APPENDIX C. Bayesian network (BN) model development and additional results for Westslope Cutthroat Trout invasion barrier case study.

<u>Citation</u>: 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(XX):xx-xx.

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I. Model summary and node definitions for Bayesian Network (BN) to analyze barrier decisions for Westslope Cutthroat Trout in the middle Clark Fork River, USA.

List of additional or modified nodes

Model summary

We modified an existing BN used to evaluate individual barrier decisions assuming a static climate (Peterson et al. 2008) to facilitate the same analysis under climate change. The following paragraphs describe the nodes added to the published model and present a diagram of the final model used to conduct the analysis (Figure B1).

Briefly, the BN considers the environmental factors influencing habitat for Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*) and nonnative Brook Trout (*Salvelinus fontinalis*), the species' interactions, and how construction or removal of invasion barriers (i.e., the management decision) may affect persistence of local a Cutthroat Trout population. Details on the development and application of this model are found in Peterson et al. (2008); the context and decision framework are considered in Fausch et al. (2006, 2009). *Summer Water Temperature*, *Hydrologic Regime* and *Stream Size* nodes were already used in the model to describe habitat potential across streams. We simply used those to consider how climate might alter those conditions and the interactions of barriers, Brook Trout and Cutthroat Trout in the future. To account for climate-related changes to stream width, we added a *Summer Mean*

Flow as a root node. We estimated *Stream Width* from macroscale hydrologic model (variable infiltration capacity, or VIC) outputs using a linear regression. Winter flooding and bed scour can cause mortality of embryos and fry of fall spawning stream salmonids like Brook Trout (Nehring and Anderson 1993; Latterell et al. 1998), and flood frequency and magnitude is anticipated to influence their distribution under climate change (Wenger et al. 2011b). To account for this we added a *Winter High Flow w95* root node (Wenger et al. 2010) with a link to hydrologic regime to formalize the concept that increasing flood frequency is associated with rain-on-snow precipitation events and a transitional hydrologic regime. This link and the resulting conditional probability table quantifies this relationship, which will only affect fall-spawning Brook Trout in this model. Cutthroat Trout can be indirectly affected by this hydrologic change through a reduction in population strength of Brook Trout and any associated attenuation of biotic interactions.

The Cutthroat Trout BN predicted persistence of a population upstream from existing or potential migration barriers. Model output could be mapped for groups of continuous or connected stream segments, with migration barriers creating discontinuities and changing the extent of habitat available to that population. The BN predicted population persistence 20 years after a management action regarding a barrier (Peterson et al. 2008), so imposing a new set of climate conditions yielded a prediction about the persistence probability of the cutthroat population 20 years later.

Node definitions and rationale

Summer Air Temperature

Summer Air Temperature was defined as mean summer air temperature averaged across the watershed that drains to the stream segment in which the site was located (dtemp following Wenger et al. 2011a). The BN for Cutthroat Trout had five existing states for summer water temperature (Peterson et al. 2008), and we generated air temperature categories corresponding to those water temperature states by examining the relationship between Brook Trout occurrence and the mean summer air temperature at point (ptemp variable from Wenger et al. 2011b), from which we infer that mean summer water temperature is ~0.8 × mean summer air temperature.

States defining *Summer Air Temperature*: *<9^{o}C; 9-13^{o}C; 13-18^{o}C; 18-22^{o}C; >22^{o}C*

Summer Water Temperature

Summer Water Temperature is defined as in Peterson et al (2008): mean summer water temperature over the stream network from 15 July to 15 September. The conditional probability table for *Summer Water Temperature* was based on the air-water temperature conversion described above.

States defining *Summer Water Temperature*: *<7^{o}C; 7-10^{o}C; 10-15^{o}C; 15-18^{o}C; >18^{o}C*

Table C 1. Conditional probability table for *Summer Water Temperature.* Values represent the probability that *Summer Water Temperature* is in particular state, conditioned on the values of the parent node.

Parent node	*Summer Water Temperature*				
Summer Air Temperature	<7 °C	7-10 °C	10-15 °C	15-18 °C	>18 °C
<9 °C	1	0	0	0	0
9-13 °C	0	1	0	0	0
13-18 °C	0	0	1	0	0
18-22 °C	0	0	0	1	0
>22 °C	0	0	0	0	1

Winter High Flow w95

Winter High Flow w95 was defined as the expected number of days in the "winter" (considered here as December 1-February 28) in which flows are among the highest 5% of all flow days for the year (following Wenger et al. 2010; Wenger et al. 2011a; Wenger et al. 2011b). High flows in the post-spawning period of embryo incubation and pre-emergence are believed to influence the occurrence and productivity of fall-spawning trout species (Nehring and Anderson 1993; Latterell et al. 1998; Fausch et al. 2001; Wenger et al. 2011b), and w95 was negatively related to occurrence of Brook Trout and bull trout in the interior Columbia River basin (Wenger et al. 2011a). The w95 metric is assumed to represent flows with power capable of mobilizing much of the stream bed, displacing and killing embryos and pre-emergent or newly emerged fry under some channel and bed conditions, but not necessarily destroying all embryos and individuals within any stream segment (e.g., Wenger et al. 2011a). We defined three states for w95 based on the range of observed values from Wenger et al. (2011a).

States defining *Winter High Flow*: *<1 time per winter; 1-4 times per winter; >4 times per winter*

Summer Mean Flow

Summer Mean Flow was defined as the mean surface water flow in cubic feet per second (cfs) during the summer (considered here as the first day after June 1 when flows fall below the mean annual value, through September 30; from Wenger et al. 2010, 2011a). *Summer Mean Flow* is used to estimate *Stream Size* (see below), and provides a link between climate-influenced changes in hydrologic conditions and the geomorphic variable (summer wetted width or *Stream Size*) that is most commonly measured in fish distribution studies (Dunham and Rieman 1999). The node definition and derivation of states was identical to that of the *Summer Mean Flow* node in the bull trout model (see Appendix A)

States defining *Summer Mean Flow*: *<0.2 cfs; 0.2 to 1.19 cfs; 1.19 to 43.3 cfs; >43.3 cfs*

Stream Width

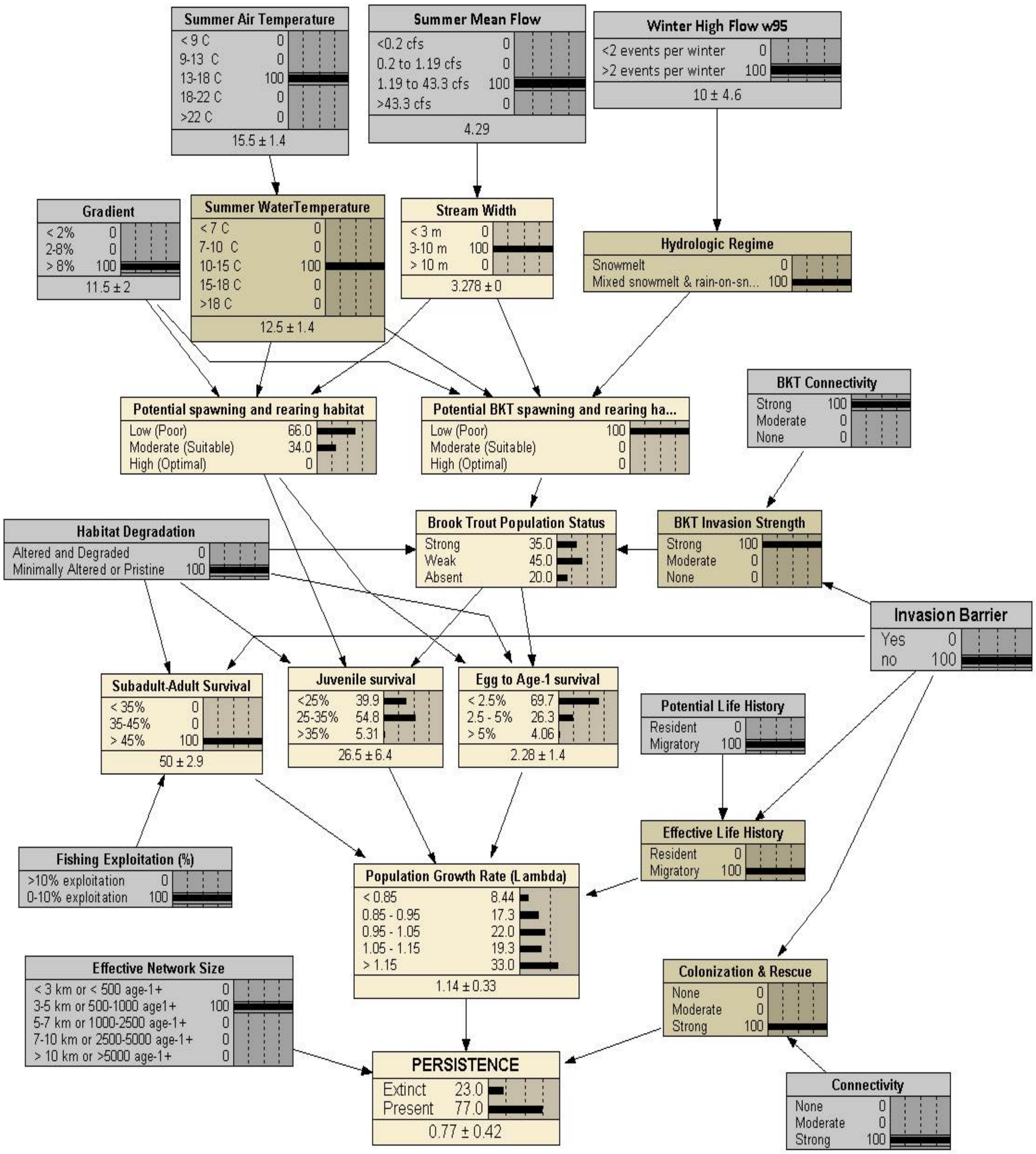
Stream Width was defined as the mean wetted width over the stream network during base flow, as in Peterson et al. (2008). The state definitions were also identical. Probabilities for *Stream Width* were estimated directly from *Summer Mean Flow* using the linear regression equation $\ln(Stream\ Width) = 0.625 + (0.386 * \ln(Summer\ Mean\ Flow))$ where S*tream Width* is wetted width (m) and *Summer Mean Flow* is in cubic feet per second (cfs) (based on data from Wenger et al. 2011a for N=2197 sites where stream width data were available; R^2=

0.481, Intercept 0.625, SE 0.169; slope 0.386, SE=0.00855). This regression equation was solved for *Stream Width* and encoded directly into the BN.

States defining *Stream Width*: *<3 m*; *3-10m*; *>10m*

Table C 2. Conditional probability table for *Stream Size.* Values represent the probability that *Stream Size* is in particular state, conditioned on the values of the parent node.

Parent node	*Stream Size*		
Summer Mean Flow	< 3m	3-10 m	>10 m
<0.2 cfs	1	0	0
0.2 to 1.19 cfs	0	1	0
1.19 to 43.3 cfs	0	0	1
>43.3 cfs	0	0	0



InvAD Version 1.1, 13 February 2007
Modelers: Peterson, DP; Rieman, BE; Dunham, JB; Fausch, KD; and MK Young
Documentation: www.fs.fed.us/rm/boise/publications/index.shtml
Modified 7 June 2012 by DP Peterson to include climate change nodes
Contact: Douglas Peterson, USFWS, doug_peterson@fws.gov, 360-425-6072 x302

Figure C 1. Bayesian network (BN) used to analyze barrier removal decision for Westslope Cutthroat Trout. This is a version of the BN presented in Peterson et al (2008) expanded to include three new nodes (*Summer Air Temperature, Summer Mean Flow*, *Winter High Flow w95*) to model factors anticipated to respond strongly to climate change. The BN was implemented using Netica, and represents the parameterized version of the conceptual model presented in Figure 4 (Peterson et al. Unpublished ms).

II. Detailed results for three examples analyzed with the Cutthroat Trout BN (Figure B1)

Silver Creek

In Silver Creek, barrier removal maximized probability of persistence Cutthroat Trout population in future climate scenarios (Figure B2, Table B 3). Persistence probability decreased from 0.87 to 0.76 between historical and 2040s time periods if the population remained isolated by a barrier, but persistence was predicted to be ≥ 0.96 in both time periods if the barrier was removed.

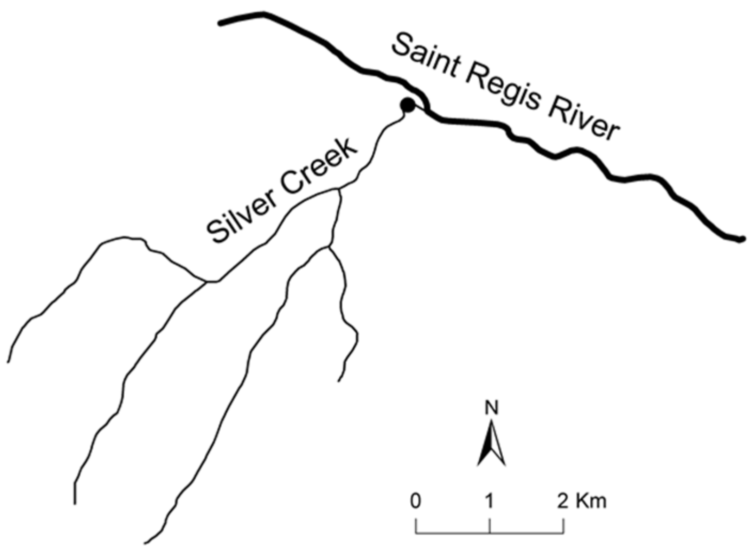


Figure C 2. Schematic of Silver Creek showing location of existing fish migration barrier (•).

Table C 3. Input conditions and results for Silver Creek example. Columns 2-5 contain results for the four scenarios considered (barrier or not, historical or future environmental conditions). State values for input (root) nodes that did not differ among scenarios were: Habitat degradation = Minimally Altered or Pristine, Fishing = 0-10% exploitation, BKT_connectivity = Moderate, Effective network size = > 10 km or >5000 age-1+, Life History Potential = Migratory, CT_Connectivity = Strong, and Gradient = 2.7%.

	Node value or state, by scenario			
Node name [1]	1	2	3	4
Barrier removed	No	Yes	Yes	No
Time Period & Global Climate Model	Historical	Historical	2040s_PCM	2040s_PCM
P(Persistence)	0.866177	0.972961	0.760724	0.966423
E[Lambda]	1.06898	1.26389	0.919525	1.21025
std-dev Lambda	0.317956	0.340305	0.269615	0.336853
Air Temperature	17.2411	17.2411	19.2968	19.2968
Water Temperature - ^{o}C	10-15	10-15	15-18	15-18
SummerMeanFlow – cfs	7.63	7.63	5.42	5.42
WinterHighFlow95 – frequency	3.45	3.45	7.35	7.35
finding InvasionBarrier	Yes	no	Yes	no
Colonization & Rescue	None_Isolated	Strong	None_Isolated	Strong

[1] Column provides node names and value or statistic calculated for that node; “P” indicates a probability calculated by the model for discrete nodes, “E” indicates a probability (or expected value) calculated by the model for continuous nodes, and “std-dev” indicates Gaussian standard deviation calculated for continuous nodes.

Dominion Creek

In Dominion Creek, we considered scenarios involving removal of the upper barrier (with and without Brook Trout removal) and removal of both barriers (Figure B3). For all comparisons there was no difference between historical conditions and the 2040s climate; removing the upper barrier and eradicating Brook Trout increased the predicted cutthroat population persistence in the longer segment from 0.25 to 0.41 for both periods (Table B4). Removing both barriers produced an identical estimate of 0.77. The lack of difference is attributed to the counteracting effects of temperature and stream flow on Cutthroat Trout survival. Between the historical period and the 2040s, increased air temperature caused water temperature to shift from the optimal (10-15^{o}C) to the high (15-18^{o}C) categories which made conditions less amenable to recruitment and survival (of Cutthroat Trout). Concurrently, projected changes in summer base flow caused the stream size variable to change from the 3-10 m state to the <3 m state, which improved spawning and rearing conditions for Cutthroat Trout. The choice of state values in the nodes representing temperature, mean flow, and stream size contributed to this cancellation effect. A small change in temperature and flow resulted in a shift between state categories and the crossing of a biologically-significant threshold or inflection point encoded in the model; in this case, the effects were simply in opposite directions.

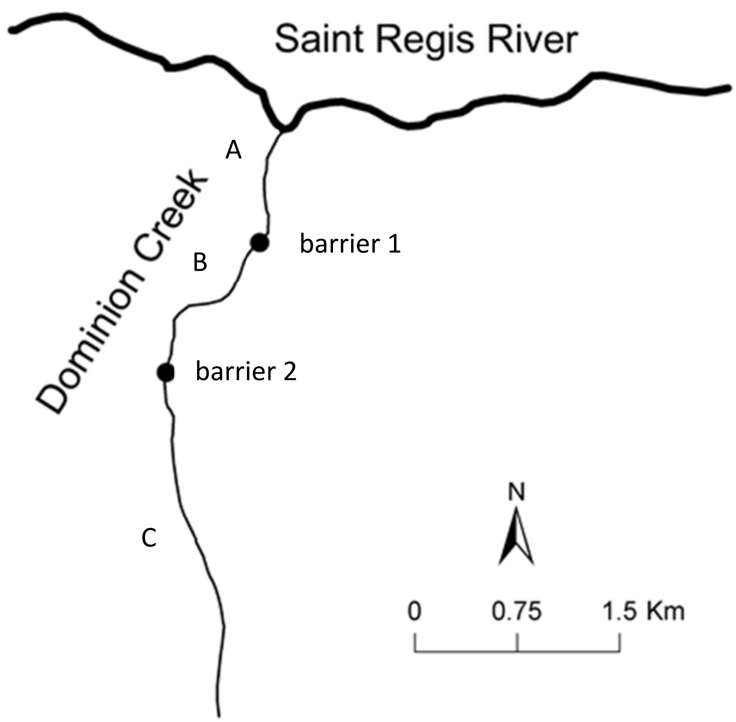


Figure C 3. Schematic of Dominion Creek showing location of two existing fish migration barriers (•).   Stream reaches between existing barriers are designated by letters A, B and C.

Table C 4. Input conditions and results for the Dominion Creek example. Stream reaches (Reach) are depicted in Figure B3. State values for input (root) nodes that did not differ among scenarios were: Habitat degradation = Minimally Altered or Pristine, Fishing = 0-10% exploitation, and Gradient = 9.6%; values for other root nodes are given in the table. The table shows results for 16 different scenarios numbered 2-20 (scenarios 1, 5, 13, and 16 were not of interest for this analysis).

	Node value or state, by scenario				
Node name[1]	2	3	4	6	7
Barrier removed	None	None	None	None	None
Brook Trout	Present	Remove	Absent	Present	Remove
Reach	B	B	C	B	B
Time period & GCM	Historical	Historical	Historical	2040s_PCM	2040s_PCM
P(Persistence)	0.079794	0.11847	0.11847	0.079794	0.11847
E[Lambda]	0.775388	0.937053	0.937053	0.775388	0.937053
std-dev Lambda	0.23553	0.269435	0.269435	0.23553	0.269435
finding Temperature_Air - ^{o}C	17.6787	17.6787	17.6787	19.7369	19.7369
finding SummerMeanFlow - cfs	4.29	4.29	4.29	2.99	2.99
finding WinterHighFlow95 - freq	0.65	0.65	0.65	3.85	3.85
finding BKT_Connectivity	Strong	None	None	Strong	None
finding InvasionBarrier	no	no	no	no	no
finding LifeHistory_Potential	Resident	Resident	Resident	Resident	Resident
finding CT_Connectivity	None	None	None	None	None
finding EffectiveNetsize	< 3 km or < 500 age-1+	< 3 km or < 500 age-1+	< 3 km or < 500 age-1+	< 3 km or < 500 age-1+	< 3 km or < 500 age-1+
Water Temperature – ^{o}C	10-15	10-15	10-15	15-18	15-18
E[StreamWidth] – m	3.27765	3.27765	3.27765	2.8513	2.8513
Stream Width - m	3-10	3-10	3-10	<3	<3
Hydrologic Regime	Snowmelt	Snowmelt	Snowmelt	Mixed	Mixed
Invasion Strength	High	None	None	High	None
Life History	Isolated_Resident	Isolated_Resident	Isolated_Resident	Isolated_Resident	Isolated_Resident
Colonization & Rescue	None_Isolated	None_Isolated	None_Isolated	None_Isolated	None_Isolated

Table C 4 (continued).

	Node value or state, by scenario				
Node name[1]	8	9	10	11	12
Barrier removed	None	1	1	1	1
Brook Trout	Absent	Present	Absent	Present	Absent
Reach	C	A_B	C	A_B	C
Time period & GCM	2040s_PCM	Historical	Historical	2040s_PCM	2040s_PCM
P(Persistence)	0.11847	0.309153	0.11847	0.309153	0.11847
E[Lambda]	0.937053	1.14361	0.937053	1.14361	0.937053
std-dev Lambda	0.269435	0.326884	0.269435	0.326884	0.269435
finding Temperature_Air - ^{o}C	19.7369	17.6787	17.6787	19.7369	19.7369
finding SummerMeanFlow - cfs	2.99	4.29	4.29	2.99	2.99
finding WinterHighFlow95 - freq	3.85	0.65	0.65	3.85	3.85
finding BKT_Connectivity	None	Strong	None	Strong	None
finding InvasionBarrier	no	no	no	no	no
finding LifeHistory_Potential	Resident	Migratory	Resident	Migratory	Resident
finding CT_Connectivity	None	Strong	None	Strong	None
finding EffectiveNetsize	< 3 km or < 500 age-1+	< 3 km or < 500 age-1+	< 3 km or < 500 age-1+	< 3 km or < 500 age-1+	< 3 km or < 500 age-1+
Water Temperature – ^{o}C	15-18	10-15	10-15	15-18	15-18
E[StreamWidth] – m	2.8513	3.27765	3.27765	2.8513	2.8513
Stream Width - m	<3	3-10	3-10	<3	<3
Hydrologic Regime	Mixed	Snowmelt	Snowmelt	Mixed	Mixed
Invasion Strength	None	High	None	High	None
Life History	Isolated_Resident	Migratory	Isolated_Resident	Migratory	Isolated_Resident
Colonization & Rescue	None_Isolated	Strong	None_Isolated	Strong	None_Isolated

Table C 4 (continued).

Node name[1]	Node value or state, by scenario			
	14	15	17	18
Barrier removed	2	2	2	2
Brook Trout	Present	Remove	Present	Remove
Reach	B_C	B_C	B_C	B_C
Time period & GCM	Historical	Historical	2040s_PCM	2040s_PCM
P(Persistence)	0.251003	0.414362	0.251003	0.414362
E[Lambda]	0.775388	0.937053	0.775388	0.937053
std-dev Lambda	0.23553	0.269435	0.23553	0.269435
finding Temperature_Air - °C	17.6787	17.6787	19.7369	19.7369
finding SummerMeanFlow - cfs	4.29	4.29	2.99	2.99
finding WinterHighFlow95 - freq	0.65	0.65	3.85	3.85
finding BKT_Connectivity	Strong	None	Strong	None
finding InvasionBarrier	no	no	no	no
finding LifeHistory_Potential	Resident	Resident	Resident	Resident
finding CT_Connectivity	None	None	None	None
finding EffectiveNetsize	3-5 km or 500-1000 age1+	3-5 km or 500-1000 age1+	3-5 km or 500-1000 age1+	3-5 km or 500-1000 age1+
Water Temperature – °C	10-15	10-15	15-18	15-18
E[StreamWidth] – m	3.27765	3.27765	2.8513	2.8513
Stream Width - m	3-10	3-10	<3	<3
Hydrologic Regime	Snowmelt	Snowmelt	Mixed	Mixed
Invasion Strength	High	None	High	None
Life History	Isolated_Resident	Isolated_Resident	Isolated_Resident	Isolated_Resident
Colonization & Rescue	None_Isolated	None_Isolated	None_Isolated	None_Isolated

Table C 4 (concluded).

Node name[1]	Node value or state, by scenario	
	19	20
Barrier removed	1_2	1_2
Brook Trout	Present	Present
Reach	A_B_C	A_B_C
Time period & GCM	Historical	2040s_PCM
P(Persistence)	0.769901	0.769901
E[Lambda]	1.14361	1.14361
std-dev Lambda	0.326884	0.326884
finding Temperature_Air - °C	17.6787	19.7369
finding SummerMeanFlow - cfs	4.29	2.99
finding WinterHighFlow95 - freq	0.65	3.85
finding BKT_Connectivity	Strong	Strong
finding InvasionBarrier	no	no
finding LifeHistory_Potential	Migratory	Migratory
finding CT_Connectivity	Strong	Strong
finding EffectiveNetsize	3-5 km or 500-1000 age1+	3-5 km or 500-1000 age1+
Water Temperature – °C	10-15	15-18
E[StreamWidth] – m	3.27765	2.8513
Stream Width – m	3-10	<3
Hydrologic Regime	Snowmelt	Mixed
Invasion Strength	High	High
Life History	Migratory	Migratory
Colonization & Rescue	Strong	Strong

[1] Column provides node names and value or statistic calculated for that node; "P" indicates a probability calculated by the model for discrete nodes, "E" indicates a probability (or expected value) calculated by the model for continuous nodes, and "std-dev" indicates Gaussian standard deviation calculated for continuous nodes.

Deep Creek

Results for Deep Creek imply that removing all barriers (Brook Trout invade) instead of just the upper two (no Brook Trout) will result in a larger relative increase in persistence under climate change (0.11 to 0.53, an 0.42 absolute increase but 3.7-fold relative increase) compared to historical environmental conditions (0.15 to 0.59, a 0.44 absolute increase but 3.0-fold relative increase). Including habitat remediation provided an even greater relative benefit under climate change (persistence = 0.73, a 5.5-fold increase) than under historical conditions (0.77, a 4.2-fold increase). Conversely, we saw little relative difference in benefit before or after climate change when Brook Trout were absent, we controlled for habitat extent (i.e., upper barriers removed) and then implemented habitat restoration. In this scenario probabilities increased from 0.11 to 0.30 with climate change and 0.15 to 0.40 without; a 1.7-fold increase for both.

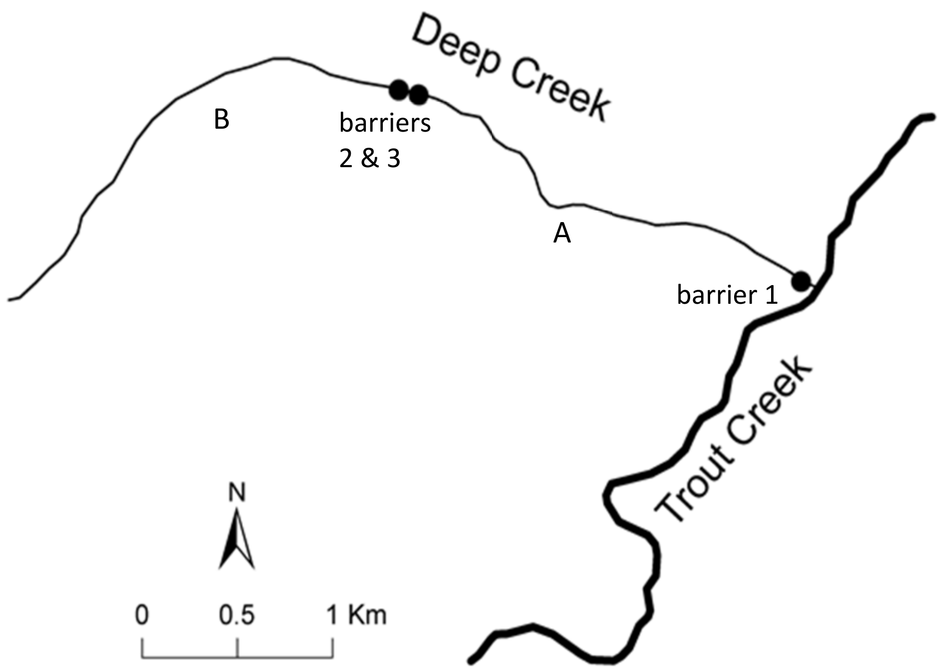


Figure C 4. Schematic of Deep Creek showing location of three existing fish migration barriers (•).   Stream reaches between existing barriers are designated by letters A and B.

Table C 5. Input conditions and results for the Deep Creek example. Stream reaches (Reach) are depicted in Figure B4. State values for input (root) nodes that did not differ among scenarios were: Fishing = 0-10% exploitation, Gradient = 9.2%; BKT Connectivity = Strong, CT Connectivity = Strong, and LifeHistory Potential = Migratory; values for other root nodes are given in the table. The table shows results for 16 different scenarios numbered 1-16.

	Node value or state, by scenario			
Node name	1	2	3	4
Barrier removed	None	None	None	None
Brook Trout	Absent	Absent	Absent	Absent
Reach	A	A	A	A
Habitat_Improvement	no	no	yes	yes
Time period & GCM	Historical	2040s_PCM	Historical	2040s_PCM
P(Persistence)	0.0582635	0.0521164	0.114171	0.0890807
E[Lambda]	0.662909	0.623962	0.919525	0.825631
std-dev Lambda	0.181538	0.154831	0.269615	0.222451
finding Temperature_Air - ^{o}C	17.7634	19.7666	17.7634	19.7666
finding SummerMeanFlow - cfs	5.31	4.22	5.31	4.22
finding WinterHighFlow95 - freq	0.8	2.65	0.8	2.65
finding HabitatDegradation	Altered and Degraded	Altered and Degraded	Minimally Altered or Pristine	Minimally Altered or Pristine
finding InvasionBarrier	Yes	Yes	Yes	Yes
finding EffectiveNetsize	< 3 km or < 500 age-1+	< 3 km or < 500 age-1+	< 3 km or < 500 age-1+	< 3 km or < 500 age-1+
Water Temperature - ^{o}C	10-15	15-18	10-15	15-18
E[StreamWidth] - m	3.55894	3.2569	3.55894	3.2569
Stream Width - m	3-10	3-10	3-10	3-10
Hydrologic Regime	Snowmelt	Mixed	Snowmelt	Mixed
Invasion Strength	None	None	None	None
LifeHistory_Effective	Isolated_ResidentOnly	Isolated_ResidentOnly	Isolated_ResidentOnly	Isolated_ResidentOnly
Colonization & Rescue	None_Isolated	None_Isolated	None_Isolated	None_Isolated

Table C 5 (continued).

Node name	Node value or state, by scenario 5	6	7	8
Barrier removed	1	1	1	1
Brook Trout	Present	Present	Present	Present
Reach	A	A	A	A
Habitat_Improvement	no	no	yes	yes
Time period & GCM	Historical	2040s_PCM	Historical	2040s_PCM
P(Persistence)	0.225453	0.19827	0.309153	0.284332
E[Lambda]	0.950894	0.890242	1.14361	1.08919
std-dev Lambda	0.320812	0.282299	0.326884	0.309106
finding Temperature_Air - ^{o}C	17.7634	19.7666	17.7634	19.7666
finding SummerMeanFlow - cfs	5.31	4.22	5.31	4.22
finding WinterHighFlow95 - freq	0.8	2.65	0.8	2.65
finding HabitatDegradation	Altered and Degraded	Altered and Degraded	Minimally Altered or Pristine	Minimally Altered or Pristine
finding InvasionBarrier	no	no	no	no
finding EffectiveNetsize	< 3 km or < 500 age-1+	< 3 km or < 500 age-1+	< 3 km or < 500 age-1+	< 3 km or < 500 age-1+
Water Temperature - ^{o}C	10-15	15-18	10-15	15-18
E[StreamWidth] - m	3.55894	3.2569	3.55894	3.2569
Stream Width - m	3-10	3-10	3-10	3-10
Hydrologic Regime	Snowmelt	Mixed	Snowmelt	Mixed
Invasion Strength	High	High	High	High
LifeHistory_Effective	FullExpression	FullExpression	FullExpression	FullExpression
Colonization & Rescue	Strong	Strong	Strong	Strong

Table C 5 (continued).

Node name	Node value or state, by scenario 9	10	11	12
Barrier removed	2_3	2_3	2_3	2_3
Brook Trout	Absent	Absent	Absent	Absent
Reach	A_B	A_B	A_B	A_B
Habitat_Improvement	no	no	yes	yes
Time period & GCM	Historical	2040s_PCM	Historical	2040s_PCM
P(Persistence)	0.146756	0.113161	0.396571	0.301321
E[Lambda]	0.662909	0.623962	0.919525	0.825631
std-dev Lambda	0.181538	0.154831	0.269615	0.222451
finding Temperature_Air - ^{o}C	17.7634	19.7666	17.7634	19.7666
finding SummerMeanFlow - cfs	5.31	4.22	5.31	4.22
finding WinterHighFlow95 - freq	0.8	2.65	0.8	2.65
finding HabitatDegradation	Altered and Degraded	Altered and Degraded	Minimally Altered or Pristine	Minimally Altered or Pristine
finding InvasionBarrier	Yes	Yes	Yes	Yes
finding EffectiveNetsize	3-5 km or 500-1000 age1+	3-5 km or 500-1000 age1+	3-5 km or 500-1000 age1+	3-5 km or 500-1000 age1+
Water Temperature - ^{o}C	10-15	15-18	10-15	15-18
E[StreamWidth] - m	3.55894	3.2569	3.55894	3.2569
Stream Width - m	3-10	3-10	3-10	3-10
Hydrologic Regime	Snowmelt	Mixed	Snowmelt	Mixed
Invasion Strength	None	None	None	None
LifeHistory_Effective	Isolated_ResidentOnly	Isolated_ResidentOnly	Isolated_ResidentOnly	Isolated_ResidentOnly
Colonization & Rescue	None_Isolated	None_Isolated	None_Isolated	None_Isolated

Table C 5 (concluded).

Node name	Node value or state, by scenario			
	13	14	15	16
Barrier removed	1_2_3	1_2_3	1_2_3	1_2_3
Brook Trout	Present	Present	Present	Present
Reach	A_B	A_B	A_B	A_B
Habitat_Improvement	no	no	yes	yes
Time period & GCM	Historical	2040s_PCM	Historical	2040s_PCM
P(Persistence)	0.585083	0.532251	0.769901	0.734126
E[Lambda]	0.950894	0.890242	1.14361	1.08919
std-dev Lambda	0.320812	0.282299	0.326884	0.309106
finding Temperature_Air - ^{o}C	17.7634	19.7666	17.7634	19.7666
finding SummerMeanFlow - cfs	5.31	4.22	5.31	4.22
finding WinterHighFlow95 - freq	0.8	2.65	0.8	2.65
finding HabitatDegradation	Altered and Degraded	Altered and Degraded	Minimally Altered or Pristine	Minimally Altered or Pristine
finding InvasionBarrier	no	no	no	no
finding EffectiveNetsize	3-5 km or 500-1000 age1+	3-5 km or 500-1000 age1+	3-5 km or 500-1000 age1+	3-5 km or 500-1000 age1+
Water Temperature - ^{o}C	10-15	15-18	10-15	15-18
E[StreamWidth] - m	3.55894	3.2569	3.55894	3.2569
Stream Width - m	3-10	3-10	3-10	3-10
Hydrologic Regime	Snowmelt	Mixed	Snowmelt	Mixed
Invasion Strength	High	High	High	High
LifeHistory_Effective	FullExpression	FullExpression	FullExpression	FullExpression
Colonization & Rescue	Strong	Strong	Strong	Strong

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