InvAD 1.1 User's Guide (updated 10 December 2007)

Decision support tool for conservation of westslope cutthroat trout: a Bayesian belief network (BBN) to analyze tradeoffs between threat of brook trout invasion and intentional isolation

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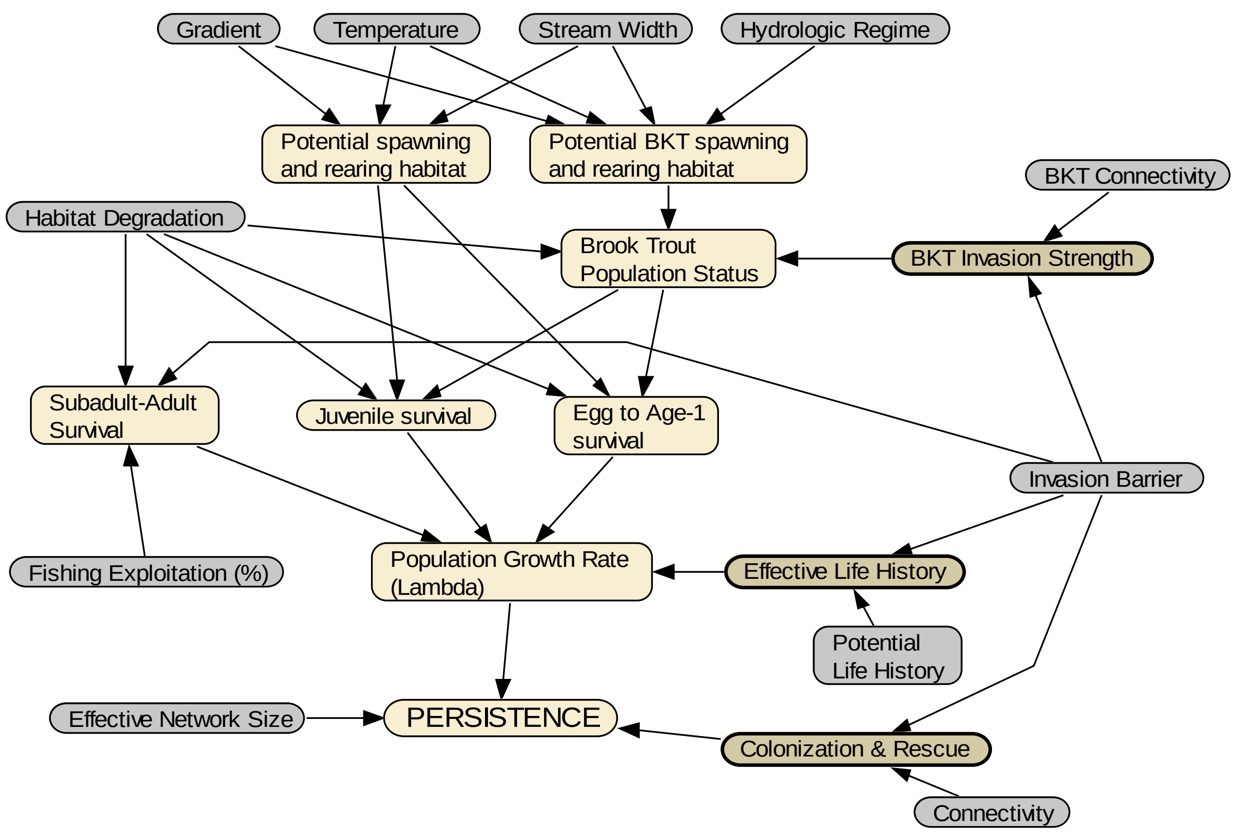
The purpose of this decision support tool is to provide a conceptually simple analytical tool for analyzing tradeoffs between the threat of nonnative trout invasion relative to that resulting from intentional isolation by migration barriers. The tool was developed primarily to deal with ecological interactions (predation & competition) between nonnative brook trout and native westslope cutthroat trout (WCT), but the model can help assess the threat of isolation that follows from avoiding contact with hybridizing species.

The BBN predicts the probability that westslope cutthroat trout will persist in a stream network at the end of 20 years given a set of habitat and environmental conditions affecting WCT and brook trout, their potential interactions, and the history and characteristics of the populations. Model output is best interpreted as relative predictions that can help a biologist or manager choose among management options for a particular stream (whether to remove, maintain or install a barrier), and help prioritize conservation actions among streams.

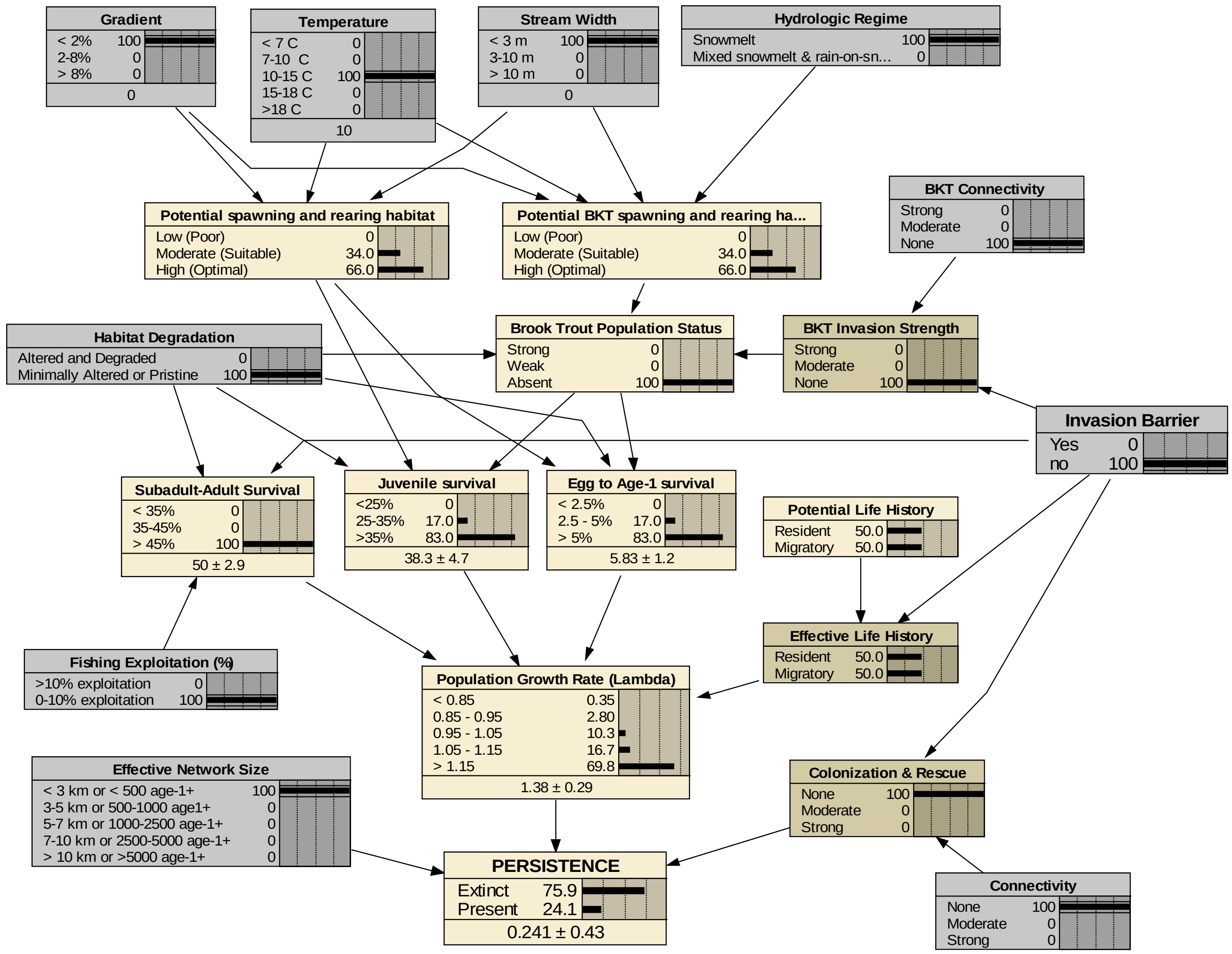
The BBN is represented by a *conceptual diagram* (below) that describes the variables affecting both species (labeled boxes) and the conditional relationships among those variables (arrows).



Software: The decision support tool is executed using the software program NETICA. Both PC and Mac versions of NETICA can be downloaded free of charge at http://www.norsys.com/download.html. The "limited mode" (free) version of NETICA can open and run BBN models having up to 60 variables.

Network structure: The file "InvAD 1.1.dne" contains the BBN that predicts persistence of WCT. *Nodes* are the individually-labeled boxes connected by arrows. Nodes can be represented by a labeled box (as in the preceding conceptual diagram) or as *belief bars* (below) which depict the probability of that node being in two or more *states*. The probabilities are represented by percentage values and size of the black bars next to each state name. Input nodes, denoted by gray boxes below, are those that only have arrows from them and whose state probabilities can be quickly changed to depict different environmental conditions or management alternatives.

BBN to analyze tradeoffs between brook trout invasion
versus intentional isolation of westslope cutthroat trout



InvAD Version 1.1, 13 February 2007
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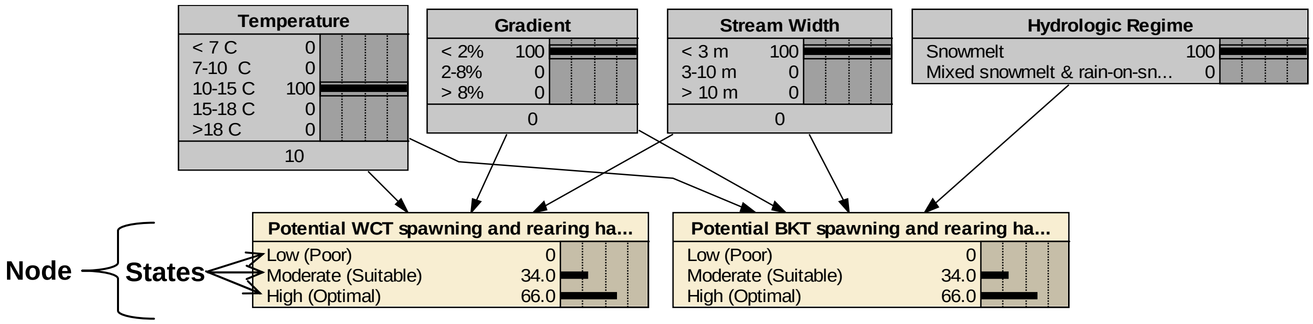
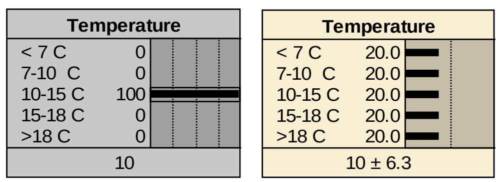
Documentation: www.fs.fed.us/rm/boise/publications/index.shtml

For example, the portion of the model that addresses natal habitat predicts that a stream network will have 66% probability of having "optimal" spawning and rearing conditions for both WCT and brook trout if temperature is 10-15^{o}C, gradient is <2%, stream width is <3 m, and the hydrologic regime is snowmelt runoff.



Having percentages or the bars distributed among states represents uncertainty. For example in the Temperature nodes below, the one on the left says we are certain that the mean summer water temperature is between 10 and 15^{o}C, whereas the one on the right says we have no information about stream temperatures so the probabilities are uniformly distributed.

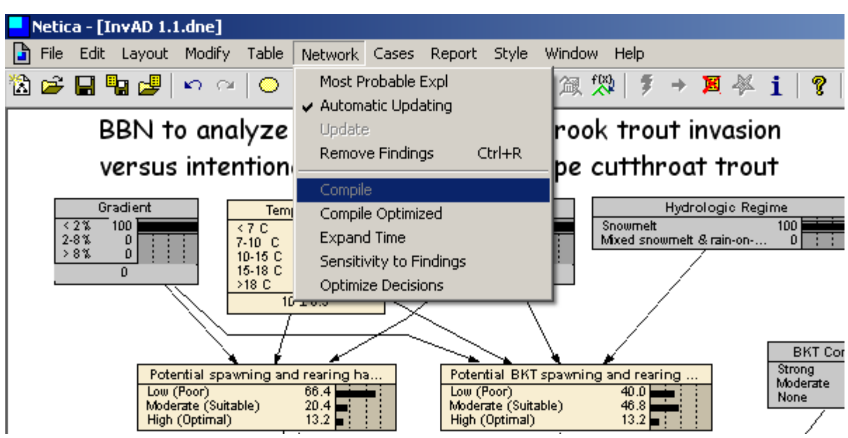


The BBN model file contains built-in documentation that describes each node and conditional probability tables that define relationships among nodes.

<u>Using the network:</u>

1. Open the .dne file using NETICA.

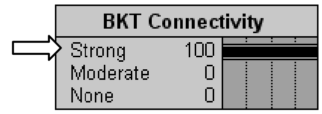
2. Compile the BBN: If the compile toolbar  is yellow, then compile the network by selecting "Network → Compile" or simply clicking on the compile button.



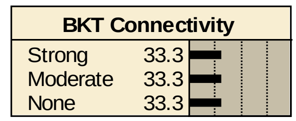
3. Define environmental and habitat conditions for a particular stream and explore management scenarios by changing the state probabilities for any of the nine input nodes and observing the resulting changes in the probabilities at dependent nodes of interest, such as *Persistence*.

4. Changing the probabilities for input nodes

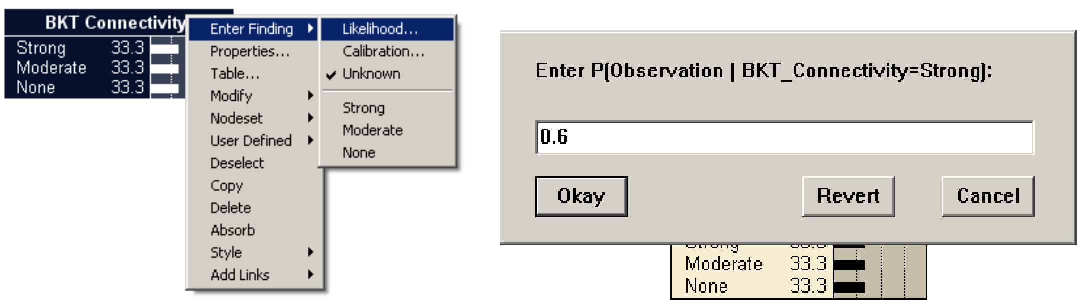
    a. Single click on the name of the desired state to make the probability 100% for that state



    b. To change from 100% probability for one state to uniform probabilities, single click on the state name



    c. For a different distribution of the prior probabilities at input nodes, right mouse click on the desired node and select "Enter Finding → Likelihood" to open a series of dialog boxes that allows you to sequentially enter probabilities for each state. For example, to enter a probably of 0.6 (60%) at the node for *BKT Connectivity*:



5. The effect of an existing or planned invasion barrier is represented by setting the *Invasion Barrier* node to "yes", which will influence or constrain the probabilities for – *Invasion Strength*, *Effective Life History*, and *Colonization & Rescue,* and *Subadult-adult WCT Survival*. Note that the model assumes the barrier will be completely effective, so the probabilities will either be 100% yes (or 100% no).

    a. <u>No barrier</u> (Invasion barrier = "no") – *Invasion Strength*, *Effective Life History*, and *Colonization & Rescue* can have state probabilities defined by data or informed opinion

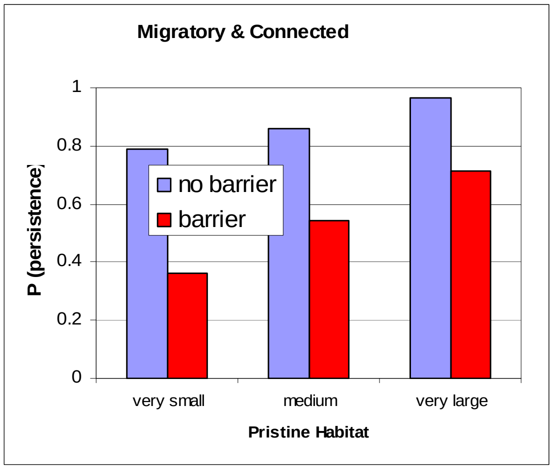
    b. <u>Barrier</u> (Invasion barrier = "yes") – presence of a barrier constrains the probabilities of the three movement-related nodes because the barrier precludes brook trout invasion (i.e., *Invasion Strength = None*), limits the ability of a WCT population to express a migratory life history (i.e., *Effective Life History = Resident*), and stops immigration from other WCT populations (i.e., *Colonization & Rescue = None*).

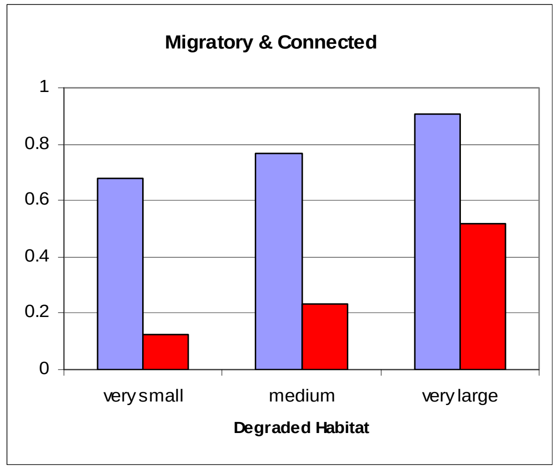
6. The terminal node *Persistence* describes the probability of WCT cutthroat trout persisting in at least one segment of a stream network over a 20 year period.

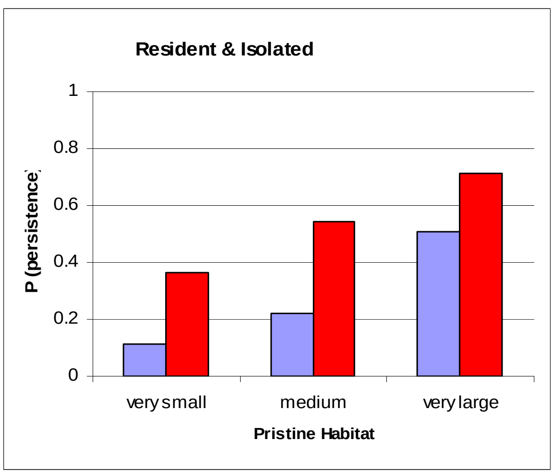
7. To view the node definitions, double click on the desired node to open a dialog window and select the "Description" tab in the lower left dialog field.

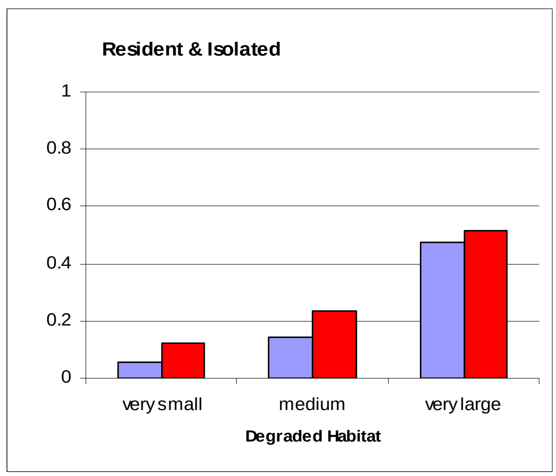
8. Saving analyses: The limited mode version of NETICA will not permit saving or editing a BBN with more than 15 nodes. To save analyses capture the screen image of the BBN (Ctrl + Print Screen **or** Select All + Copy) and paste the image into a document, presentation, etc.

General Example: As an example we explored the tradeoffs for hypothetical streams where habitat suitability for WCT brook trout was mostly ideal (66% probability of optimum) and invasion by brook trout was imminent. In a series of analyses we contrasted the use of a barrier for different effective network (population) sizes (very small, medium, vary large), with and without demographic connection (i.e., migratory life history and immigration from other WCT populations) and pristine or degraded watershed conditions. The apparent utility of using a barrier changes dramatically depending on these conditions. Results under low fishing exploitation for WCT are below.









Other threats and management alternatives

Hybridization – A thorough treatment of hybridization threats to WCT was beyond the scope of the current model, whose goal was to assess the threat from brook trout. However as a conservative simplifying assumption, hybridization might be considered as an "all-or-none" threat to WCT such that if a hybridizing species can disperse into the stream network then one assumes that hybridization will occur. Conceptually, the threats associated with intentionally isolating a WCT population to protect it from hybridization are identical to those from a competitor or predator. Please note that the existing model is not designed to assess or predict the threat of hybridization which may depend on a suite of ecological factors. We urge caution in applying the model to hybridization questions and remind the user that additional refinement of the existing model, or development of an analogous hybridization model, would be required to formally consider the threats of hybridization.

Brook trout eradication – The relative benefit of eradicating brook trout can be indirectly considered in the model. For example, if brook trout are already present in a stream network then the *BKT Connectivity* node can be adjusted to depict a high probability of a strong brook trout population, then switched to "none" to represent eradication. Alternatively, one could directly change the probabilities in the *BKT Population Strength* node (e.g., toggle between "none" or "strong") and compare the resulting predictions. Caution – if eradication is being considered in conjunction with a barrier, then it is important to remember that the WCT will be demographically isolated if they are not already, and the input nodes would need to be set accordingly.

General BBN resources

If you have further interest in the development and application of Belief Networks, refer to Cain (2001) or Marcot et al. (2006).

Cain, J. 2001. Planning improvements in natural resources management: Guidelines for using Bayesian networks to support the planning and management of development programmes in the water sector and beyond Centre for Ecology and Hydrology, Crowmarsh Gifford, Wallingford, Oxon, United Kingdom. (we can provide a copy of you're interested).

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. Can. J. For. Res. 36: 3063-3074. (available at: http://www.spiritone.com/~brucem/bbns.htm)

Technical support and documentation for the invasion-isolation BBN

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Documentation*:*

Peterson, D. P., Rieman, B. E., Dunham, J. B., Fausch, K. D., and M. K. Young. In press. Analysis of tradeoffs between threats of invasion by nonnative trout and intentional isolation for native westslope cutthroat trout. Canadian Journal of Fisheries and Aquatic Sciences.

This manuscript and supporting documentation for the BBN can be obtained by contacting Doug Peterson or Bruce Rieman (brieman@fs.fed.us), or by accessing the publications page of the Boise Aquatic Science Lab, Rocky Mountain Research Station: www.fs.fed.us/rm/boise/publications/index.shtml