Trends in bull trout abundance across Montana: 1998-2024

Montana Fish, Wildlife & Parks

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Executive Summary

Bull trout are listed as threatened under the U.S. Endangered Species Act (ESA). Redd counts are the primary method for evaluating the status of bull trout in the United States and play a critical role in informing listing decisions. We conducted a trend analysis of bull trout redd counts throughout Montana from the time of ESA listing (1998) to present to provide an updated status of bull trout state-wide. Among the 64 local populations examined (defined by the U.S. Fish and Wildlife Service 2005), 34 had significant declines in the number of redds, while only 2 had significant increases. Further, redd counts declined in 11 of 22 core areas, with increases observed in none. Overall, across all consistently monitored sections, bull trout redd counts declined by 66%. The severe declines of bull trout since Federal listing underscores the critical need to implement and rigorously evaluate conservation strategies to ensure the long-term viability of this native species in Montana.

Introduction

Bull trout (*Salvelinus confluentus*) were listed under the United States Endangered Species Act (ESA) in 1998 (U.S. Fish and Wildlife Service 1999). Since ESA listing, Montana Fish, Wildlife & Parks (FWP) has partnered with federal, state, tribal, and provincial agencies, non-governmental organizations, and private companies to implement extensive conservation actions, including suppression of non-native fish, habitat restoration, and acquiring land to protect critical bull trout habitat. To assess these conservation efforts and inform status and trend, bull trout populations and core areas (as defined by the U.S. Fish and Wildlife Service (2005)) have been consistently monitored using redd count surveys.

Redd counts are used to monitor migratory adult bull trout because they are noninvasive and are highly correlated with the number of the spawning females in migratory populations (Johnston et al. 2007), and trends in redd counts provide a strong indication of trends in bull trout populations (Muhlfeld et al. 2006). The last published report of bull trout trends focused on Montana included data through 2014 (Kovach et al. 2018). Here, we provide an updated redd count trend analysis with 27 years of data, spanning from 1998 to 2024, to help characterize the status of bull trout in Montana.

Methods

Redd counts

Bull trout redd surveys are the primary method FWP uses to monitor the presence, abundance, and trends of migratory bull trout populations in Montana. We define migratory bull trout as individuals approximately 350 mm in total length or larger that create redds larger the than 1 m. Annual redd counts are highly correlated with the abundance of spawning adult females and offer a reliable, noninvasive proxy for assessing population trends when collected consistently in space and time by trained observers (Muhlfeld et al. 2006; Johnston et al. 2007).

Surveys are structured according to biologically-based geographical units assigned by the U.S. Fish and Wildlife Service. Redd surveys are conducted at fixed index sites, local populations are comprised of one or more index sites, and core areas contain one or more connected local populations (U.S. Fish and Wildlife Service 2015). Index sites have consistent upstream and downstream bounds and cover often long reaches where bull trout historically spawned (Rieman and Myers 1997). These sites typically encompass the majority of spawning activity in each population, although the proportion varies by core area (e.g., counts in the Flathead River watershed are further from a census). Biologists periodically investigate areas outside the reaches to determine if spawning has shifted, especially in recent years where redd numbers in some areas have declined precipitously. Redds outside of index sites are recorded separately and are not included in this analysis.

FWP follows several additional protocols to ensure redd counts lead to robust trend detection. A redd is counted only when both a pit and tailspill are visible (Schmetterling 2000). Multiple digs or superimposed redds in the same location are conservatively counted as a single redd. Surveys are conducted at a similar time each year, timed to occur after most spawning has taken place but while early redds remain visible. Because spawning typically begins once water temperatures fall below 9°C and can extend over several weeks depending on flow (Swanberg 1997), some early or late redds may be missed. However, this likely represents a small portion of total redds. When adult bull trout are observed in high numbers during surveys, biologists may conduct follow-up visits to improve accuracy.

Redd surveys are particularly effective for monitoring migratory bull trout. Outside of the spawning season, migratory fish are widely dispersed and difficult to sample, even when populations are healthy. During spawning, however, they aggregate in known reaches and create large redds that are generally distinguishable from those of other species. Conversely, resident bull trout typically do not exceed 300 mm in total length, and their redds can be difficult to differentiate from brook trout redds, which may overlap in space and time. In some areas, brown trout or kokanee salmon spawning may also resemble bull trout redds, but spatial and temporal overlap is uncommon.

For the trend analysis presented here, we included only local populations identified as fully or partially migratory and with at least 15 years of redd count data from the time of ESA listing (1998) to present. After applying these criteria, our data set comprised 98 index sites representing 64 local populations across 22 core areas.

Analyses

We used a Poisson generalized linear mixed model with an AR1 correlation structure to estimate the population growth rates (*r*) based on redd count data. This model is a type of state space model because of the separate error distribution for the population dynamics equation and the observation equation. The population dynamics equation is an extension of the standard exponential growth equation. Specifically, the log of true, unobserved number of redds at index site *i* in year t $\left(N_{i,t}\right)$ is:

$$log\left(N_{i,t}\right) = log\left(N_{i,0}\right) + r_{pop[i]} * t + w_{i,t}$$

where $r_{pop[i]}$ is the intrinsic growth rate of a local population - the main parameter of interest, $N_{i,0}$ is the initial number or redds in each index site, and $w_{i,t}$ is the auto-correlated error term assuming an AR-1 correlation structure. $w_{i,t}$ is a function of a normally distributed error term $\varepsilon_{i,t}$ and the previous years error:

$$w_{i,t} = \rho * w_{i,t-1} + \varepsilon_{i,t}$$

$$\varepsilon_{i,t} \sim Normal(0, \sigma_i)$$

where ρ is the autocorrelation parameter and σ_i is the standard deviation for the process error for each index site. σ_i is assumed to come normal distribution:

$$\sigma_i \sim Normal(\mu_\sigma, \sigma_\sigma)$$

Note that $r_{pop[i]}$ is calculated for the local population, while σ_i applies to the index site. This assumes local populations follow a common overall trend across index sites, yet allows for individual index sites to deviate from the trend annually-for example, due to temporal variation in spawning locations within the local population. The number of observed redds $(counts_{i,t})$ is assumed to come from a Poisson distribution of the number of true redds:

$$counts_{i,t} \sim Poisson(N_{i,t})$$

This state-space formulation has several advantages over the more conventional Normal-Normal approach (Kéry and Schaub 2012). Unlike models that assume an AR1 correlation with $\rho = 1$, we estimated ρ, which is important when using redd counts as an index for adult female abundance-for example, since spawning proportions can vary annually. Additionally, using a Poisson distribution is appropriate for count data. Preliminary power analyses indicate that our model has higher precision for population growth rate while still accounting for temporal autocorrelation, offering a balance between the more conservative Normal-Normal state-space model and the less conservative log-linear regression (Kovach et al. 2018)

We aggregated the estimated local population growth rate at the core area and statewide levels. Specifically, for each Bayesian iteration, we took the mean of the estimated population growth rate weighted by the mean redd count across all local populations in the relevant group. Likewise, the total number of redds state-wide was calculated by summing the true, latent number of redds across all index sites.

Models were analyzed in a Bayesian framework in the program *NIMBLE* (Valpine P. et al. 2017; Valpine P et al. 2023), with additional analyses conduced in the program *R* (R Core Team 2021). We report the probability of direction (*pd*) and 90% credible intervals (*CRI*) to evaluate the statistical support for population declines and expansions.

Results

Out of the 64 bull trout local populations examined, 34 were significantly declining and 2 were significantly increasing, based on 90% *CRIs* (Figure 1). Twenty-eight local populations had strong declines, with population growth rate (*r*) less than -0.05, which implies a decline of at least 73% since listing. The mean estimate of population growth was negative in 83% of local populations. Further, 58% of populations had a negative population growth estimate and a mean redd count under 30 (Figure 2), suggesting that over half of the local populations were small and declining.

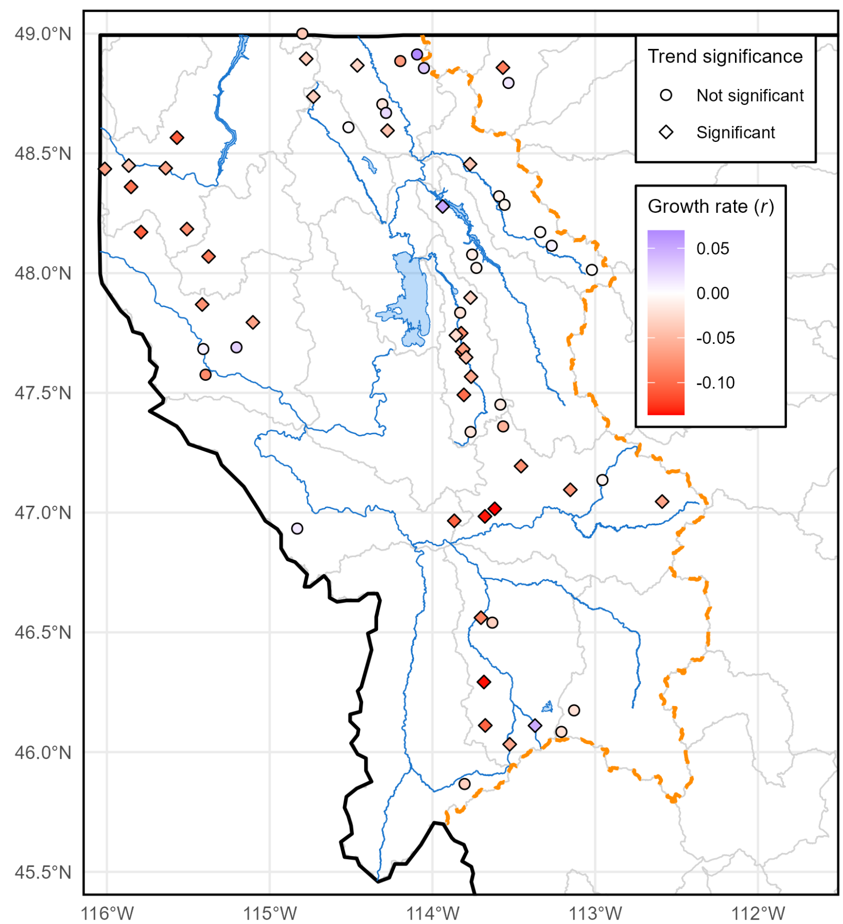

Figure 1. Population growth rates (*r*) based on redd counts of bull trout local populations in Montana. Diamonds indicate 90% CRIs that do not overlap 0, suggesting evidence for a significant trend in redd numbers. The orange dashed line represents the Continental Divide.

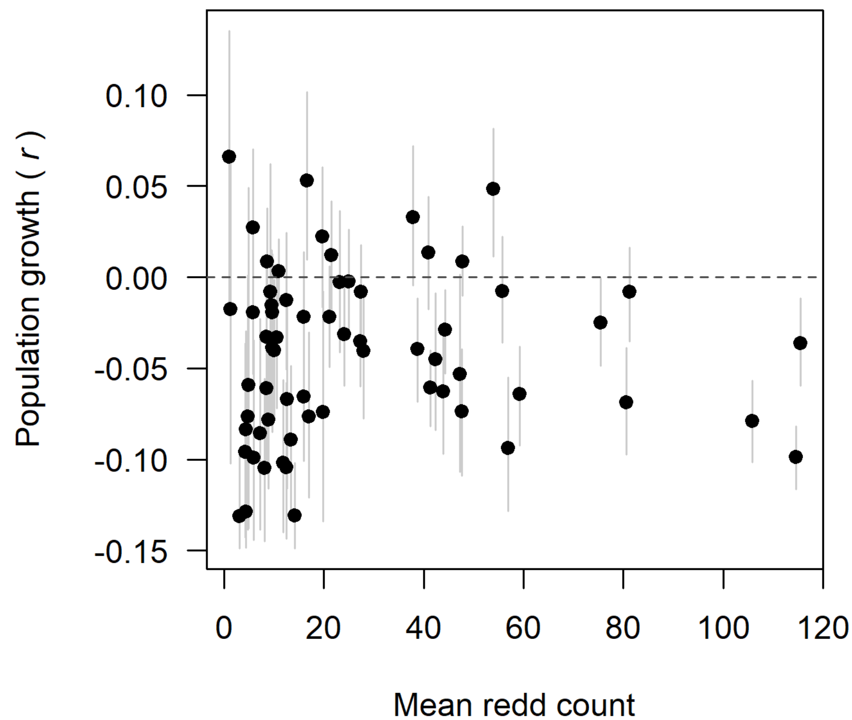

Figure 2. Mean redd counts versus population growth rate (*r*) based on redd counts of bull trout local populations in Montana. Confidence bands represent 90% *CRIs*.

Among the 22 core areas examined, the number of bull trout redds significantly declined in 11 core areas. Bull trout did not significantly increase in any core area. The core areas with the largest declines were Bull Lake, Swan, and Kootenai River below Libby Dam (Table 1). State-wide, the total number of estimated redds across all local populations declined from 2799 to 983 between 1998 and 2024. The mean population growth rate (weighted by mean redd count) among all populations was -0.041 (90% *CRI* = -0.046 to -0.036), or an overall decline of 65.6% (90% *CRI* = 61.2 to 69.8%) since listing.

Table 1: Summary of population growth (r) and significant trends in core areas.

Core area	Weighted Mean r	Number of populations		
		Total	Declining	Increasing
Bull Lake	-0.094 (-0.128, -0.055)	1	1	0
Swan	-0.067 (-0.077, -0.057)	9	8	0
Kootenai River	-0.061 (-0.078, -0.043)	6	6	0
Akokala Lake	-0.059 (-0.138, 0.049)	1	0	0
Clearwater River & Lakes	-0.059 (-0.101, -0.021)	2	1	0
LPO	-0.059 (-0.076, -0.041)	6	3	0
Blackfoot River	-0.046 (-0.063, -0.03)	5	4	0
Lake Koocanusa	-0.036 (-0.058, -0.013)	2	1	0
Upper Stillwater Lake	-0.035 (-0.06, -0.011)	1	1	0
Bitterroot	-0.033 (-0.072, 0.005)	1	0	0
Middle Clark Fork	-0.028 (-0.054, -0.003)	2	1	0
Rock Creek	-0.023 (-0.04, -0.007)	6	4	1
Upper Clark Fork River	-0.022 (-0.043, 0)	2	0	0
Lindbergh Lake	-0.019 (-0.053, 0.013)	1	0	0
Cyclone Lake	-0.018 (-0.102, 0.068)	1	0	0
Holland Lake	-0.016 (-0.05, 0.015)	1	0	0
St Mary	-0.012 (-0.037, 0.013)	2	1	0
Flathead Lake	-0.01 (-0.02, 0)	9	3	0
Whitefish Lake	0.003 (-0.015, 0.021)	1	0	0
Hungry Horse Reservoir	0.003 (-0.019, 0.026)	3	0	1
Quartz Lakes	0.033 (-0.005, 0.072)	1	0	0
Bowman Lake	0.066 (-0.018, 0.135)	1	0	0
Montana-wide	-0.041(-0.046, -0.036)	64	34	2

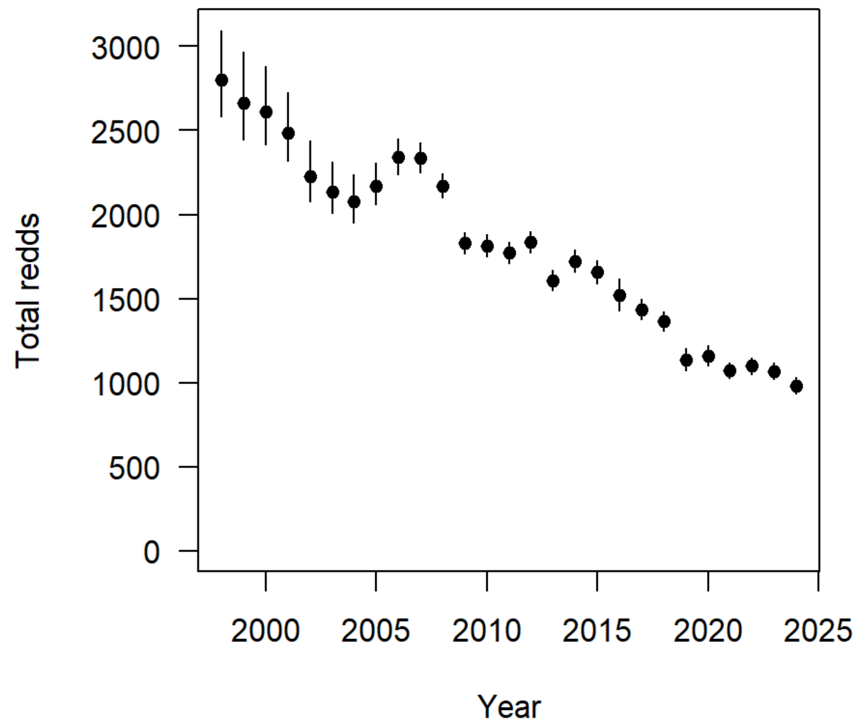

Figure 3. Total estimated number of redds across all populations. Confidence bars are 90% *CRI*s.

Discussion

Our results provide further evidence of ongoing declines in bull trout populations in Montana. We found significant declines in 53% of local populations — substantially higher that the 13% reported in the last intensive redd count analysis focused on Montana, which included 10 fewer years of data (Kovach et al. 2018). Other research also indicates that bull trout have undergone reductions in habitat use and distribution within the state (Eby et al. 2014; LeMoine et al. 2020; Bell et al. 2021). Together, our findings and previous studies suggest that both the abundance and distribution of bull trout in Montana have likely decreased since their listing under the Endangered Species Act.

Several potential sources of bias could cause redd count trends to deviate from true population trends. For example, climate-driven shifts in phenology could influence the timing and location of spawning, potentially reducing how representative index sites are over time. Biologists are aware of this issue and periodically search for additional spawning locations. New spawning areas have not been detected for several years. Current surveys are still believed to capture the majority (>90%) of spawning activity by migratory fish. Although some redds are inevitably missed, the extensive surveys are highly representative of the overall spawning activity. Continued climate warming may delay the onset of spawning, shifting peak redd formation later into the fall. If this occurs, survey timing will need to be adjusted accordingly to ensure redd counts remain accurate.

Further, although trend analyses can be sensitive to the chosen time window (d'Eon-Eggertson et al. 2015; Keith et al. 2015), the period from ESA listing (1998) to the present is both meaningful and appropriate, given that declines preceding listing were among the primary drivers of federal protection, and the span since listing is long enough to evaluate sustained population trends. Importantly, although this report summarizes average population growth rates across 64 local populations, individual populations often exhibit more complex dynamics. However, the goal of this report is to evaluate broad-scale trends in bull trout abundance across the state.

Finally, it is worth emphasizing that this report likely underrepresents the full extent of bull trout decline in Montana. Many strong declines and local extirpations occurred prior to ESA listing—particularly in historically important areas such as the upper Clark Fork and Flathead river basins. Although this report captures population trajectories since 1998, the cumulative decline over the past several decades has been considerably greater.

Despite concerning trends, many redds still remain on the landscape, and it is important to note that some of the largest bull trout populations (South Fork Flathead and North Fork Flathead, BC) were not included in this report because of data limitations. Nevertheless, continued conservation actions directed at bull trout are necessary to avoid local population extirpation across many watersheds in Montana.

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References

Bell, D.A., Kovach, R.P., Muhlfeld, C.C., Al-Chokhachy, R., Cline, T.J., Whited, D.C., Schmetterling, D.A., Lukacs, P.M., and Whiteley, A.R. 2021. Climate change and expanding invasive species drive widespread declines of native trout in the northern rocky mountains, USA. Science Advances **7**(52): eabj5471. American Association for the Advancement of Science. doi:10.1126/sciadv.abj5471.

d'Eon-Eggertson, F., Dulvy, N.K., and Peterman, R.M. 2015. Reliable identification of declining populations in an uncertain world. Conservation Letters **8**(2): 86–96. Wiley. doi:10.1111/conl.12123.

Eby, L.A., Helmy, O., Holsinger, L.M., and Young, M.K. 2014. Evidence of climate-induced range contractions in bull trout *Salvelinus confluentus* in a rocky mountain watershed, USA. PLoS ONE **9**(6): e98812. doi:10.1371/journal.pone.0098812.

Johnston, F.D., Post, J.R., Mushens, C.J., Stelfox, J.D., Paul, A.J., and Lajeunesse, B. 2007. The demography of recovery of an overexploited bull trout, *Salvelinus confluentus*, population. Canadian Journal of Fisheries and Aquatic Sciences **64**: 113–126. doi:10.1139/F06-172.

Keith, D., Akçakaya, H.R., Butchart, S.H.M., Collen, B., Dulvy, N.K., Holmes, E.E., Hutchings, J.A., Keinath, D., Schwartz, M.K., Shelton, A.O., and Waples, R.S. 2015. Temporal correlations in population trends: Conservation implications from time-series analysis of diverse animal taxa. Biological Conservation **192**: 247–257. Elsevier. doi:10.1016/j.biocon.2015.09.021.

Kéry, M., and Schaub, M. 2012. Bayesian population analysis using WinBUGS: A hierarchical perspective. Academic Press.

Kovach, R.P., Armstrong, J.B., Schmetterling, D.A., Al-Chokhachy, R., and Muhlfeld, C.C. 2018. Long-term population dynamics and conservation risk of migratory bull trout in the upper columbia river basin. Canadian Journal of Fisheries and Aquatic Sciences **75**: 1960–1968. Canadian Science Publishing. doi:10.1139/cjfas-2017-0466.

LeMoine, N.P., Al-Chokhachy, R., Sepulveda, A.J., Thoma, D.P., Tercek, M.T., and Muhlfeld, C.C. 2020. Landscape resistance mediates the distribution of native fish in riverscapes under climate change. Global Change Biology **26**(10): 5492–5508. doi:10.1111/gcb.15260.

Muhlfeld, C.C., Taper, M.L., Staples, D.F., and Shepard, B.B. 2006. Observer error structure in bull trout redd counts in montana streams: Implications for inference on true redd numbers. Transactions of the American Fisheries Society **135**(3): 643–654.

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from https://www.R-project.org/.

Rieman, B.E., and Myers, D.L. 1997. Use of redd counts to detect trends in bull trout (*Salvelinus confluentus*) populations. Conservation Biology **11**: 1015–1018.

Schmetterling, D.A. 2000. Redd characteristics of fluvial westslope cutthroat trout in four tributaries to the blackfoot river, montana. North American Journal of Fisheries Management **20**: 776–783.

Swanberg, T.R. 1997. Movements of and habitat use by fluvial bull trout in the blackfoot river, montana. Transactions of the American Fisheries Society **126**(5): 735–746.

U.S. Fish and Wildlife Service. 1999. Endangered and threatened wildlifeand plants; determination of threatened status for bull trout in the conterminous united states. Federal Register Notice, U.S. Fish; Wildlife Service.

U.S. Fish and Wildlife Service. 2015. Recovery plan for the coterminousUnited states population of bull trout (*Salvelinus confluentus*). U.S. Fish; Wildlife Service.

Valpine P, de, C, P., D, T., N, M., C, A.B., F, O., C, W.C., A, R., D, T.L., and S, P. 2023. NIMBLE: MCMC, particle filtering, and programmable hierarchical modeling.

Valpine P., de, Turek, D., Paciorek, C.J., Anderson-Bergman, C., Lang, D.T., and Bodik., R. 2017. Journal of Computational and Graphical Statistics.