**Deep Drawdowns at Rimrock Lake are Associated with Decline in Bull Trout Redd Counts the Following Year**

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Executive Summary

* Fish are entrained through Tieton Dam each year
* Operations to support flip-flop irrigation deliveries in the late summer and early fall, lead to deep drawdowns
* Deep drawdown are know to lead to increased kokanee entrainment
* These drawdowns may influence bull trout indirectly through impacts on prey base and habitat quality, and directly through entrainment
* We found that there is a significant association between the depth of drawdown at Rimrock Lake (minimum annual pool elevation) and the number of bull trout redds observed the following year in the South Fork Tieton River and Indian Creek populations.
* A model built on these observations predicts that drawdowns below ~30,000 acre-feet are associated with ~40 fewer redds than expected from the linear trend in the following year.

Introduction

Some modification of the following:

The Rimrock populations share several threats related to the presence and operation of Tieton Dam. In addition to blocking upstream passage, Tieton Dam entrains fish through its unscreened outlet works. Rimrock Lake is rapidly drawn down in late summer and early fall to support “flip-flop” operations of the Yakima Project and meet irrigation demands (Figure 1). The rate of entrainment for fish in reservoir habitats is determined by forebay habitat usage and the velocity at the intake (Coutant & Whitney, 2000; Harrison et al., 2019, 2020). Many Rimrock bull trout are expected to be in upstream spawning habitats during peak flip-flop water delivery. However, Rimrock bull trout have been documented in the forebay during the period when peak flows occur (Mizell & Anderson, 2008, p. 42). Studies conducted in 2002 and 2003 estimated 145 and 120 bull trout were entrained from Rimrock Lake each year, respectively (Hiebert, 2004; Hiebert et al., 2003). Given population estimates in Rimrock Lake at the time (James, 2002), this represent an annual entrainment rate of ~7%. Genetic stock identification of bull trout collected in stilling basin just below Tieton Dam found fish from each of the three Rimrock local populations (Small et al., 2009, p. 26).

Entrained bull trout likely suffer injury and mortality (Algera et al., 2020). While the rate of injury and mortality for adult bull trout entrained through Tieton Dam are not known, kokanee have been used as surrogates to estimate mortality for sub-adult bull trout. Mortality is estimated at 45% for sub-adults (Courter & Vaughan, 2011). Bull trout that survive entrainment are permanently displaced from the lake and unable to contribute to the productivity of their natal streams. Few entrained fish are expected to spawn elsewhere (Mizell & Anderson, 2015, p. 108).

Drawdowns of Rimrock Lake also pose a threat to bull trout through impacts on bull trout prey base. Unlike other reservoirs in the Yakima Project, Rimrock Lake was not a natural lake, and operations at Tieton Dam can draw Rimrock down to extremely low levels. Complete drawdowns of Rimrock Lake occurred four times, (1926, 1931, 1973, and 1979), and are associated with collapse of the Rimrock kokanee fishery the following year (Mongillo & Faulconer, 1980). The kokanee fishery did not recover from the 1973 drawdown for six years, despite stocking, and 95 – 99% of the population was lost to entrainment during the 1979 drawdown (Mongillo & Faulconer, 1980, pp. 31, 34). Analysis of kokanee catch records also indicate that deep drawdowns, defined as those below ~30,000 af, measurably reduce kokanee abundance and productivity (Mongillo & Faulconer, 1980, p. 31), prompting the Systems Operation Advisory Committee to recommend maintaining Rimrock above this level in 2001. Rimrock has been drafted beneath 30,000 af eight times since 1981, but only once since the 2001 recommendation (Figure 1).

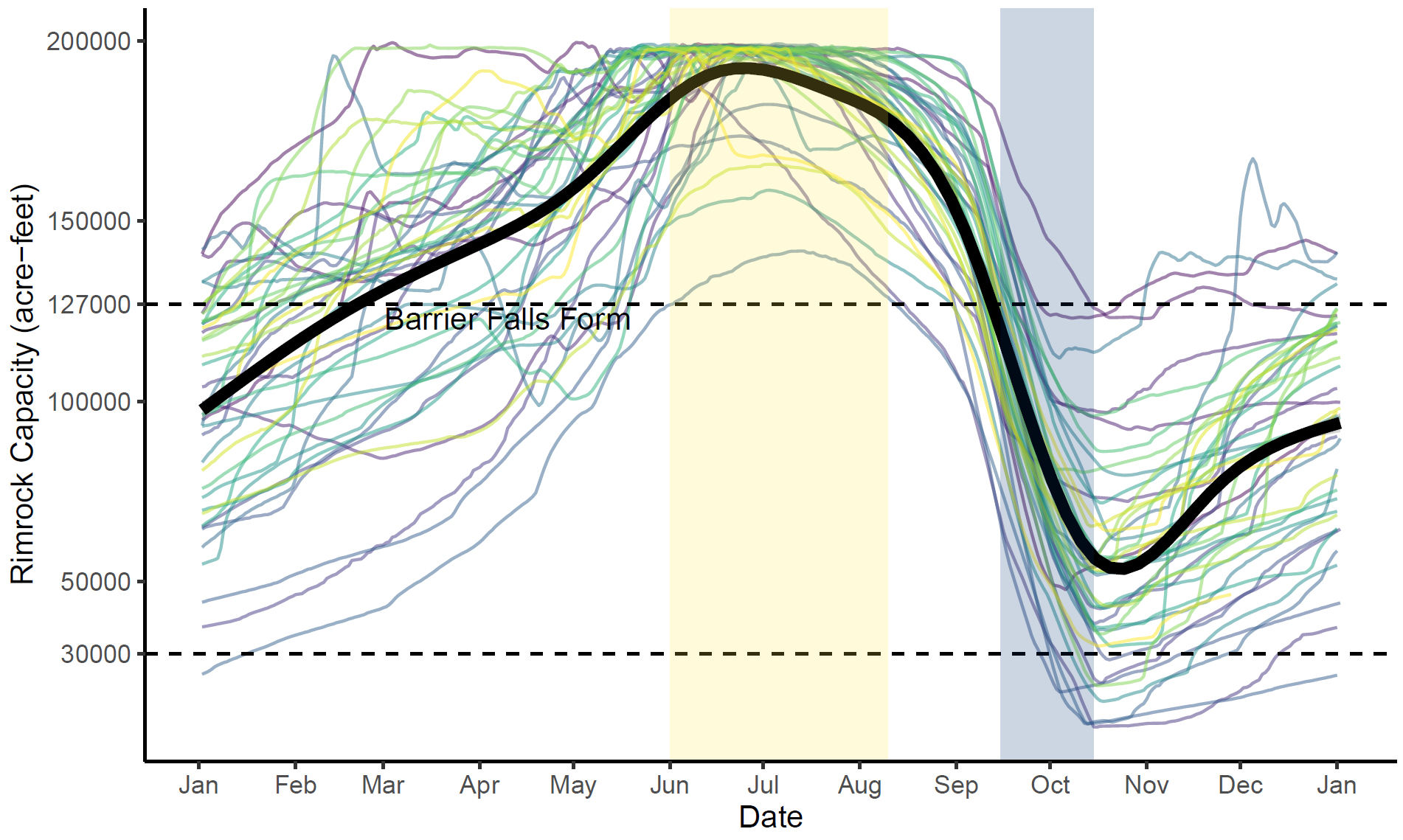


Figure 1: Volume of Rimrock Lake through the year demonstrating winter drawdown, and the overlap of flows with migration timing and formation of a passage barrier at the mouth of South Fork Tieton River.

Colored lines are individual years from 1981- 2023, with more recent years in lighter (yellow) colors. Yellow period from June to mid-August approximates peak upstream migration, blue period from mid-August to October approximates peak downstream, post-spawn migration of adults. Heavy black line is loess-smooth of all years. Data from Bureau of Reclamation Hydromet.

Statement of question paragraph

Methods Summary

One paragraph summary of methods

Results / Discussion

Supplemental Methods

Include a full, reprodcuble methods section here, with link to github and R notebook.

Supplemental results

Main results should only show relationship between drawdown and redds. More detailed results that support the analysis should go here

* No relationship with two and three year lags
* snowpack