

Analyzing Tradeoffs Between the Threat of Invasion by Brook Trout and Effects of Intentional Isolation for Native Westslope Cutthroat Trout

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Abstract

Native fishes often face simultaneous threats from habitat fragmentation and invasion by nonnative trout. Unfortunately, management actions to address one may create or exacerbate the other. A consistent decision process would include a systematic analysis of when and where intentional use or removal of barriers is most appropriate. We developed a Bayesian belief network (BBN) as a tool for such analyses. We focused on native westslope cutthroat trout (*Oncorhynchus clarkii lewisi*) and nonnative brook trout (*Salvelinus fontinalis*). We considered the environmental factors influencing them, their potential interactions, and the effects of isolation on the persistence of local cutthroat trout populations. The tradeoffs between isolation and invasion were strongly influenced by the size and quality of the stream network to be isolated and existing demographic linkages within and among populations. A strength of our approach was that it captured interactions where effects would otherwise be difficult to visualize. The model can be used to conduct site-level analysis of barrier management relative to other possible conservation actions, such as habitat improvement or angling restrictions, and to help prioritize actions among streams. By eliciting precise definitions of conservation priorities, the model can also help clarify management objectives and facilitate communication among biologists, managers, and the public.

Introduction

Conservation of inland cutthroat trout (*Oncorhynchus clarkii* spp.) can involve either the placement or removal of migration barriers to address threats from invading species and habitat fragmentation. There are important tradeoffs, because barriers that may limit invasion can also isolate a native population making it more vulnerable to local extinction through a variety of processes. Projects to install or remove barriers may proceed without a formal analysis that considers potential tradeoffs from addressing these competing threats. Because resources for conservation management are limited, effective prioritization is important. Tradeoffs may be relatively clear to biologists and managers with intimate knowledge of a particular system, and their efforts can be focused effectively. Elsewhere, the tradeoffs may be more ambiguous or the data and experience more limited, and the result may be a decision that is influenced more by personal philosophy or public pressure than by knowledge. When the differences in these choices cannot be clearly supported and articulated, the decision process can appear inconsistent and arbitrary to the public or the administrators who fund these projects. A consistent decision process would include an analysis of the relative risks associated with either action.

Fausch et al. (2006) provided a synthesis of the science and theory relevant to this issue and proposed a framework that could help guide an appropriate analysis. The analysis could be complex because of the potential interaction of multiple physical and ecological processes. For example, the probability that brook trout (*Salvelinus fontinalis*) may invade and displace cutthroat trout from any stream may depend on the physical characteristics defining the suitability of stream habitat for either species (e.g. Peterson et al. 2004), the condition of that habitat (e.g. Shepard 2004), the size, connectivity and complexity of the available habitat network (Rieman and Dunham 2000), distance of potential source populations, fishing pressure, and their interactions (Figure 1). Many biologists may inherently understand those processes for systems they have studied in detail, but consistent evaluation of these processes across multiple populations and environments could be improved by a formal assessment tool.

We explored the application of a Bayesian belief network (BBN) as a tool to facilitate such analyses (Cain 2001). We focused on westslope cutthroat trout (*Oncorhynchus clarkii lewisi*; hereafter WCT) and nonnative brook trout and current understanding of environmental factors

influencing both species, their potential interactions, and the effects of isolation on the persistence of individual WCT populations.

Methods

We started with a conceptual model that represented the key processes and conditions we believe important to the biology of WCT and their interactions with invading brook trout (Figure 1). The conceptual model was formalized as a belief network by linking a series of conditional probability tables that quantified the key relationships implied by the arrows in the conceptual model (Figure 2). Estimation of the probability distributions for these relationships involved professional opinion, data based on actual species observations, and simulation of demographic characteristics with traditional matrix and diffusion-approximation population models. The resulting BBN predicted the probability of WCT occurrence in a stream segment after 20 years. The details are available in Peterson et al. (In Press).

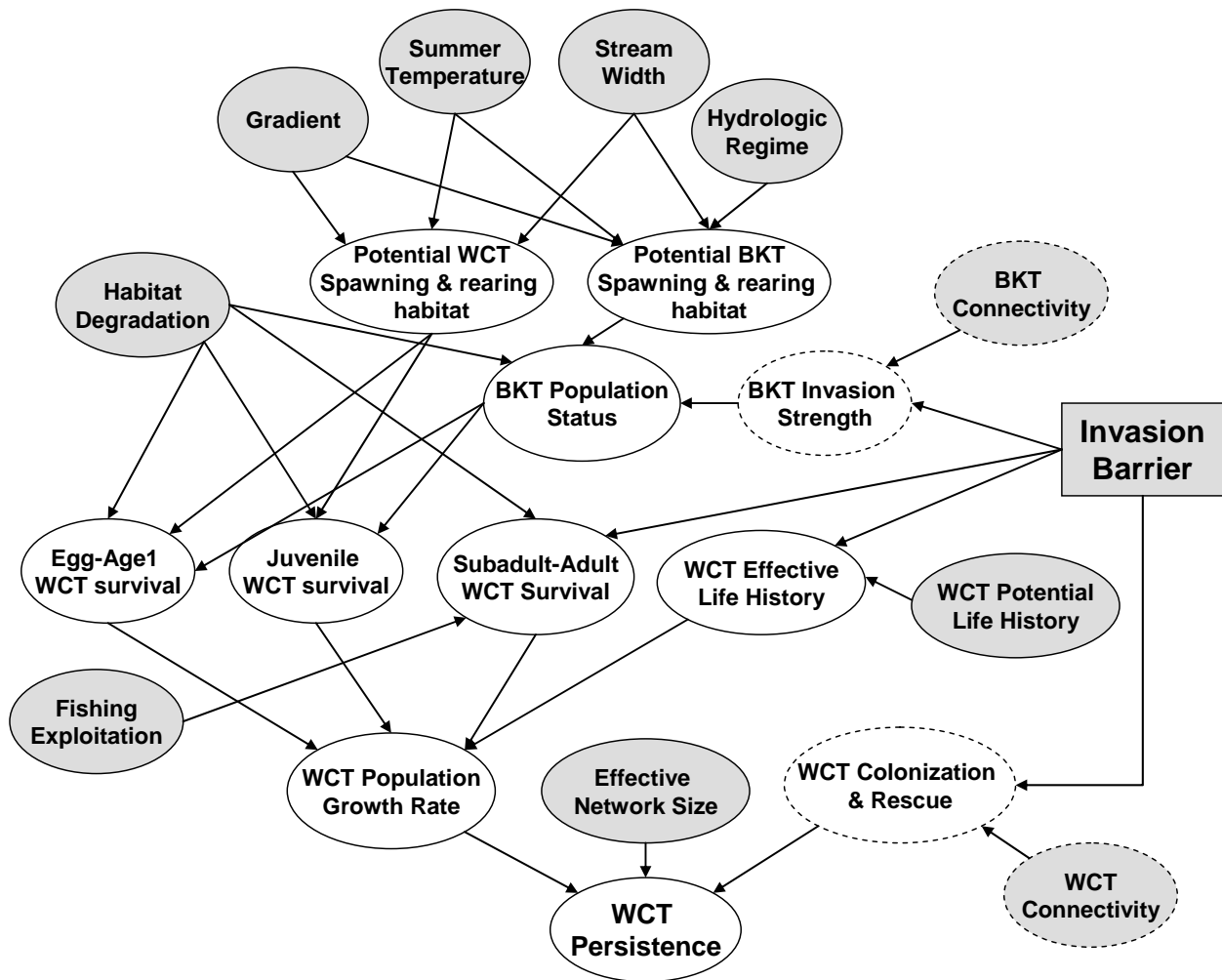


Figure 1. A conceptual model depicting environmental conditions and processes influencing the persistence of westslope cutthroat trout (WCT) and tradeoffs between intentional isolation and invasion by brook trout (BKT). Arrows indicate conditional dependencies between variables. Input variables (prior conditions) believed to affect WCT and BKT populations are those having only arrows from them (shaded ovals, e.g., *gradient, temperature, stream width, etc.*). Dashed lines indicate variables originating outside the local stream network. This model was implemented as a Bayesian Belief Network (see Figure 2) by developing conditional probabilities between dependent variables.

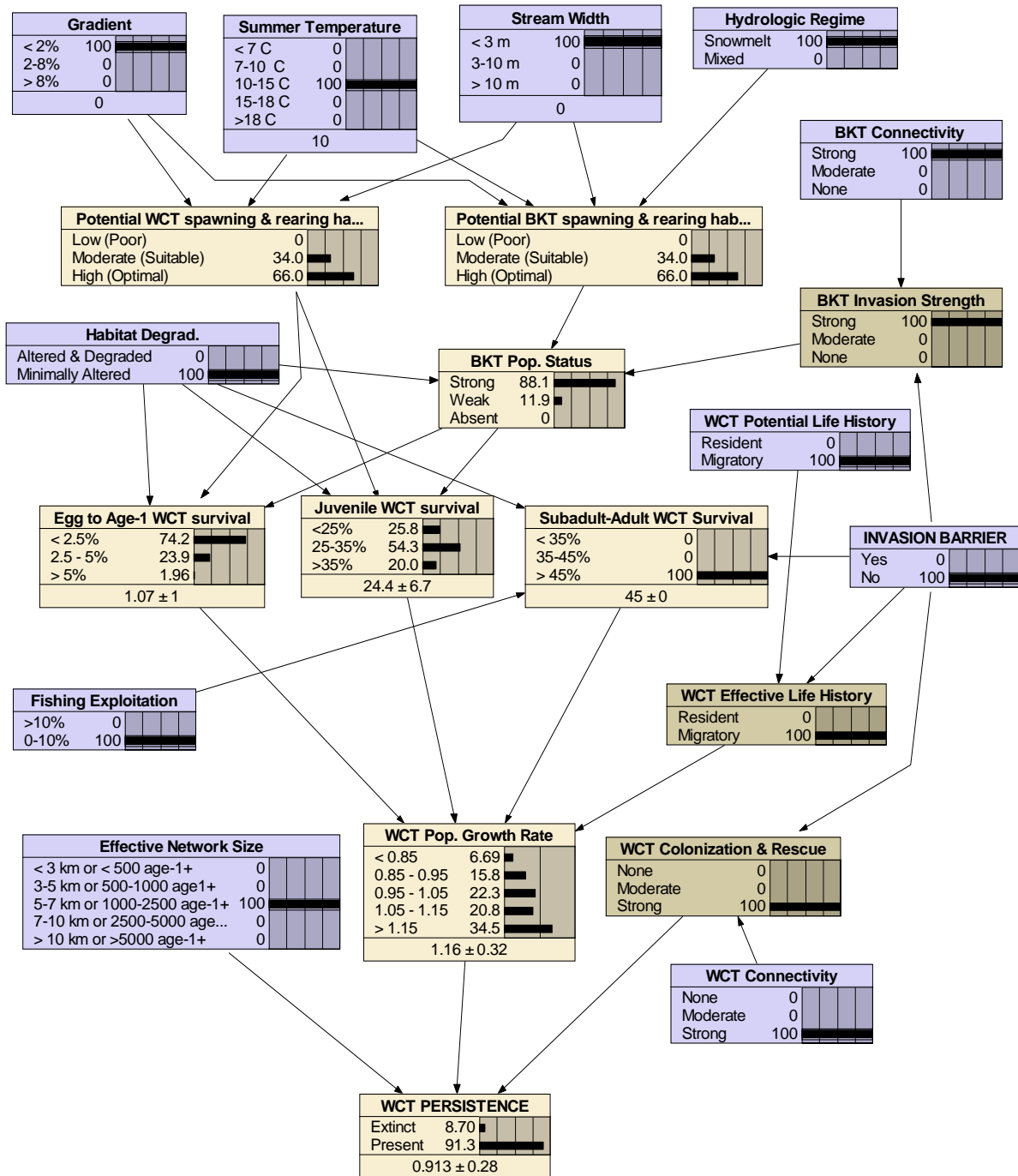


Figure 2. Bayesian Belief Network (BBN) to analyze tradeoffs between intentional isolation and invasion. The state or range of values each variable can take are listed below the title of each variable (e.g., for *gradient*, the possible states are <2%, 2-8%, and >8%). The size of the bar and the corresponding percentage values next to each state indicate the probability that the variable is in that state, conditioned on the state of the variables that influence it. To evaluate the effects of barrier installation or removal in a particular stream, the user can determine the initial conditions for a stream network by entering probabilities for the input variables, change the state of *invasion barrier* (i.e. from Yes to No), and measure the change in probabilities of *persistence*, or any intermediate variable of interest. In this example all input variables were set to 100% for one of the possible states.

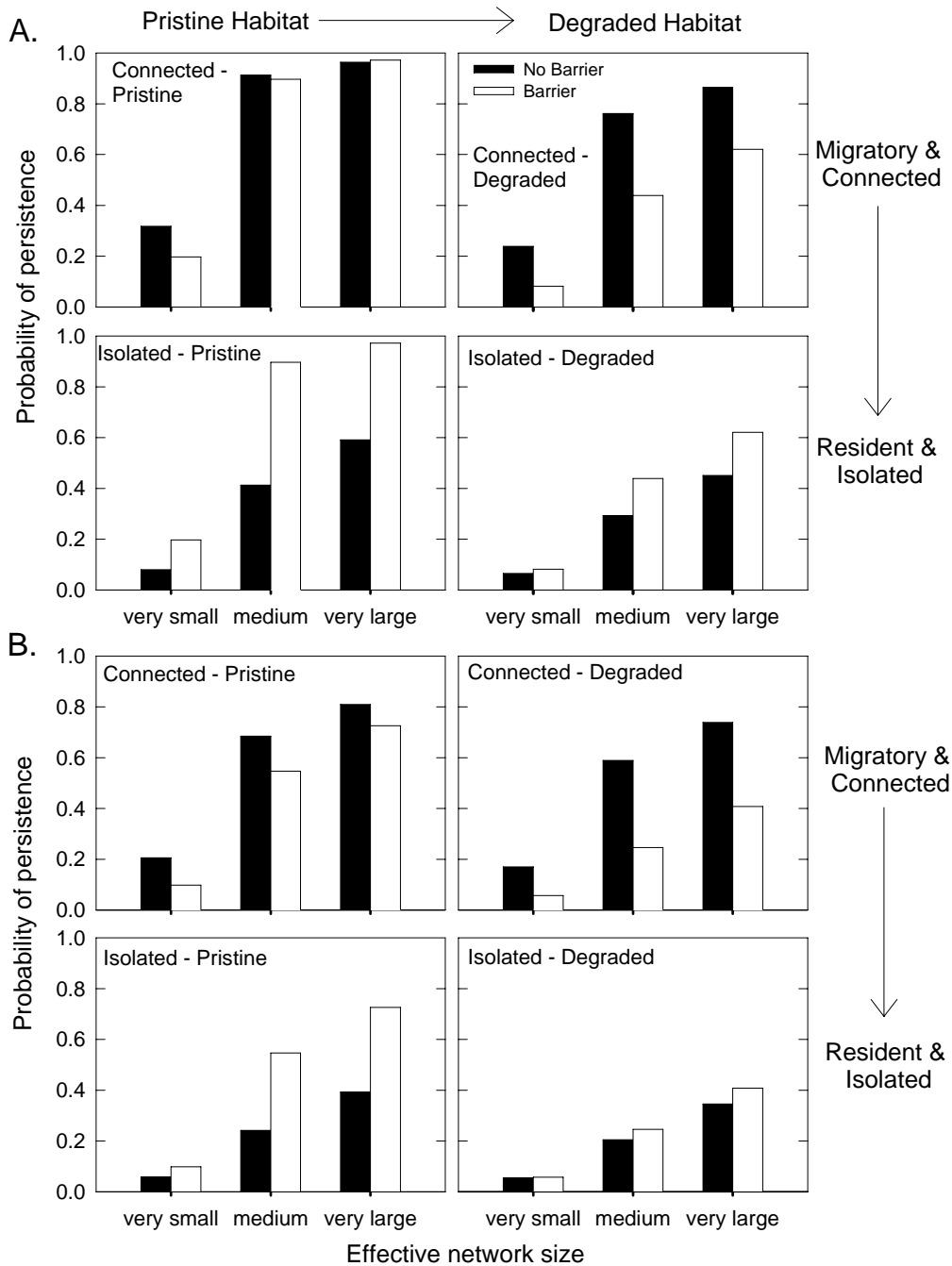


Figure 3. Predicted response of westslope cutthroat trout (WCT) to installation of an invasion barrier using the Bayesian Belief Network . Bars denote the predicted probability of persistence relative to habitat size and quality, life history expression and connection to other WCT populations , under low (A) and high (B) fishing exploitation. Results assume that brook trout invasion is imminent in a stream network with a snowmelt hydrologic regime, characterized by small (<3 m wide) low-gradient (<2%) tributary streams with moderate summer water temperatures (10-15°C). For reference, the middle black bar in the upper left panel of Figure 3B represents the prediction for the initial conditions represented in Figure 2.

Results and Discussion

Analysis with the BBN across a range of environmental conditions indicated the predicted tradeoff between isolation and invasion was strongly influenced by size of the stream network (or WCT population) to be isolated and existing demographic linkages within and among cutthroat trout populations. Intentional isolation was predicted to benefit demographically isolated WCT populations facing likely invasion by brook trout. Intentional isolation generally reduced the probability of persistence for migratory populations regardless of invasion threat. The relative benefits or risks associated with isolation depended strongly on the size and quality of available habitats that would be isolated (Figure 3).

Our results suggest that the utility of a barrier should be weighed based on some understanding of these characteristics. Peterson et al. (In Revision) provide several examples of how the BBN could be used to evaluate management alternatives and prioritize limited resources associated with the installation or removal of barriers. We believe the model can also facilitate communication among parties interested in these management issues.

The BBN we developed was based on current understanding of brook trout invasions and the consequences of incidental or intentional isolation for WCT. Like any model, potential users should be aware of its limitations. Predictions can only be interpreted in terms of the relative differences between management options or a set of environmental conditions, not as absolute probabilities (e.g., Ralls et al. 2002). A BBN provides guidance during the decision process, but does not supplant or replace a human decision (Marcot 2006), nor does it substitute for the professional knowledge of an experienced fishery biologist. It does, however, allow biologists and managers to more clearly think about the relative effects of brook trout and isolation on WCT populations, and to quickly visualize and evaluate the effects of complex interactions. As a working hypothesis, the BBN can be directly tested, updated, or modified using examples from fishery management or challenged and revised based on new empirical or theoretical results.

The use of this BBN does not solve the often opposing problems of brook trout invasion and habitat fragmentation facing WCT or other native fishes in western North America. Rather, it provides a process and framework for thinking through the issues, clearly documenting and defining knowledge and uncertainty, and identifying conservation values and objectives. Site-specific analysis using our model or similar BBNs may help identify management options and tradeoffs in a particular stream. The greater utility, however, may be using the model to explore the relative benefits of isolation or connection across a collection of WCT populations and using that information to implement more strategic conservation programs and prioritize limited resources.

A working version of the model and a user's guide may be obtained from:
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