Status of Swan Valley River Cutthroat Trout Populations and Conservation Recommendations

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Executive Summary

Although once widespread in the Swan River Valley, native westslope cutthroat trout have declined in numbers and are now largely found only in certain headwater streams and stocked mountain lakes. We believe the primary cause of decline has been from non-native brook trout, rainbow trout, and Yellowstone cutthroat trout. We have identified 22 remnant westslope cutthroat trout populations that we consider large enough (at least 100 fish) and genetically non-hybridized enough (no more than 5 percent hybridized) to be appropriate for conservation. They vary between them in size and security. This report compiles information on those 22 populations.

In 2011 and 2016, we collaboratively gathered information on each westslope cutthroat population's relative abundance, brook trout abundance, genetic integrity (admixture), number of effective breeders, genetic heterozygosity, habitat area, water temperature and other habitat quality metrics. We have learned that the total of number westslope cutthroat trout estimated in each population ranges from just 131 in Owl Creek, to our largest 2,846 in Sixmile Creek. The densities per 100m^2 ranged widely and some of the smallest streams appear far more productive than larger streams. We have also learned that brook trout are present in 10 of the 22 populations. We speculate they will gain ground in some populations but may struggle in others that have high gradients or very cold water. Of the remaining 12 streams that have not been compromised, we identify 3 that have definitive anthropogenic or natural barriers to upstream migration, 7 that have high gradient areas that so far appear to have confounded invasion and 2 that have no known reason why brook trout are absent (Groom Creek and Upper Swan River).

We have repeatedly analyzed population genetics over the years to search for nonnative alleles with ever increasing laboratory sensitivity. Initially (2011) we found five populations to have no introgression and remainder averaging 99 percent genetically non-hybridized westslope cutthroat trout. But in 2016, we were unsure if any populations were still entirely non-hybridized. We found 17 of 22 populations to be at least 99 percent genetically non-hybridized and none had more than 2.2 percent introgression. However a simultaneous research project underway on 7 populations did not concur and found 5 populations are still non-hybridized. There may be a decline in the number of non-hybridized individuals over time but this could be artifact of increased analysis sensitivity. Using advancements in genetic science, we estimated the genetically effective number of breeders (N_b) that produced offspring that survived >1 year in these populations to range from just 10 (Groom Creek) to over 100 (Kraft Creek). Many streams had less than 50 effective breeding individuals which may be of concern for their long term persistence, especially those in isolated habitat. We found all but one population had similar heterozygosity regardless of size or isolation. The lone exception was the Herrick Run population, which had substantially reduced heterozygosity.

We found half of the 22 populations to have ideal water temperatures for westslope cutthroat trout, but nine are very cold and two are warm. These 11 streams have detrimental water temperatures but they may harbor populations that are uniquely adapted to those extremes. We found no correlation of temperature to westslope cutthroat trout density or brook trout abundance. Habitat quality within the study area was either fair or good and has no obvious relation to westslope cutthroat trout abundance.

With this comprehensive dataset, we have identified potential threats to each specific population ranging from brook trout invasion, upstream and/or downstream hybridization, and loss of habitat quality due to climate change, fire or land management. We then offer recommendations for future conservation efforts.

Contents

Background and Purpose of Report

In the Swan River Valley, native westslope cutthroat trout (*Oncorhynchus clarkii lewisi*, hereafter "cutthroat trout") have been reduced in numbers and/or genetic integrity and now occupy only about 20 percent of their historic distribution (Flathead National Forest et al. 2010). We believe that the primary cause of decline is competitive pressure from nonnative brook trout (*Salvelinus fontinalis*) and competition and hybridization with rainbow trout (*O. mykiss*) and Yellowstone cutthroat trout (*O. c. bouvieri*). Other stressors include loss of habitat quality especially in low elevations, restricted habitat availability in high elevations, historic recreation harvest, and climate change.

In 2009, we collaboratively assembled all our available information to identify remnant strongholds, which we call "Conservation Populations". We defined two minimal criteria to quality as a Conservation Populations. First, we defined a minimum population size of 100 age 1+ cutthroat trout based on our professional judgment. Second, we required known or suspected genetic integrity of 95 percent or more native alleles. This exceeds the 90 percent threshold used by an inter-agency conservation agreement (Montana Cutthroat Trout Steering Committee 2007) but we had no known situations between 90 and 95 percent. We excluded streams with overwhelming brook trout numbers although we did not precisely define at what point there were too many brook trout. Based on this we felt we had 21 Conservation Populations in the Swan River Valley. Most are distinct tributaries that are not adjacent or tributaries to each other. However Cat Creek is a tributary to Dog Creek and we cautiously decided to treat these as two separate populations since the confluence area is relatively devoid of cutthroat trout. In subsequent years our findings supported the approach since Dog Creek appears to have less introgression than Cat Creek. In 2010, we split out Red Butte Creek from the Kraft Creek watershed due to apparent different species composition. We removed Lion Creek from our roster in 2013 due to insufficient number of cutthroat trout but concurrently added Soup Creek due to new information on this population's genetic integrity. This left us with 22 Conservation Populations and they are shown on Figure 1. The 22 known Conservation Populations vary greatly in size, security, and long-term viability.

Previous conservation measures largely focused on habitat restoration such as minimizing impacts from forest roads, removing undesirable fish migration barriers and private land habitat restoration. Some of this work is still on-going. Since 2010, added focus has been given to preventing and remediating the threat from invasive species. Three intentional barriers to upstream fish passage have been installed to date, namely Whitetail Creek (2010), Red Butte Creek (2014) and Smith Creek (2016). Due to concern about reduced genetic heterozygosity ("inbred") in Herrick Run Creek (described in this report), a limited amount of non-hybridized fish were stocked in this stream from 2013-2014. Potential future conservation actions may include installing additional barriers or enhancing natural barriers, moving some fish from healthy populations to bolster depressed populations, translocating or reintroducing fish to depopulated areas, continued removal of invasive species, and increases in diverse habitat restoration measures on public and private land. Furthermore, a large-scale planning effort is currently underway for roughly half of the populations on National Forest system lands and this work focuses on restoring resilient fish habitat by means of reintroducing fire disturbance and minimizing road-related impacts (the Mid-Swan Landscape Restoration and Wildland Urban Interface Project).

As of 2010, available data for each Conservation Population varied from highly detailed (Kraft Creek) to completely unexplored (Swan River and South Fork Cold Creek). We organized ourselves as the Swan Valley Native Fish Committee and began a more comprehensive inventory of our Conservation

Populations in 2011. New advances in conservation genetics and funding from the USDA Collaborative Forest Landscape Restoration Program also helped spur the effort. The objective in 2011 was to more systematically determine size and genetic health of each Conservation Population, plus gain further information on brook trout invasion, in order to set conservation priorities. Subsequent monitoring work took place in 2016 in order to monitor trends and predict future vulnerability for each conservation population. We also hope to evaluate efficacy of conservation work completed to date in regards to genetic purity, genetic diversity, and viable/sustainable populations over time. A third, comprehensive monitoring effort is anticipated in 2021.

In addition to our comprehensive monitoring, complimentary work by researchers at the U.S. Forest Service's National Genomics Center for Wildlife and Fish Conservation (NGC) is looking at how life history traits shift under isolation for a subset of these streams. Furthermore data regarding water temperature has greatly increased since 2010 and some habitat sampling has been completed. This report summarizes all known information and provides a series of recommendations to help conserve and restore cutthroat trout in the Swan River Valley.

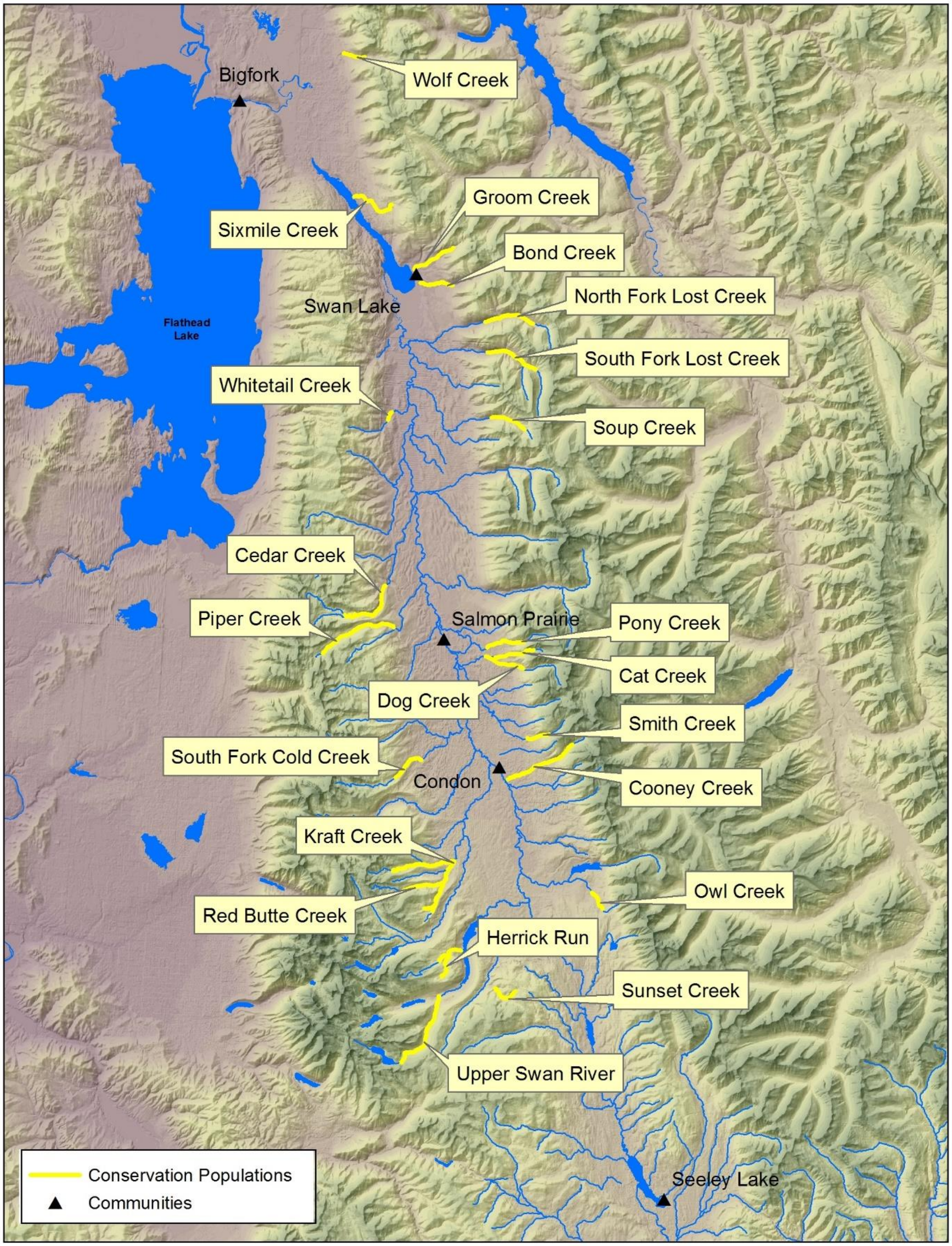


Figure 1. Westslope cutthroat trout Conservation Populations in the Swan River Valley, Montana.

Study Area

The Swan River Valley in northwest Montana is a glacial valley that still largely shaped by hydrologic processes unaltered by humans. The river is unconfined and the valley is saturated with thousands of lakes and wetlands. Other than a single dam at the terminus of the valley, there are no other dams or reservoirs. The Swan River Valley is elongated and feather-shaped with dozens of tributaries. The valley is bordered by the Mission Mountains on the west and by the Swan Range on the east. Forest ecosystems are biologically diverse relative to other forested regions in the Rocky Mountains due to the convergence of maritime and continental climatic influences as well as topographic complexity and steep elevation gradients. Elevation range is 935 – 2,852 m (3,068 - 9,356 ft) and average annual precipitation ranges from approximately 38 - 53 cm (15 - 21 in). Approximately 93 percent of the Swan River Valley is public land managed by the Flathead National Forest and the Montana Department of Natural Resources and Conservation.

Water quality in the Swan River Valley is generally considered good. A review of aerial photographs of the Swan River from 1934 to 1985 found no evidence that land management had resulted in increased river erosion or channel instability (Grant et al. 1989). A 2001 assessment by the Montana Department of Environmental Quality (DEQ) found the river to have very little bank erosion and no evidence of anthropogenic degradation of stream banks (Montana Department of Water Quality 2004). While the river is not considered impaired, the Montana DEQ lists Swan Lake as a “threatened” water body and Goat Creek as “impaired” water body due to concern about poor dissolved oxygen level and turbidity, respectively. Montana DEQ no longer considers Jim Creek as “impaired” due to road-related restoration work. A 2012 nation-wide assessment of watershed conditions, known as the Watershed Condition Framework, initially listed 20 out of the 23 sub-watersheds were “functioning appropriately.” Since then considerable work has taken place to minimize impacts of forest roads in two watersheds (Jim Creek and Cold Creek) and they are now considered recovered. Beaver Creek remains the sole watershed regarded as “functioning at risk”. Additionally, monitoring of 44 tributary streams in Swan River Valley from 1997 to 2015 found no significant difference in habitat quality between streams in roaded and un-roaded landscapes, except for substrate sizes. Substrate sizes tended to be smaller in roaded watersheds (Gardner 2015).

The Swan River Valley also maintains its entire native aquatic species assemblage. Bull trout (*Salvelinus confluentus*) dwell in Swan Lake, Holland Lake and Lindbergh Lake and spawn in various tributaries. All spawning tributaries plus the entire length of Swan River and the three lakes are designated as Critical Habitat. Native mountain whitefish (*Prosopium williamsoni*), sculpin (*Cottus* speces) and several other species occupy Swan River.

Westslope cutthroat trout were once frequently caught in the Swan River and occupied almost every tributary in the valley. Cutthroat trout likely functioned as a “metapopulation” with multiple resident populations in tributaries plus, perhaps, some migratory fluvial fish that reared in the Swan River. It is assumed that some individuals strayed between populations to facilitate re-colonization after a disturbance and also maintain genetic heterozygosity. Cutthroat trout were not present in most high-elevation mountain lakes, although it is plausible they historically colonized Glacier, Cold, Hemlock and Cedar Lakes (Lamar 2008). In recent years, the distribution and abundance of native cutthroat trout has sharply declined in river and tributary streams. Anglers rarely catch cutthroat trout in the river. Many high mountain lakes have been stocked with westslope cutthroat trout, some of which are now self-sustaining. This has resulted in the curious shift of cutthroat trout distribution from low elevations to high elevations. It is speculated that many modern anglers only experience cutthroat trout in mountain lakes and are largely unaware of their historic riverine distribution.

Non-native, wild (self-sustaining) rainbow trout are now the most frequently captured species. Montana Fish, Wildlife & Parks maintain a catch and release rainbow trout fishery in the lower half of the river. Non-native, wild brook trout are also numerous and found in nearly every tributary, sometimes at very high densities. Non-native Yellowstone cutthroat trout and golden trout were previously stocked in some headwater lakes although this practice has been recently discontinued. Non-native northern pike (*Esox lucius*) are present in Swan Lake but presumed to have a minor impact on cutthroat trout since they rarely move upriver.

Population Measures: Methods and Results

Population size estimates - Methods

Field crews electrofished 20 of the 22 Conservation Populations in 2011-2012. Although the work took two seasons to complete, for clarity the rest of this report will describe the initial sample as 2011. Bond Creek and Cooney Creek were deferred due to relatively recent data already available. Sampling protocols followed Temple and Pearsons (2007) and most populations were estimated by multiple pass depletion in a presumed representative area, which was then extrapolated for the entire stream. All fish that appeared to be cutthroat trout were numerated as westslope cutthroat trout for this exercise (genetic information collected separately). No putative rainbow trout were captured in any sample. In some streams we were unable to complete population estimates due to channel conditions that precluded using block nets or other logistic constraints, so we utilized single pass relative abundance instead. All species encountered were measured to the nearest cm total length and released alive near point of capture. Population estimates and relative abundances are for age 1+ fish, which are defined as at least 7cm total length. Fish less than 7cm were assumed to be young-of-year and not counted in estimates. Following this work, we determined that Lion Creek did not support a viable population and removed it from the list of Conservation Population. At the same time Montana DNRC independently discovered Soup Creek supported a viable and nearly non-hybridized population, so we subsequently added that to our roster.

In 2016, we re-sampled 21 of the 22 streams, again deferring Bond Creek since it was sampled independently by Montana FWP in 2013. This time we focused on multiple short one-pass efforts scattered over a larger area. Each stream typically had 3-5 samples. This information was extrapolated for a larger area to estimate total relative abundance. Again all putative cutthroat trout were assumed to be westslope cutthroat trout and no rainbow trout were captured in any sample. Field crews recorded every species encountered and measured to the nearest mm total length. Fish less than 70mm were not included in estimates. Thus the 2016 effort sampled more locations over a large area and improved our understanding of cutthroat trout geographic distribution but sacrificed monitoring of population estimates. Based on data regarding habitat area available (see section on Habitat Measurement), the total relative abundance was then standardized to density per 100m^2. For details on number of sites sampled and how population estimates were derived for each stream see Appendix A.

Population size estimates - Results

Total estimated population sizes or relative abundances for cutthroat trout and brook trout are presented below in Table 1. The current relative abundance ranges from just 131 fish (Owl Creek) to 2846 fish (Sixmile Creek), with a median of 1149 fish per population. Density of cutthroat trout ranged from just 2 fish per 100m^2 (Kraft Creek) to 26.7 per 100m^2 (Sixmile Creek), with a median of 8.2 per 100m^2. The most numerous abundance and greatest density of cutthroat trout was Sixmile Creek. Upper Swan River, Kraft Creek and Piper Creek all have very low densities of cutthroat trout but due to the sheer size of the habitat, they had large total abundances. Curiously, the very small populations of Sunset, Owl and Whitetail had fairly high densities.

Brook trout were present in 10 of 22 Conservation Populations. Of those 10 streams, brook trout density ranged from just 0.2 fish per 100m^2 (Pony Creek) to 3.8 fish per 100m^2 (Cooney Creek). The biomass occupied by brook trout in Cooney Creek and Kraft Creek suggest these streams may previously have contained more cutthroat trout but are now functioning below potential.

Knowledge gained in 2011 helped direct sampling strategy in 2016 to improve confidence in findings. Thus, although the 2016 inventory did not collect actual population estimates, this data is believed more accurate than 2011. Figure 2 displays 2016 findings on total abundance and relative density. Findings between 2011 and 2016 are not comparable. For example, in 2016 the Upper Swan total abundance was reduced to new data in remote reaches that found earlier sampling downstream had overestimated the productivity. This does not imply actual population loss over time.

Table 1. Estimated population size (or relative abundance) for each conservation population. Populations are listed alphabetically.

Stream	Total Brook trout abundance (age 1+)			Total Cutthroat Trout abundance (age 1+)		
	2011 Relative abundance	2016 Relative abundance	2016 Density per 100m^2	2011 Pop est. (95% CI)	2016 Relative abundance	2016 Density per 100m^2
Bond[a]		538	3.6		1,168	7.9
Cat	45	45	0.6	407 (300-512)	592	7.9
Cedar	0	0	0	958 (864-1,158)	1,282	4.0
Cooney[b]		1,340	3.8		1,300	3.8
Dog	412	215	2.5	550 (463-635)	1,104	12.8
Groom	0	0	0	2,052 (1,820-2,286)	1,685	12.7
Herrick Run	0	0	0	154 (27-180)	471	3.5
Kraft	4,657	965	1.5	4,302[c]	1,292	2.0
N F Lost	0	0	0	1,627 (1,541-1,712)	1,097	5.5
Owl	40	40	2.9	110 (71-153)	131	9.3

Piper	0	0	0	4,100[c]	2,212	2.5
Pony	200	30	0.2	1,282 (1,126-1,435)	1,560	12.3
Red Butte	20	172	1.1	1,953 (1,770-2,137)	1,515	9.5
S F Cold	0	65	0.6	244[c]	566	5.6
S F Lost	0	0	0	1,667 (1,365-1,968)	2,092	8.3
Sixmile	0	0	0	740[c]	2,846	26.7
Smith	100	130	3.2	371 (339-403)	571	14.2
Soup	0	0	0	300-800[c]	454	6.7
Sunset	3	0	0	236 (205-268)	340	7.7
Upper Swan	0	0	0	2,339[c]	1,853	2.9
Whitetail	0	0	0	75-300[c]	148	6.0
Wolf	0	0	0	410-845[c]	823	7.4

[a] Bond Creek was sampled in 2013.

[b] No data collected in Cooney Creek in 2011 or 2016. However in 2017 population estimate was 1300 with 580-2390 at 95% confidence interval for majority of stream. One reach unsampled.

[c] No confidence intervals available. 2011 Soup and Whitetail Creeks population estimates provided by Jim Bower (DNRC biologist, personal contact).

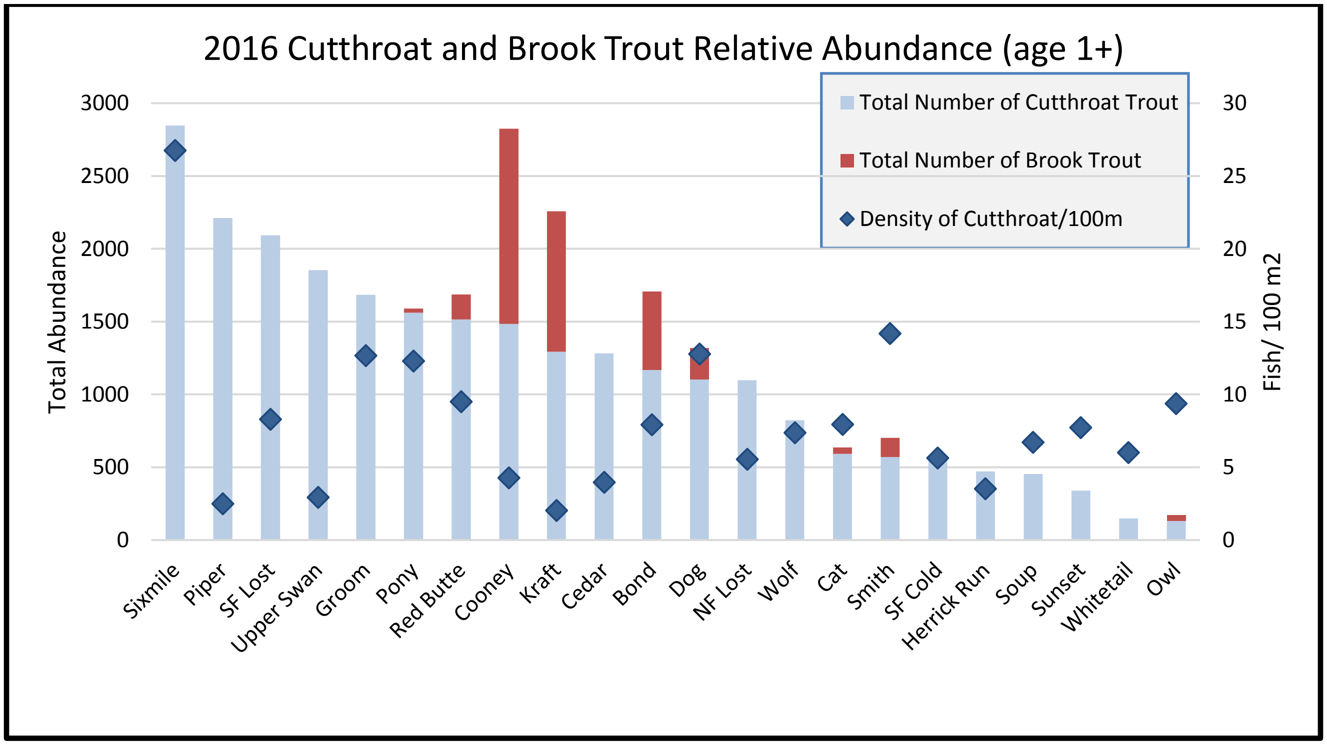


Figure 2. Relative abundance of cutthroat trout and brook trout, sorted from left by cutthroat trout abundance. Blue diamonds indicate density of cutthroat trout per 100m^2.

Cutthroat trout estimated number of breeders – Methods

Effective population size (N_e) is a representation of the theoretical number of reproductive individuals needed to maintain the genetic characteristics of the population (in other words large enough to tolerate a stochastic event or genetic drift). Although no empirical research for minimum cutthroat trout N_e exists, the “50/500 rule” is commonly discussed in conservation management (Rieman and Allendorf 2001). This “rule” recommends a N_e of 50 and a population of 500. However, because cutthroat trout have overlapping generations, N_e is challenging to define and it is more feasible to compute the number of breeders (N_b) for each cohort. The N_b approximates the number of reproductively successful breeders (families) for each cohort and when summed for a generation it should theoretically equate to N_e.

During the 2016 inventory, we sought to collect at least 30 cutthroat trout tissue samples per population at multiple locations (in order to minimize the number of siblings). We typically sampled at three locations between 500-1000m apart but this was not always feasible due to logistics or insufficient habitat length. We further attempted to collect at least 10 individuals per age 1, 2 and 3 cohorts and used total length frequencies to define those cohort size ranges. Because of considerable overlap in size ranges, we were not confident that we correctly assigned age. Samples were preserved in either ethyl alcohol or on chromatography paper and analyzed at the University of Montana’s Conservation Genetics Lab. Software algorithm LDNe NeEstimator V2.01 was used to compute N_b for individual cohorts using >500 SNP loci. Only individuals with less than 1 percent rainbow trout admixture were utilized. Three conservation populations (Bond, Wolf, Herrick Run) were deferred for logistic challenges.

Cutthroat trout estimated number of breeders - Results

The total estimated N_b (either pooled or individual cohorts summed) ranged from 9.8 (Groom Creek) to 108.6 (Kraft Creek), with a mean of 39.0. Pooling cohorts introduces a bias that results in 10-15 percent overestimation of actual per-cohort N_b (Waples et al. 2014). Table 2 displays Nb for each stream and then downward adjusts an average of 0.12 to compensate for cohort pooling. Two populations (Owl and Pony Creeks) had small sample sizes, in that the N_b signal (gametic disequilibrium) was weaker than sampling noise, therefore N_b could not be computed and is regarded as “infinite”.

Luikart et al (in review) describe that per-cohort Ne is expected to be approximately 28 percent larger than per-cohort N_b. Given N_b, we increased this value by 0.28 to estimate N_e as shown in Table 2. We treat these findings cautiously. Due to sampling challenges of identifying cohorts and subsequent pooling and also inference for N_e, we do not conclude that any particular population meets or fails the “50/500 rule”. Low values for N_b could reflect a limited viable spawning habitat, environmental/stochastic juvenile mortality, presence of large females that dominate production, inbreeding depression or other factors. The high N_b for Kraft and Cedar Creeks meet expectation for those large systems, but we were pleasantly surprised by Owl Creek and Whitetail Creek which are small populations. The low N_b for Groom, Sixmile South Fork Lost, Soup and Sunset Creeks causes us to wonder about their long term sustainability. N_b estimator assumes little or no immigrants to the population. Immigrants are unlikely in Sixmile, South Fork Lost and Soup Creeks due to apparent isolation, but possible in Groom Creek and

Sunset Creek. Additional monitoring of N_b in age 0 and 1 fish in 2019-2022 would be invaluable for both local management and advancement of conservation science.

Table 2. Findings for estimates of N_b, as well as inferred N_e and total estimated relative abundance. Streams listed alphabetically. No data available for Bond, Herrick Run or Wolf Creeks. Infinite N_b means no estimate is possible because sample noise exceeds gametic disequilibrium.

	Sample Size	N_b (p 0.95 Confidence Interval)	Corrected N_b due to pooling	Inferred N_e *(recommend min 50)*	Relative abundance *(recommend min 500)*
Cat	29	40.9 (39.6-42.2)	36	46.1	592
Cedar	19	64.1 (58.9-70.1)	56.4	72.2	1,282
Cooney	13	30.1 (28-32.4)	26.5	33.9	1,300
Dog	27	37.2 (35.8-38.6)	32.7	41.9	1,104
Groom 2 demes, results combined	38	9.8 (9.5-10)	8.6	11.0	1,685
Kraft 2 demes, results combined	31	108 (99.2-119.7)	95.6	122.3	1,292
N F Lost	34	55.2 (53.7-56.8)	48.6	62.2	1,097
Owl	7	Infinite		NA	131
Piper	31	40.2 (39-41.5)	35.4	45.3	2,212
Pony	20	Infinite		NA	1,560
Red Butte	21	34.3 (32.6-36)	30.2	38.6	1,515
S F Cold	25	48.4 (46.6-50.3)	42.6	54.5	566
S F Lost 2 demes, results combined	40	18.9 (17-21)	16.6	21.3	2,092
Sixmile 2 demes, results combined	33	13.8 (13.4-14.2)	12.1	15.5	2,846
Smith	26	41.4 (39.9-43.1)	36.4	46.6	571
Soup	28	22.2 (21.7-22.7)	19.5	25.0	454
Sunset	29	23.7 (23.1-24.3)	20.8	26.7	340

Upper Swan	28	39.2 (37.8-40.6)	34.5	44.1	1,853
Whitetail	13	36.0 (33.2-39.1)	31.7	40.6	148

Cutthroat trout genetic admixture (hybridization) - Methods

During the 2011-2012 inventory, we collected genetic materials from 18 of 22 Conservation Populations in order to ascertain any admixture (hybridization) with nonnative rainbow trout and/or Yellowstone cutthroat trout alleles. Field crews anesthetized putative westslope cutthroat trout and clipped fin tissue (typically caudal) of the first 30 cutthroat trout encountered, unless judged too small such as less than 50mm. Crews were instructed to gather at least 30 samples, but encouraged to gather more when possible. Samples were preserved in ethyl alcohol and analyzed by the University of Montana's Conservation Genetics Lab (UM). The lab kept all geographic samples separate until genetic differentiation analysis suggested they functioned as one breeding population. As mentioned before, two populations (Cooney and Bond) were not inventoried at all in 2011-2012. For three populations (South Fork Cold, Whitetail and South Fork Lost) we did not collect new genetic samples since sampling was completed less than 5 years prior and admixture assumed to be relatively unchanged.

The 2011-2012 inventory yielded 513 usable samples that were genotyped at 95 loci for single nucleotide polymorphisms (SNP). From the 95 SNP loci, in 2011 the Conservation Genetics Lab identified 19 diagnostic loci for rainbow trout, 20 diagnostic loci for Yellowstone cutthroat trout and 20 diagnostic loci for westslope cutthroat trout, thus a total of 57 species-diagnostic loci. The 2012 samples were completed in a similar manner but with the addition of two more westslope diagnostic loci for a total of 59 species-diagnostic loci. Ten percent of all samples were re-extracted and genotyped for quality control, yielding 2.4 percent error largely in variable (non-diagnostic) loci. Two individual samples from Dog Creek had conflicting results and were subsequently removed from dataset. Additional information on genotype extraction methods are found in Gardner et al. (2012).

In 2016, field crews again collected genetic materials from 21 of 22 Conservation Populations but used different methods. Crews were instructed to collect at least 10 samples for three putative age cohorts (total of 30 samples) scattered over a wide geographic area, although additional samples were encouraged. This work was to estimate number of breeders (N_b) described elsewhere and we utilized the same tissue for admixture evaluation. Field crews were not always capable of collecting representative cohorts and the number of samples per stream ranged from 8 (Owl Creek) to 107 (NF Lost Creek). Samples were preserved in ethyl alcohol and analyzed by UM using Rapture methodology (Ali et al. 2016). Rapture utilizes over 200 Yellowstone cutthroat trout diagnostic and over 700 rainbow trout diagnostic loci. Information on laboratory techniques are provided in Amish et al. (2018).

In addition to the Rapture analysis, 7 populations were sampled by National Genomics Center for Wildlife and Fish Conservation (NGC), which is a part of the Forest Service Rocky Mountain Research Station. The NGC is working on an independent study on isolation consequences to heterozygosity. Samples from 6 of these 7 populations were simultaneously done by UM's Rapture methodology, although not all the same individuals were used. Wolf Creek, however, was only assessed by the NGC.

In 2016, the NGC study collected 23-193 samples across 3-4 locations for each stream. Samples were spaced 500 to 2.5 km apart, except Whitetail Creek which has less than 1 kilometer of habitat. Whitetail Creek had two samples approximately 400 m apart. Samples were preserved on chromatography paper and stored at ambient temperature until DNA extraction occurred. A minimum of 40 samples per population, across a range of size classes, were then used for genetic analysis (except Whitetail Creek which only had 23 samples). Samples were analyzed across 16 microsatellite loci following methods outlined in Carim et al. (2016a and b). The dual studies on six streams was not intended to contrast methods since they vary in sample size and primarily did not utilize the same individuals.

One population (Bond Creek) was sampled in 2013 and not included in either the 2011 or 2016 inventory. The Bond Creek sample came from 29 cutthroat trout captured at two locations and analyzed with 59 diagnostic loci (just like 2012 inventory work). Herrick Run was collected in 2016 but results are still pending.

Cutthroat trout genetic admixture (hybridization) - Results

All sample sizes, methods and results are presented in Table 3. Although data are available that distinguished introgression from Yellowstone cutthroat trout from rainbow trout, this report combines them as nonnative alleles. In most cases, all fish collected from a stream had no genetic differentiation (Fst ~0) thus assumed to be one mixed population. If there was potential for two or more genetically different populations, results were cautiously separated into two or more demes. We do not have enough information to be confident that the demes are truly reproductively isolated. Curiously, none of the streams with multiple demes flagged in 2011 were apparent in 2016 and vice versa. This may indicate low or ephemeral differentiation or sampling error. For clarity, Table 2 lumps all stream samplings into one row but does indicate a range when analysis suggests there may be multiple demes. Figure 3 illustrates the percentage of nonnative alleles and percentage of non-hybridized individuals for most of the conservation populations.

Of the 2011-2013 samples that used either 57 or 59 diagnostic loci, the mean amount of nonnative admixture was 1 percent. Kraft Creek was the most introgressed at 6 percent nonnative alleles. The mean percentage of non-hybridized individuals per sample was 70 percent but five streams no hybridized individuals at all (Groom, Red Butte, Sixmile, Smith and Wolf Creeks). However, in 2016, the 18 streams with Rapture methodology found every stream was slightly hybridized. The percentage of non-hybridized individuals ranged from 75 percent (Upper Swan) to only 2 percent (Sunset), with a mean of 35 percent. The mean amount of nonnative admixture among populations remained 1 percent, ranging from 0.1 percent (Upper Swan and Whitetail) to 2.2 percent (North Fork Lost).

As shown in Figure 3, the percentage of non-hybridized individuals captured in the 2016 sample did not correlate well with the population level admixture. The Upper Swan River appears to have both the greatest number of non-hybridized individuals and the least population level admixture, while North Fork Lost Creek falls on the opposite end of the spectrum. But other populations are variable, which presumably reflects their unique history of admixture. Both Sunset Creek and Smith Creek are about 1 percent introgressed but vary greatly in the number of non-hybridized individuals remaining. This may indicate a hybridization event is much more recent in Smith Creek than Sunset Creek. Data from Kraft Creek found a reversal of hybridization and a reduction of introgression from 0.8 – 12 percent in 2011 (2 demes) to 1.8 percent in 2016 (1 deme). This unexpected reversal may be due to several factors such as sampling error, temporal variation in allele frequency, or non-hybridized immigrants moving into this un-isolated stream.

The 2016 Rapture methodology results suggest a universal increase of hybridization since 2011-2012 with no populations remaining that are absolutely non-hybridized. However, 5 out of 7 populations analyzed with NGC microsatellites in 2016 still found no evidence of introgression (namely Groom, Sixmile, Cooney, Whitetail and Wolf Creeks). These conflicting findings may be due in part to NGC use of fewer diagnostic loci and/or (to some extent) different individual fish sampled. Red Butte and South Fork Lost Creeks had consistent results between the two methodologies of very low levels of admixture (less than 1 percent).

Regardless of analytics, we conclude that all populations still exceed the minimum threshold of 95 percent native alleles. Furthermore, 17 of the 22 Conservation Populations are at least 99 percent non-hybridized (1 percent or less admixture) and thus retain especially high conservation value. The potential decline in the number of non-hybridized individuals almost across the board from 2011 to 2016 is concerning and may be an inevitable result of the legacy of rainbow trout and Yellowstone cutthroat trout in the Swan River valley. However, because of inconsistent methodology and the unexpected reversal in Kraft Creek, we do not have confidence that any change over time is real. Data is best used to evaluate conservation priorities rather than monitoring change.

Table 3. Results of cutthroat trout genetic admixture from 2011 and 2016. All 2016 results are from UM Rapture findings unless otherwise designated with red font. Red font indicates results provided by NGC microsatellite.

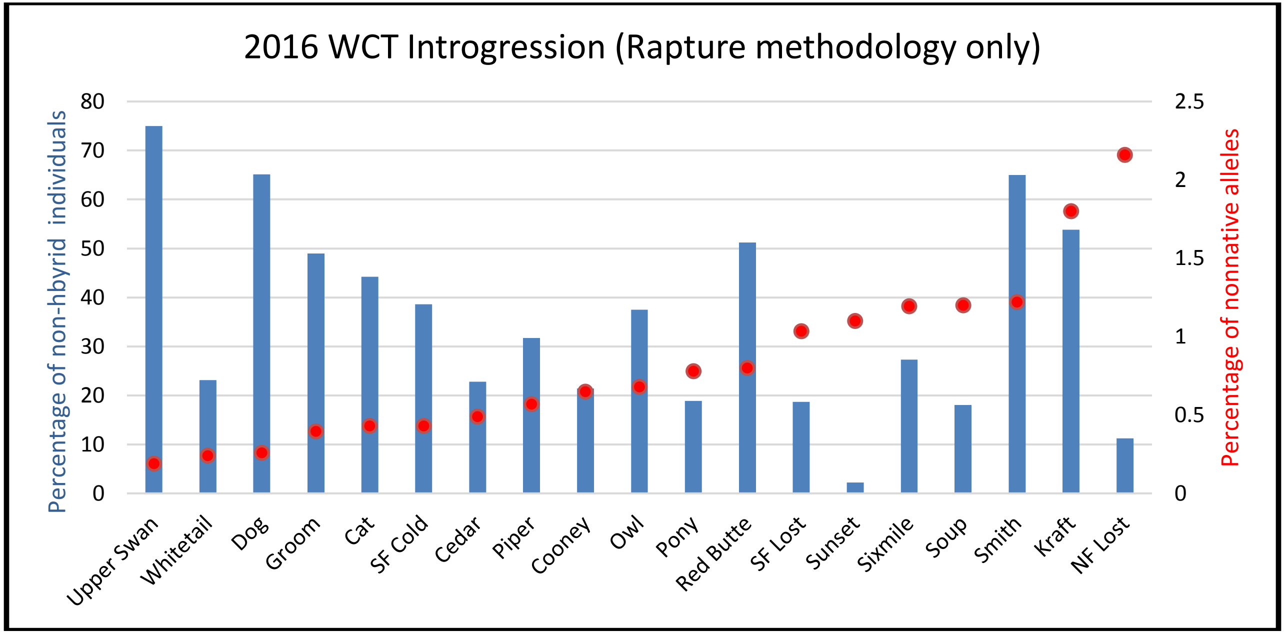
Stream	2011-2012			2016		
	Sample size	Percentage of non-hybridized individuals	Admixture	Sample size	Percentage of non-hybridized individuals	Admixture
Bond[a]	29	55%	0.5%			
Cat	31	71%	0.5%	52	44%	0.4%
Cedar 2 demes?	34	54-80%	0.2-1%	35	23%	0.5%
Cooney				14 78	21% 100%	0.6% 0%
Dog	40	97%	0.02%	43	65%	0.3%
Groom 2 demes?	30	100%	0%	51 68	43-57% 100%	0.3-0.5% 0%
Herrick Run	34	97%	0.1%			
Kraft 2 demes?	37	22-70%	0.8-12%	39	54%	1.8%
N F Lost	30	10%	2%	107	11%	2.2%
Owl	24	21%	0.3%	8	37%	0.7%
Piper 2 demes?	56	59-70%	1-4%	41	32%	0.6%
Pony	30	57%	0.7%	37	19%	0.8%

Red Butte	14	100%	0%	41 80	51% 99%	0.8% 0.08%
S F Cold				42	55%	0.4%
S F Lost multiple demes?[b]				64 46	6-23%	0.9-1.2% 0.3%
Sixmile 2 demes?	30	100%	0%	55 76	25-30% 100%	0.9-1.5% 0%
Smith	30	100%	0%	40	65%	1.2%
Soup				50	18%	1.2%
Sunset	28	68%	0.6%	45	2%	1.1%
Upper Swan	34	94%	0.2%	40	75%	0.2%
Whitetail				13 23	23% 100%	0.2% 0%
Wolf	30	100%	0%	60	100%	0%

[a] Bond Creek was sampled in 2013

[b] South Fork Lost Creek may have many demes. The Rapture results suggest at least 2 but the NGC found many possible demes and abandoned tally of them.

Figure 3. Results from 2016 genetic introgression, with Rapture methodology only. Populations are sorted from left by the least introgressed as shown in red circles. Blue bars are the percentage of non-hybridized individuals from the total number of fish sampled. Results are pending for Herrick Run and Wolf Creek. The NGC microsatellite methodology results are not shown in order to reduce clutter.



Cutthroat trout population heterozygosity - Methods

Using the same tissue samples collected in the 2011 work, 11 of the 22 conservation populations were assessed for variation, or Heterozygosity, within population. A total of 31 polymorphic loci (but not species diagnostic loci) were assessed for non-hybridized or minimally hybridized individuals from each population (range 8-34 individuals). Heterozygosity was calculated by a comparison of expected verses observed of the 11 stream dataset.

As part of the NGC study on long-term effects of isolation, heterozygosity of 14 polymorphic microsatellite loci was assessed on 6 conservation populations in 2016. Four of these happened to coincide with 2011 study streams but used different markers. As a result, estimates cannot be directly compared to monitor trend within populations. South Fork Lost Creek was initially planned for sampling but fieldwork found multiple waterfalls that potentially resulted in numerous demes and this stream was eliminated from their study.

Cutthroat trout population heterozygosity - Results

The results of the 2011 and 2016 heterozygosity samples are provided in Table 4. In 2011, the mean heterozygosity among populations was 0.200 (range: 0.163-0.280), not including Herrick Run. Heterozygosity for Herrick Run was nearly an order of magnitude lower in (He = 0.028) compared to the mean among other populations. The percentage of loci polymorphic (% PM) was also lowest at Herrick Run (13 percent) compared to the mean of 70 percent among populations. These data suggest Herrick Run could potentially be suffering reduced fitness due to low variation and inbreeding. The relatively high F_{IS} (deficit of heterozygotes) in Kraft Creek suggests that this stream may actually consist of two demes.

The 2016 analysis using NGC microsatellites found that the six populations tested had a heterozygosity between 0.28 (Wolf Creek) and 0.47 (Cooney Creek). The mean value across all 6 streams was 0.39. It is noted that the observed heterozygosity in the 2016 NGC work is higher than the 211 work but this is likely due to different marker types.

Table 4. Findings of heterozygosity in 2011 and 2016. N refers to number of individuals sampled. He is expected heterozygosity and Ho is observed heterozygosity. Fis is deficit of heterozygotes and %PM is the percentage of polymorphic loci. Streams are listed alphabetically.

	2011					2016				
Stream	N	He	Ho	F_{IS}	% PM	N	He	Ho	F_{IS}	% PM
Cedar	10	0.201	0.196	0.029	78%					
Cooney						78		0.47		
Dog	40	0.29	0.29	0.004	94%					
Groom	30	0.265	0.259	0.014	94%	68		0.41		
Herrick Run	34	0.028	0.021	0.006	12%					
Kraft	8	0.18	0.242	0.271	78%					
Owl	25	0.28	0.293	0.027	87%					
Red Butte	14	0.2	0.232	0.146	59%	80		0.4		
Sixmile	30	0.208	0.208	0.011	75%	76		0.41		
Smith	28	0.21	0.22	0.02	65%					
Upper Swan	34	0.238	0.245	0.009	91%					
Whitetail						23		0.38		
Wolf	30	0.163	0.162	0.002	59%	60		0.28		

Habitat Measures: Methods and Results

Habitat Area - Methods

We estimated the available habitat (surface) area by multiplying length by width. Length of occupied habitat in each stream was determined by one of three possible methods. One method is to utilize information available from electrofishing inventories and location of known or suspected barriers to fish migration. Barriers consisted of either natural (abrupt waterfalls or areas of high gradient) or artificial (road culverts, water diversion or intentional barriers). We do not have confidence in effectiveness of every barrier and furthermore, in some situations of prolonged high gradient reaches, we are uncertain where to precisely delineate the break in fish distribution. We spatially assigned barriers as either confirmed or suspected based on best data or professional judgment.

The second method utilized Environmental DNA (eDNA) to delineate the upper limits of cutthroat trout distribution in six streams. Samples were collected using outlined by Carim et al. (2016a) and analyzed following methods in Wilcox et al. (2015). This information was combined with other sampling information (e.g., nearest downstream electrofishing inventory or positive eDNA detection) to estimate the upper terminus. We did not use eDNA to estimate lower terminus.

The third method was estimation based on GIS computation of stream gradient from 10 foot DEM of the surrounding hillside. To locate the upper terminus we selected a prolonged area (at least 200m) of 15 percent minimum gradient. Lower terminus was selected as change in computed gradient located between electrofishing inventories with substantially different findings (abundant verses sparse numbers of cutthroat trout). We consider the GIS estimations to be the least accurate of the methodologies. Appendix A details for each population how the total length was determined.

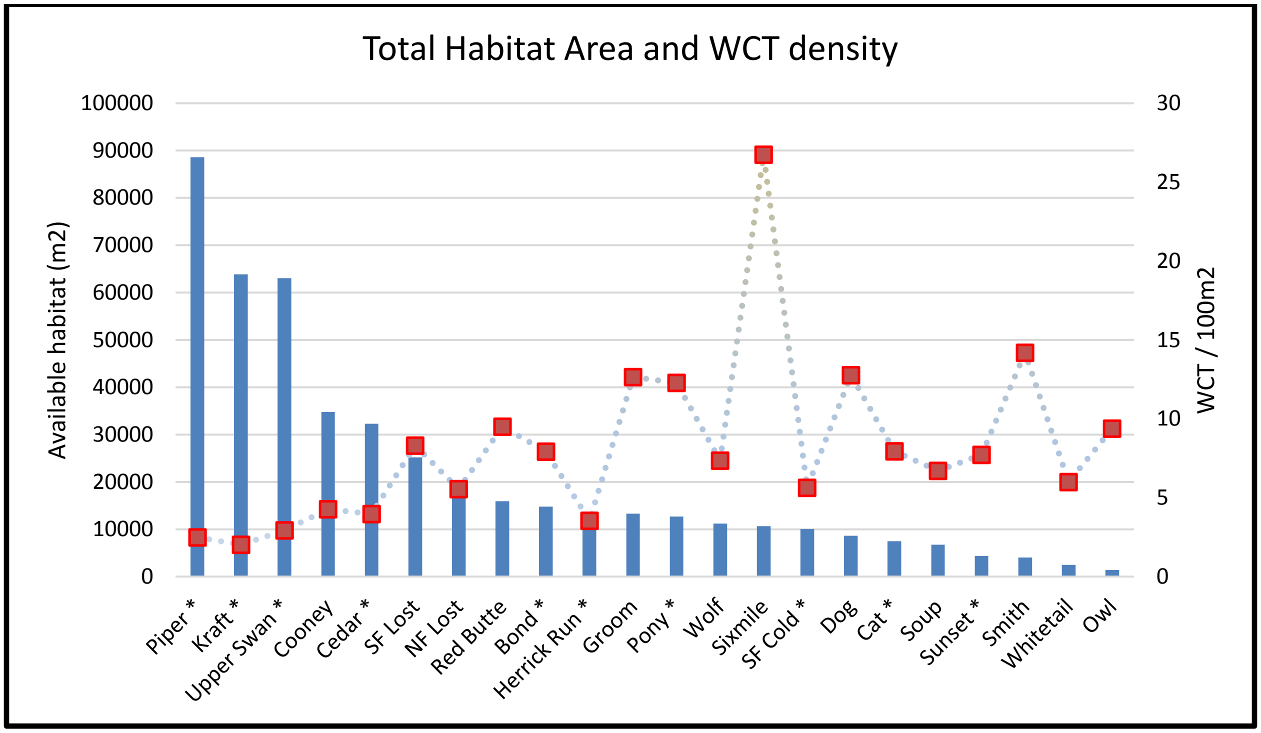
We estimated habitat width based on average of multiple ocular observations during electrofishing inventories. Width is the wetted perimeter during low flows. We multiplied the average width by total length to estimate the entire surface area available and then used that for fish densities described above.

Several Conservation Populations have one or more lakes in the headwaters that contain cutthroat trout. We recognize that these lakes probably provide emigrants from time to time that supplement the downstream Conservation Populations. We are not able to quantify the frequency or amount of this exchange. We speculate that some lakes are perched above high gradient reaches and thus only provide outward migrants (e.g. Cat Lake), while others could have routine exchange with riverine populations and contribute to total available habitat (e.g. Piper Lake). We did not include lake acreage in our habitat area measurements but we denote their presence in Figure 4.

Habitat Area – Results

The length of stream habitat stretched from 0.8 km in Whitetail Creek to 12.8 km in Kraft Creek, with a mean of 4.55km. Wetted width ranged from 1m in Owl Creek to 11m in Piper Creek, with a mean of 3.9m. The total habitat area ranged from 88,594m^2 in Piper Creek to just 1,397m^2 in Owl Creek. While the average of total habitat area is 21,119m^2, three large streams (Piper, Kraft and Upper Swan River) skew the data. The median is 13,008m^2 of available habitat. Figure 4 below illustrate the total habitat available and denotes those with upstream lake(s).

Figure 4. Total available habitat and cutthroat trout density per stream. Streams with * indicate having one or more headwater lake.



Water Temperature - Methods

We deployed data loggers within 21 of the 22 Conservation Population streams to record water temperatures. Data loggers were submerged in pools and recorded hourly to the nearest hundredth of Celsius. Our dataset extends from 1998 to 2018 although the number of annual observations per stream varies from a minimum of 1 year to 8 years. Although the more recent data includes yearlong observations, here we include only growing season (summer) data for reporting consistency. Care was used to select a location we felt best typified the whole area but we recognize that some streams may have more of a range of temperatures, especially the longer systems. At the time of this writing, no data is available yet for Soup Creek.

We computed three metrics of water temperature. First, we computed the Maximum Weekly Average Temperature (MWAT) which is the average temperature per 24 hours for the warmest seven consecutive dates each year. Because we did not deploy data loggers in every year for every stream, we recognize that some summers are simply warmer than others and that variance can skew findings for streams with just a handful of data. To compensate for this we utilized an unrelated dataset from elsewhere in the Swan River Valley that annually recorded information at eight locations from 2005-2016 (data available at Swan Lake Ranger District files). Using a mean of those eight data loggers, we assigned a compensation value for each year of how much each summer was warmer or cooler than the running 11 year average. This compensation value was then added or subtracted from MWAT to find Adjusted MWAT. Finally, we reported the mean number of days per year with at least one measurement at 15 C or higher. We selected 15 C as a threshold for the beginning of stress to adult cutthroat trout (Bear et al. 2007) (Sugden et al. 1998).

Water Temperature - Results

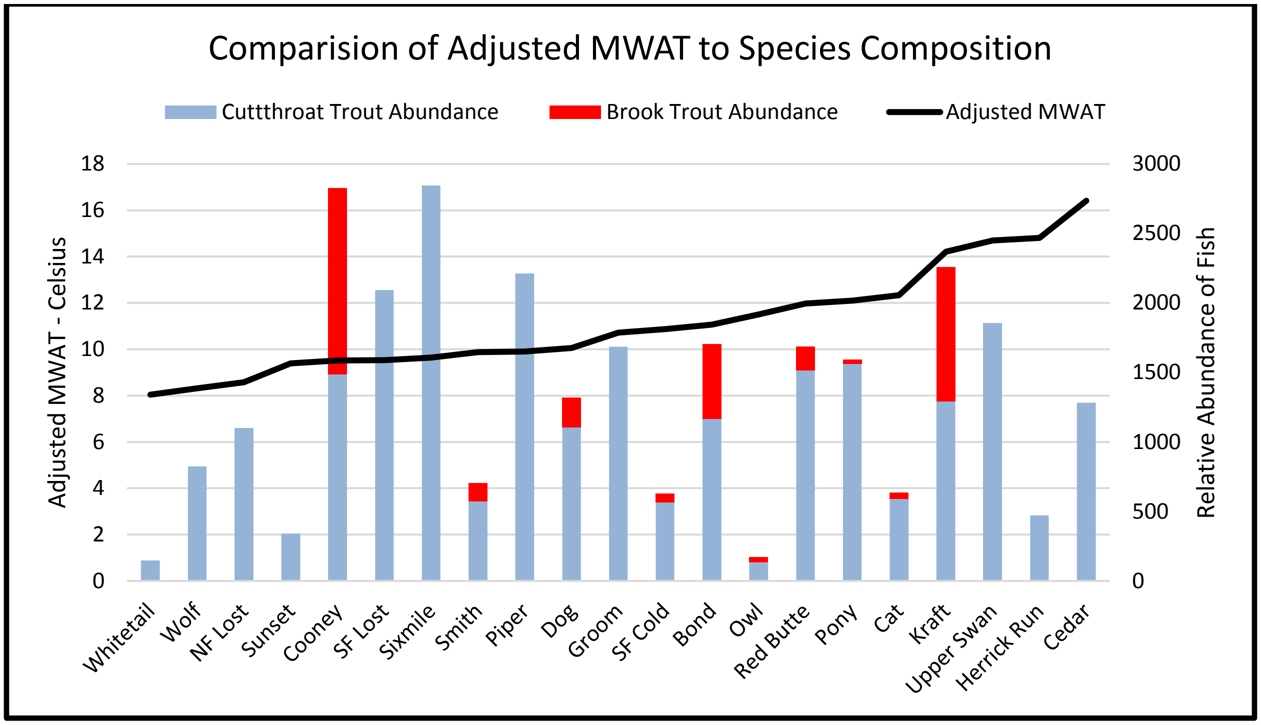
Stream MWAT temperatures ranged from 8.04 C (Whitetail Creek) to 16.29 C (Cedar Creek), with a mean of 10.9 C. Adjusted MWAT values were fairly similar but slightly rearranged rankings of each stream. Fifteen of the 21 monitored streams had no days in any year that met or exceeded 15 C. Results are provided on Table 5 below. Nine streams had adjusted MWAT of less than 10 C. These streams are so cold they may be detrimental to juvenile survival and growth. Conversely, Cedar Creek and Herrick Run both averaged 37 days per year over 15 C which is reportedly stressful. We do not consider these 11 streams on the fringe of optimal conditions to be less valuable, they may harbor uniquely adapted populations.

As shown in Figure 5, we found no correlation with species distribution and Adjusted MWAT. Brook trout invasion does not appear related to water temperature, although we recognize that the presence of full or partial barriers in some streams confounds the observation. We also examined species density and amount of admixture with nonnative alleles against water temperature and found no correlation.

Table 5. Number of years of recorded temperature monitoring, MWAT, adjusted MWAT and average number of days above 15 C per stream. Streams are listed alphabetically.

Stream	No. of Years	MWAT (°C)	Adjusted MWAT (°C)	Avg number of days ≥ 15 C
Bond	3	10.74	11.06	0
Cat	4	12.52	12.34	0
Cedar	7	16.29	16.41	37
Cooney	6	9.51	9.75	0
Dog	4	10.33	10.05	0
Groom	8	10.76	10.72	0
Herrick Run	4	13.65	14.81	37
Kraft	3	13.45	14.21	25
NF Lost	4	8.05	8.57	0
Owl	6	11.73	11.5	0
Piper	6	10.03	9.9	0
Pony	5	12.34	12.1	0
Red Butte	2	11.98	11.98	22
SF Cold	3	10.29	10.87	0
SF Lost	1	9.74	9.53	0
Sixmile	3	10.52	9.64	0
Smith	4	9.56	9.87	0
Sunset	3	9.56	9.39	0
Upper Swan	4	14.95	14.7	28
Whitetail	3	8.04	7.8	0
Wolf	6	8.23	8.32	0

Figure 5 Comparison of the Adjusted MWAT to 2016 relative abundance of cutthroat trout and brook trout. Streams are sorted from left by the coldest Adjusted MWAT. Soup Creek does not yet have water temperature data and is not shown.



Road Densities - Methods

Road density is the total length of roads (all ownerships, all status of use) divided by the watershed area. We used GIS National Hydrography Dataset to delineate the entire contributing watershed above each conservation population. Locations of roads were provided by the Flathead National Forest GIS layer of roads, which included known private, county or state roads. However in 11 conservation populations, the Mid-Swan Landscape Restoration Project planning team updated and corrected the road information using LiDAR and aerial imagery. These are considered more accurate than the original GIS layer.

Road Densities - Results

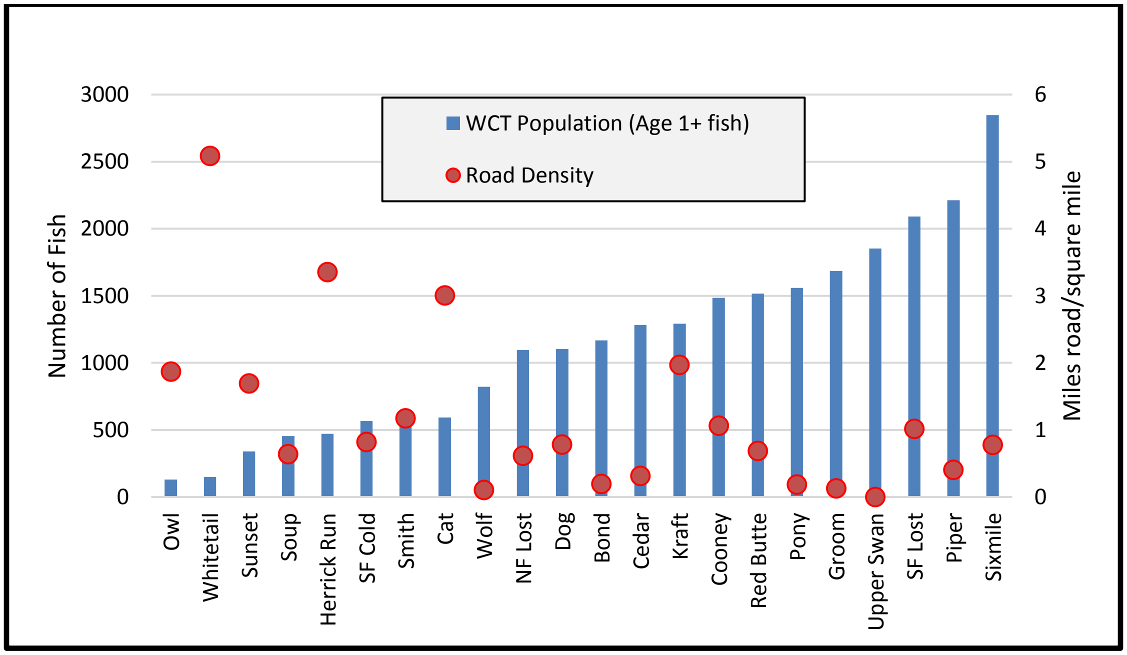
Road densities (Table 6) ranged from 0 miles/mi^2 (Upper Swan) to 5.1 miles/mi^2 (Whitetail). Figure 6 illustrates total cutthroat trout population size compared to road density. Regression analysis indicates a statistically significant inverse relation of road density to cutthroat trout population size ($p = 0.009$, df=20). However road density is not related to cutthroat trout density or brook trout population size.

Table 6. Miles of road, drainage area, and road density for each stream. Drainages denoted with * are considered more precise than others.

Drainage	Miles of road	Drainage area (mi^2)	Road density (mi/mi^2)
Bond	1.44	7.45	0.2
Cat*	6.43	2.14	3.0
Cedar*	3.56	11.38	0.3
Cooney	7.3	6.87	1.1
Dog*	3.6	4.61	0.8
Groom	0.34	2.71	0.1

Hemlock	3.0	5.53	0.5
Herrick Run	16.48	4.92	3.4
Kraft	19.81	6.07	3.3
Lion	43.7	31.7	1.4
NF Lost*	6.67	10.88	0.6
Owl	4.18	2.24	1.9
Piper*	3.24	8.01	0.4
Pony*	0.48	2.64	0.2
Red Butte	2.71	3.97	0.7
SF Cold*	4.92	6.01	0.8
SF Lost*	12.58	12.41	1.0
Sixmile	2.29	2.96	0.8
Smith*	3.40	2.90	1.2
Soup*	3.02	4.74	0.6
Sunset	5.4	3.19	1.7
Upper Swan	0	11.10	0
Whitetail*	23.03	4.53	5.1
Wolf	0.52	5.02	0.1
Average	6.11	6.01	1.17

Figure 6. Population (age 1+ fish) and road density within each 5th code HUC.



Habitat Quality - Methods

While cutthroat trout are widely recognized to be sensitive to habitat quality, defining minimum thresholds has proven challenging and the species can be found in many habitats (McIntrye and Rieman 1995). However, research conducted in absentia of recreational harvest and non-native fish species has found some correlations of habitat to cutthroat trout growth and/or density. Habitat variables are closely linked and can be difficult to isolate. For example, deep pools are beneficial for trout to survive winter but that variable is correlated to watershed size and gradient. The following summarizes local data in comparison to recommendations from published reports, and then offers qualitative ranking of “good,” “fair,” and “poor.”

Embryo survival is linked to substrate composition in spawning areas. Weaver and Fraley (1990) found an inverse relationship of fry emergence with percentage of materials <6.35 mm. Available data consists of pebble counts in bankfull transects of riffles, which is assumed to adequately correlate to actual redd substrates. Using simple averaging of all data per stream, those with less than 20 percent of materials <6 mm will be considered “good,” those with 20-30 percent will be “fair,” and those greater than 30 percent are “poor.”

Fry survival until the first winter is linked to water temperature and substrate size. Coleman and Fausch (2007) observed a positive relationship with growing season degree days to persistence of translocated cutthroat trout and concluded that warmer water temperatures facilitated better growth of fry, thus improved survival in winter. Growing season degree days are a cumulative value of the daily average temperature from the onset of 5 °C water in the spring until cessation of growth in the fall at 4 °C. Available data consists of hourly water temperature readings when conducted throughout the growing season. Those with more than 900 degree days are “good,” those 800-900 are “fair,” and those with less than 800 are “poor.” Coarse substrates that are not embedded in fine materials offer improved foraging and cover for fry (Hickman and Raleigh 1982, McIntrye and Rieman 1995), although quantitative values are elusive. Curiously Hawkins et al. (1996) observed weak association of mean substrate size of 144 mm with adult cutthroat trout density rather than juveniles. Available data consists of the median particle size in riffles (the D_{50}) which is assumed to adequately describe overall channel substrates and implies embeddedness. Those with D_{50} greater than 100 mm are assumed “good,” while 100-30 mm is “fair,” and less than 30 mm is “poor.” Because substrate size is not well defined quantitatively, greater emphasis is placed on growing season degree days. Substrate size will only influence evaluation when it is polar opposite of degree days (e.g. “poor” compared to “good”) and result in a “fair” evaluation.

Juvenile and adult survival is linked to three criteria: the quantity of pools, the depth of pools, and water temperature. Harig and Fausch (2002) reported the best model of cutthroat trout persistence in headwater streams was the frequency of large pools, water temperature, and bankfull pool width, although no specific thresholds were offered. Large pools are defined as residual depths (maximum depth minus crest depth) greater than 0.3 m. Brown and MacKay (1995) observed adult winter survival was correlated with depths over 0.8 m, typically in pools, although this study did not measure residual depths and thus was confounded by discharge condition. Reviewing the discharge of streams in that study, it is assumed this correlates to approximately 0.5 m residual depth. Available data for pools consists of the frequency and residual depth of pools. Average residual depth of pools greater than 0.4 m will be assumed “good,” those between 0.4 and 0.3 m are “fair,” and those less than 0.3 m are “poor.” Hawkins et al. (1996) observed a non-significant relationship of 25 percent of habitat in pools with adult survival, while Hickman and Raleigh (1982) suggest 30 percent. Assuming a conversion of 10 pools per 100 m equates to roughly 25-30 precent frequency, those streams with greater than 10 pools per 100 m are assumed “good,” between 7-10 pools per 100 m are “fair,” and those with less than 7 pools are “poor.”

Cutthroat trout are considered sensitive to water temperature and can experience stress or mortality when temperature is too warm over a period of time. Bear et al. (2007) found optimal maximum temperature for adults at 13 to 15 °C, whereas a Sugden et al. (1998) literature review reported a range of 12-15 °C. Lethal values are reported at 27 °C (McIntrye and Raleigh 1995) and 20 °C (Hickman and Raleigh 1982). Available data is Maximum Weekly Maximum Temperature (MWMT), which is the maximum daily temperature of the seven warmest consecutive days. This is superior to using a simple, single value of absolute maximum temperature recorded or finding a mean value for a specific calendar month. Values from 12 to 15 °C are considered “good,” values of 15-18 °C are “fair,” and those greater than 18 °C are “poor.” Minimum thresholds are not known but apparently values less than 12 °C are not optimal and thus considered “fair.” Because quantitative findings for adult survival are stronger for residual pool depth and water temperature than pool frequency, those two attributes are weighted more in consideration. Pool frequency is only used as a tie-breaker if the other criteria disagree.

The last criterion is simple consideration of amount of habitat available, regardless of any specific quality metric. A review by Hawkins et al. (1996) of multiple habitat features was not able to model cutthroat trout density to any specific habitat feature, nor was it able to correlate with habitat availability. However, the combination of the two may be important. This suggests that cutthroat trout populations can persist in low habitat quality if space is large enough. Conversely, cutthroat trout could persist in a very small amount of space if the habitat is superior quality. This also explains Harig and Fausch (2002) finding that a simple threshold of watershed size 14.7 km^2 also correlated with isolated population persistence. Using watershed size alone would not be appropriate in this situation because isolated areas may only have a small amount of surface water in a large watershed (for example, Whitetail Creek) or conversely may benefit from a headwater lake. The closest example of a 14.7 km^2 Swan Valley watershed with normal surface water connectivity and no lake is the Dog Creek watershed at 12 km. Dog Creek has approximately 3,700 m of habitat. Peterson et al. (2013) reported that low quality habitat that was at least 1,700 m was likely to retain cutthroat trout, while just 200 m of higher quality was also sufficient. Using a median value between the two studies, we assumed that at least 2,700 m of habitat would be “good,” between 2,700 m and 200 m is “fair,” and less than 200 m is “poor.”

Habitat Quality - Results

The following table summarizes the four attributes of habitat quality for all streams. Placing a value of 1-3 for each attribute (1 is poor, 2 is fair, and 3 is good) allows an overall summary score. Those streams with a summary score of 10-12 have good overall habitat conditions. Streams with 6-9 have fair overall habitat conditions. Streams with less than 6 have poor overall habitat conditions. Not all streams have robust data regarding habitat. Those with little or no data are noted with “a”.

According to our scoring system, none of the streams received a “poor” habitat quality rating (Table 7). Fourteen of the streams were rated “good” and the remaining eight streams were “fair.” However, nine of the streams were lacking in robust data for this analysis. Owl Creek and Whitetail Creek rated the lowest (overall score = 7), and ten streams scored an 11. The consistently most limiting variable was juvenile and adult survival which was only “fair” for the majority of streams. The mean habitat quality score was 9.8. See Appendix B for detailed scores for each variable.

Table 7. Habitat quality scores for each Conservation Population. Streams are listed alphabetically. Those that lack data on at least one variable are denoted with [a] after the score.

Name	Embryo survival	Fry survival	Juvenile & adult survival	Basin scale, general	Overall Habitat Condition
Bond	Good	Good	Fair	Good	Score 11 **Good**[a]
Cat	Fair	Fair	Fair	Good	Score 9 **Fair**
Cedar	Good	Good	Fair	Good	Score 11 **Good**
Cooney	Good	Good	Fair	Good	Score 11 **Good**[a]
Dog	Good	Good	Fair	Good	Score 11 **Good**
Groom	Good	Good	Fair	Good	Score 11 **Good**
Herrick Run	Fair	Fair	Fair	Good	Score 9 **Fair**
Kraft	Good	Good	Fair	Good	Score 11 **Good**
NF Lost	Good	Good	Fair	Good	Score 11 **Good**
Owl	Poor	Fair	Fair	Fair	Score 7 **Fair**
Piper	Good	Good	Fair	Good	Score 11 **Good**
Pony	Good	Good	Fair	Good	Score 11 **Good**[a]
Red Butte	Fair	Good	Fair	Good	Score 10 **Good**[a]
SF Cold	Fair	Fair	Fair	Good	Score 9 **Fair**[a]
SF Lost	Fair	Fair	Poor	Good	Score 8 **Fair**[a]
Sixmile	Fair	Good	Fair	Good	Score 10 **Good**[a]
Smith	Good	Good	Fair	Fair	Score 10 **Good**[a]
Soup	Good	Fair	Fair	Good	Score 10 **Good**[a]
Sunset	Fair	Fair	Fair	Fair	Score 8 **Fair**

Upper Swan River	Good	Good	Fair	Good	Score 11 **Good**
Whitetail	Poor	Fair	Fair	Fair	Score 7 **Fair**
Wolf	Good	Good	Poor	Fair	Score 9 **Fair**

[a] Habitat data lacking for at least one variable.

Conservation Strategy

We recommend long-term conservation of all 22 populations using flexible, adaptive but purposeful techniques. We feel that all 22 populations are worthy of conservation, at least to some degree. Given that cutthroat trout only occupy about 20 percent of their historic range in the Swan River Valley, we do not want to lose further ground. We also note that each population would be considered worthy of conservation per the 2007 Montana inter-agency strategy (Montana Cutthroat Trout Steering Committee 2007). However, because the populations vary in size, genetic integrity, and security we do not propose a "one size fits all" strategy, nor do we consider all equal priority.

We approach conservation with a flexible and adaptive management style. We are not locked into only saving cutthroat trout within the current distribution of the 22 populations. We might expand one population further upstream or downstream or even add other newly discovered populations to our roster. If we do this, we may simultaneously allow another population to fade away in order to conserve limited financial resources (we would never intentionally harm a population). Even though we are aware of the deleterious effect of invasive species, we do not propose to isolate all 22 conservation populations at this time. Our hesitation is based on incomplete understanding of migratory cutthroat trout needs. We cannot identify which tributary streams, if any, are required for migratory cutthroat trout and thus cannot recommend which need connectivity. Instead we propose to isolate populations with the highest conservation value and greatest likelihood of success. Likelihood of successful isolation requires suitable landscape that allows a barrier and few invasive fish that need removal. Those conservation populations with lower conservation value and/or lower likelihood of success will remain connected until we learn otherwise.

We have several tools at our disposal and we intend to use them wisely. These tools include (in no order):

- Installing upstream migration barriers to block invasive species. This requires a naturally confined landscape and may be achieved by either modifying a natural cascade or installing artificial dam or modifying a road culvert.
- Eradicate/remove brook trout upstream of a barrier by electrofishing or piscicide. We would not attempt suppression or eradication without a downstream barrier.
- Searching for important areas of rainbow trout or hybrid reproduction and suppressing their productivity by electrofishing. This would help conserve genetic integrity of connected (not isolated) cutthroat trout populations.
- Translocating non-hybridized cutthroat trout to vacant areas with suitable habitat. This would increase the geographic distribution and diversity of habitat types.

- Translocating non-hybridized fish to bolster existing population with reduced heterozygosity (“genetic rescue”).
- Supplemental stocking non-hybridized fish in headwater lakes to bolster population size downstream.
- Removal of rainbow trout or Yellowstone cutthroat trout from headwater lakes by means of piscicide and subsequent stocking of non-hybridized Westslope cutthroat trout.
- Facilitating beaver colonization in streams with limited surface water or warm temperatures in order to reduce impacts from climate change. Beaver dams typically recharge groundwater supply.
- Reducing negative effects from forest roads. This may include reducing erosion from road surface, reducing potential of culverts failing and washing out, providing adequate fish passage and/or relocating away from riparian areas.
- Planting shrubs and trees in riparian areas that have less than normal shade or wood recruitment and/or dominated by invasive weeds.
- Facilitating prescribed fire in watersheds we feel may be excessively harmed in an uncontrolled wildfire. We consider watersheds that have areas of potential mass wasting and/or extreme slopes adjacent to fish habitat and/or less than 1 kilometer of habitat to be at risk from temporary but harmful effects from a wildfire. A prescribed fire would allow a subsequent uncontrolled wildfire to have less adverse impacts.

No single person or agency can implement everything. We intend to continue to work in a collaborative fashion and seek consensus as much as possible. We hope conservation would take place on both public and private lands. We will employ the best available science as it unfolds. We expect further advancements in many fields, but especially in the fields of climate change science and conservation genetics. In order to adapt to developing science, we are aware of the need for a rigorous yet feasible monitoring plan. Being human, we are bound to make mistakes. As we discover mistakes in our data or ineffective restoration techniques, we will acknowledge them and correct as necessary. Our conservation strategy is certain to change over time.

To complement and advance the WCT prioritization of this report, Swan Valley Connections will create an additional document that catalogues all sites for restoration within the watershed. This will be a “living document” that is accessible and amendable by partners in trout recovery.

In order to prioritize our work, we employ a decision matrix that utilizes value and risk, as shown on Table 8. First, we sort each population into three value categories. “Very high conservation value” is for populations 99 to 100 percent non-hybridized and also appear to meet the “50/500 rule”. As described earlier, our data regarding introgression, population size and N_b is not perfect but we will use all available information. We consider populations at least 99 percent non-hybridized but only partially achieve the “50/500 rule” as “high conservation value”. Finally, we consider populations more than 1 percent introgressed and/or below both aspect of “50/500 rule” to be “moderate conservation value”. Since all 22 populations are valued, none would be considered “low value”.

Next, we evaluate the current risk to the population. While habitat degradation is a serious concern, the impact from invasive species is often irreversible and irreparable. Thus if brook trout or additional hybridized fish could gain access (or further expand if already present), the risk is classified “High”. We consider a “Moderate” risk for situations of habitat degradation, potential effects from climate change, reduced heterozygosity, or uncertain risk of future invasion. These factors are deleterious but not irreversible. We classify “Low” risk for things that stress but do not pose substantial harm to the population such as excessively cold water or potential but uncertain impacts from wildfires.

These criteria help us sort out conservation measures that are urgently needed, second level priority or opportunistic. Urgent conservation needs would be our highest priority for funding and second level is obviously second. Opportunistic conservation would take place if circumstances became available such as interest from private landowner or coincidental agency work.

Table 8. Conceptual matrix on prioritizing restoration.

	Very High Conservation Value	**High Conservation Value**	**Moderate Conservation Value**
High Risk			Second Level Priority
Moderate Risk	Urgent	Second Level Priority	Opportunistic
Low Risk	Opportunistic	Opportunistic	Opportunistic

Current Conservation Tasks and Priorities

Based on our current understanding, we have compiled each population’s conservation value and risk. We recognize this sorting may change in the future with new data. We have also identified any known specific threats and possible restoration opportunities. Using the matrix in Table 8, we color coded restoration opportunities as “Urgent”, “Second Level Priority” and “Opportunistic”.

Table 9. List of threats, risk and potential conservation measures. Priority categorization based on matrix in Table 8 and color coded. Streams listed alphabetically

Stream	Value	Threats or Limitations	Risk	Conservation Measure & Priority
Bond	Very high? Nb unknown	Brook trout present. May expand	High	Evaluate feasibility of barrier and subsequent removal brook trout. Urgent
		Slight introgression from rainbow, possibly both from headwater lakes and downstream	High	Evaluate current genetic integrity of lakes, correct with piscicide or stocking if deleterious. Urgent.
		Riparian area high risk for landslides. Wildfire may have harmful effects.	Moderate	Use prescribed fire to lower fire intensity. Urgent
Cat	Very High	Brook trout present. May expand. Slight introgression with rainbow. May expand	High	Evaluate feasibility of barrier and subsequent removal brook trout. Consider joint conservation with Dog Creek. Urgent

		Slight introgression from Yellowstone cutthroat, possibly from Cat Lake	High	Evaluate current genetic integrity of Cat Lake, correct with piscicide or stocking if deleterious. Urgent.
		Fair habitat condition. Possible degradation from road network?	Moderate	Evaluate road network and address problems. Urgent
Cedar	Very High	Brook trout are present downstream but apparently have not invaded past high gradient patch.	Moderate	Evaluate if isolation is secure. Urgent
		Slight introgression from rainbow and Yellowstone, possibly from headwater lakes	High	Evaluate current genetic integrity of lakes, correct with piscicide or stocking if deleterious. Urgent.
		Warm water temperature, may be aggravated by climate change	Moderate	Evaluate feasibility of beaver colonization. Urgent
		Majority of habitat surrounded by steep terrain. Wildfire may have harmful effects.	Moderate	Use prescribed fire to lower fire intensity. Urgent
Cooney	High	Brook trout present. May expand. Rainbow trout also apparently have recently invaded. However bull trout also present.	High	Evaluate feasibility and desirability of barrier with subsequent brook trout and rainbow trout removal. May opt to keep connectivity. Urgent
		Riparian vegetation extensively modified	Moderate	Plant riparian area. Second level priority.
Dog	High	Brook trout present. May expand. Very slight introgression of both rainbow and Yellowstone, presumably from downstream	High	Evaluate feasibility of barrier and subsequent removal brook trout. Consider joint conservation with Cat Creek. Urgent
Groom	High	Brook trout found intermittently, not yet successful colonization. May expand. Very slight from both rainbow and Yellowstone introgression from downstream source	Moderate	Evaluate desirability of barrier. May opt to keep connectivity. Second level priority
Herrick Run	Moderate	Reduced heterozygosity. Genetic rescue attempted 2013-2014, unknown effectiveness.	Moderate	Evaluate need for additional genetic rescue. Opportunistic

		Fair habitat condition. Possible degradation from road network? One known undesirable culvert barrier	Moderate	Evaluate road network and address problems. Opportunistic
		Warm water temperature and limited flows, may be aggravated by climate change	Moderate	Facilitate beaver colonization. Opportunistic
Kraft	Moderate	Brook trout present and expanding. Introgression with rainbow trout, presumably from downstream	High	Evaluate desirability of barrier with subsequent brook trout removal. May opt to keep connectivity. Second level priority
		Warm water temperature, may be aggravated by climate change	Moderate	Facilitate beaver colonization. Opportunistic
		High road density but no known impacts	Low	Evaluate road network and address problems
NF Lost	Moderate	Brook trout are present downstream but apparently have not invaded past high gradient patch. However introgressed with rainbow trout, presumably from downstream	Moderate	Evaluate if isolation is secure. Opportunistic
		Stream is very cold and may be limiting productivity	Low	Nothing feasible
		Majority of habitat surrounded by steep terrain. Wildfire may have harmful effects.	Low	Use prescribed fire to lower fire intensity. Opportunistic
Owl	Moderate	Brook trout present and expanding. Very slight introgression with rainbow, presumably from downstream	High	Evaluate desirability of barrier and subsequent removal of brook trout. May opt to keep connectivity. Second level priority
		Fair habitat condition. Uncertain cause	Low	Evaluate riparian and road network. Address problems. Opportunistic
		Short habitat length. Wildfire may have harmful effects	Low	Reduce fuels and introduce prescribed fire to lower fire intensity. Opportunistic
Piper	Very High	Brook trout are present downstream but apparently have not invaded past high gradient patch.	Moderate	Evaluate if isolation is secure. Urgent
		Slight introgression from rainbow and Yellowstone,	High	Evaluate current genetic integrity of lakes, correct

		possibly from headwater lakes		with piscicide or stocking if deleterious. Urgent.
		Majority of habitat surrounded by steep terrain but had recent Rx fire	Low	Maintain periodic prescribed fire. Opportunistic
Pony	Very High	Brook trout present. May expand.	High	Evaluate feasibility of barrier with subsequent brook trout removal. Urgent
		Slight introgression from rainbow and Yellowstone. Unknown if upstream or downstream	High	Evaluate current genetic integrity of lakes, correct with piscicide or stocking if deleterious. Urgent.
Red Butte	High	Secure barrier in place and brook trout eradication underway but still incomplete.	High	Complete brook trout eradication. Urgent
		Warm water temperature, may be aggravated by climate change	Moderate	Facilitate beaver colonization. Second level priority
SF Cold	Very High	Brook trout present. May expand	High	Evaluate feasibility of barrier with subsequent brook trout removal. Urgent
		Slight introgression from rainbow and Yellowstone. Likely from both upstream and downstream	High	Evaluate current genetic integrity of lakes, correct with piscicide or stocking if deleterious. Urgent.
		Fair habitat condition. Uncertain cause	Low	Evaluate riparian and road network. Address problems. Opportunistic
SF Lost	Moderate	Brook trout are present downstream but apparently have not invaded past high gradient patch. Slight Yellowstone introgression, presumably from downstream	Moderate	Evaluate if isolation is secure. Opportunistic
		Fair habitat condition. Uncertain cause	Low	Evaluate riparian and road network. Address problems. Opportunistic
		Majority of habitat surrounded by steep terrain. Wildfire may have harmful effects.	Low	Use prescribed fire to lower fire intensity. Opportunistic
Sixmile	High	Secure barrier in place but aging structure on private land	Moderate	Obtain conservation easement and protect barrier. Second level priority

Smith	Moderate	Secure barrier in place and brook trout eradication underway but still incomplete.	High	Complete brook trout eradication. Second level priority
		Short habitat length and majority of length surrounded by steep terrain. Wildfire may have harmful effect	Low	Use prescribed fire to lower fire intensity. Opportunistic
Soup	Moderate	Brook trout are present downstream but apparently have not invaded past high gradient patch. Rainbow and Yellowstone introgression, presumably from downstream	Moderate	Evaluate if isolation is secure. Opportunistic
		Majority of habitat surrounded by steep terrain. Wildfire may have harmful effects.	Low	Use prescribed fire to lower fire intensity. Opportunistic
Sunset	Moderate	Brook trout are present downstream but apparently have not invaded past high gradient patch.	Moderate	Evaluate if isolation is secure. Opportunistic
		Slight rainbow and Yellowstone introgression, may be from either upstream or downstream	High	Evaluate current genetic integrity of headwater lake, correct with piscicide or stocking in deleterious. Second level priority
Upper Swan	High	Brook trout present downstream but have not entered area for unknown reasons	Low	Designated wilderness. No feasible option
		Very slight introgression from rainbow and Yellowstone. May be from either upstream or downstream	High	Evaluate current genetic integrity of headwater lake, correct with piscicide or stocking in deleterious. Urgent
		Warm water temperature, may be aggravated by climate change	Moderate	Designated wilderness. No feasible option
		Majority of habitat surrounded by steep terrain. Wildfire may have harmful effects.	Low	Use prescribed fire to lower fire intensity. Opportunistic
Whitetail	Moderate	Secure barrier in place and brook trout eradication underway but still incomplete.	High	Complete brook trout eradication. Second level priority

		Fair habitat condition. Possible degradation from road network?	Moderate	Evaluate road network and address problems. Opportunistic
		Stream is very cold and may be limiting productivity	Low	Nothing feasible
		Short habitat length. Wildfire may result in degraded habitat	Low	Reduce fuels and introduce prescribed fire to lower fire intensity. Opportunistic
Wolf	Very High? Nb unknown	Brook trout are present downstream but apparently have not invaded past high gradient patch.	Moderate	Evaluate if isolation is secure. Urgent
		Stream is very cold and may be limiting productivity.	Low	Nothing feasible
		Short habitat length and majority surrounded by steep terrain. Wildfire may have harmful effects.	Low	Use prescribed fire to lower fire intensity. Opportunistic

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