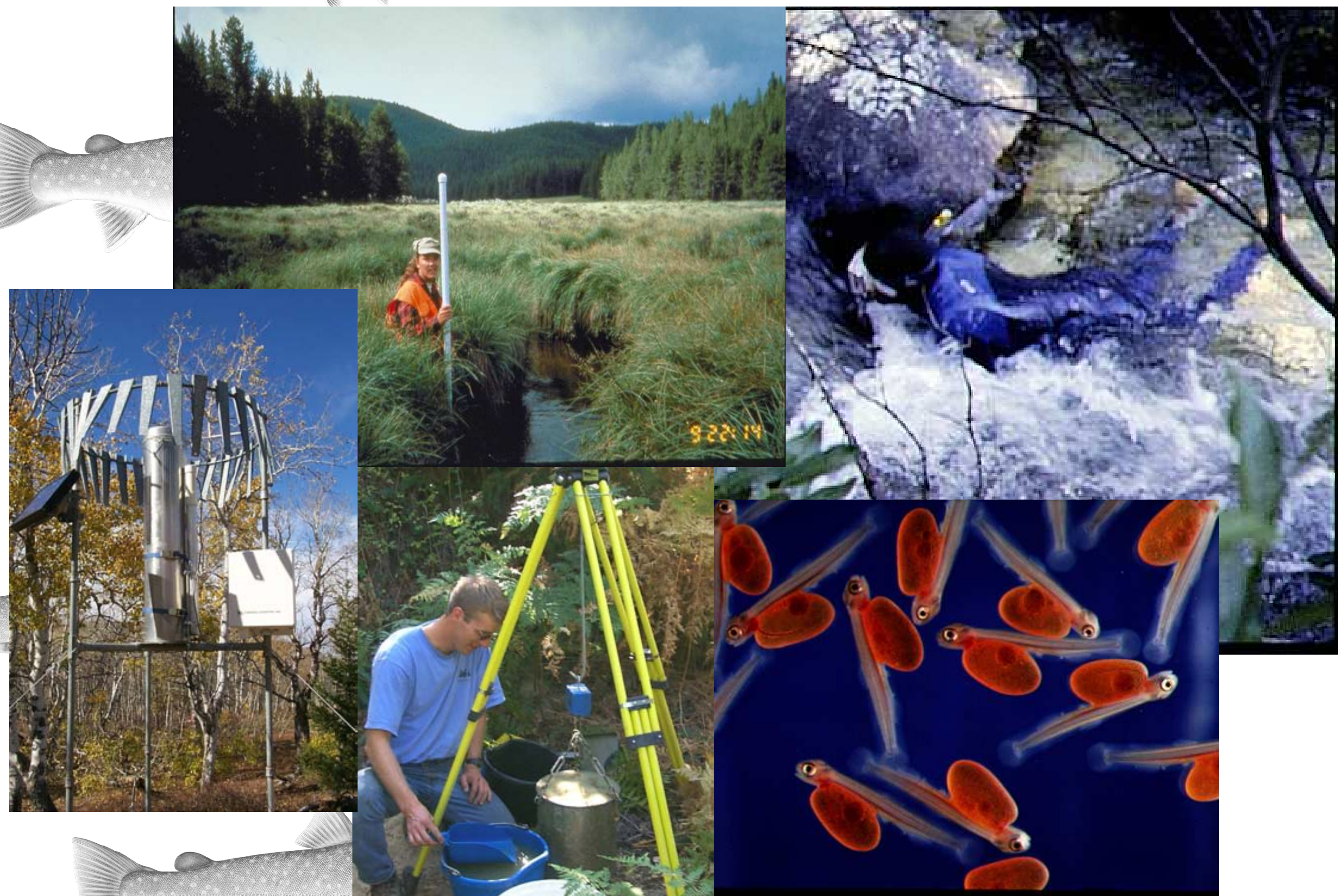
-Improve model predictions by using higher resolution air temperature / flow inputs or improving radiation submodel (LiDAR representation of riparian structure?)

-Forecast habitat distributions associated with future climate & fire scenarios (which areas may be most sensitive to change?)

-Other applications: 1) explore physical processes affecting stream temperature, 2) develop more efficient monitoring protocols for stream networks (stream temperature, water quality, biological attributes), 3) integrate results with outputs from other models (biological, hydrological)



US Forest Service
Rocky Mountain Research Station



<u>website:</u> www.fs.fed.us/rm/boise