Application of IF^3 Decision Support Models for Bull Trout Habitat in Clear Creek, Idaho.

Matthew R. Dare, Charles H. Luce, David A. Nagel, Thomas A. Black, Kari Grover Wier, Devon H. Green

Project Report

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Abstract

This report describes the application of the IF^3 decision support models in Clear Creek. Clear Creek is located in central Idaho and is a tributary to the South Fork Payette River. The genesis of the project was the need to assemble information to assist resource managers in incorporating the habitat needs of bull trout *Salvelinus confluentus* into a proposal for landscape restoration treatments in the drainage. Upper Clear Creek supports both resident and migratory bull trout and previous research suggests two other tributaries, Fruitcake Creek and Long Creek, contain suitable bull trout habitat. IF^3 is designed to identify areas where habitat conditions render sensitive aquatic habitats resilient to wildfire as well as areas where restoration would result in resilience. Although, thermally suitable, the amount of habitat in Fruitcake Creek and Long Creek suggests that these tributaries would probably not sustain bull trout without external support. Upper Clear Creek is considerably larger than either of the other bull trout habitat networks and IF^3 predictions suggest this habitat network is relatively resilient to fire. Factors that may decrease the resilience of Upper Clear Creek include increased human presence, isolation, and the loss of the migratory component of the population. Active management of aquatic habitat in Upper Clear Creek does not appear to be necessary at this time. If large-scale, high-severity fire constitutes a threat to bull trout habitat in Upper Clear Creek, fuel reduction treatments in areas downstream of this portion of the drainage could lessen the chance fuels connectivity would allow fire from outside the drainage into Upper Clear Creek.

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Introduction

The IF^3 decision support models were designed to assist forest managers in the identification of opportunities and conflicts associated with proactive timber/fuel management in areas that support sensitive aquatic species. IF^3 stands for Integrating Fire, Fish, and Forests. The genesis of these models is the commonly held idea that sensitive aquatic habitats present a problem to forest managers because they simultaneously are not resilient to wildfire or proactive fuels treatment intended to increase their resilience to wildfire (Rieman and Clayton 1997; Rieman et al. 2000). The underlying assumption of the IF^3 approach is that large aquatic habitats embedded within a neighborhood of supporting habitat are robust to fire and post-fire disturbances and represent areas where intensive management is probably not necessary. On the other end of the resilience spectrum, small or isolated habitats and habitats in close proximity to human infrastructure are areas where active pre-fire management would likely benefit the aquatic and terrestrial components of the forest ecosystem while minimizing the chance of large-scale disturbance which may jeopardize human lives and infrastructure. In these areas the IF^3 approach can be used to identify threats to aquatic habitats and the likelihood management activities would increase their resilience. The models can be used to answer a variety of questions including 1) where are aquatic habitats resilient to fire and post-fire disturbances such as debris flows?; 2) where would active management of aquatic or terrestrial habitat (e.g. barrier removal, road improvement or removal) be necessary in order to increase the resilience of aquatic habitats to disturbance?; and 3) where are areas that fire and post-fire disturbances conflict with management goals for aquatic or terrestrial habitat (e.g. the wildland urban interface). IF^3 is designed as a framework for synthesizing data on terrestrial habitat conditions, aquatic habitat vulnerability, and the distribution of sensitive aquatic species in order to identify threats to a watershed. Briefly, current conditions are integrated with the potential for disturbance to develop a map of risks highlighting areas where management could have the greatest potential for protecting aquatic species in the wake of fire and post-fire disturbance. The models output persistence probabilities for aquatic habitat networks that constitute critical spawning and rearing habitat for the focal species. The relative nature of these predictions affords resource managers the opportunity to integrate this information into management plans developed for forest lands supporting multiple uses. The plastic nature of IF^3 means that models can be applied in a number of contexts provided data are available to accurately characterize current conditions and the array of threats facing habitat networks.

Clear Creek is a tributary to the South Fork of the Payette River, and is managed under the jurisdiction of the Boise National Forest's Lowman Ranger District. The District Hydrologist and Fish Biologist requested RMRS assist in the application of the IF^3 models to Clear Creek to identify potential restoration opportunities which may benefit bull trout populations. This report summarizes the results of the analysis which resulted from collaboration between the Lowman Ranger District and RMRS to understand how the distribution of bull trout *Salvelinus confluentus* habitat in Clear Creek might inform decisions regarding land management in the drainage. This report does not include an exhaustive exposition of analytical methods used to derive inputs for the IF^3 models. We provide an overview of the GIS methods used and provide additional detail in areas where previously established methods were adapted for Clear Creek. The report concludes with a discussion of the implications of this research focusing on the importance of bolstering the resilience of Upper Clear Creek.

Methods

Study area—Clear Creek, a tributary to the South Fork of the Payette River, is located in central Idaho (Figure 1). The 4th-order watershed includes 209.5 km of perennial streams within a 148 km^2 drainage area. Elevation within the watershed ranges from 1,158 to 2,651 msl and potential vegetation groups occur along this gradient with mixed-conifer groups including Ponderosa pine *Pinus ponderosa* and Douglas fir *Pseudotsuga menziesii,* common at lower elevations transitioning to subalpine fir *Abies lasiocarpa* and Lodgepole pine *Pinus contorta* groups at higher elevations. The southern portion of the drainage contains an extensive road network and human infrastructure. Human influence decreases dramatically in the northern portion of the basin. The Lowman Fire burned 24 km^2 of the downstream end of the basin in 1989.

Three bull trout habitat networks have been identified in the Clear Creek drainage: Long Creek, Fruitcake Creek, and Upper Clear Creek (Figure 1). Of these, only Upper Clear Creek has been surveyed and is known to contain bull trout (Table 1). The Upper Clear Creek network includes about 105 km of perennial streams. Within the network, BNF biologists have identified a 9.9 km reach of known spawning and rearing habitat (Figure 2). Both life histories are represented in the Upper Clear Creek population (D. Green, Lowman Ranger District, personal communication); however, it is not known whether spawning and rearing occurs outside of the

9.9 km reach. Following spawning, migratory bull trout move into the South Fork of the Payette River, approximately 25 kilometers downstream.

GIS analysis— This analysis was based on the characterization of current conditions and potential threats to each stream segment within the drainage. The Clear Creek stream network was generated from a 30-m digital elevation model (DEM) using the ArcGIS software extension; Terrain Analysis Using Digital Elevation Models (TauDEM; Tarboton 1997). TauDEM calculated the geomorphic characteristics of each segment (length, slope, contributing area, etc). Upstream and downstream boundaries of stream segments are defined by tributary junctions. Each stream segment has an associated catchment: the terrestrial landscape which drains directly into it.

The TauDEM stream layer was integral to the construction of several GIS layers used by the IF^3 decision-support models. Current conditions within habitat networks included in the models were total network length, presence of isolating or fragmenting barriers, stream length influenced by fine sediment, terrestrial vegetation conditions, and life-history potential of the habitat network. Potential threats included the proportion of total network length prone to critical post-fire temperature elevations and the proportion of total network length prone to post-fire debris flows.

Barriers to fish movement were identified using a GIS layer containing information on a culvert inventory in Clear Creek. Culverts identified as being barriers to juvenile or adult bull trout movement were located in order to evaluate the isolation and fragmentation status of each network. Culvert inventory information was provided by the Lowman Ranger District. Isolating barriers were those that prevented movement of fish upstream into a habitat network. Fragmenting barriers were those occurring within the boundaries of a habitat network. For fragmented networks, the proportion of total network length not fragmented was used as in index of the effect of fragmentation.

Fine sediments have the potential to negatively impact the quality of spawning and rearing habitat for bull trout. We evaluated the extent of fine sediment inputs in the bull trout networks in Clear Creek using the Geomorphic Road Analysis and Inventory Package (GRAIP) developed by RMRS. We assumed an undisturbed fine sediment load of 10 tons/km^2 based on a 20-year dataset collected in the Silver Creek experimental watersheds in the Middle Fork of the Payette River, approximately 30 km away (Kirchner et al. 2001). We defined high sediment loads as those > 50% over background undisturbed levels. GRAIP data were collected in 2004 in a joint effort between the RMRS, the Boise National Forest and the EPA. The total stream length of segments having "high" sediment loads were summed for each bull trout habitat network and summarized as a proportion of the total network length.

We evaluated probable fire sizes and severities within bull trout networks in Clear Creek based on potential vegetation group (PVG). We used data from Hessburg et al. (2007) to develop a probability distribution of fire patch sizes for eight PVGs in the Clear Creek drainage. Patches are openings in a forest canopy created by fire and their size is a function of forest type and fire severity (Agee 1998). When modeling post-fire disturbance we used patch size rather than total fire area because we assumed post-fire disturbance would be spatially coincident with patches of high-severity fire inside fire perimeters (Benda et al. 2003, Dunham et al. 2007). A GIS layer describing the distribution of PVGs, determined from Landsat data, in the Clear Creek drainage was provided by the Lowman Ranger District. The amount of each PVG within the three bull trout networks was calculated by masking the PVG layer with network boundary polygons and then summarizing the frequency of each vegetation group within each polygon.

The life-history potential of a habitat network was evaluated based on network size and the proportion of total network length having modeled stream sizes suitable for migratory bull trout. Generally, stream networks with contributing areas < 400-500 ha are considered too small to support migratory bull trout because large, migratory fish very rarely use such small streams (Rieman and MacIntyre 1995; Dunham and Rieman 1999).

Riparian vegetation characteristics for the drainage were based on Landsat Thematic Mapper imagery collected in 2002. Riparian vegetation was classified as forested, shrub, or open and corresponding average light transmission values for each vegetation class were used to model accumulated radiation for each stream segment in the drainage. We used a decaying accumulation function in TauDEM to estimate the amount of accumulated light radiation entering a stream segment from the 2-km stretch of stream directly upstream of that segment. Accumulated radiation values for each stream segment were converted to maximum summer stream temperatures using a regression equation developed for mountain streams in south-central Idaho (C. Luce, unpublished data). Additional inputs to the regression model were elevation and aspect. The potential for post-fire stream temperature changes to affect bull trout habitat was evaluated by modeling stream temperature using current (unburned) riparian vegetation conditions and hypothetical post-burn radiation values developed by reclassifying forested vegetation as shrub and shrub vegetation as open. Stream segments were classified as having a potential thermal threat if post-fire maximum summer stream temperatures were greater than 16 °C, a temperature threshold for bull trout suitability identified by previous research (Rieman and MacIntyre 1995; Dunham et al. 2003).

Debris flows are discrete disturbances that initiate following precipitation in areas that have experienced high-severity fire. There are several mechanisms responsible for generating post-fire debris flows (Miller et al. 2003). Extensive post-fire tree mortality can lead to landslides in areas were tree roots provided soil stability on steep slopes (Schmidt et al. 2001). High-severity fire can also create hydrophobic conditions in surface sediment resulting in overland water flow creating bulking debris flows (Cannon et al. 2001; Luce 2005). We modeled the potential for both of these types of debris flows in Clear Creek. The extent to which debris flows would be transported downstream was evaluated based on channel confinement and slope characteristics. Empirical rules for debris initiation and transport were developed based on extensive post-fire research in the Boise River basin (C. Luce, D. Nagel, unpublished data).

IF^3 implementation—The IF^3 decision support models are structured as Bayesian Belief Networks that incorporate information on current conditions and the extent of fire and fire-related threats at the stream segment scale to develop predictions that a habitat network will support a fish population for 25 years. The models are based on the synthesis of stream segment scale information to characterize conditions at the habitat network scale. Current conditions incorporated into the models include network size, fragmentation, connectivity to supporting habitat, fine sediment influence, and terrestrial vegetation conditions. Threats in the model include post-fire debris flows and post-fire stream temperature increases. Current conditions and constraints on the productivity of a focal network can be compared to the potential for fire to result in the realization of threats to develop a probability of persistence. Persistence probabilities are intended to be interpreted relative to other networks or to alternative conditions that can be evaluated by changing input states. For example, it's possible to evaluate the effect barrier removal has on the persistence probability of an isolated stream network. The IF^3 models were constructed and implemented in Netica (Norsys Software Corporation, v. 3.19).

Two circumstances were modeled. The IF^3 *Persistence* model was used to develop initial persistence probabilities for each bull trout network in Clear Creek. The Persistence model incorporates information on likely fire sizes and severities using a conditional probability table wherein the probability of a fire occurring decreases exponentially as fire size increases. We used a probability distribution of fire sizes developed by Hessburg et al. (2007) for the Persistence model. We used the IF^3 *Gaming* model to evaluate network persistence in the context of large-scale, high-severity fire. The Gaming model does not explicitly include information on vegetation characteristics. Instead, the user specifies a proportion of the basin burned and evaluates persistence given conditions in the network and the amount of habitat prone to disturbance.

For Upper Clear Creek we evaluated persistence assuming networks were suitable for 1) resident bull trout and 2) resident and migratory bull trout. Because of the small size of the Fruitcake Creek and Long Creek habitat networks, we only evaluated the suitability of these drainages for resident fish. In Long Creek and Fruitcake Creek we used total stream length as the initial network size input for IF^3. We evaluated two network sizes in Upper Clear Creek. Upper Clear Creek contains approximately 22 km of streams suitable for migratory bull trout spawning; therefore, we used this value to evaluate the resilience of the entire habitat network. Secondly, we evaluated the persistence probability of 9.2 km of known bull trout spawning and rearing habitat. In addition to life-history diversity, we considered the effect of burning 25, 50, 75, and 100% of each network using the IF^3 Gaming model. For Upper Clear Creek, we evaluated the effect of low, mixed, and high severity burns, whereas we only considered the effect of high-severity burns in the smaller Fruitcake Creek and Long Creek networks. In Upper Clear Creek we evaluated the persistence probability within the known distribution of spawning and rearing habitat for bull trout (Figure 2). A GIS layer containing this information on the location and length of identified spawning and rearing habitat was provided by the Lowman Ranger District.

Current conditions within each habitat network facilitated an examination of a number of network-specific questions using IF^3. Specific questions addressed were 1) how would improving habitat quality by reducing fine sediment loads improve the persistence probability of the bull trout networks in Fruitcake Creek?; 2) what is the effect of removing downstream passage barriers on the persistence probability of the bull trout network in Long Creek?; and 3) what is the effect of maintaining a migratory life history on the persistence probability of the bull trout network in Upper Clear Creek?

Results

Watershed status and threat distribution—Because of their small size, we focused on evaluating the persistence probability of the total stream length in Fruitcake Creek and Long Creek with respect to the resident life-history form only. The habitat network in Long Creek is currently isolated by a barrier located between the downstream end of the habitat network and Long Creek's confluence with Clear Creek (Figure 1). Approximately 10% of the total stream length inside the boundary of the Upper Clear Creek watershed is fragmented by barriers on tributary streams (Figure 1); however, there are more than 90 km of non-fragmented habitat in this network. Our analysis using GRAIP revealed no significant fine sediment inputs in any of the bull trout patches (Table 1). We identified a single stream segment within the Fruitcake Creek network that had fine sediment loads greater than 50% of background undisturbed levels. These results suggest that fine sediment does not constitute a threat to bull trout habitat in this basin at this time. Fruitcake Creek is the only bull trout network in which a road is present at the headwaters. A substantial number of waterbars have been constructed on this and other roads within the Fruitcake Creek basin. It appears, based on our analysis using GRAIP, that this treatment is successfully limiting the amount of fine sediment reaching stream channels in this basin despite a relatively high road density.

Debris flow and thermal threats were ubiquitous in all three networks (Table 1). About a third of the Upper Clear Creek habitat network is vulnerable to debris flows suggesting the full network is fairly robust to debris flows. However, 56% of the known spawning and rearing habitat in Upper Clear Creek is vulnerable to debris flows (Figure 2). This suggests debris flows may pose a greater risk to bull trout in this network if spawning and rearing is restricted to the 9.9 km of known habitat. Temperature modeling revealed that maximum summer stream temperatures in Clear Creek range from 10 °C in the headwater areas to 24 °C in the lower portions of the drainage. Within habitat networks, modeled summer maximum temperatures were consistently < 16 °C with slightly higher temperatures in the downstream portions of each network. Analysis of post-fire vegetation patterns revealed that 100% of the stream length within all three bull trout networks would have maximum summer temperatures > 16 °C. This suggests large-scale, high-severity burning of riparian areas could eliminate suitable spawning and rearing habitat for bull trout in Clear Creek.

IF^3 output—Conditions in Fruitcake Creek and Long Creek suggest these networks have a relatively low probability of supporting resident bull trout in the long term (Table 2). We varied conditions in the Persistence model in order to evaluate the role that Upper Clear Creek would play as external supporting habitat for the two smaller networks. The presence of supporting habitat resulted in a dramatic increase in the persistence probability of both networks (Table 2). For Long Creek, the advantage of supporting habitat can only be derived if isolating barriers are removed. Persistence model predictions for Upper Clear Creek were higher due primarily to the larger size of Upper Clear Creek (Table 2). When we considered the smaller network comprised of known spawning and rearing habitat the persistence probability decreased. However, this smaller network still had a persistence probability of 0.86 due primarily to the presence of a migratory component in the population. We evaluated the effect of the loss of the migratory component and found substantial reductions in the persistence probability of both the large and small network in Upper Clear Creek (Table 2).

We evaluated several scenarios pertaining to the effect of aquatic and terrestrial habitat management on the persistence of the bull trout networks in Clear Creek using the IF^3 Gaming model. Approximately 50% of the stream length in Fruitcake Creek receives substantial fine sediment inputs from upslope areas. If management actions were initiated to eliminate sediment inputs, the Gaming model suggested that the persistence probability of the habitat network in Fruitcake Creek would increase by 21%, in the absence of fire (Figure 3a). Similar increases are achieved by reconnecting Long Creek to downstream habitat by the removal or repair of a passage barrier (Figure 3b). High severity fire occurring in more than 50% in Fruitcake Creek eliminates the benefit of pre-fire management by reducing the size of these networks considerably (Figure 3a). All of these scenarios are based on the assumption that Upper Clear Creek functions as source habitat for Fruitcake Creek and Long Creek. Gaming model predictions for both Fruitcake Creek and Long Creek are considerably lower in the absence of supporting habitat, with both networks having a 15% probability of persistence in the absence of fire (Figure 3a, 3b).

Because of the importance of Upper Clear Creek as documented bull trout habitat, we modeled a variety of scenarios varying network length, life history diversity, fire size, and fire severity

(Figures 3c, 3d). Assuming an initial network size of 20-25 km, it appears that Upper Clear Creek is very robust to fire, regardless of fire severity. However, Figure 3c highlights the importance of maintaining a migratory component in the bull trout population as persistence probabilities for migratory populations were consistently 20-50% higher than corresponding resident populations (Figure 3c). In a large network, fire severity has a substantial impact on persistence probability as low and mixed severity fires, which result in less tree mortality, are less likely to activate hazards. However, when we considered the 9 km of known bull trout spawning and rearing habitat in Upper Clear Creek, life history diversity and fire size, but not fire severity, produced changes in persistence probability (Figure 3d). Model results for the 9 km of known bull trout habitat highlight the effect of maintaining a migratory life history is pronounced relative to the larger network illustrated in Figure 3c.

Discussion

Managing fish— The amount of habitat suitable for migratory bull trout in Fruitcake Creek and Long Creek appears to be limited by stream size. We identified less than a kilometer of streams sufficiently large to support migratory bull trout within the boundaries of each habitat network. The minimum stream size criterion we used was based on previous research in the Boise River basin where migratory bull trout rarely are observed in streams smaller than 2-m wide (Rieman and MacIntyre 1995; Dunham and Rieman 1999). This does not mean that these two drainages would not support resident bull trout which are considerably smaller at maturity and would likely use these smaller streams. If bull trout colonized either drainage, IF^3 predictions suggest long-term persistence is largely dependent on the external support from Upper Clear Creek (Figure 3a, 3b). Research related to the potential for fish population recovery following disturbance has demonstrated recovery is greatly enhanced when supporting habitat is present (Detenbeck et al. 1992; Rieman et al. 1997) and these results are consistent with the prevailing paradigm in metapopulation biology (Hanski and Gilpin, 1997; Hanski, 1999; Rieman and Dunham, 2000; Fleishman et al., 2002) and conservation biology (Caughley, 1994; Hilderbrand, 2003; Armstrong, 2005; Fausch et al., 2006; Falcy and Estades, 2007). Because of their mobility, migratory bull trout play a critical role in post-disturbance colonization (Rieman et al. 1997). Because of their small size it is not likely Fruitcake Creek and Long Creek could sustain migratory bull trout; therefore, the population in Upper Clear Creek is the most likely source for bull trout to colonize these drainages following disturbance. This highlights the importance of optimizing habitat conditions in Upper Clear Creek in order to facilitate future expansion of the species' range in the basin.

Regardless of the occupancy status of Fruitcake Creek and Long Creek, long-term presence of bull trout in the Clear Creek drainage is hinged upon the presence of migratory bull trout in Upper Clear Creek. Modeling results suggest that the 9.2-km reach of known bull trout spawning habitat would continue to support bull trout even after large portions of the drainage experience high-severity fire (Figure 3d). These results are contingent upon migratory bull trout being available to provide demographic support to the population following disturbance. The probability that Upper Clear Creek would continue to support bull trout decreases dramatically when the migratory component is removed from the population (Figure 3c, 3d). The efficacy of migratory bull trout at post-disturbance colonization can be illustrated using observations in Rattlesnake Creek, a tributary to the South Fork of the Boise River (Rieman et al. 1997). High-severity fires were believed to eradicate bull trout in most of Rattlesnake Creek in 1992. Bull trout densities returned to pre-fire levels by 1994. Large, migratory bull trout were observed in Rattlesnake Creek in September 1993. The authors postulated that these individuals had migrated from downstream areas following the 1992 fires and successfully spawned in Rattlesnake Creek. It is unlikely the bull trout population in Rattlesnake Creek would have recovered as rapidly as it did if these large, highly fecund individuals were not present in the population.

Three tributaries to Clear Creek are currently isolated by barriers: Long Creek, Big Spruce Creek, and Horse Creek. The latter two drainages are located in the southwestern portion of the Upper Clear Creek bull trout habitat network (Figure 1). These drainages are relatively small and would be unlikely to support migratory fish; however, they do contain over 20 km of habitat that biologists feel would be suitable bull trout habitat (K. Grover Wier, personal communication) and it’s possible they could support resident fish (see above). However, the possibility of the expansion of their current range into these drainages is limited by the presence of barriers. Barrier repair or removal should be the first step in any future management activity designed to increase the suitability of these drainages for bull trout.

There is a surprisingly stark demarcation between the downstream boundary of known bull trout habitat and the upstream terminus of a road along Upper Clear Creek (Figure 2). There is approximately 5 km of Clear Creek adjacent to this road that appears to be suitable habitat for migratory bull trout. There are a variety of mechanisms by which a road can reduce the suitability of a stream reach for bull trout (Luce et al. 2001). In this region, roads along the southern bank of stream can lead to increased water temperatures because more light reaches the stream. Poorly designed or maintained roads can lead to increased fine sediment loads which reduces the quality of spawning and rearing habitat by filling in interstitial spaces and reducing food supplies for young fish (Furniss et al. 1991; Waters 1995). Roads also facilitate the introduction of pathogens and increased angling pressure which may be negatively correlated to bull trout presence and abundance (Dunham and Rieman 1999). This road runs along the north bank of Upper Clear Creek; therefore, it is unlikely to be impacting stream temperatures to the point they are unsuitable for bull trout. It is also possible that humans directly impact the bull trout population via angling. Again, the degree to which angling pressure or illegal harvest is impacting the migratory bull trout in this drainage is not known. However, given the small numbers of migratory fish documented in Upper Clear Creek, even accidental harvest could dramatically impact the population. Examining the amount of angling pressure in the Clear Creek drainage may reveal the extent to which direct human use could be limiting the use of this reach by bull trout. Debris flows currently threaten approximately 56% of the known spawning and rearing habitat in Upper Clear Creek. Debris flow threat, however, is concentrated in the upstream portions of this part of the habitat network. Management actions designed to increase the use of the lower portion of the habitat network would facilitate the expansion of bull trout use into 5-km of stream not vulnerable to debris flows (Figure 2).

Managing forests— The Lowman Ranger District is analyzing areas within the Clear Creek watershed where fuel reduction treatments would be beneficial to improving forest health and lessening the chance of high-severity fire. These areas include Fruitcake Creek, Long Creek, Horse Creek, and Big Spruce Creek (Figure 1). There are several reasons why fuels treatments in one or more of these watersheds would be advantageous. First, because these watersheds do not support bull trout populations currently, the decision to perform fuels treatment here or in other downstream watersheds does not create a conflict with the preservation of sensitive fish habitat. Secondly, each of these watersheds contains an existing road network which could be used during fuels treatment. Analysis of sediment inputs using GRAIP suggests these roads do not contribute large quantities of fine sediment to stream channels. Provided road densities are maintained at current levels, our analysis suggests fuels treatments in these areas will not reduce the potential for these watersheds to support bull trout in the future. Lastly, a prevailing southwesterly wind in the Clear Creek drainage could facilitate the spread of wildfire into Upper Clear Creek from downstream areas; therefore, breaking the connectivity of fuels between Upper Clear Creek and areas to the south and west could be advantageous. Fuels treatment in Fruitcake Creek, Long Creek, Horse Creek, and Big Spruce Creek would effectively insulate Upper Clear Creek from wildfire originating in portions of the Clear Creek watershed to the south and west.

If mechanical fuels treatments are performed in Big Spruce Creek and Horse Creek there is an opportunity for convergent restoration of fuels and roads in these drainages. Analysis using GRAIP revealed that while fine sediment yields from the road networks in these drainages were 100-140% of undisturbed levels. While fine sediment yields in this range were not sufficient to affect the output of IF^3, they are still elevated relative to undisturbed levels. The existing road networks in these drainages would facilitate mechanical fuels treatments without the creation of additional roads. Following treatment, it may be advantageous to remove or repair roads in these drainages in order to insure potential bull trout habitat is not degraded. Road repair using waterbars has been used in other areas in the basin (e.g. Fruitcake Creek) with successful results and could be performed in Big Spruce Creek and Horse Creek if decreasing road density, via removal, is not considered a viable option.

At this time there is limited opportunity for mechanical fuels treatment within the Upper Clear Creek habitat network. Much of Upper Clear Creek is within the boundary of the Red Mountain Roadless Area; therefore, there is no potential to construct a road network to support mechanical fuels treatments in this area. Additionally, most of the headwaters of Clear Creek are managed following the guidelines for “Recommended Wilderness” in the Boise National Forest’s Forest

Plan. Even if there was an opportunity to perform fuels treatment in this portion of the watershed, it is not clear that it would be advantageous from the perspective of bull trout persistence. Much of Upper Clear Creek contains high-elevation conifer forest in which fuel loads do not reflect a legacy of fire suppression and fuels treatment would be unlikely to reduce fire severity. Additionally, the creation of a road network to support fuels treatment in this portion of the watershed could result in increased fine sediment, reducing the quality of existing bull trout spawning and rearing habitat.

Managing fire—It is outside the purview of the IF^3 process to develop a comprehensive fire management strategy for Clear Creek; however, the results of our analysis suggest every effort should be made to reduce the chance of large-scale high severity fire in Upper Clear Creek which supports the only occupied bull trout habitat in the Clear Creek watershed. The historical fire regime for the dominant potential vegetation type (PVG 7 – warm, dry subalpine fir) in Upper Clear Creek is "mixed2". The "mixed2" fire regime is characterized by a mosaic burn with vegetation mortality ranging from 50-90%. Consequently, there exists the potential of a severe wildfire in the Upper Clear Creek area. The typical wind pattern in this drainage is southwest to northeast. Fire starts have been recorded throughout the drainage, including southwest of Upper Clear Creek, making the spread of a wildfire into Upper Clear Creek from another portion of the drainage probable. At this time most of Upper Clear Creek is within the Boise National Forest's Wildland Fire Use area; therefore, naturally occurring fires may be allowed to occur on the landscape under appropriate conditions. Prescribed fire is also an option within the Clear Creek drainage and prescribed burning could be used in the South Fork of Clear Creek in order to decrease the probability of widespread high-severity fire and subsequent debris flows. Debris flows in this portion of the Upper Clear Creek habitat network could have catastrophic impacts on the bull trout population if they occurred in the late summer when migratory individuals were present.

Recommendations— As a result of the IF^3 process, the Lowman Ranger District identified two restoration priorities and associated treatments that may help to sustain the resident and migratory populations in the Clear Creek drainage:

1) Improve connectivity to suitable habitat by removing or repairing culvert barriers

   a. Big Spruce Creek (3 culverts)

   b. Horse Creek (2 culverts)

   c. Long Creek (1 culvert)

2) Reduce the threat of a high severity wildfire in Upper Clear Creek through fuel reduction treatments (thinning and/or prescribed fire) in the following subwatersheds:

   a. Big Spruce Creek

   b. Horse Creek

   c. Fern Creek

   d. Monumental Creek

In conclusion this report summarizes the results of collaboration between resource managers with the Lowman Ranger District and researchers at RMRS. The time from initial contact to project completion was approximately 7 weeks. The size of the watershed and nature of the application of IF^3 undoubtedly contributed to the relatively short time taken to successfully complete this project. However, it is also clear that open lines of communication and between collaborators and the readily available data were also factors in the rapid completion of the project. Future applications of IF^3 will probably require additional inputs of time and money, particularly in drainages with a dearth of spatial data. However, the flexibility of the IF^3

framework allowed us to efficiently adapt the models to Clear Creek and output potentially influential results.

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Table and figure labels

Table 1.— Summary of current conditions and potential threats to three habitat networks in Clear Creek, Idaho. The location of habitat networks were modeled based on elevation and stream size. Within Upper Clear Creek, biologists have identified approximately 9.9 km of bull trout spawning and rearing habitat. We evaluated persistence for both modeled and known habitat networks in Upper Clear Creek using IF^3.

Table 2.—Summary of predictions of IF^3 Persistence model for three habitat networks in Clear Creek, Idaho.

Figure 1.—Clear Creek, Idaho. Bull trout habitat networks highlighted in gray.

Figure 2.—Detail of Upper Clear Creek including distribution of 9 km of known bull trout spawning and rearing habitat and the extent of modeled debris flow threat.

Figure 3.— Summary of the IF^3 Gaming model predictions for three drainages in Clear Creek, Idaho. A: Fruitcake Creek; B: Long Creek; C: Upper Clear Creek modeled habitat, 22 km length; D: Upper Clear Creek known habitat, 9 km length.

Table 1.—Summary of current conditions and potential threats to three habitat networks in Clear Creek, Idaho. The location of habitat networks were modeled based on elevation and stream size. Within Upper Clear Creek, biologists have identified approximately 9.9 km of bull trout spawning and rearing habitat. We evaluated persistence for both modeled and known habitat networks in Upper Clear Creek using IF^3.

Status	Area (km^2)	Length (km)	Isolation[1]	Frag[2]	Sed (%)[3]	DF (%)[4]	Thermal (%)[5]
			Fruitcake Creek				
Modeled	5.5	10.4	N	N	0.05	0.94	1.0
			Long Creek				
Modeled	7.8	7.9	Y	N	0	1.0	1.0
			Upper Clear Creek				
Modeled	80.5	104.6	N	Y	0	0.3	1.0
Known	37.2	9.9	N	Y	0	0.56	1.0

[1]Network is isolated if a barrier isolates entire network from surrounding watershed

[2]Network is fragmented if barriers exist inside network boundaries. Fragmentation is incorporated into IF^3 by reducing the initial network size by the length of the isolated portion.

[3]Sedimentation is expressed as the proportion of total network length having predicted fine sediment loads > 150% of undisturbed levels (see text). Sedimentation is incorporated into IF^3 by reducing the initial network size by the total length of stream segments having high sediment loads.

[4]Debris flow hazard is expressed as the proportion of total network length predicted to experience post-fire debris flows.

[5]Thermal hazard is expressed as the proportion of total network length with predicted post-fire maximum summer stream temperatures > 16 °C.

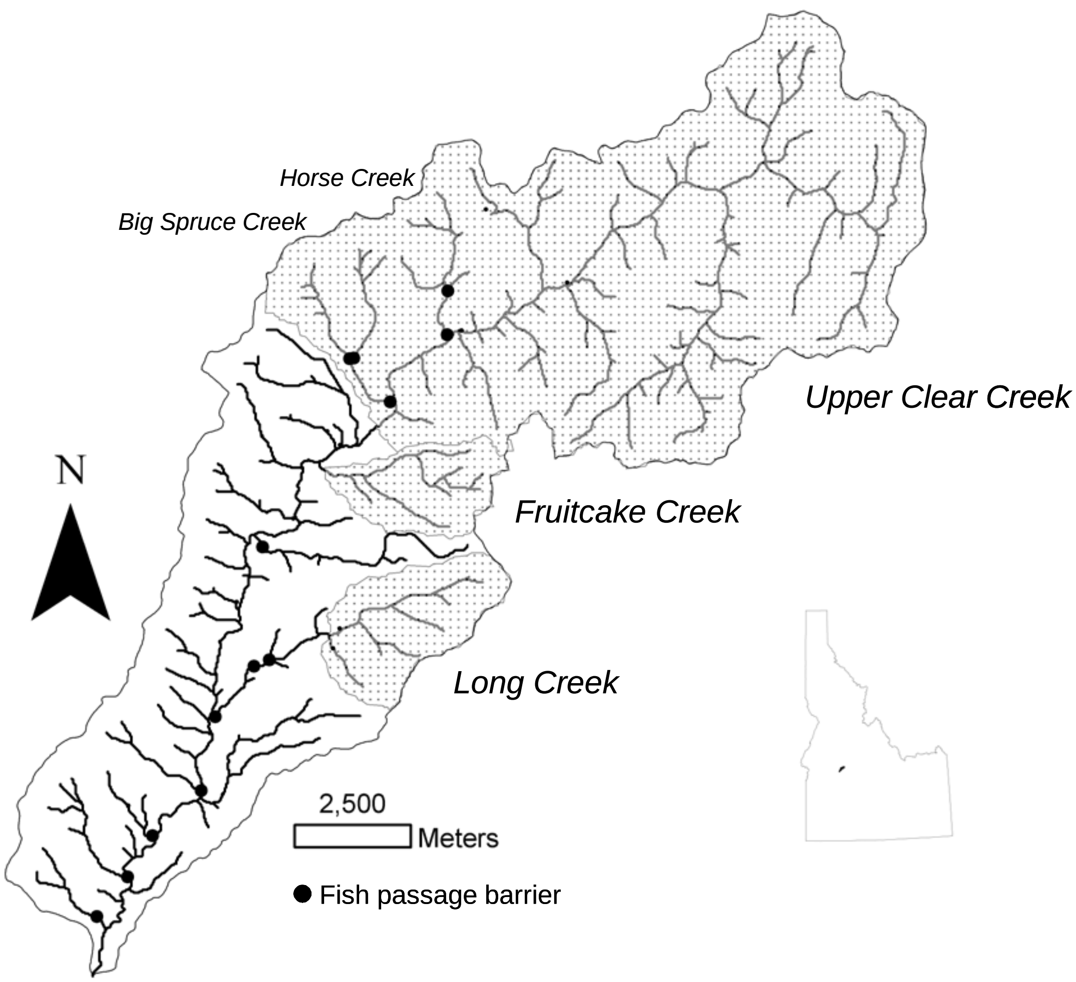
Table 2.—Summary of predictions of IF[3] Persistence model for three habitat networks in Clear Creek, Idaho.

Parameters[1]	States[2]	Persistence[3]
Fruitcake Creek		
External support	0	0.15
External support	5-10 km	0.70
Long Creek		
Isolation, External support	Y, 0	0.15
Isolation, External support	N, 0	0.15
Isolation, External support	N, 5-10 km	0.70
Upper Clear Creek		
Network length, Debris flow threat, Life history potential, Sediment	20-25 km, 25-50%, Mig, 0.1-0.2	0.96
Network length, Debris flow threat, Life history potential, Sediment	20-25 km, 25-50%, Res, 0.1-0.2	0.86
Network length, Debris flow threat, Life history potential, Sediment	5-10 km, 50-75%, Mig, 0	0.88
Network length, Debris flow threat, Life history potential, Sediment	5-10 km, 50-75%, Res, 0	0.45

[1]Parameters varied within IF[3] Persistence model to generate baseline persistence predictions.

[2]States of respective parameters within each model run. Mig – migratory and resident; Res – resident only.

[3]Predicted probability of persistence for 25 years given current aquatic and terrestrial condtions.



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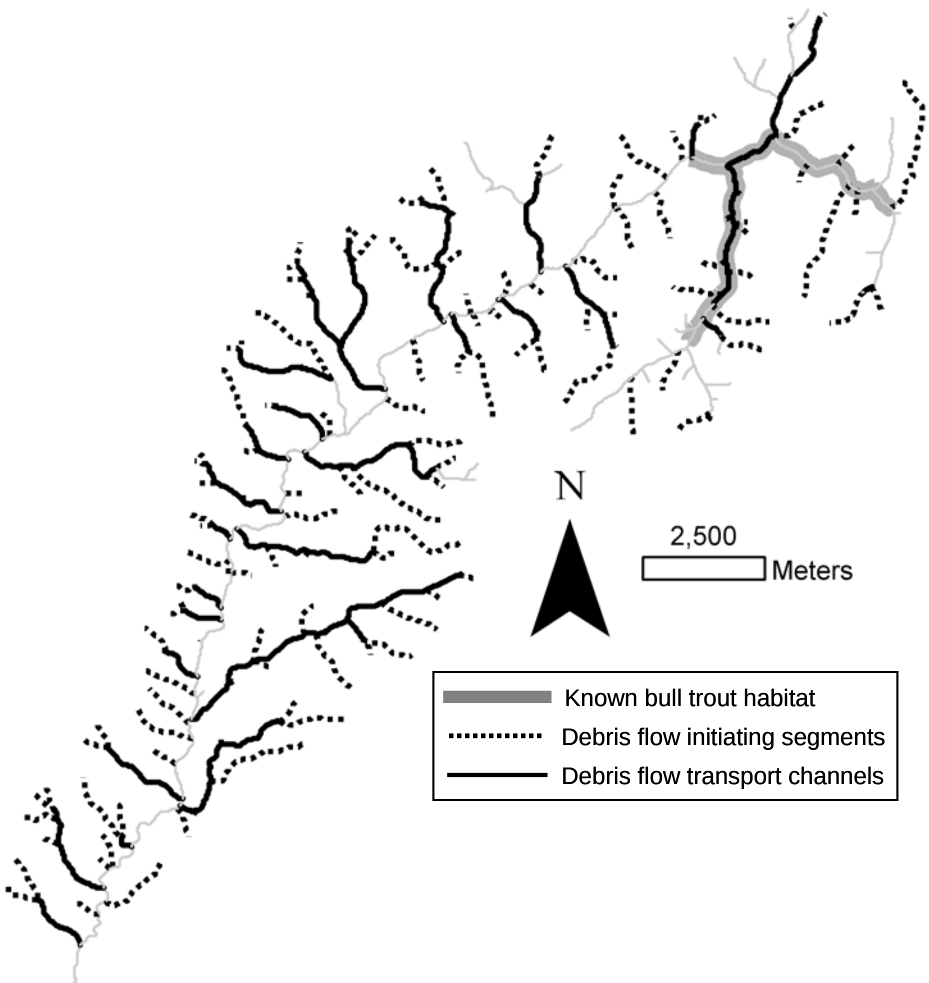

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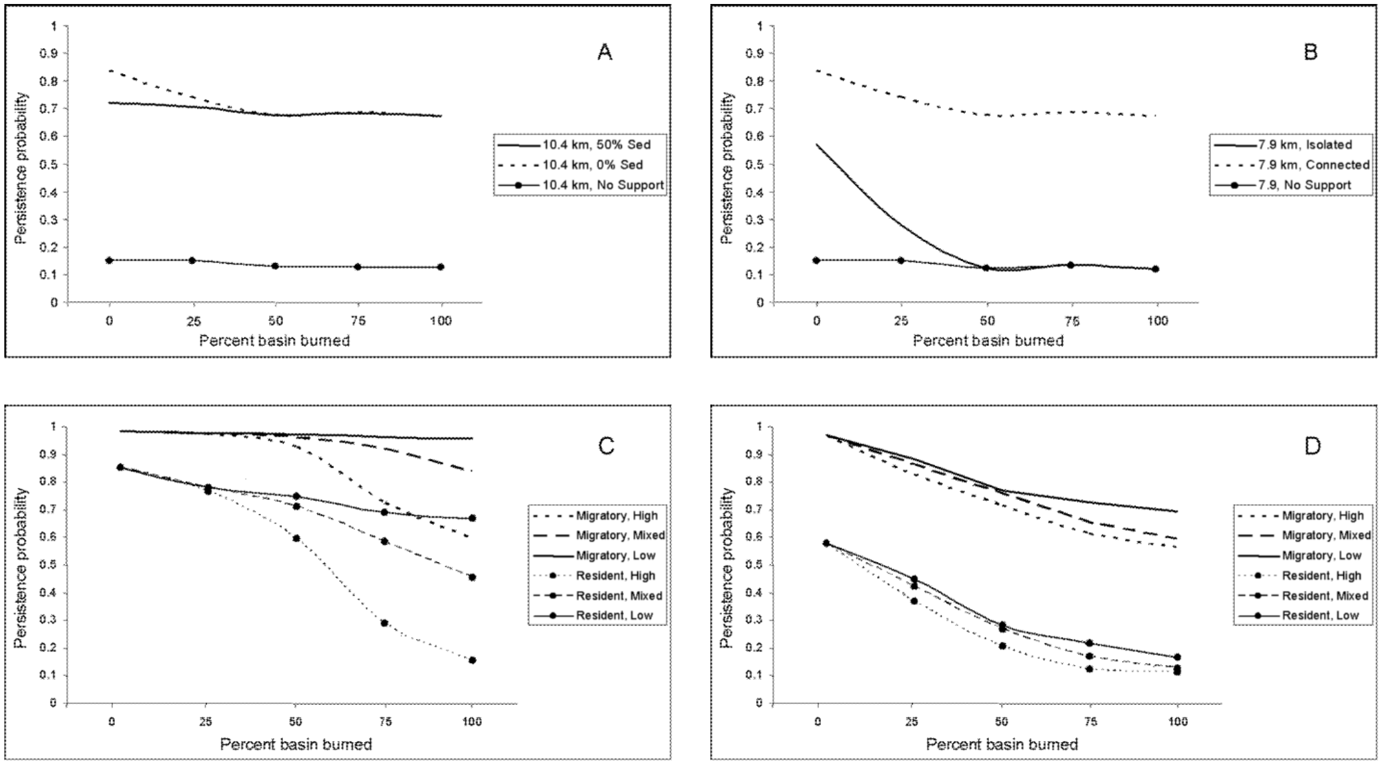

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