User's Guide: bull trout Bayesian network (BN) for Boise River

Bull trout in the Boise River Basin, USA: Bayesian network (BN) to model occupancy by stream segment under climate change

Doug Peterson, US Fish & Wildlife Service, 12 January 2013

Introduction: With the objective to rank a number of streams, watersheds, or populations for conservation, restoration, or some other purpose that requires a strategic allocation of limited management resources, we developed a simple decision support tool that integrates climatic projections and estimates the probability that a stream segment can support bull trout (*Salvelinus confluentus*). The conceptual model (Fig. 1) and parameterized Bayesian network (BN, Fig. 2) to model occurrence of bull trout in stream segments as a function of habitat suitability, occurrence of brook trout, and their interactions mediated by climate, in this case stream flows and temperature. Details on model development and node definitions are found in Peterson et al. (2013).

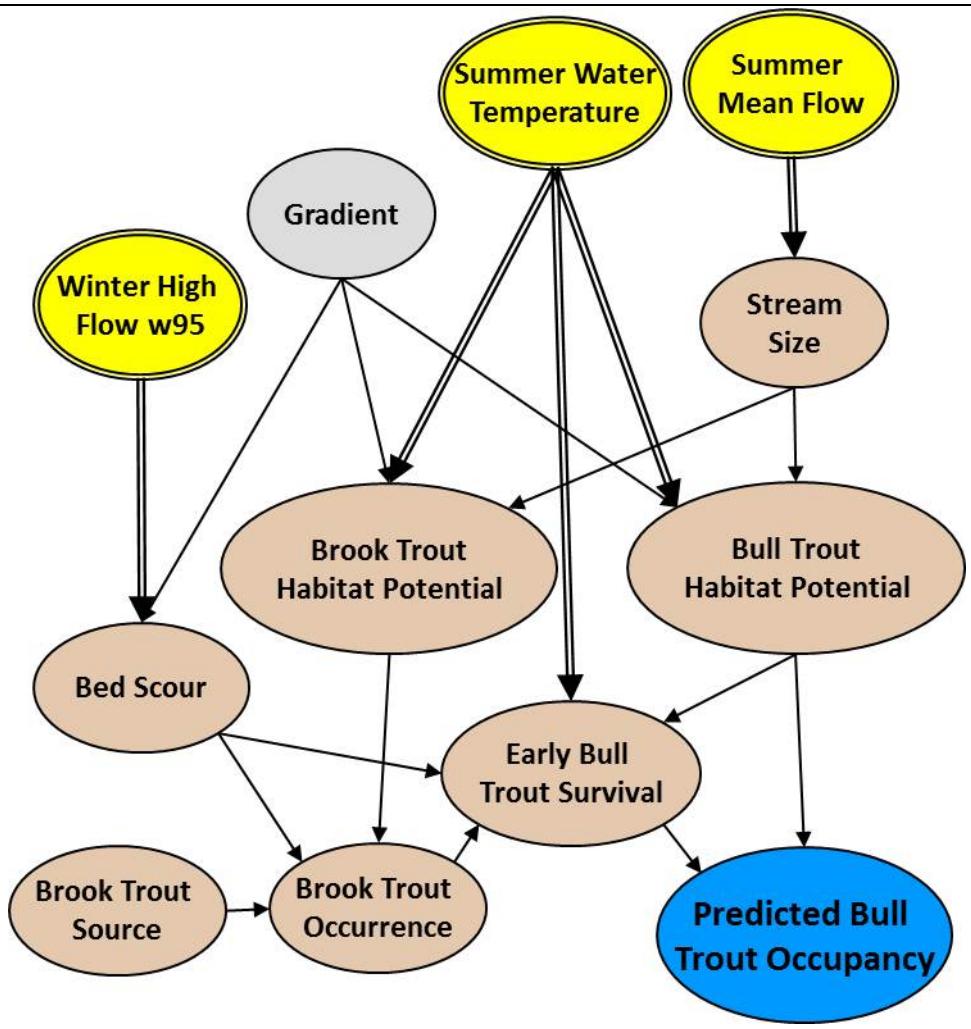


Figure 1. Influence diagram that depicts how climatically-driven changes in stream temperature and flow influence the occurrence of bull trout in stream segments within the Boise River Basin, USA.

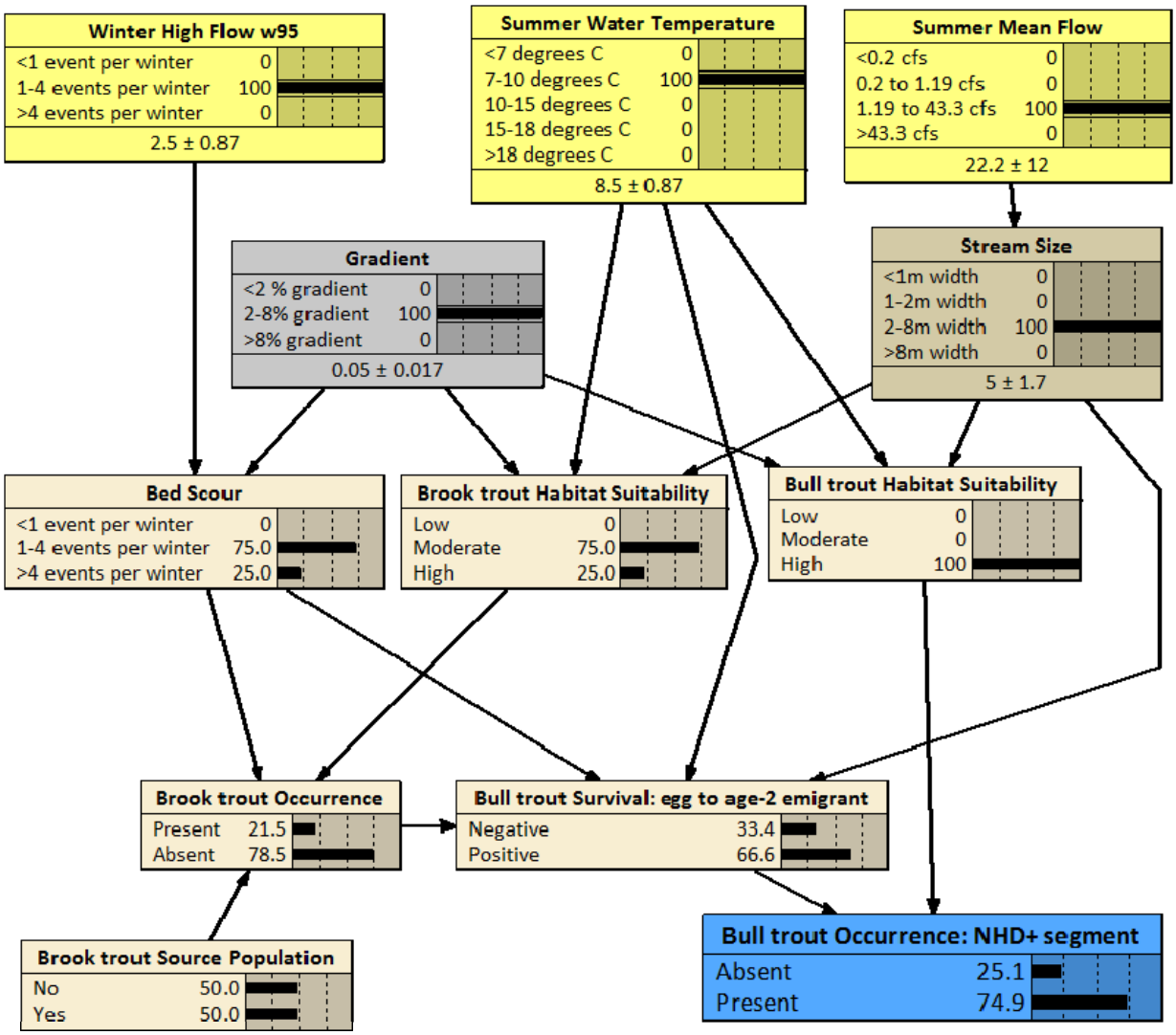


Figure 2. Bayesian network for bull trout in the Boise River basin, USA, showing node states and representative probabilities. In this example, the input conditions yield a predicted probability of occupancy of 74.9%.

Software: The decision support tool is executed using the software program Netica. Both Windows and Macintosh versions of Netica can be downloaded for free at http://www.norsys.com/download.html. The "limited mode" (free or demo) version of Netica is full featured, but limited in the model size it will run. "Boise bull trout BN 2012.neta" is small enough to execute with the demo version (Figure 2). Note: The use of trade or firm names (i.e., Netica modeling software) is for reader information and demonstration purposes only and does not imply endorsement by the US Department of Interior or USDA Forest Service of any product or service.

Model implementation: The model can be implemented in two general ways. In *interactive mode*, the user can explore the effect of changing conditions in real time for an individual stream segment. In *batch processing mode* the model can be used to evaluate a large number of cases, such as for all stream segments within a subbasin or basin. The beginning user should start first with the interactive mode to understand how the model works.

Proper use of this model: This Bayesian network (BN) was developed for bull trout in the Boise River Basin, Idaho, USA and its application was meant to demonstrate the process by which such a model can be used to inform conservation planning and management under climate change. The model is NOT meant for use in vulnerability analysis across the range of bull trout; users interested in applying this model beyond the Boise River Basin can use it for inspiration or as a template to be refined, revised or updated based on their management question(s) and parameters (probabilities) derived from justifiable criteria.

Interactive mode:

1. Open the .dne file using Netica.

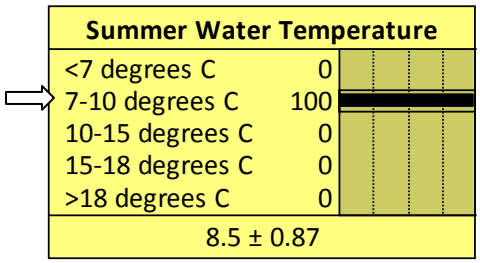
2. Compile the model:

Status of compile tool button	Required action
	Click button to compile network
	None, network is already compiled

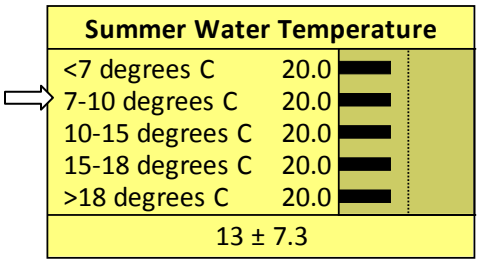
3. Input climatic and other conditions to represent the desired management scenario. Do this by changing the probabilities for nodes of interest. Typically, changes will be made for *input nodes* (e.g., summer water temperature, summer mean flow, winter high flow w95, gradient) that have arrows pointing away from them, but no arrows pointing to them.

4. How to interactively change the probabilities for input nodes

   a. Single click on the name of the desired state to make the probability 100% for that state. In this example, click on 7-10 degrees C to make the node 100% for that temperature category.

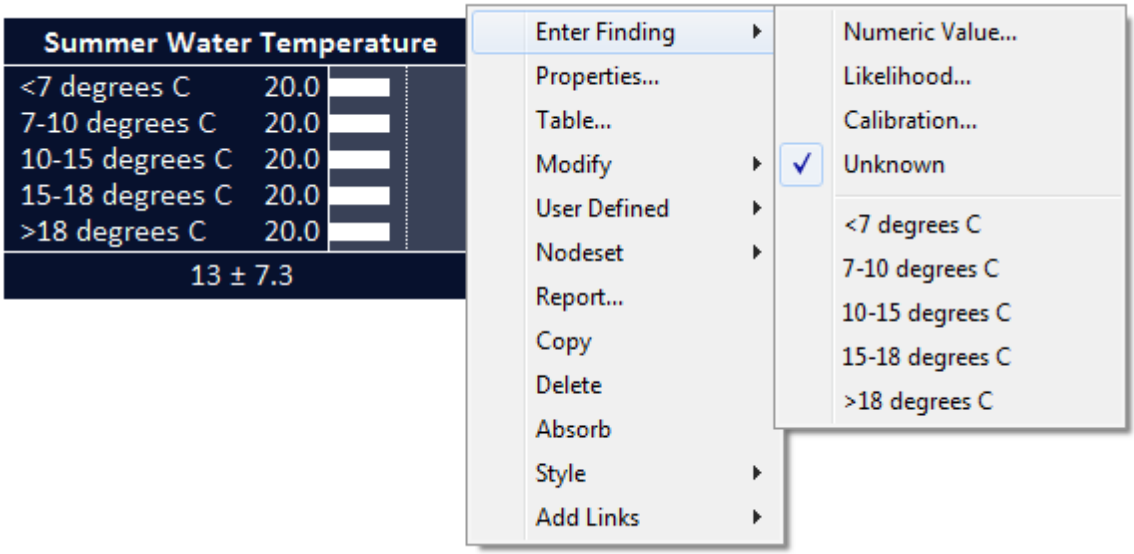


   b. To change from 100% probability for one state to uniform probabilities, single again click on the state name. In this example, click again on 7-10 degrees C (if it has 100% probability) and now the probabilities are evenly distributed among the five states. This would represent a case where the temperature was unknown.

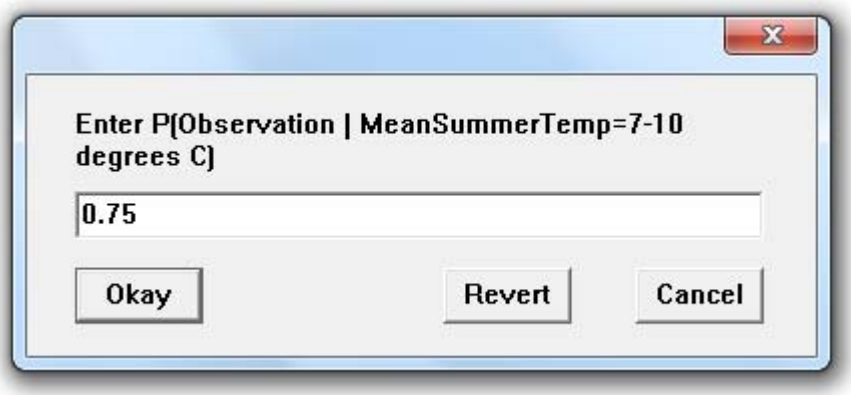


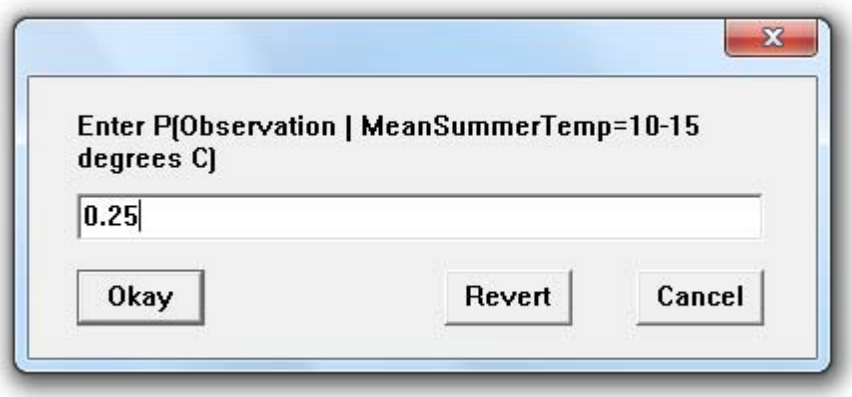
   c. To enter different combinations of probabilities in interactive mode, say 75% in 7-10 degrees and 25% in 10-15 degrees, the probabilities must be entered manually. For example, to enter a probably of 0.75 (75%) for "*Summer Water Temperature = 7-10*

degrees C" right click on the node and select "Enter Finding → Likelihood" to open a series of dialog boxes that allows you to manually enter probabilities for each state.



For the two states of interest, this will look like:





The probabilities must sum to 1.0 (or 100%) across the states of each node, so in this example you would need to enter 0 for the other three states! The end result should look like:

Summer Water Temperature	
<7 degrees C	0
7-10 degrees C	75.0
10-15 degrees C	25.0
15-18 degrees C	0
>18 degrees C	0
9.5 ± 2	

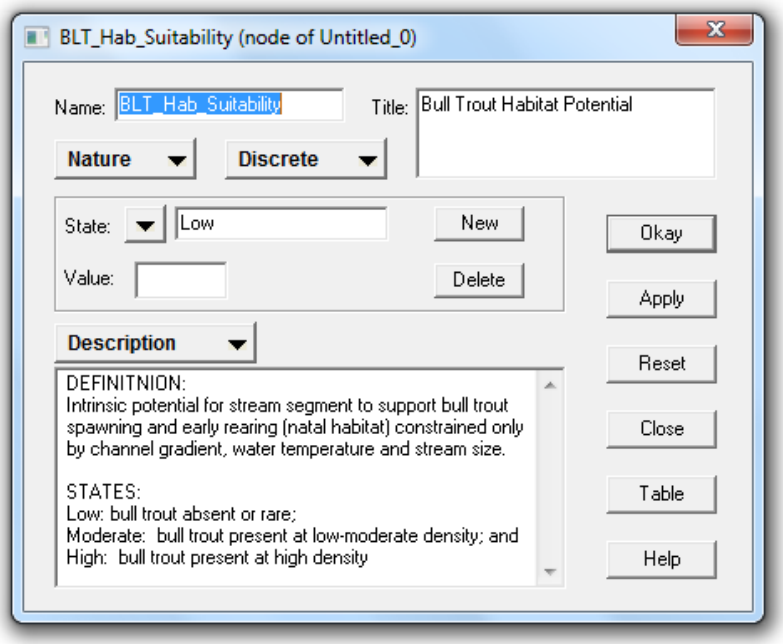
5. All the other input nodes can be manipulated as needed to create the desired set of conditions.

6. The terminal node *Bull Trout Occurrence* estimates the probability that bull trout will occur in that stream segment.

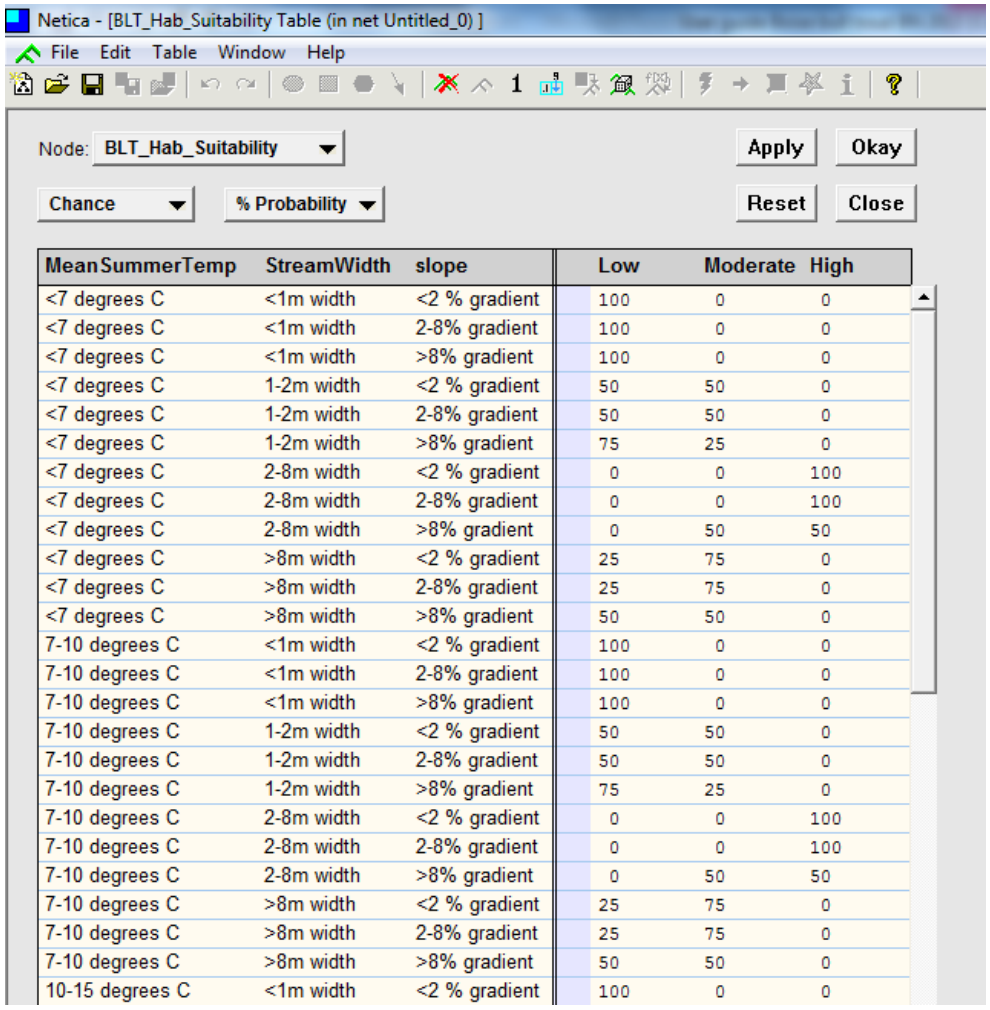
7. <u>Node definitions and underlying probabilities</u>: The BN model file contains built-in documentation that describes each node and conditional probability tables that define relationships among nodes.

    a. To view the node definition for *Bull Trout Habitat Potential*, double click a node to open a dialog window and select the "Description" tab in the lower left dialog field.

Bull Trout Habitat Potential	
Low	100
Moderate	0
High	0



b. From this dialog box, you can select click the "Table" button at lower right to view the conditional probability table for that node. A portion of the conditional probability table for *Bull Trout Habitat Suitability* looks like:



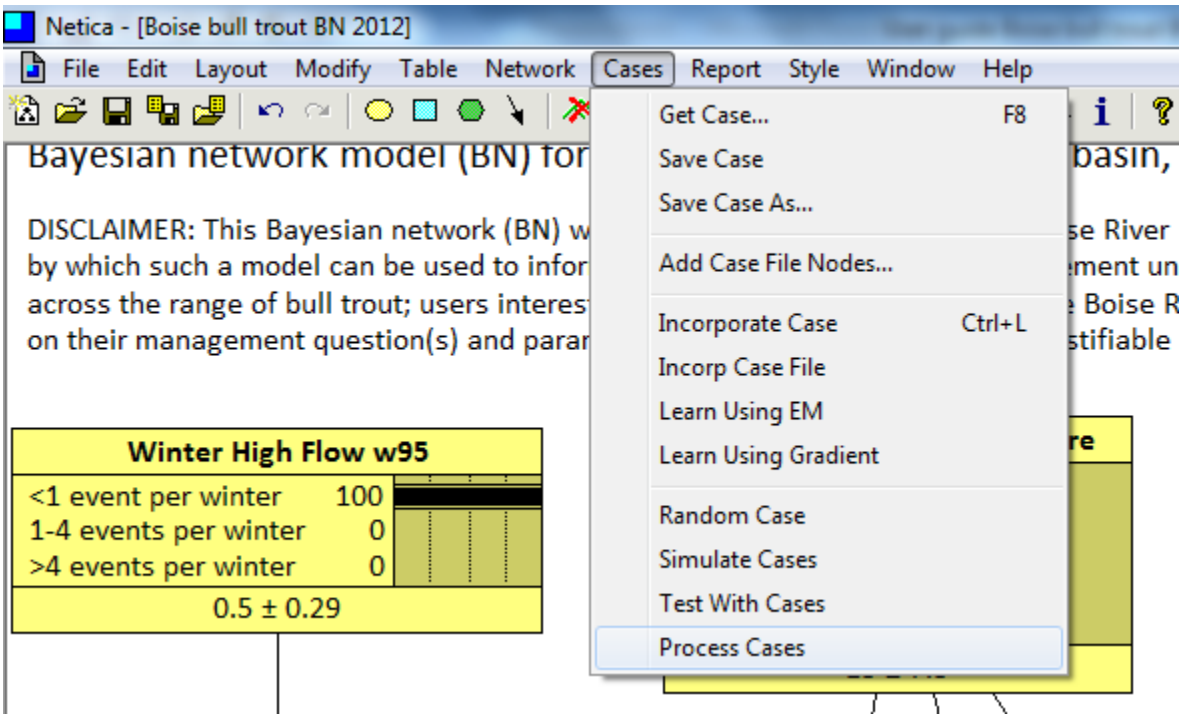
MeanSummerTemp	StreamWidth	slope	Low	Moderate	High
<7 degrees C	<1m width	<2 % gradient	100	0	0
<7 degrees C	<1m width	2-8% gradient	100	0	0
<7 degrees C	<1m width	>8% gradient	100	0	0
<7 degrees C	1-2m width	<2 % gradient	50	50	0
<7 degrees C	1-2m width	2-8% gradient	50	50	0
<7 degrees C	1-2m width	>8% gradient	75	25	0
<7 degrees C	2-8m width	<2 % gradient	0	0	100
<7 degrees C	2-8m width	2-8% gradient	0	0	100
<7 degrees C	2-8m width	>8% gradient	0	50	50
<7 degrees C	>8m width	<2 % gradient	25	75	0
<7 degrees C	>8m width	2-8% gradient	25	75	0
<7 degrees C	>8m width	>8% gradient	50	50	0
7-10 degrees C	<1m width	<2 % gradient	100	0	0
7-10 degrees C	<1m width	2-8% gradient	100	0	0
7-10 degrees C	<1m width	>8% gradient	100	0	0
7-10 degrees C	1-2m width	<2 % gradient	50	50	0
7-10 degrees C	1-2m width	2-8% gradient	50	50	0
7-10 degrees C	1-2m width	>8% gradient	75	25	0
7-10 degrees C	2-8m width	<2 % gradient	0	0	100
7-10 degrees C	2-8m width	2-8% gradient	0	0	100
7-10 degrees C	2-8m width	>8% gradient	0	50	50
7-10 degrees C	>8m width	<2 % gradient	25	75	0
7-10 degrees C	>8m width	2-8% gradient	25	75	0
7-10 degrees C	>8m width	>8% gradient	50	50	0
10-15 degrees C	<1m width	<2 % gradient	100	0	0

8. <u>Saving analyses</u>: If you cannot save changes to the model or analyses because the model size limitation of the demo version of NETICA, but wish save a record of your work, the default approach is to capture the screen image of the BN (Ctrl + Print Screen **or** Select All + Copy) and paste the image into a document, presentation, etc.

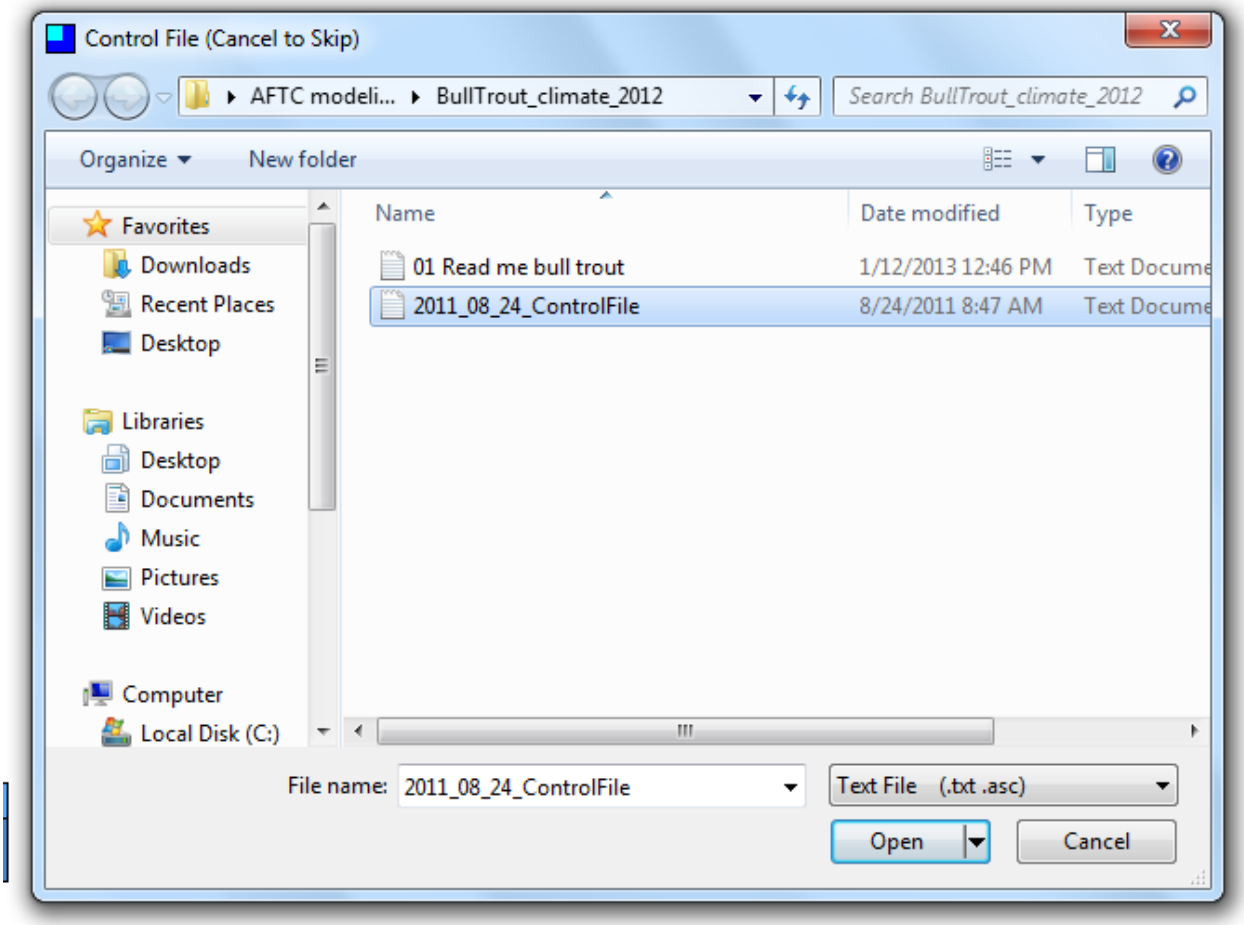
Batch processing mode:

The workflow to process a large number of cases (e.g., multiple stream segments) requires a few additional steps and preparation of two additional files: (a) a *control file* is a text file that will specify the output the BN will generate, and (b) the *case file* which is the data (findings, probabilities, observations) that you want to evaluate with the BN. Netica's help menu describes in detail how to format these files (search for "Process Cases"). Example files from the analysis in Peterson et al. (2013) are included in the .zip file contains the model and documentation. The example below uses the control and case files from the actual analysis.

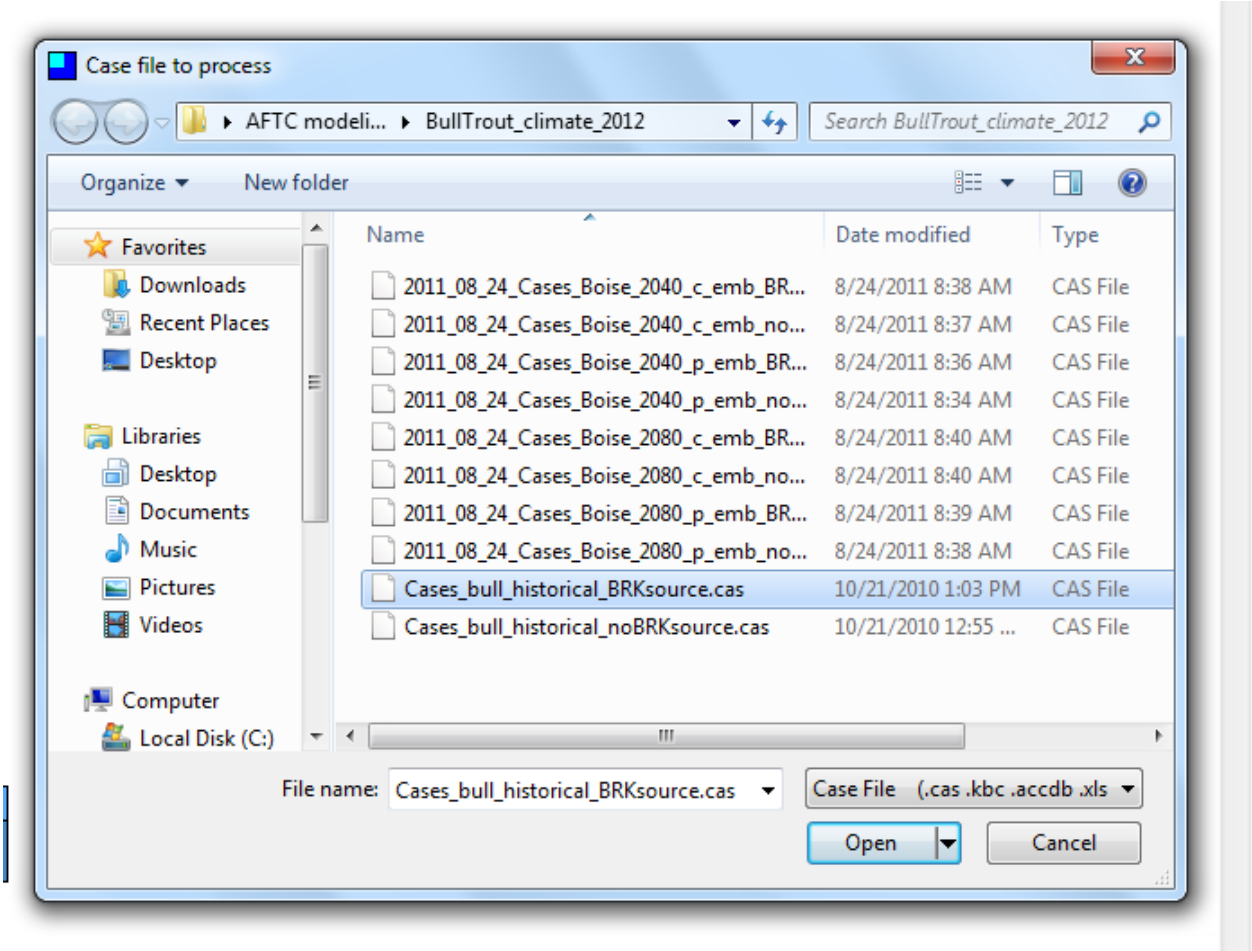
1. Open and compile the BN, and then select "Cases → Process Cases" from the menu



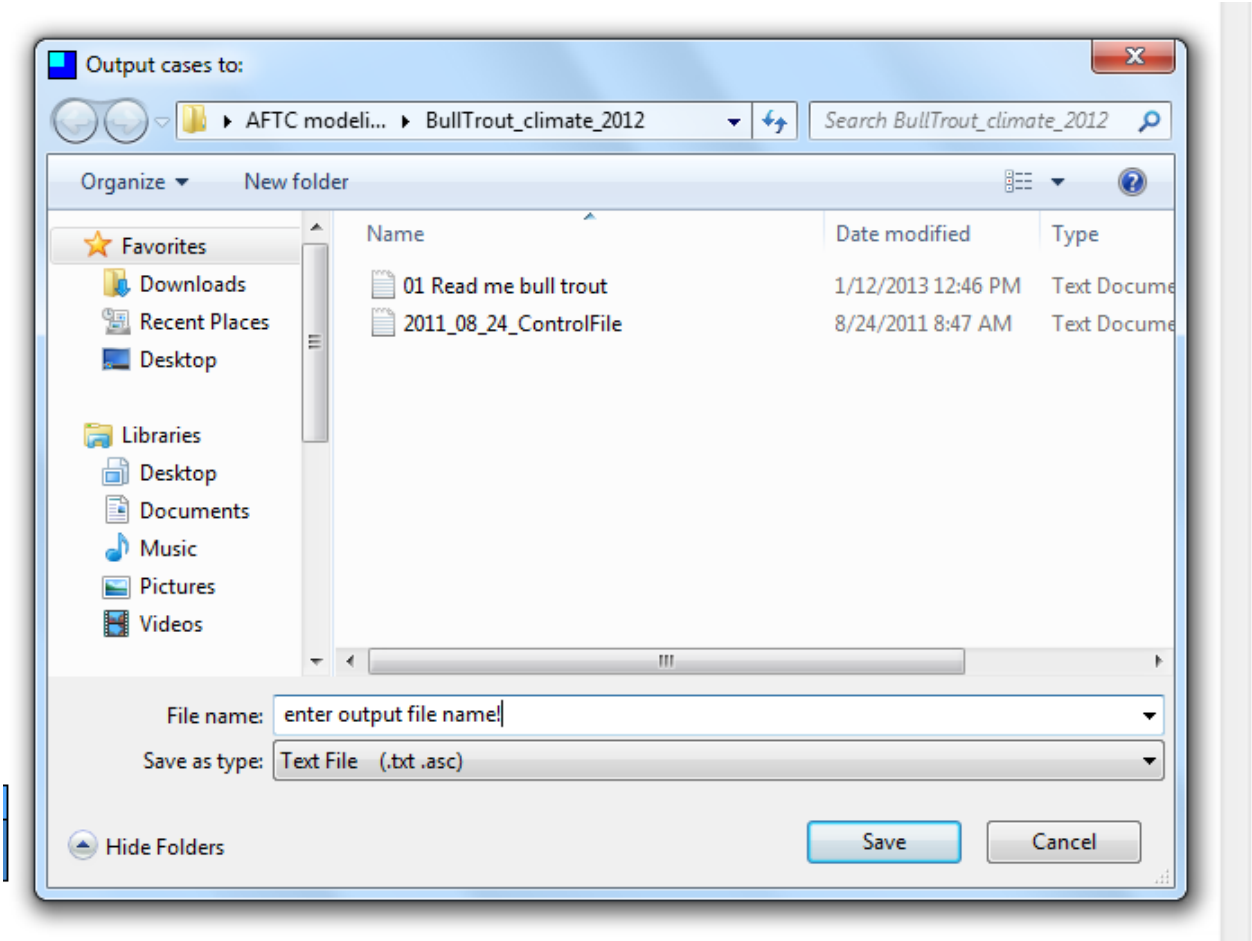
2. A standard dialog box for opening a file will appear. Choose the Control file that you wish to use, then click Open.



3. A standard dialog box for opening a file will again appear. Select the desired Case file (i.e., the "data") and click Open. In this example, the .cas file for historical environmental conditions and brook trout present is selected. After clicking Open, new dialog box for saving a file will appear.



4. Enter the name of the output file you want the results written to. Netica reads each case in the case file and enters it as "findings" in the BN. Then Netica does belief updating to calculate probabilities for all the nodes that didn't have findings, and writes the results to the output file.



5. Open the output file to view the results!

Technical support and documentation for this model

Contact:

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Model documentation and publications:

Peterson, D.P., B.E. Rieman, J.B. Dunham, K.D. Fausch, and M.K. Young. 2008. 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*). Canadian Journal of Fisheries and Aquatic Sciences 65(4):557-573. DOI: 10.1139/f07-184

Peterson, D.P., S.J. Wenger, B.E. Rieman, and D. J. Isaak. 2013. Linking climate change and fish conservation efforts using spatially explicit decision support tools. Fisheries 38(3):111-125. DOI:10.1080/03632415.2013.769157

For further reading about Bayesian networks in general:

Marcot, B.G., Steventon, J.D., Sutherland, G.D. and McCann, R.K. 2006. Guidelines for developing and updating Bayesian belief networks for ecological modeling. Canadian Journal of Forest Research 36: 3063-3074. (available at: http://www.spiritone.com/~brucem/bbns.htm)