Probabilistic models for decision support under climate change:

An example using bull trout in the Boise River basin

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Probabilistic models for decision support under climate change:

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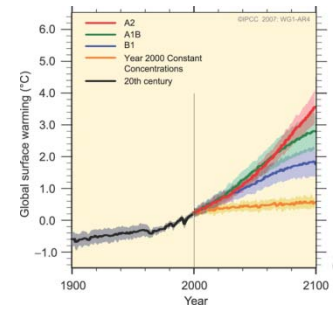
Bruce Rieman, *RMRS "retired"*

Seth Wenger, *Trout Unlimited*

Dan Isaak, *RMRS-Boise*

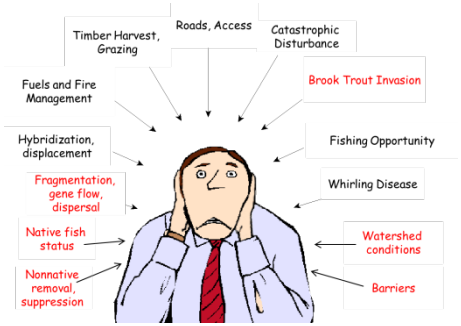
Dona Horan, *RMRS-Boise*

How do we use all this stuff?
Bringing it all together…



Decision space and uncertainty

- *Prediction error, complexity, non-stationarity*



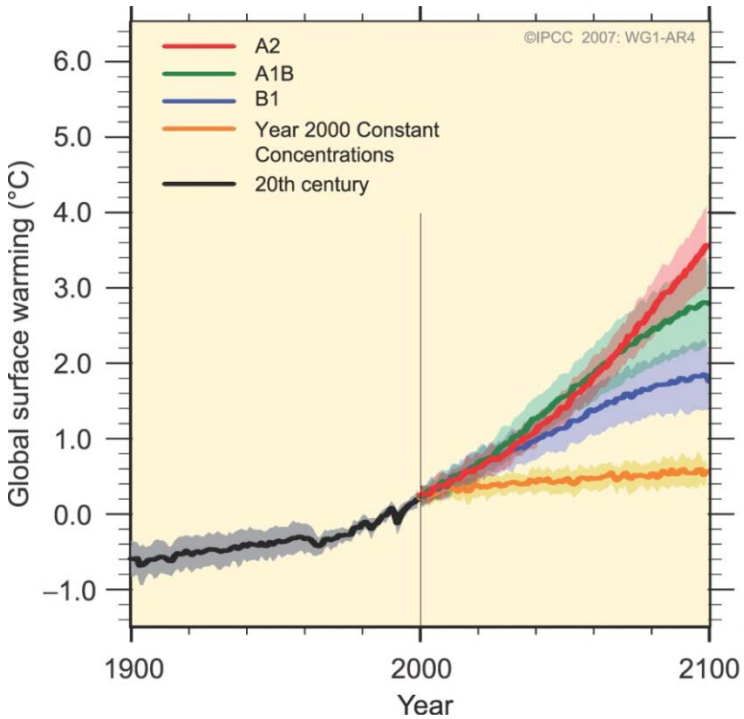
Linking data to a decision framework

- *Bayesian network (BN) approach*

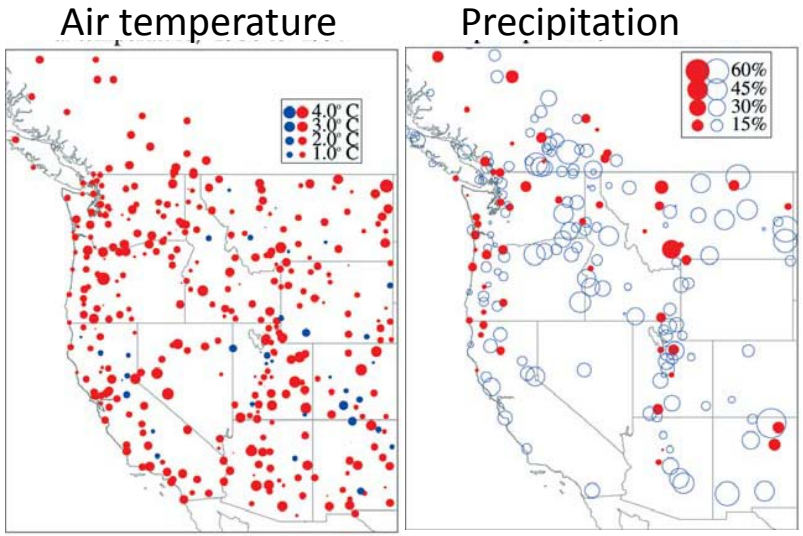
Example: Bull trout in the Boise River basin

- *Building a model*
- *Predictions and lessons learned*

Uncertainty: prediction error



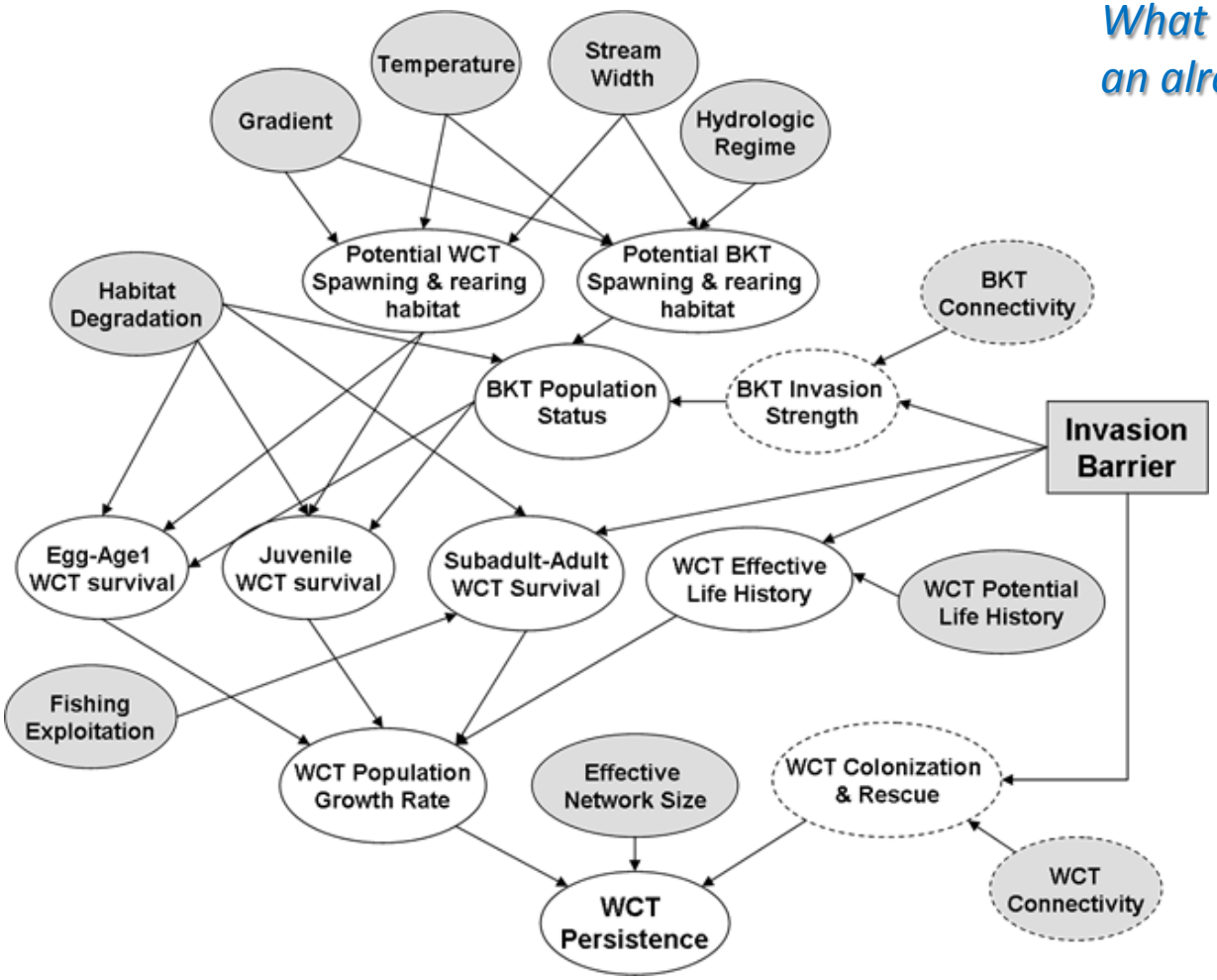
Global climate change scenarios based on different assumptions for greenhouse gas emissions and human economic trends (Fig. SPM5, from IPCC 2007, Working Group I).



Air temperature and precipitation trends across the western US, 1930-1997 (Mote et al. 2005)

Uncertainty: complexity

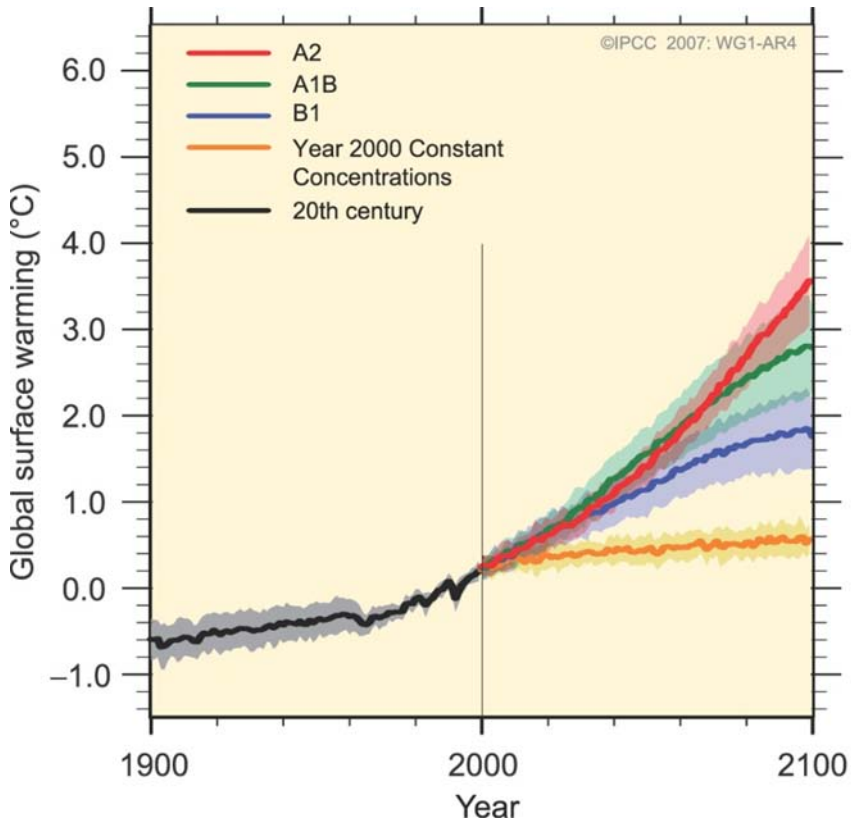
What does climate change do to an already complex problem?



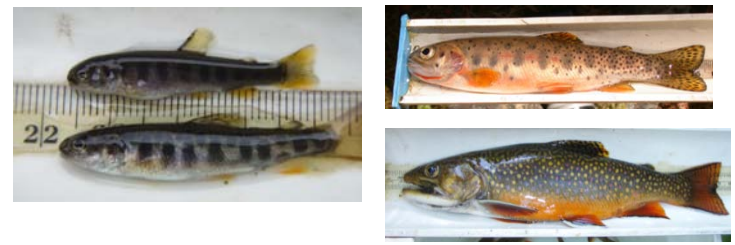
Peterson et al (2008)

Uncertainty: non-stationarity

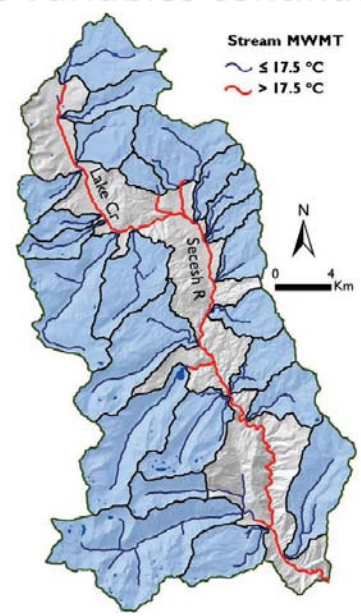
How long before these scenarios become obselete?



Will important ecological relationships hold, as we understand them now?

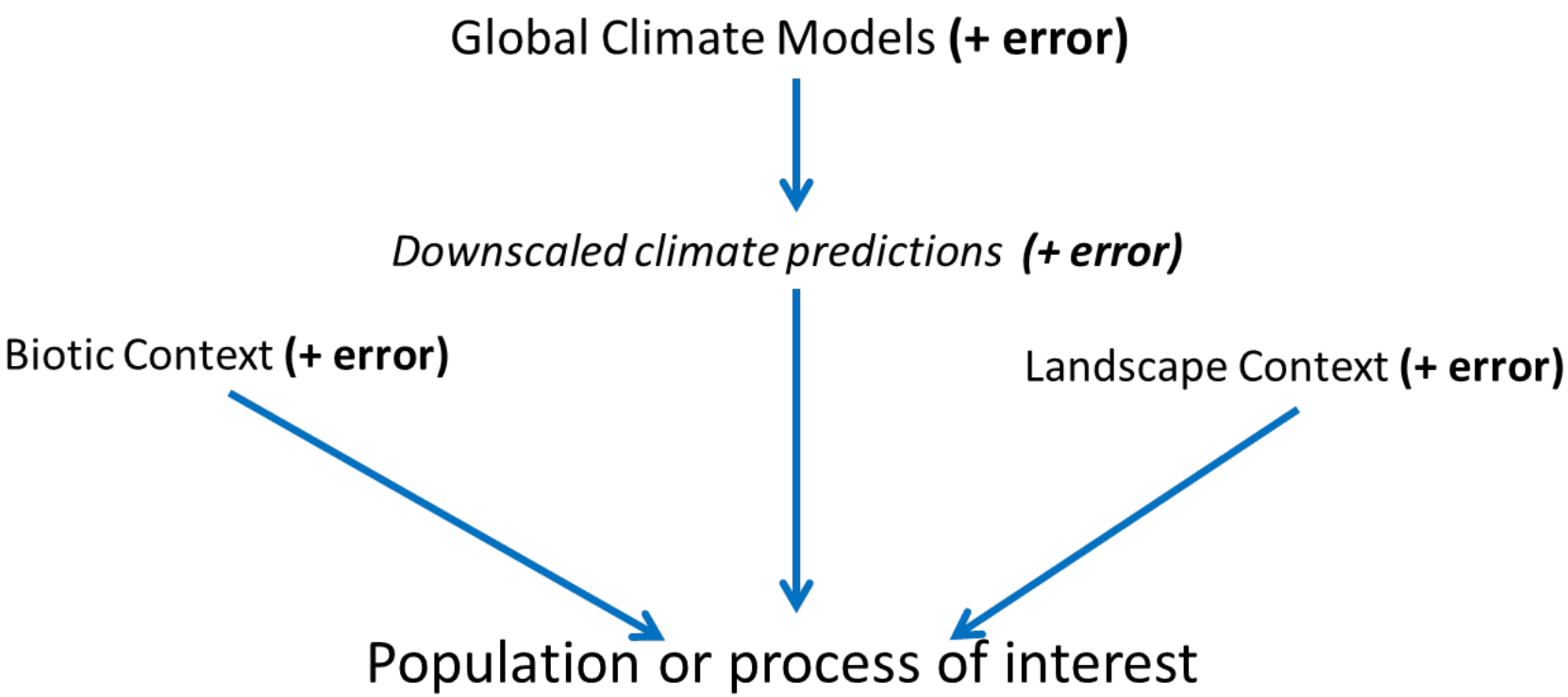


Will statistical relationships used to model climate variables continue to hold?



Isaak et al (2009)

Uncertainty: error propagation



Bayesian networks (BNs) in use

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Forest Ecology and Management 153 (2001) 43–62

Forest Ecology and Management

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Evaluation of potential effects of federal land management alternatives on trends of salmonids and their habitats in the interior Columbia River basin

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Ecological Modelling 192 (2006) 224–244

ECOLOGICAL MODELLING

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Assessing the decline of brown trout (*Salmo trutta*) in Swiss rivers using a Bayesian probability network

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Analysis of trade-offs between threats of invasion by nonnative brook trout (*Salvelinus fontinalis*) and intentional isolation for native westslope cutthroat trout (*Oncorhynchus clarkii lewisi*)

Douglas P. Peterson, Bruce E. Rieman, Jason B. Dunham, Kurt D. Fausch, and Michael K. Young

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ELSEVIER

Use of a Bayesian network for Red Listing under uncertainty

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ABSTRACT

The IUCN (International Union for Conservation of Nature) Red List is widely recognised as an authoritative assessment of the conservation status of species. However, the data available for Red Listing are often lacking or uncertain. This paper presents a Bayesian network that may be used to perform a Red List assessment of a taxon using uncertain data. In such cases, input variables can be entered as likelihoods, and the appropriate Red List category is identified by the network using Bayesian inference. Relative performance of the Bayesian network was evaluated by comparison with an alternative method (RAMAS® Red List), based on the use of fuzzy numbers. While results were generally comparable, some differences were noted for species with uncertain input data. Contrasting results may be attributed to differences in how uncertain data are analysed by the two approaches. The Bayesian network has the advantage of being more transparent, facilitating sensitivity analysis. The method consequently has potential for facilitating Red List assessments, particularly for poorly known taxa.

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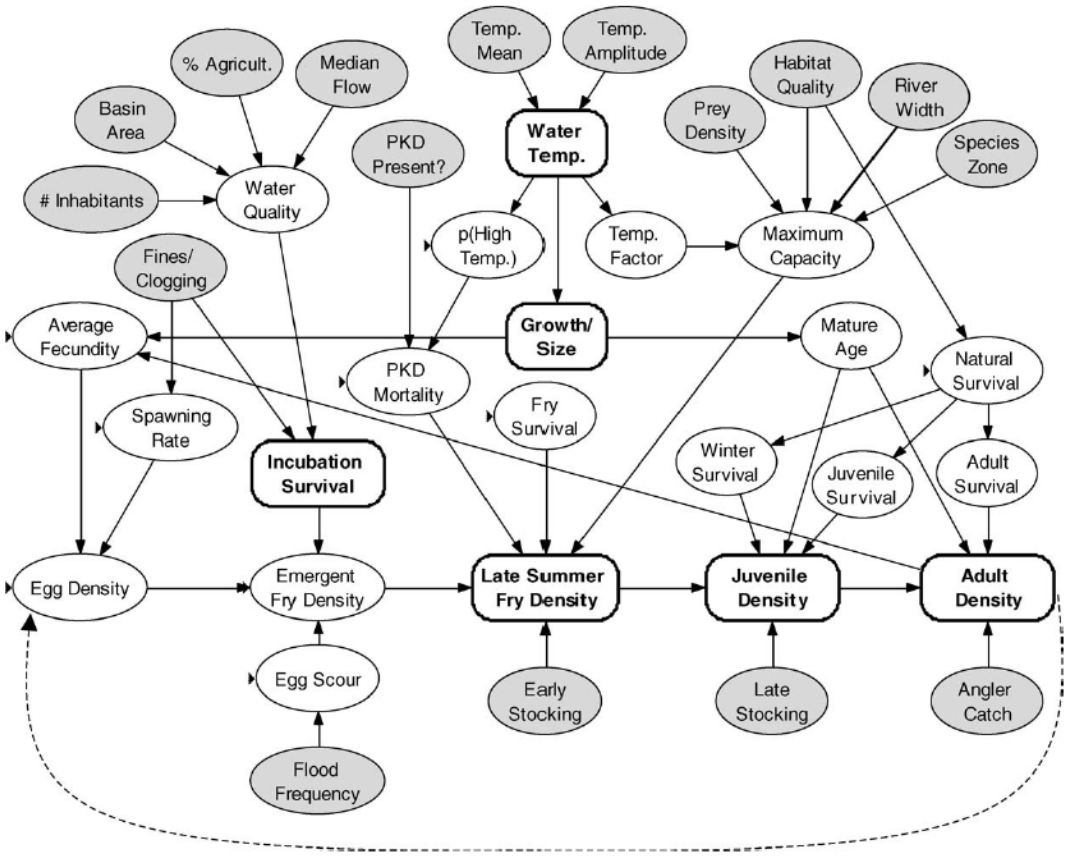
Bayesian Networks: definition & properties

BBNs: graphical models that incorporates probabilistic relationships among variables of interest (Jensen 2001)



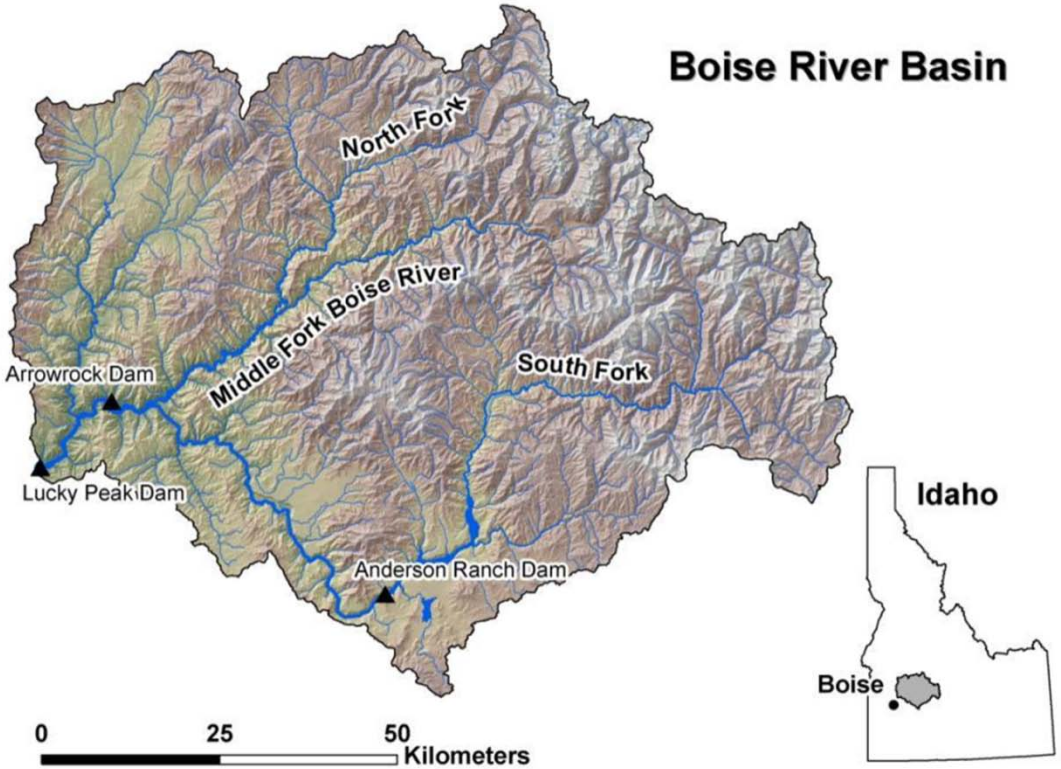
BBN predicting brown trout density from a suite of environmental, management, and land use factors (from Borsuk et al. 2006)

Useful attributes:

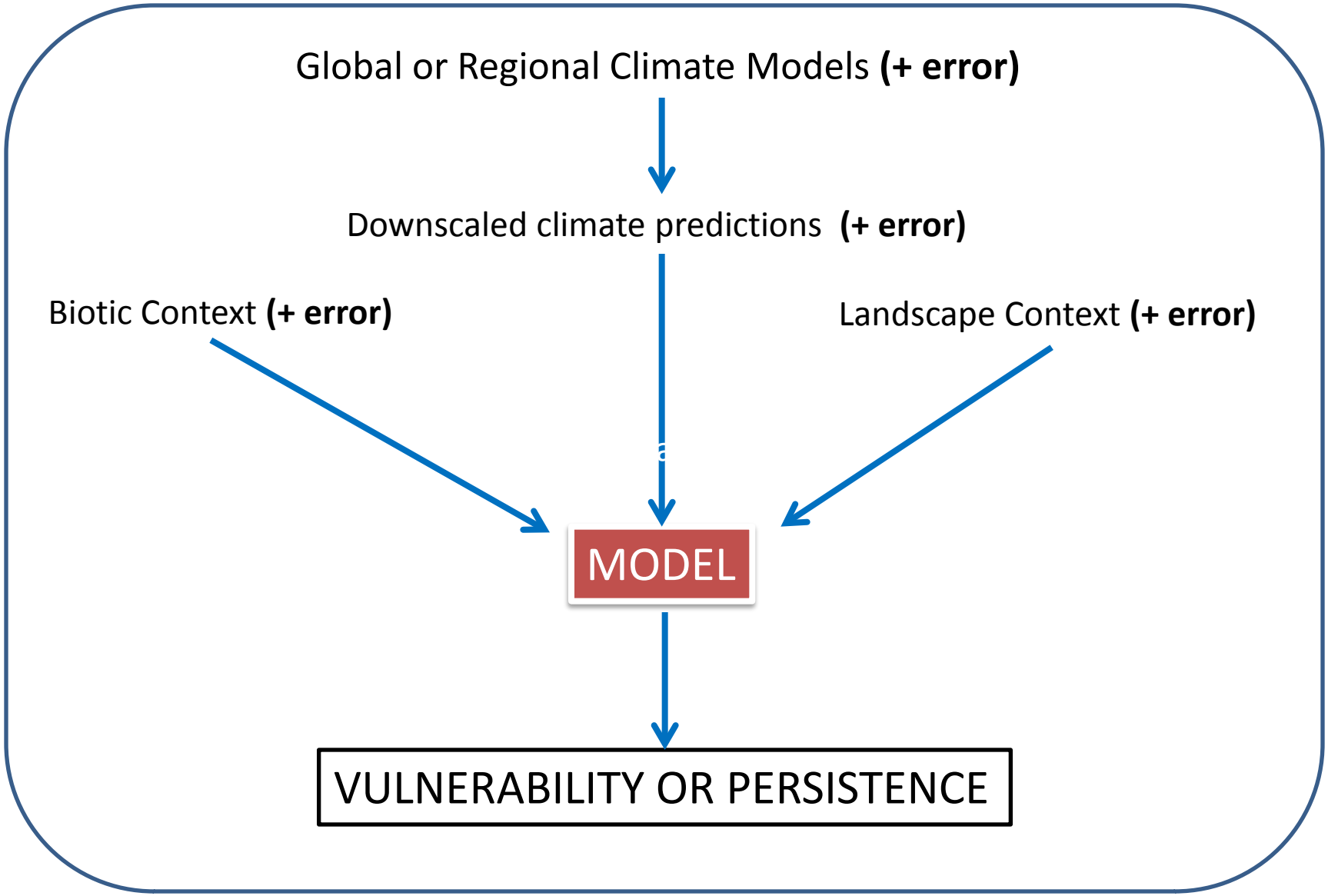
- Logical
- Probabilistic
- Transparent
- Adaptable
- Spatial representation
- Management interventions

"Portable knowledge format" (Conrady and Jouffe 2011)

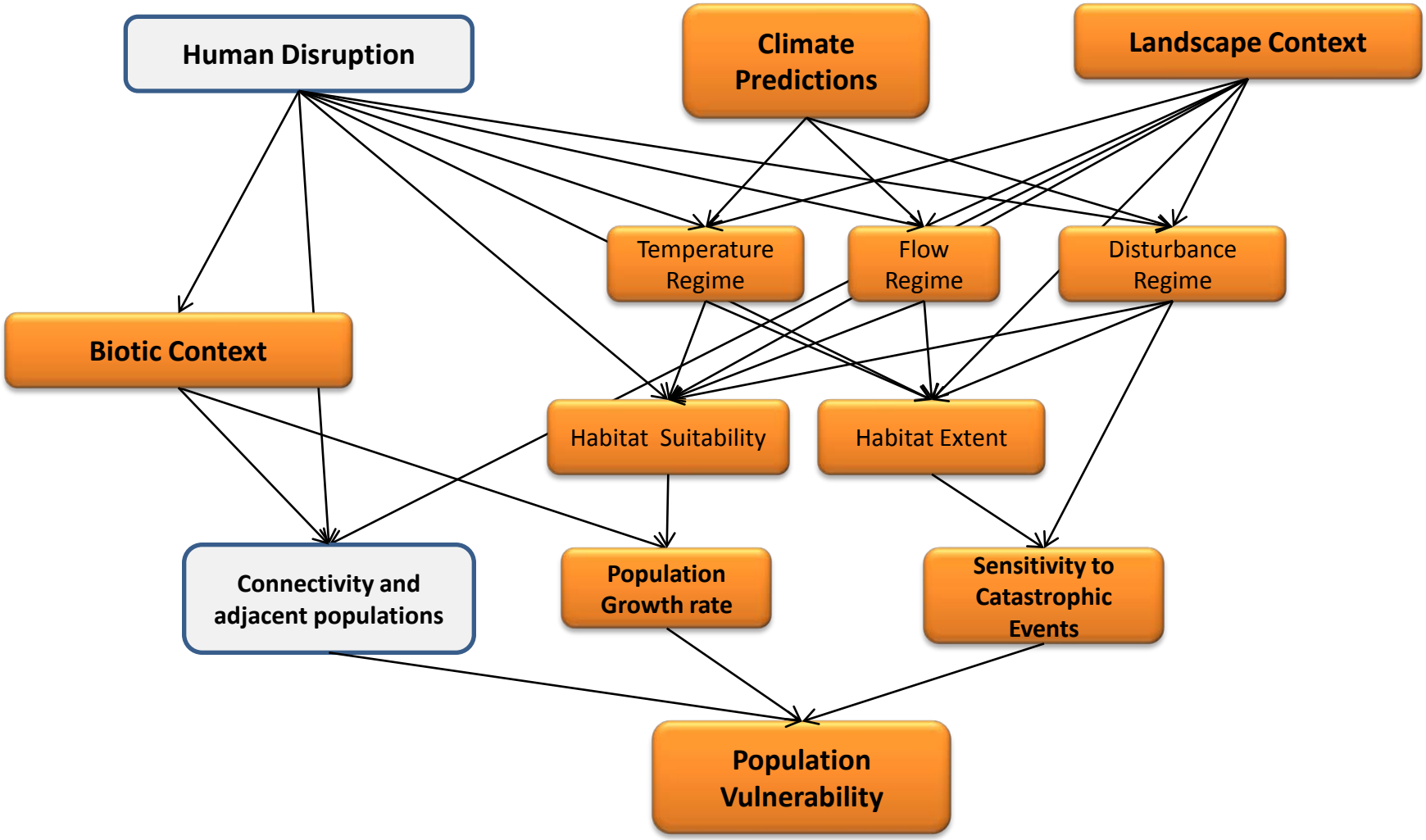
Bull trout in the Boise River basin



Concept: climate impacts on populations

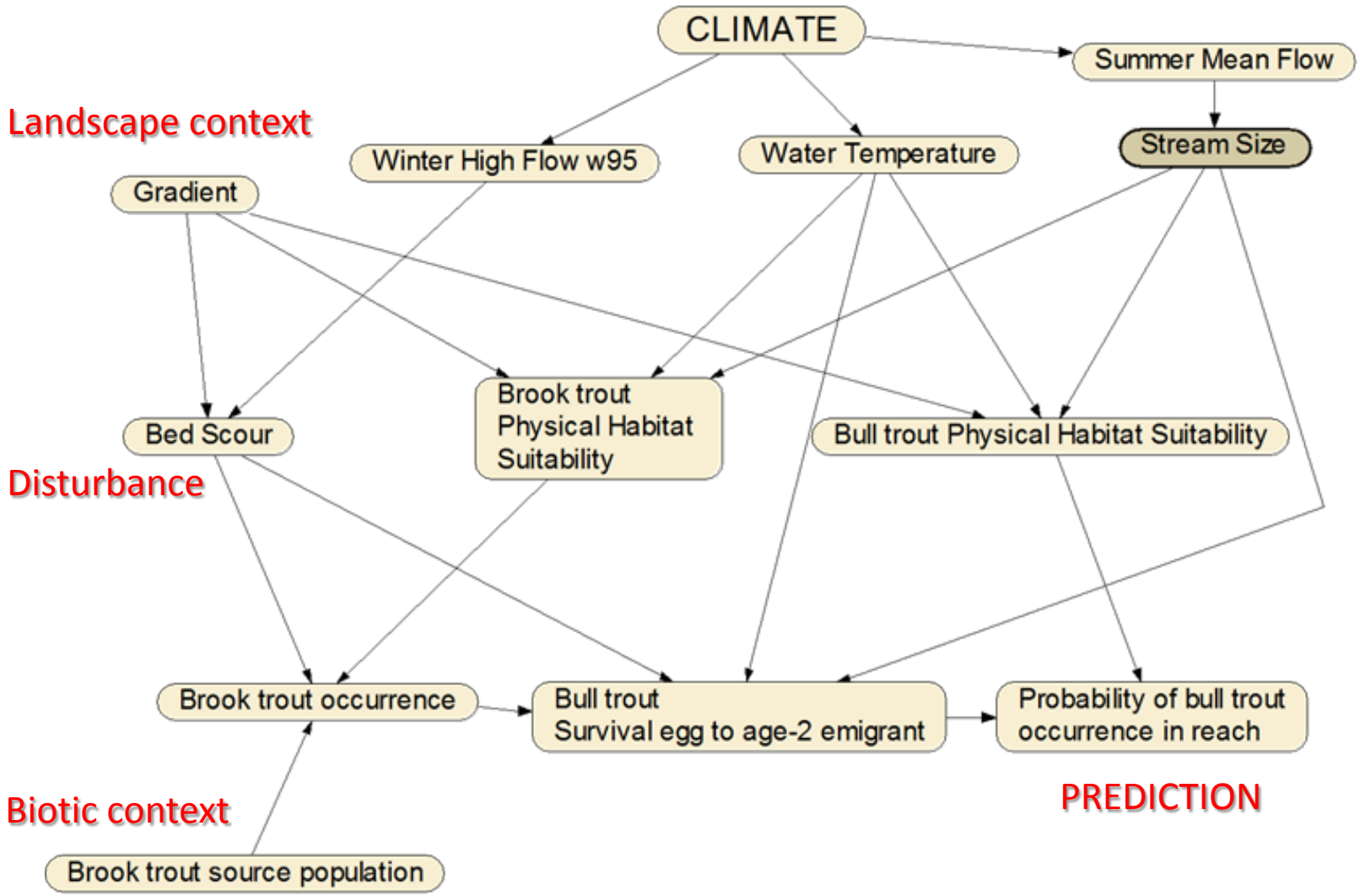


Conceptual model of vulnerability

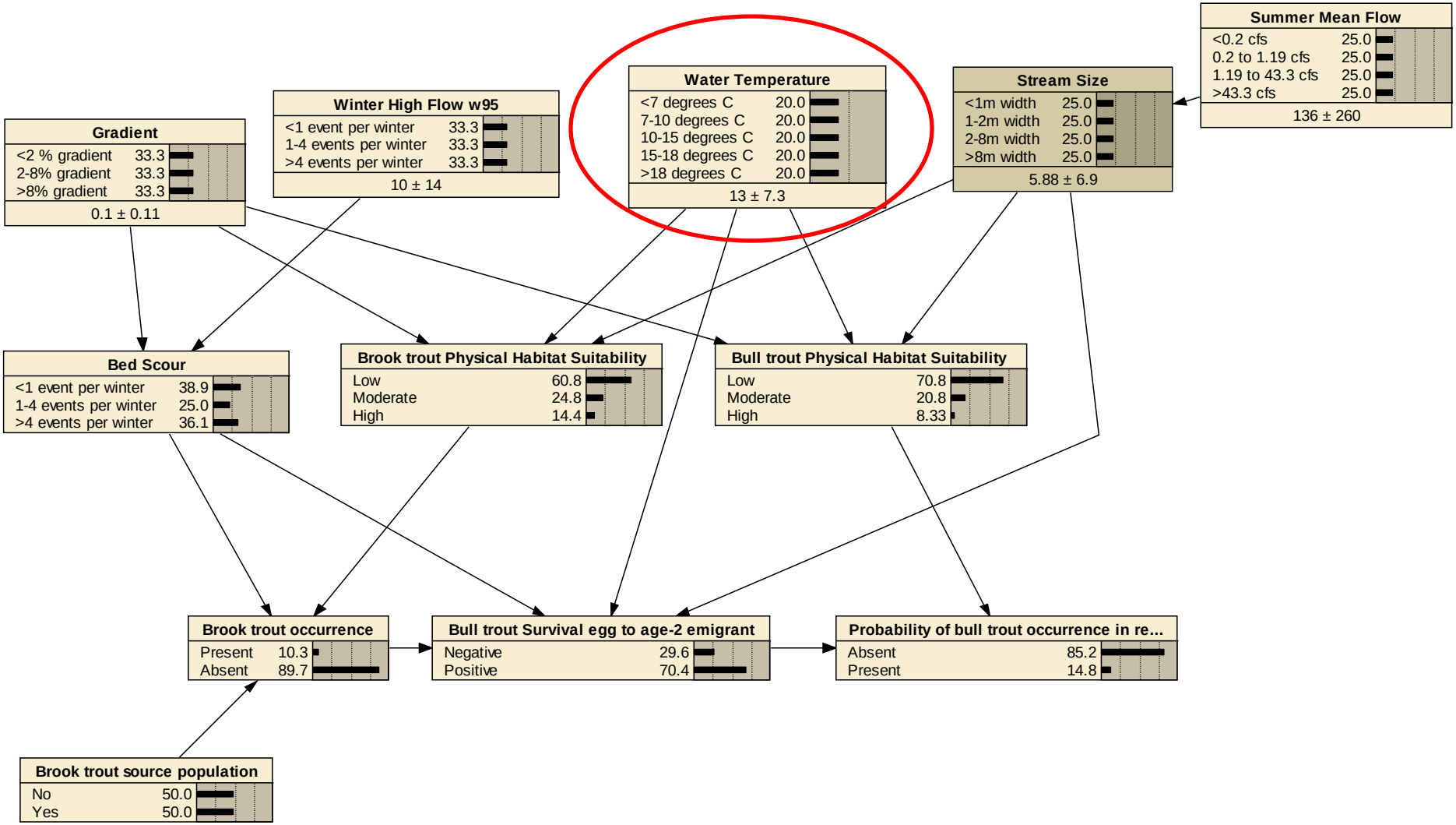


Influence diagram depicting linkages between climate, environmental context, and human disruption on vulnerability of stream salmonid populations (adapted from **Rieman and Isaak 2010**). Orange boxes represent variables considered for the Boise River basin bull trout example.

Influence diagram

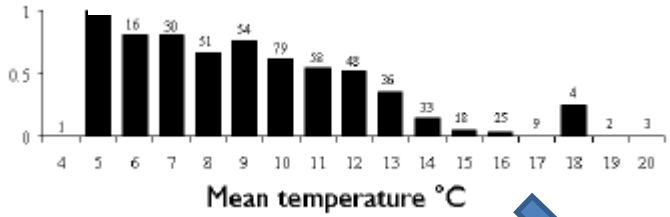


Parameterized model



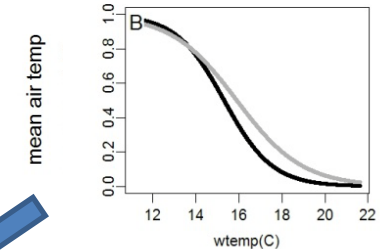
Data integration – mean summer water temperature

Juvenile bull trout occurrence



Rieman and Chandler (1999)

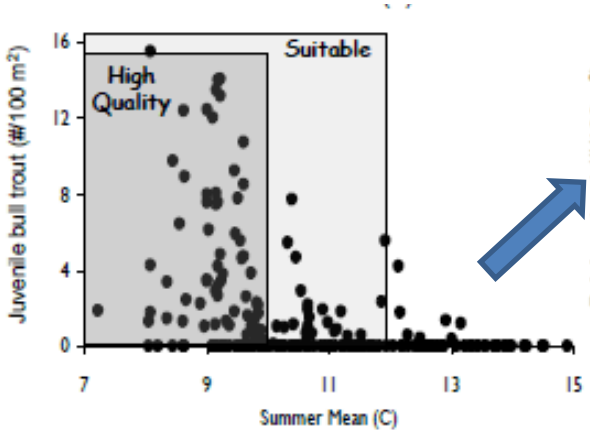
Bull trout



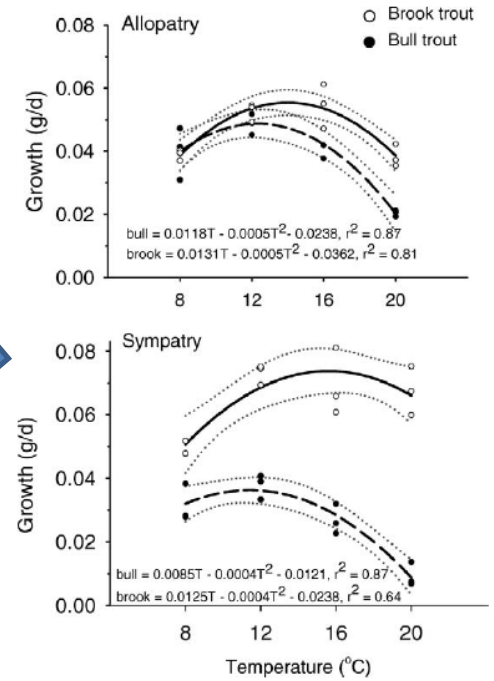
Wenger et al (in review)

BBN states for bull trout

Water Temperature		
<7 degrees C	20.0	Ideal
7-10 degrees C	20.0	Ideal
10-15 degrees C	20.0	Suitable
15-18 degrees C	20.0	Marginal
>18 degrees C	20.0	Poor
13 ± 7.3		



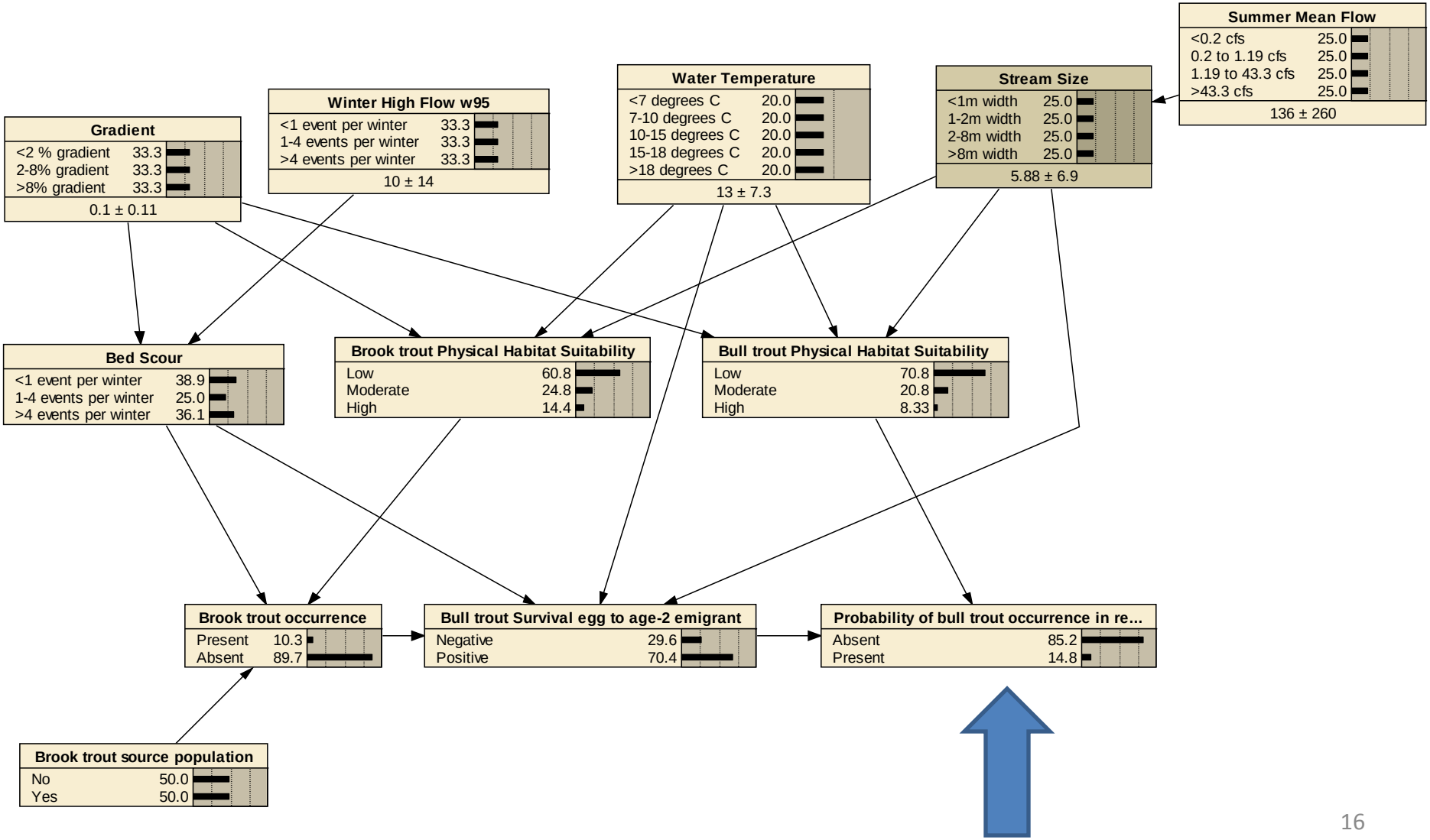
Isaak et al. (2010)



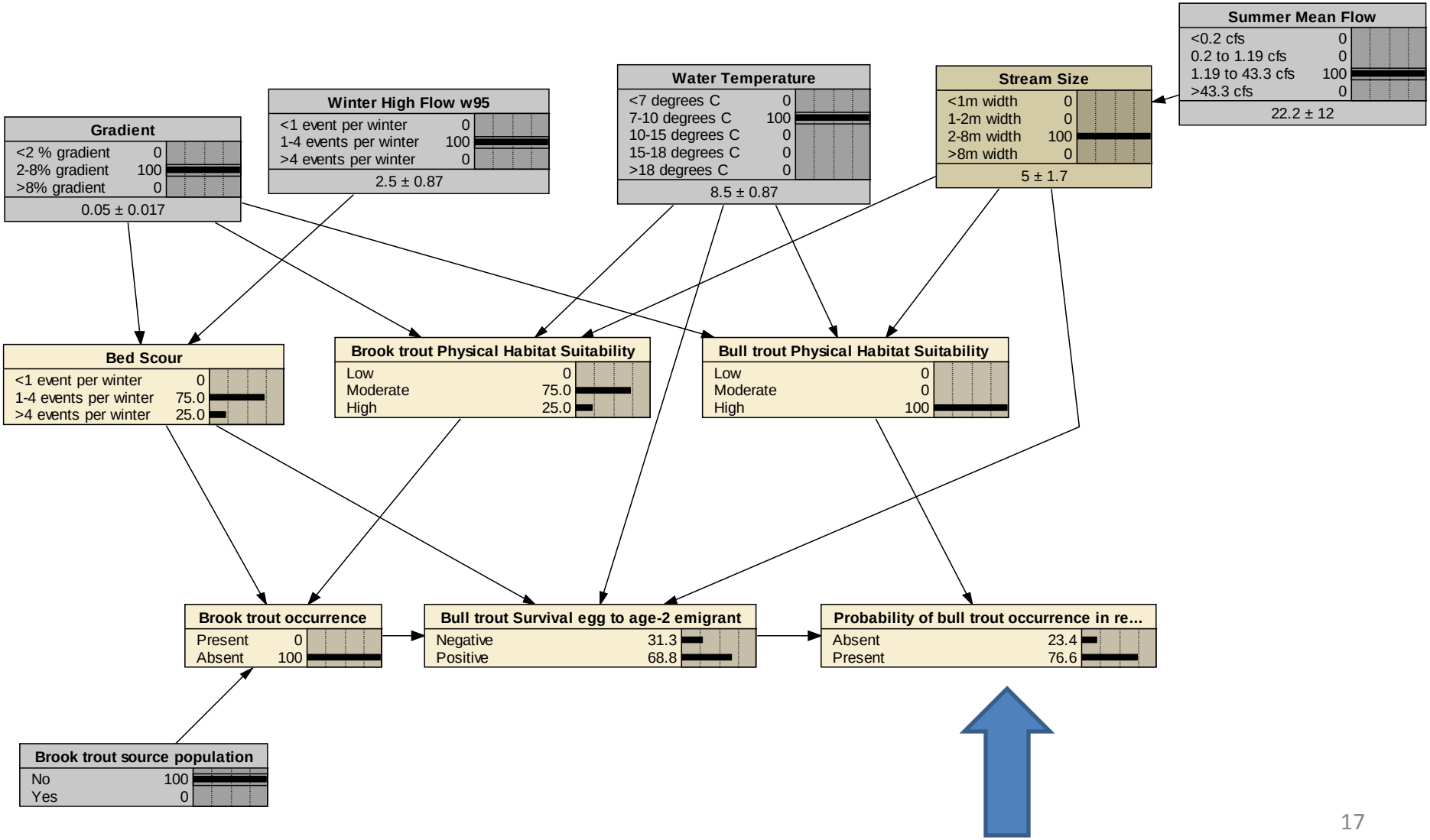
McMahon et al (2007)

Stream temperature thresholds based on empirical observations, statistical models, and controlled experiments. Other BBN variables developed using the same approach.

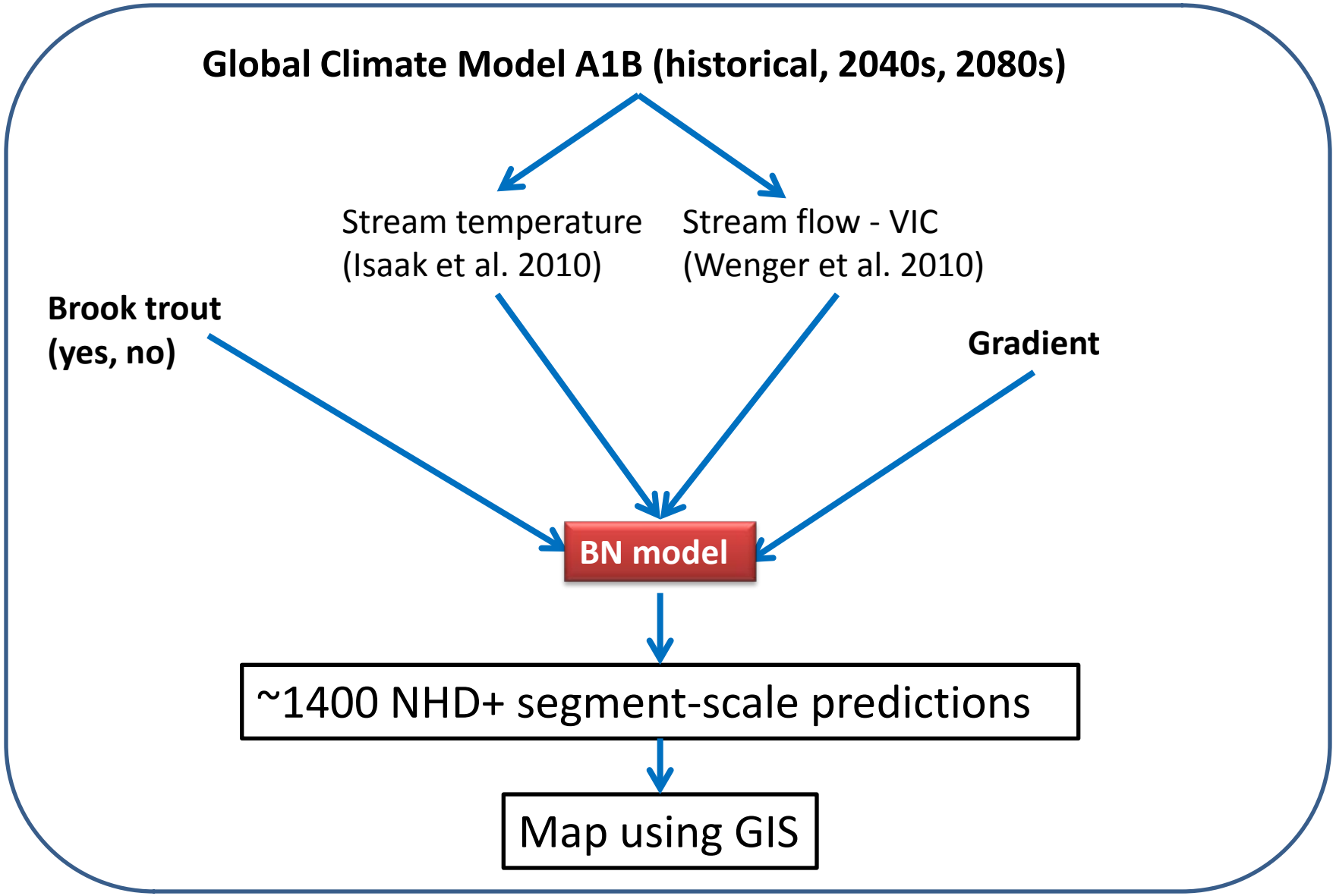
Parameterized model



Prediction based on input data

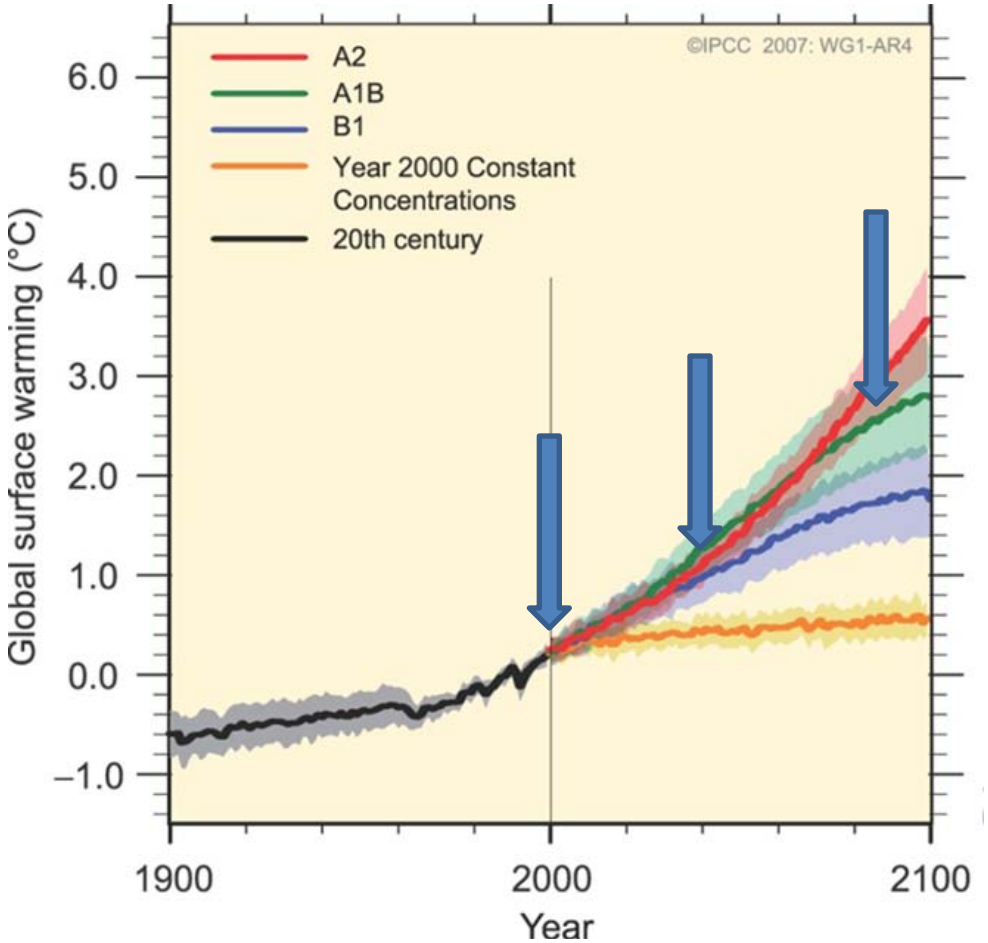


Applying the model: bull trout in the Boise R. basin

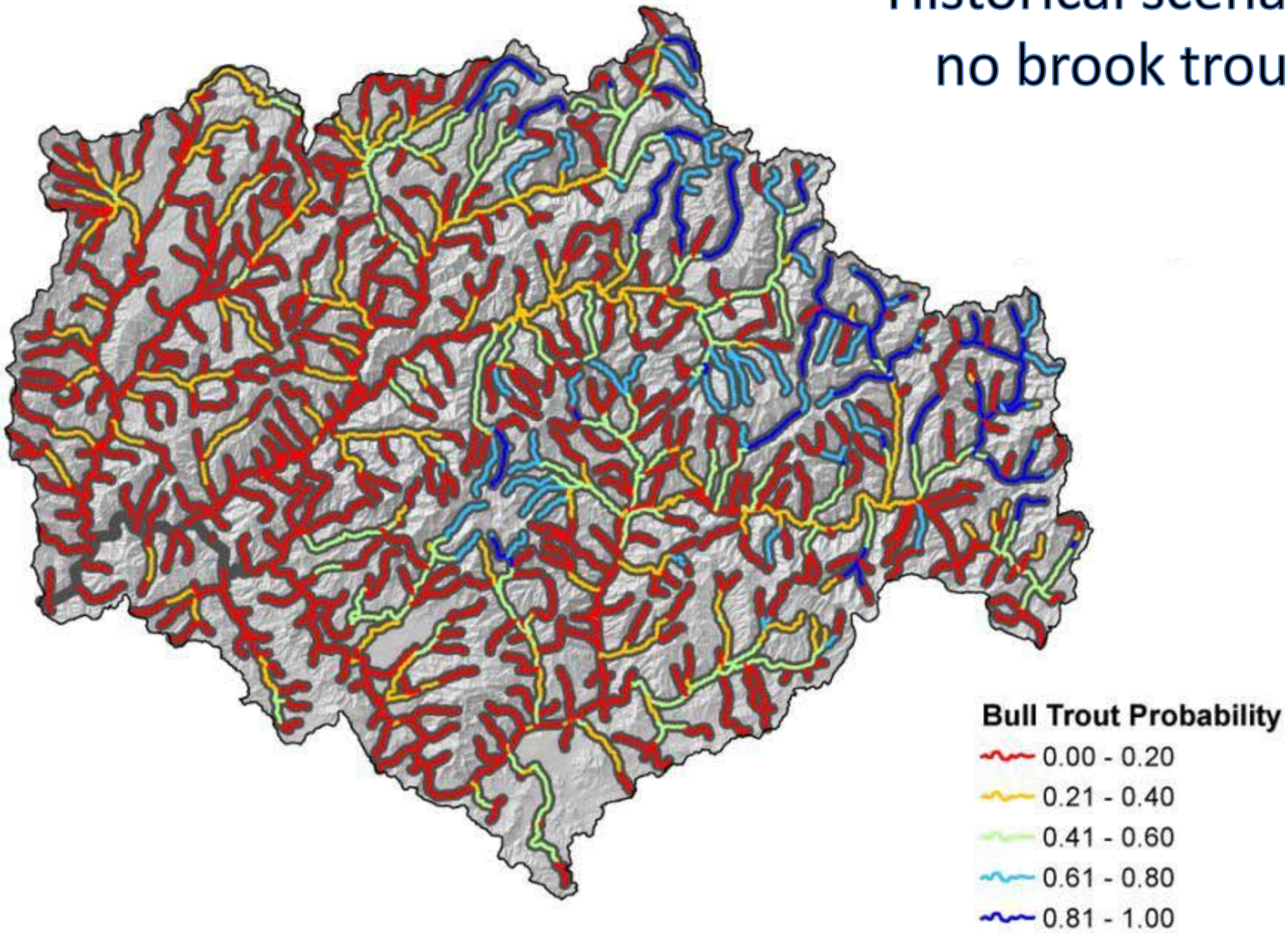


Climate change – no brook trout

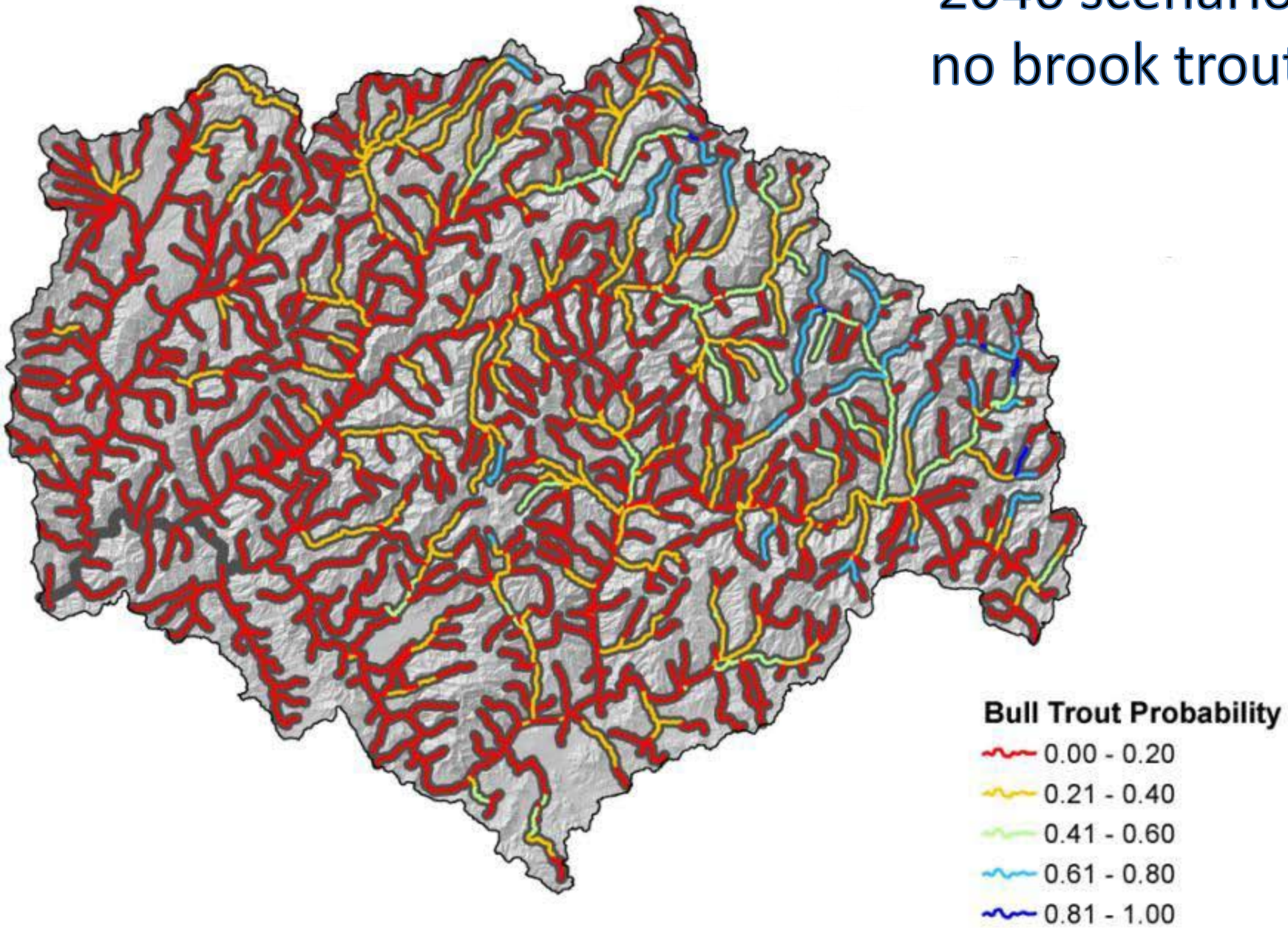
1. Historical
2. 2046
3. 2086



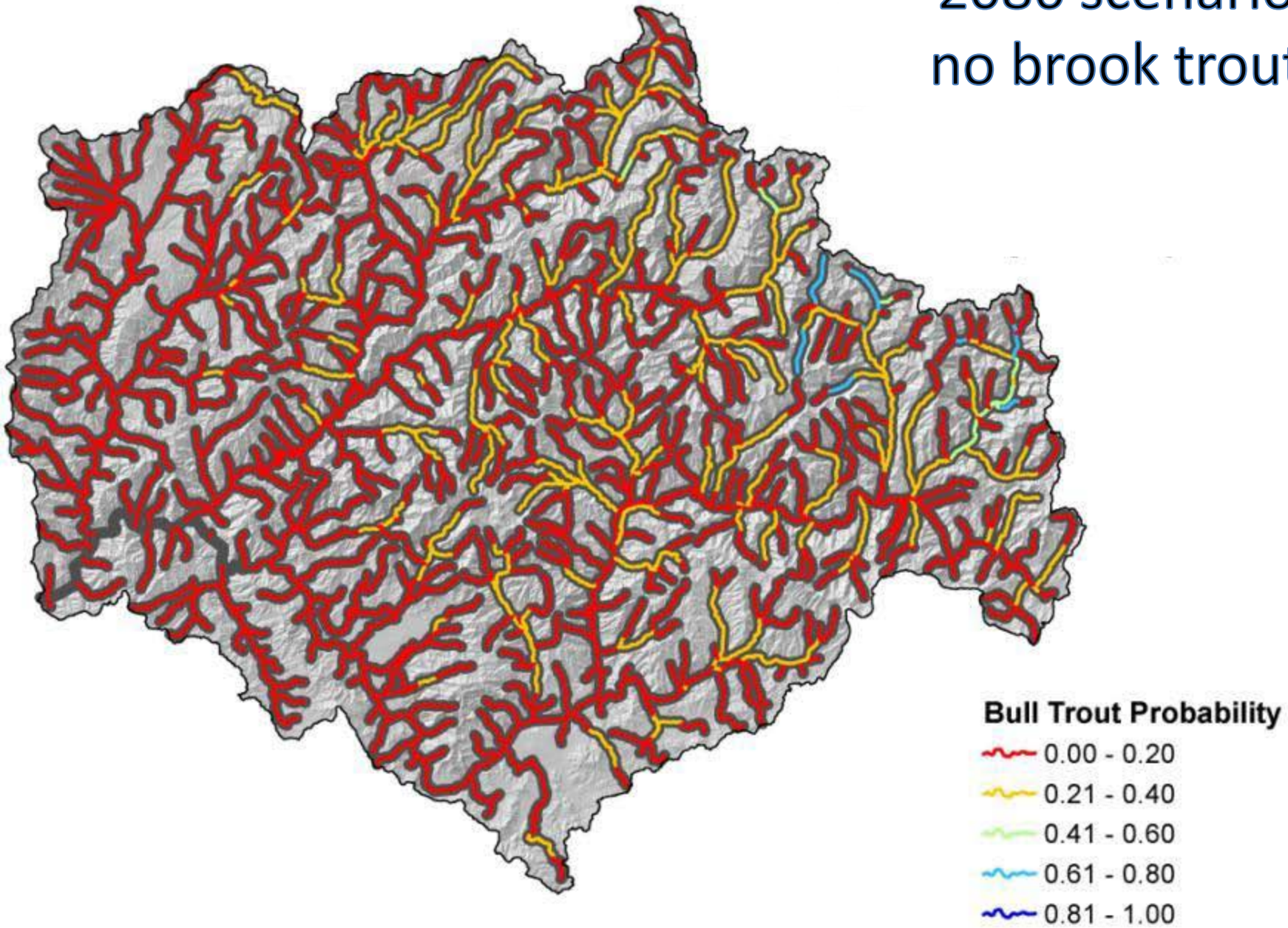
Historical scenario no brook trout



2046 scenario
no brook trout



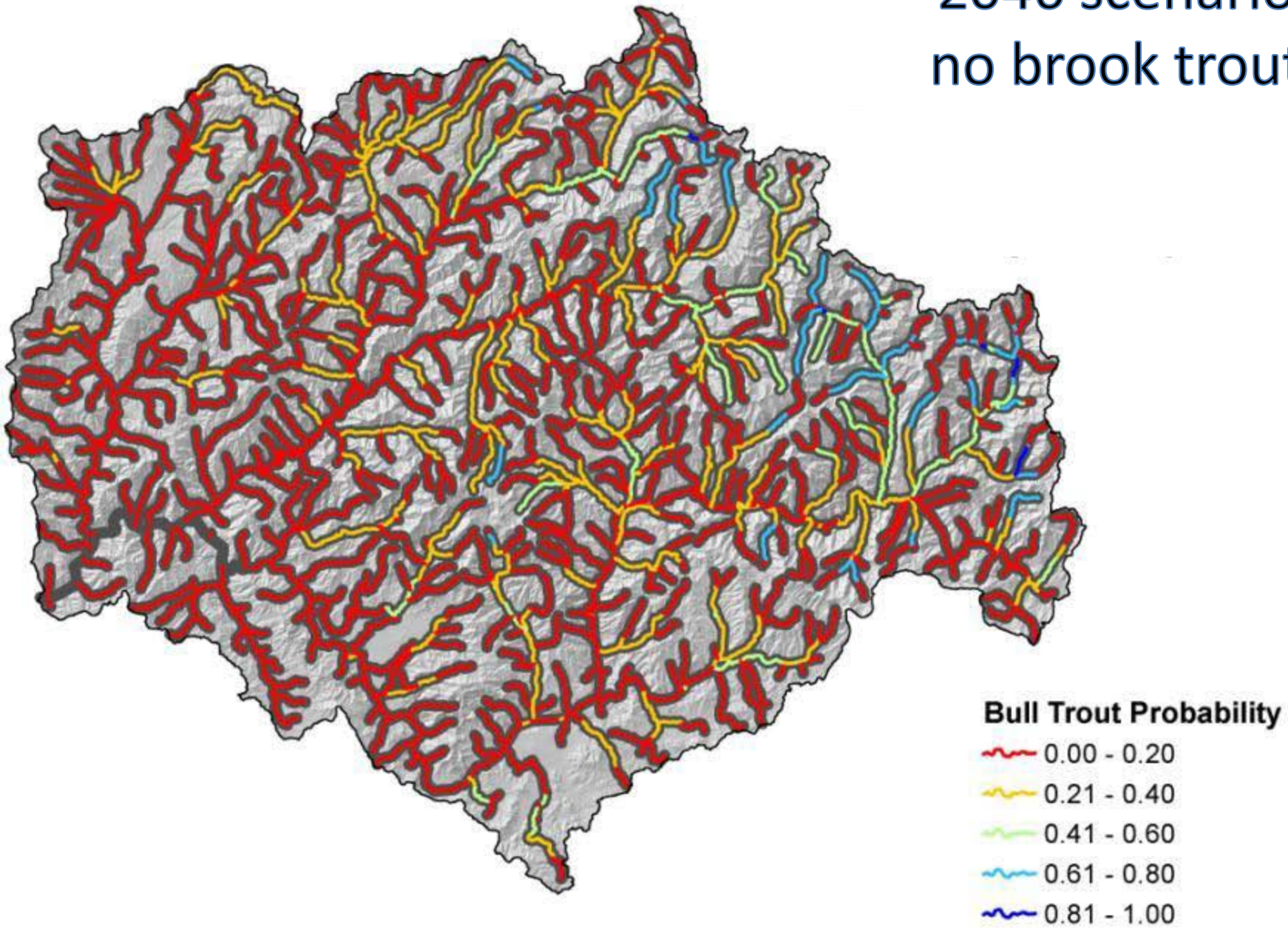
2086 scenario
no brook trout



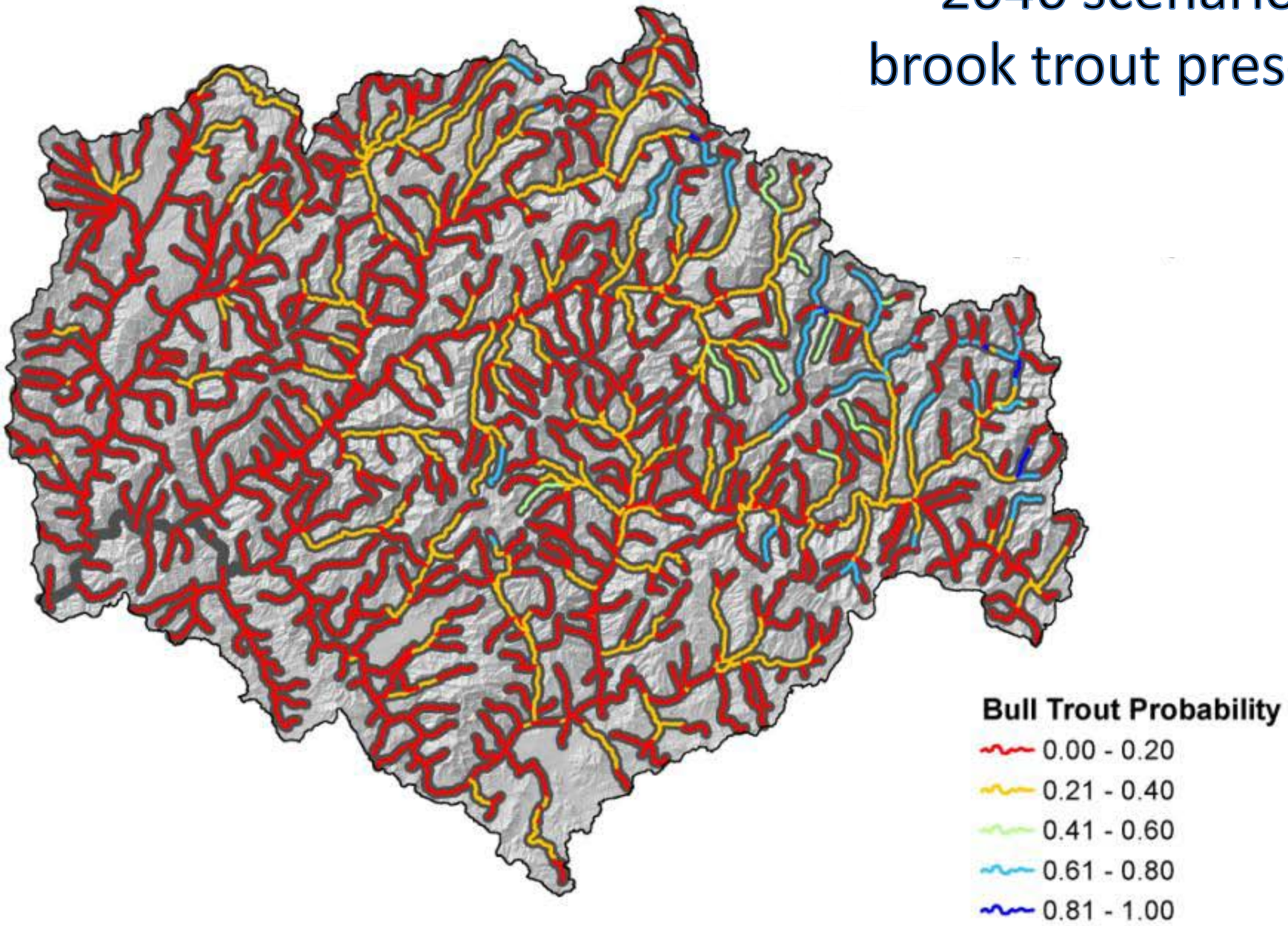
Climate change + brook trout

1. 2046 – no brook trout
2. 2046 – brook trout present

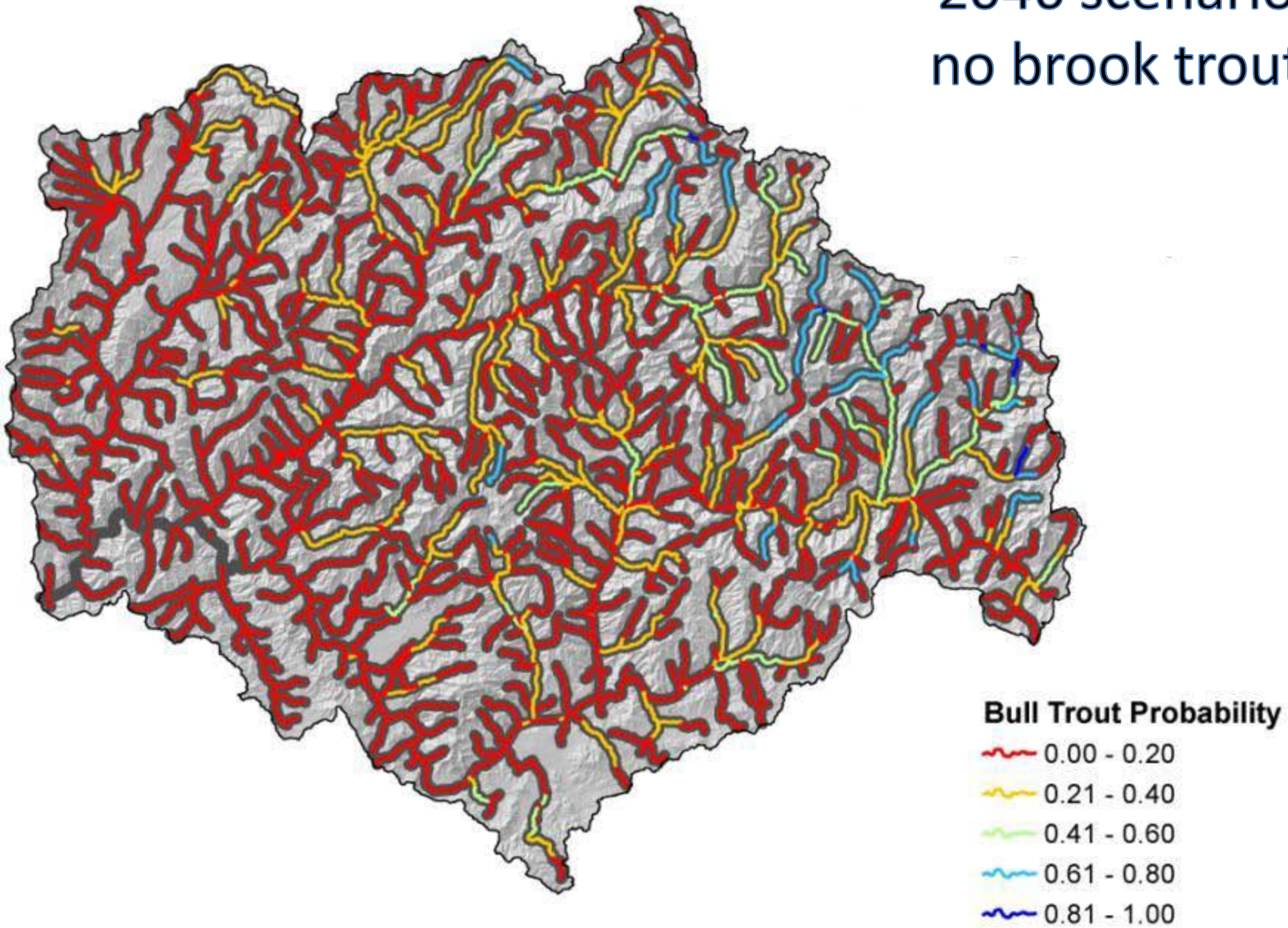
2046 scenario
no brook trout



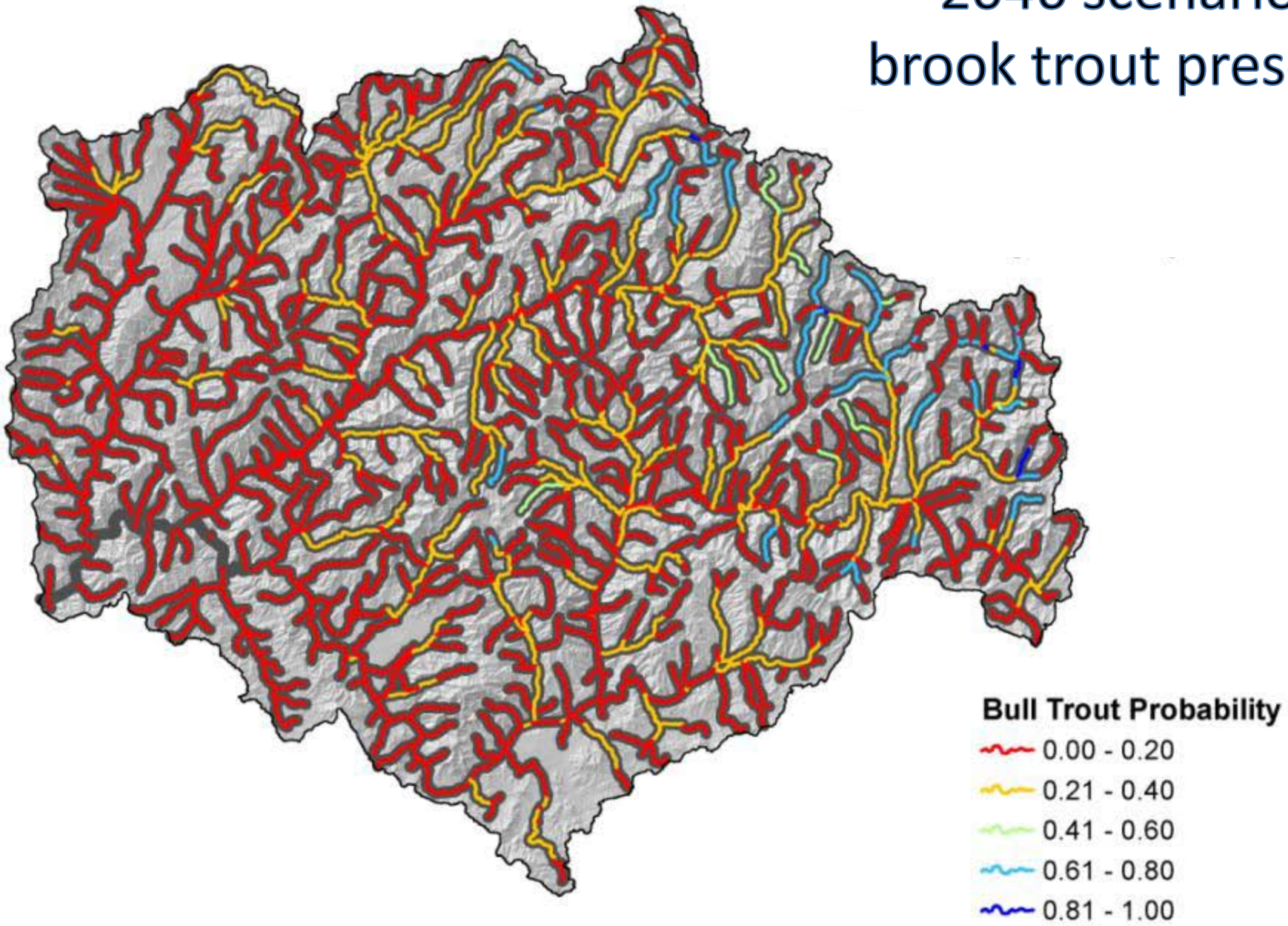
2046 scenario
brook trout present



2046 scenario
no brook trout

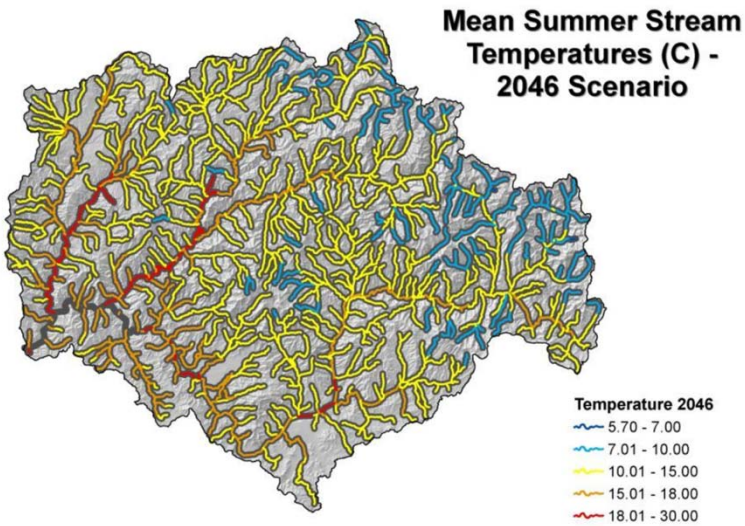


2046 scenario
brook trout present



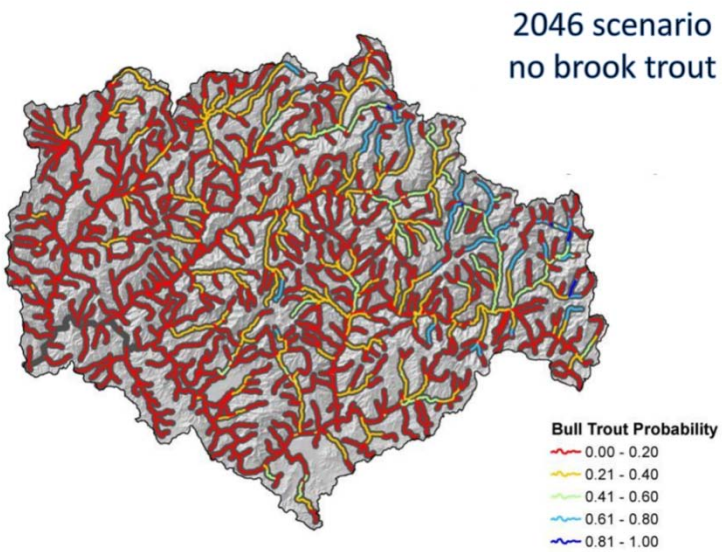
Predictions - intuitive

- ***Stream water temperature very important!***



Stream temperature model: Isaak et al. (2010)

or



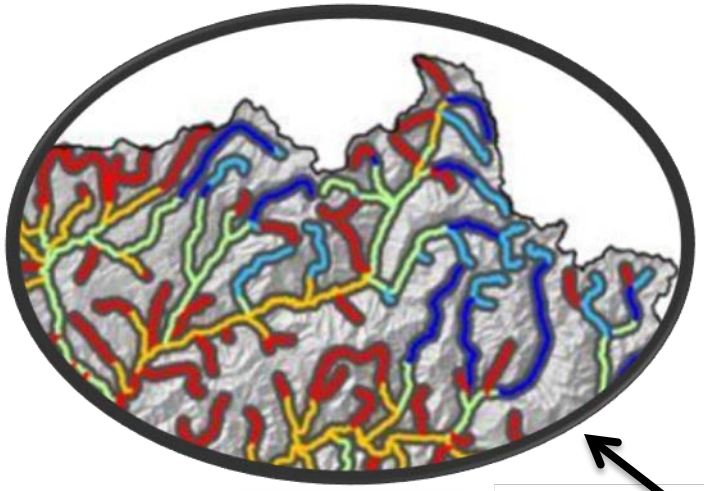
BN model

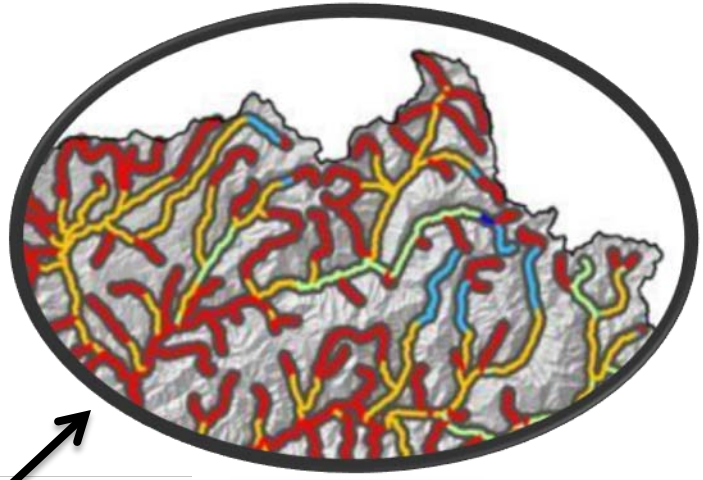
Is the BN worth the extra effort?

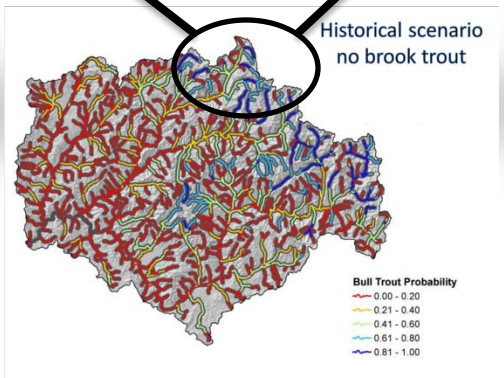
Headwaters

Historical – no brook trout

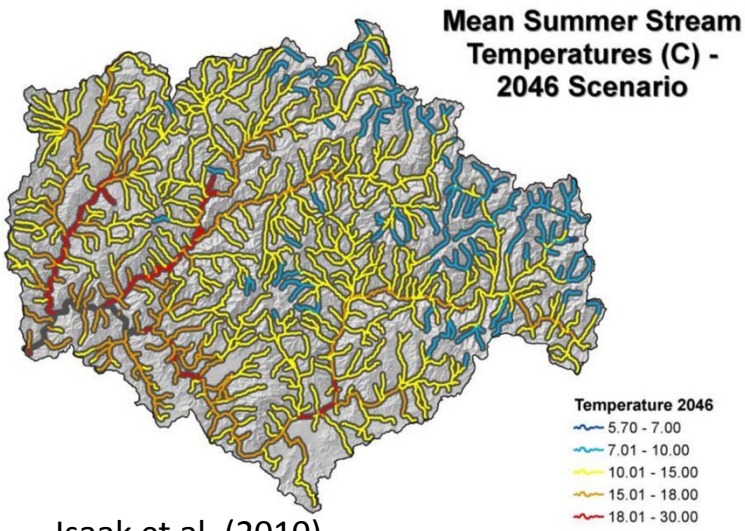
2046 – no brook trout



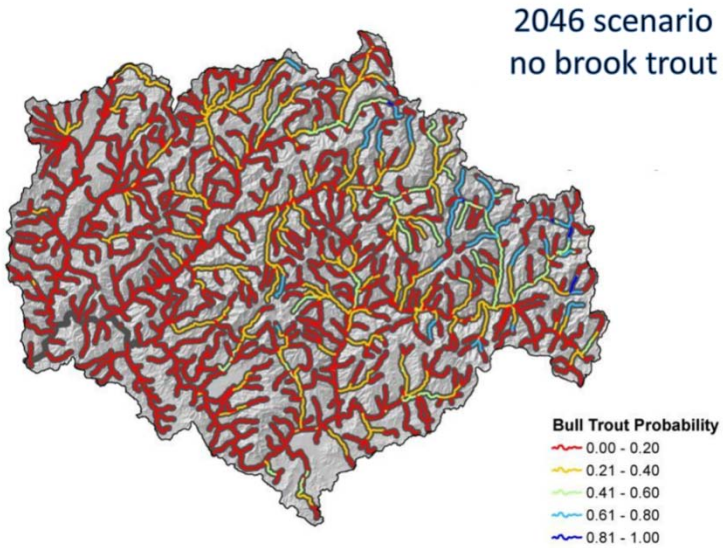




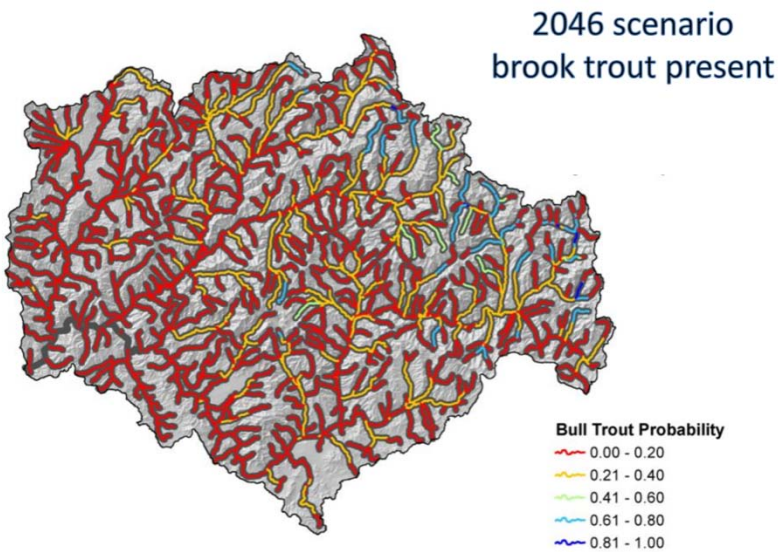
Predictions – counter intuitive



Isaak et al. (2010)



BBN model

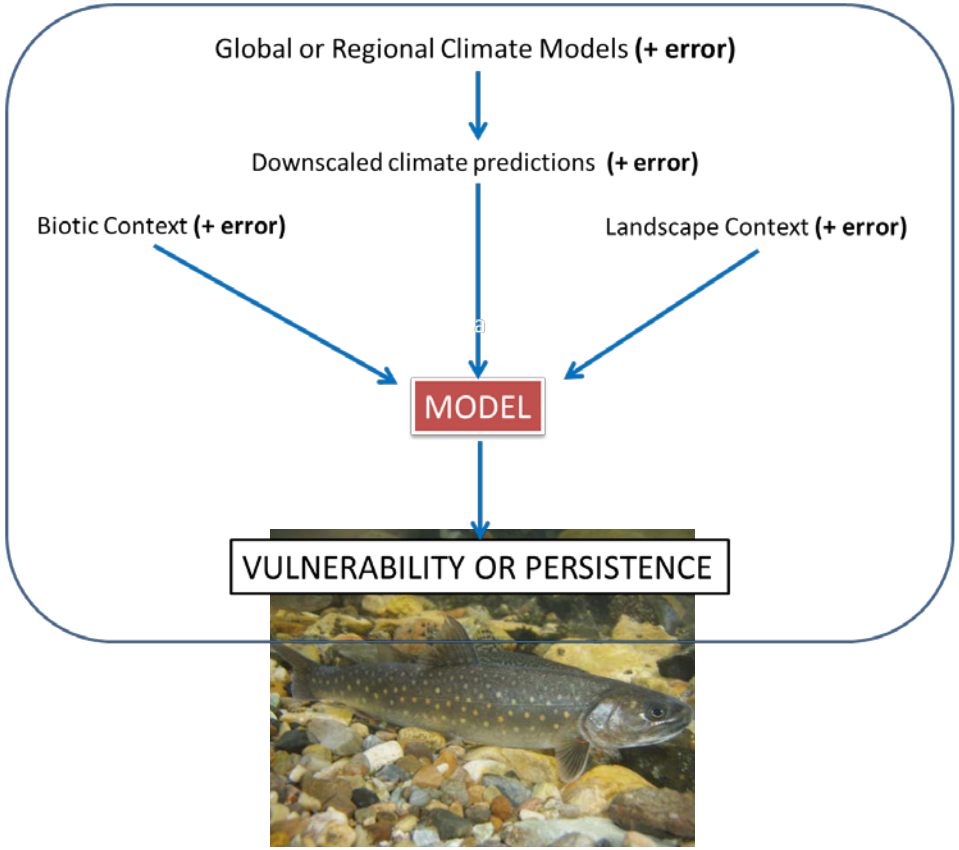


- *Brook trout effect nil when winter flooding increases and habitat favors bull trout*
- *Habitat shrinking from both directions*

Summary

- Bayesian networks are useful framework to integrate data and assess climate impacts given uncertainty

- Outcomes
  - Decision support tool
  - Process



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