Evaluating risks and opportunities for Gila trout management in the Gila National Forest.

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Project Summary

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Introduction

Fire management on the Gila National Forest (GNF) is an example of progressive integration of naturally occurring wildland fire in order to maintain forest health and minimize the chance of large-scale, catastrophic fire. Gila trout *Oncorhynchus gilae* management on the Forest reflects the precarious situation in which many populations exist due to habitat loss, isolation, and competition and genetic introgression with non-native species. Whereas historical fires and post-fire disturbances are believed to have had positive effects on large, inter-connected populations; the effects of fire are characterized currently as threats to extant patches of Gila trout habitat and resident populations. Translocation is the primary management tool for imperiled populations: fish residing in streams likely to be affected by wildland fire are moved to adjacent streams or hatcheries. This approach assumes every fire will realize a "worst-case scenario" where fire and post-fire effects, such as debris flows and ash flows, will result in complete mortality of the affected population. Considering the relatively small population sizes that resource managers are charged to protect and uncertainties associated with fire behavior and the potential for deleterious post-fire effects, translocation makes sense. However, sustainable Gila trout management will require establishing populations of sufficient size and within watersheds of sufficient area to be robust to the natural range of variability in this region. To this end resource managers have identified several patches of recovery habitat having sufficient quality to support spawning and rearing of Gila trout. Our goal was to provide resource managers with information on the potential for fire and post-fire threats to affect Gila trout populations in 21 occupied and recovery patches within the GNF. This exercise involved GIS-based mapping of potential debris flow initiation sites and travel paths and the use of a Bayesian model of patch persistence to evaluate the long-term suitability of individual patches for translocation and restoration.

We generated a poster depicting current conditions and potential threats to the 21 patches of Gila trout habitat in the GNF to aide resource professionals in prioritization of management activities. We developed this document to provide resource professionals context for the information contained in the poster. The report contains a brief overview of methods associated with mapping and GIS-based analysis of debris flows and a summary of the results of patch persistence estimates generated by a Bayesian model that integrates information on patch size, connectivity, and the potential for fire and post-fire disturbance. The report concludes with a discussion of how this information could be used by managers in planning restoration activities in the GNF.

Methods

GIS analysis

We used the ArcGIS extension TauDEM (Terrain Analysis Using Digital Elevation Models; Tarboton, 1997) to delineate a catchment for each stream segment within the GNF. Catchments represent the individual watershed of a single stream segment (a stream section bounded on the upstream and downstream end by a tributary junction). We used a GIS data layer depicting stream networks of occupied and potential Gila trout habitat to delineate a watershed for each stream network, hereafter referred to as patches. We measured the stream length, area, and isolation status of each network. For each non-isolated network we measured the stream distance to the next nearest network in order to estimate connectivity to external patches. We calculated patch connectivity based on patches occupied currently and under a scenario whereby Gila trout populations are established within each patch of recovery habitat in the GNF.

We used the DEM and a hydrography layer produced using TauDEM to evaluate the potential for debris flow initiation and downstream transport for the entire GNF. We modeled two types of debris flows. Bulking debris flows result from overland transport of water and sediment across hydrophobic soils. Hydrophobic soils result from high-severity fire. The second type of debris flow is the product of landslides that occur in areas where tree roots had previously stabilized steep hill slopes but decay after trees are killed by high-severity fire. We used the Stability Index Mapping (SINMAP) extension of ArcGIS to quantify hill-slope stability for landslide initiation. Empirical rules for initiating area size, hill slope, and hill-slope stability were developed from an analysis of debris flow occurrence in the Boise National Forest in Idaho. It is our judgment that these rules apply to watersheds in the GNF (C. Luce, personal communication).

Debris flow effects on Gila trout habitat are governed by the ability of a stream channel to transport a debris flow downstream. We identified transporting stream channels using empirical rules for stream slope and channel size and confinement based on previous research (Benda and Cundy, 1991; Fannin and Wise, 2001) and an empirical analysis of debris flow occurrence in the Boise National Forest in Idaho. We calculated the proportion of patch area prone to debris flow initiation and proportion of stream length within each patch capable of transporting debris flows in order to quantify the potential for post-fire disturbance to impact Gila trout populations and habitat.

Persistence modeling

Information on patch size, connectivity to external habitats, and the potential for post-fire debris flows served as inputs to Bayesian models of long-term patch persistence. Patch persistence is a function of patch size, external connectivity, and the potential for fire to directly and indirectly (i.e., debris flows) affect habitat patches (Figure 1). The first model we developed, called the Persistence model, integrated information on vegetation type within a patch and historical fire sizes and severities characteristic of patch vegetation. Fire size and severity information, taken from Hessburg et al., (2007), was used in Monte Carlo simulations of the burned proportion of a patch given random patch and fire sizes. Historical distributions of fire size and severity are heavily skewed towards small and low- to mixed-severity burns. Therefore, predictions from the Persistence model reflect probable population trajectories assuming frequent small and low-intensity burns that do not affect entire patches. In order simulate the effects of large, high-severity fires capable to affecting entire networks we developed a companion model, called the Gaming model, that allows user to specify a proportion of patch area burned and specific fire severity. We used the Gaming model to estimate patch persistence assuming 100% of patch area burned. We considered this a worst-case scenario for each patch because a single fire event would trigger all potential post-fire disturbances. We compared the results of the Persistence and Gaming models in order to evaluate the potential for wildland-fire use (WFU) to positively impact Gila trout habitat. Our assumption was that WFU would be implemented at scales comparable to historical fire sizes and severities and would diminish the possibility of large-scale, catastrophic fire. Additionally, persistence estimates can be used by resource managers to evaluate the suitability of particular patches for restoration and maintenance of recovered Gila trout populations.

Results

Patch characteristics

We characterized each patch based on stream length, area, isolation, and the potential for demographic support from surrounding patches (Table 1). Resource managers have intimate knowledge of the Gila River watershed; therefore, a detailed exposition of patch characteristics is unnecessary. It is important to point out that all patches currently occupied by Gila trout are isolated by barriers or distance and that under a scenario of total recovery, as defined by establishment of populations within all recovery patches, most patches would still be isolated (Table 1).

Initiating areas for debris flows and landslides are ubiquitous in the Gila River watershed (Figure 2[1]); however, the potential for debris flows to impact Gila trout habitat is constrained by the ability of the stream channel to transport material downstream. In a majority of patches, the potential for debris flows is restricted to less than a third of patch length (Table 2). This is not meant to downplay the potential for debris flows to impact fish populations: Table 2 clearly shows that debris flows can have significant effects in watersheds less than 10 km in length. However, there is a clear relationship between patch size and the proportion of habitat susceptible to debris flows (Figure 3). In the Gila River, patches containing more than 10 km of stream habitat cannot be completed affected by debris flows.

Model results suggest the greatest benefit to Gila trout will be derived from expanding the size of existing patches in the WF Gila River and Mogollon Creek drainages. Recovery work in these areas will result in larger patches and inter-patch connectivity (Table 1). Conversely, there are several patches where debris-flow potential and isolation contribute to very low persistence

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[1] Figure 2 is a map of habitat patches, patch condition, debris flow threat, and persistence created for resource managers. This document is a companion to Figure 1, which is not included in the text.

probabilities, for example McKnight and Sheep Corral Creeks (Table 1; Figure 2). If recovery efforts were successful in the WF Gila River and Mogollon Creek, protracted intensive maintenance of Gila trout populations in small, isolated drainages may be unwarranted.

Potential for wildland fire use

We developed two persistence models that allowed us to contrast the potential for long-term viability of Gila trout populations assuming fire sizes and severities akin to historical probability distributions and fires of sufficient size to affect entire patches. The latter case represents a worst-case scenario in terms of post-fire threats to long-term population persistence. In most cases, patch size, isolation, and the relative security of larger patches to post-fire disturbance, was translated to no difference in model predictions. However, we did identify four patches where the difference in model predictions was at least 17% (Table 2). We interpreted these results in the context of wildland fire use in the GNF. Assuming wildland fire use would involve fire sizes and severities akin to historical probability distributions, then wildland fire use could have positive effects on the long-term persistence of Gila trout in the Big Dry Creek Recovery Area, Iron Creek, McKnight Creek, and South Diamond Creek (Table 2; Figure 2). The benefit of wildland fire in these patches is derived from the fact they are medium-sized patches with relatively large areas prone to post-fire debris flows. Very large and very small patches are resistant to changes in persistence because of the relationship between watershed area and debris flow potential. Very large patches are relatively impervious to debris flows because they contain large streams that don’t often transport debris flows, whereas an entire small patch can be affected by a single small fire (e.g. Sheep Corral Creek, Figure 2). These results define a need for monitoring and evaluation of Gila trout population response to wildland fire use in the four watersheds where proactive fire management could positively influence Gila trout persistence.

References

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Table 1.—Characteristics of 21 patches of Gila trout habitat in the Gila National Forest.

Network	Status[1]	Length (m)	Area (ha)	Isolation[2]	External Support (m)[3]	Recovered Support (m)[4]
Big Dry	1	3,252	797	1	-	-
Big Dry Recovery	0	18,697	3,623	1	-	-
Black Canyon	1	20,442	13,040	2	-	-
Iron	0	7,793	201	2	-	-
Lower Little	1	9,108	919	0	-	2,259
Main Diamond	1	5,447	2,084	0	-	-
McKenna	0	1,863	861	0	12,590	53,982
McKnight	1	7,947	2,136	2	-	-
Mineral	0	23,904	8,334	0	-	-
Mogollon	1	20,466	8,893	1	-	-
Mogollon Recovery	0	38,679	13,325	1	-	8,633
Rain	0	8,633	2,110	0	-	18,213
Sacaton	0	2,662	885	0	-	-
SF Whitewater	0	6,727	2,799	1	-	-
Sheep Corral	1	2,841	1,130	1	-	-
South Diamond	1	10,712	3,043	0	-	-
Spruce	1	4,177	921	1	-	-
Upper Little	0	2,259	1,053	0	9,108	9,108
WF Gila River Recovery	0	53,982	15,088	1	-	-
Whiskey	1	3,433	807	0	-	39,879
White	1	12,591	1,909	0	-	41,391

[1]0 – Recovery habitat, not occupied currently; 1 – Occupied currently.
[2]0 – Not isolated; 1 – Natural barrier; 2 – Human-made barrier.
[3]Amount of Gila trout habitat within 10 stream kilometers of focal watershed. This length represents the amount of external demographic support available to the focal watershed.
[4]Amount of Gila trout habitat within 10 stream kilometers of focal watershed under a scenario of full recovery.

Table 2.—Debris flow threat and predicted probability of long-term persistence of 21 patches of Gila trout habitat in the Gila National Forest.

Network	Debris Flow Track Length (m)	BDF Initiating Area (ha)[1]	LS Initiating Area (ha)[2]	Total DF Initiating Area (ha)[3]	Persistence[4]	Wildland Fire Use Benefit[5]
Big Dry	3,252	-	465	-	0.15	-
Big Dry Recovery	11,741	33	2,069	-	0.53	0.29
Black Canyon	1,664	173	5,923	976	0.90	-
Iron	3,692	-	822	61	0.31	0.18
Lower Little	-	42	129	24	0.57	-
Main Diamond	982	142	1,065	-	0.51	-
McKenna	-	-	100	211	0.84	-
McKnight	7,947	-	1,054	-	0.15	0.36
Mineral	7,187	390	4,612	105	0.71	0.09
Mogollon	6,660	67	5,027	-	0.82	0.08
Mogollon Recovery	12,259	143	7,461	21	0.92	0.04
Rain	-	59	1,260	-	0.57	-
Sacaton	2,662	-	599	-	0.15	-
SF Whitewater	-	-	1,695	-	0.57	-
Sheep Corral	2,841	-	568	45	0.15	-
South Diamond	6,534	-	1,904	81	0.33	0.43
Spruce	4,177	-	522	-	0.15	-
Upper Little	355	24	693	-	0.70	-
WF Gila River Recovery	13,394	391	6,659	741	0.96	-
Whiskey	2,559	-	684	-	0.15	-
White	1,826	45	574	177	0.72	0.07

[1]Area of catchments within focal watershed having conditions consistent with the initiation of bulking debris flows.

[2]Area of catchments within focal watershed having conditions consistent with the initiation of landslides

[3]Area of catchments within focal watershed having conditions consistent with the initiation of either bulking debris flows or landslides.

[4]Probability that focal watershed contains spawning and rearing habitat for Gila trout assuming 100% of watershed area burns and 100% of post-fire threats are realized.

[5]Increase in persistence probability resulting from prevention of 100% burn. Fire is not excluded from watershed; however, pattern of burn is consistent with historical fire size and severity distributions.

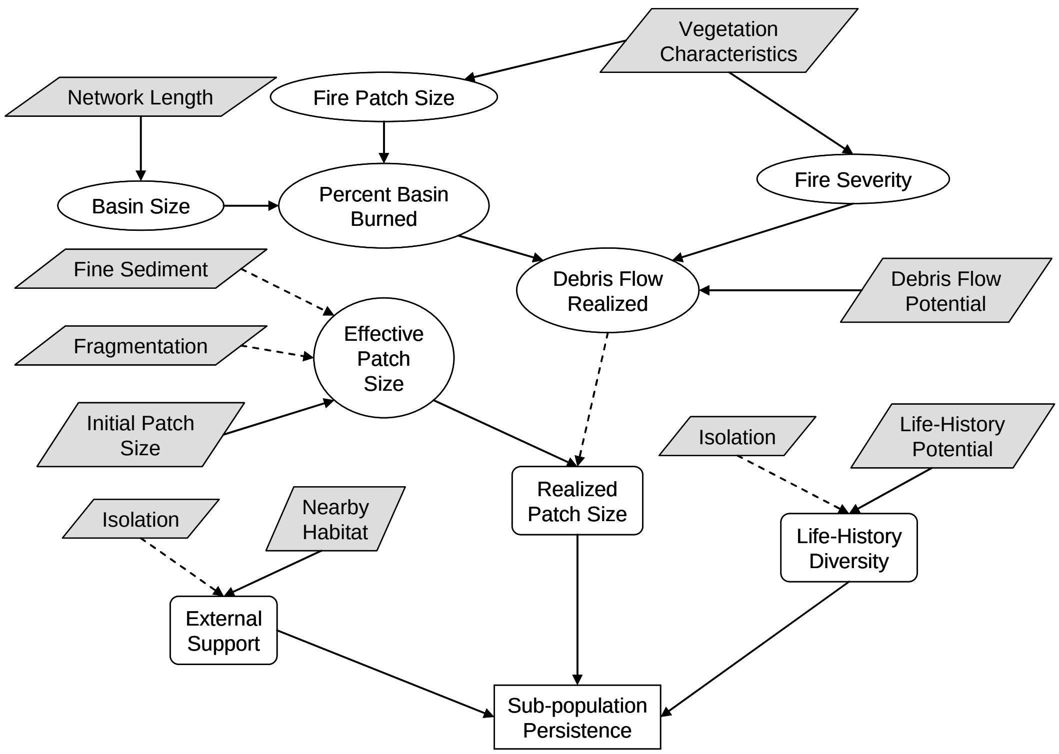

Figure 1.—Flow diagram depicting Bayesian model used to calculate persistence of habitat patches in Gila River watershed.

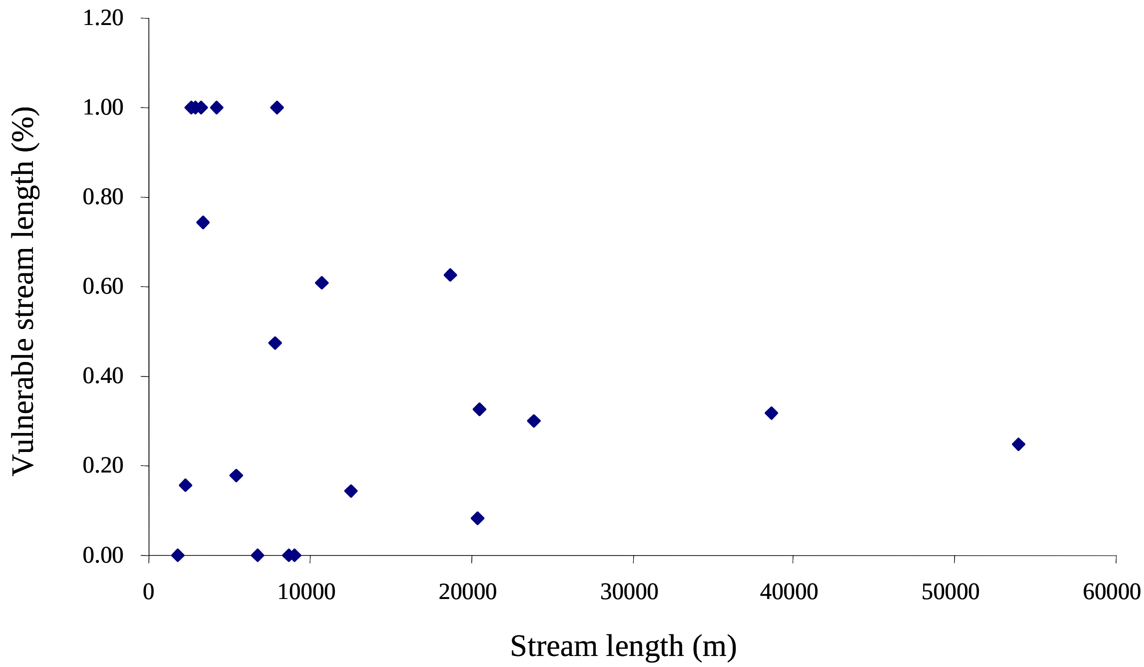

Figure 3.—Relationship between patch size, as expressed meters of stream within a patch and the proportion of stream length vulnerable to debris flows. Patches containing more than 10 km of stream habitat are substantially less vulnerable to debris flows than smaller patches.