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Student Corner

Drought and drawdown create a house of horrors:
Shrinking habitat potentially impacts fish populations in a river-reservoir system in Idaho

Introduction

Increased drought frequency due to climate change puts pressure on water supply and storage reservoirs throughout the western United States, with uncertain effects on the economically-important fisheries upstream, within, and downstream of reservoirs. Island Park Reservoir (44.418996° N, 111.396496 W°, Fremont County, Idaho, in the Western Mountain ecoregion, Figure 1) is one such mid-sized (135,205 acre-feet, 8,000 surface acres) irrigation-storage reservoir managed by the United States (U.S.) Bureau of Reclamation and the local irrigation district to meet downstream irrigation water needs. Island Park Reservoir, like many other western U.S. reservoirs, supports a community of adfluvial (migrating between waterbodies like lakes, rivers, and streams) salmonid sportfish, but is subject to high and more frequent drawdown during drought cycles.

Over the past eight years, research by the Henry's Fork Foundation, a data-driven, conservation nonprofit dedicated to the protection of the fish and wildlife resources in the Henry's Fork watershed, has sought to understand how the increased threat of drawdown due to drought could impact water quality and fish habitat, both within the reservoir as well as within its inflows and outflows.

Methods

Utilizing a combination of long-term monitoring of abiotic factors and fishes, our goal was to better understand mechanisms connecting water supply and storage with upstream, in-reservoir, and downstream water quality and fish habitat. The Henry's Fork Foundation (HFF) has a large science and technology department that maintains a network of twelve in-situ water quality monitoring devices called "sondes" that measure dissolved oxygen, temperature, conductivity, turbidity, and indices of phytoplankton production. These sondes remotely transmit real-time data to our water quality monitoring website (https://henrysforkdata.shinyapps.io/scientific_website/). In addition to our real-time water quality monitoring

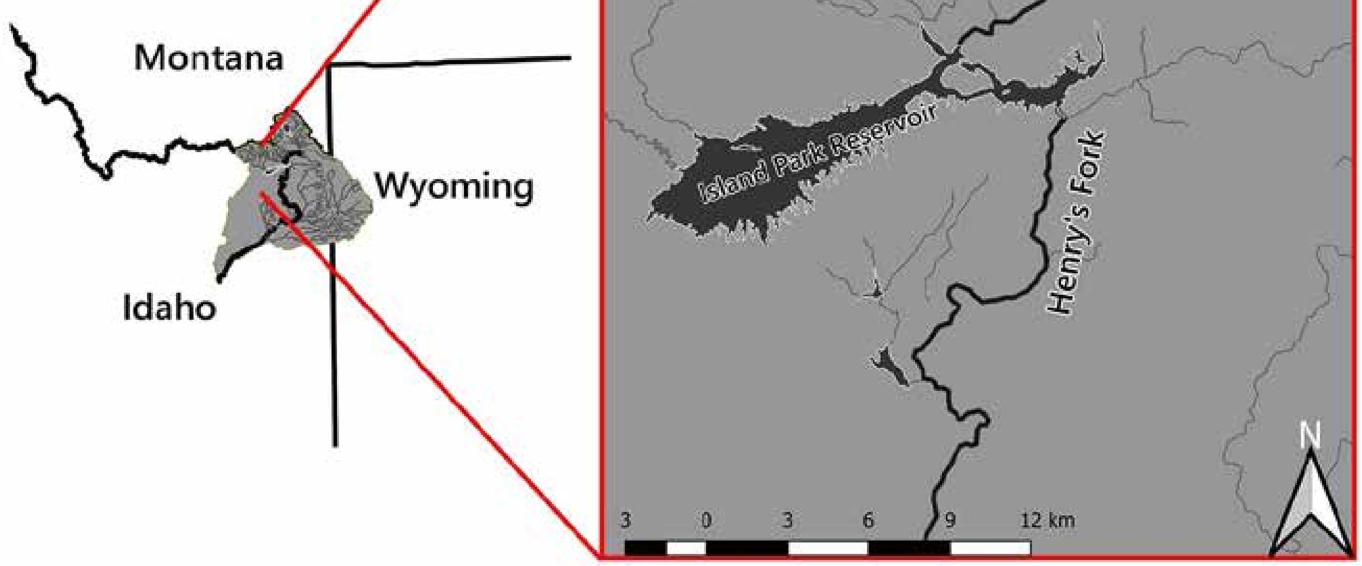

Figure 1. Island Park Reservoir and the "Upper" Henry's Fork of the Snake River watershed from Big Springs to Island Park Reservoir, Fremont County, Idaho, USA.

network, the HFF also samples vertical water quality profiles in Island Park Reservoir weekly, collects nutrient and suspended sediment samples at many locations throughout the Henry's Fork watershed, and conducts fish habitat use and availability studies throughout the Henry's Fork watershed. The Henry's Fork Foundation's science and technology program has been collecting these long-term datasets since 2014.

Results and discussion

The past seven years of scientific data collection reveal Island Park Reservoir is a lynchpin supporting the rest of the world-class, economically and ecologically important Henry's Fork fishery. Drawdown in Island Park Reservoir directly influences fish populations in the Henry's Fork system. High drawdown during the summer requires refilling Island Park Reservoir in the winter and spring. Increased drawdown thereby results in lower flows out of the dam in the wintertime, which negatively affects trout populations in the Henry's Fork downstream (Van Kirk et al. 2019). Increased drawdown in Island Park Reservoir due to drought also results in a variety of negative impacts on water quality. For example, increased drawdown in Island Park Reservoir results in increased water temperatures in downstream reaches, potentially negatively affecting trout habitat (McLaren et al. 2019).

Increased drawdown primarily due to drought also influences fish populations, habitat, and water quality in the reservoir itself and its tributaries. Based on weekly Island Park Reservoir sampling in 2021, we found that spring-fed inflow in specific locations within Island Park Reservoir creates a heterogeneous landscape of water temperature and dissolved oxygen (Figure 2). In the summertime, the highest-quality salmonid habitats are near these spring-fed inflows. Higher drawdown increases water temperatures in deep water in Island Park Reservoir, forcing cold-water sportfish like Rainbow Trout (*Oncorhynchus mykiss*) and Kokanee Salmon (*Oncorhynchus nerka*) into these spring-fed inflows (Figure 3). These patterns suggest the quantity of inflow as well as the extent to which springs and seeps are submerged controls the quality and quantity of sportfish habitat. In dry years, decreased inflow and lower water levels resulting from drawdown may concentrate

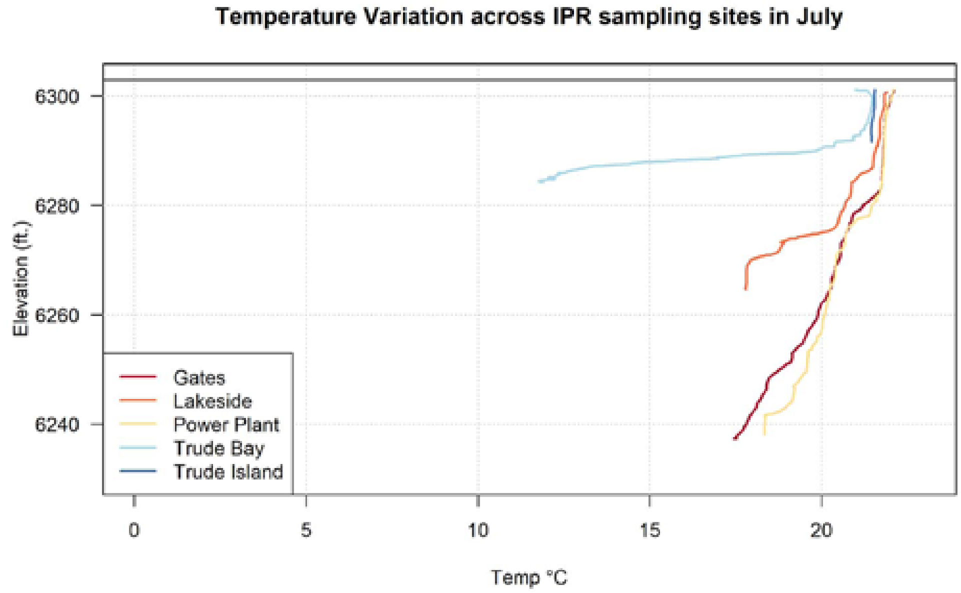

Figure 2. Vertical water temperature profiles at five different locations in Island Park Reservoir collected on the same date in July. Temperature profiles display clear temperature heterogeneity among locations in the Henry's Fork. Locations "Trude Bay" and "Lakeside" display clearly cooler waters at depth compared to other locations. These cool locations are the result of spring-fed inflows. Kokanee salmon require water temperatures cooler than 18 C. Water temperatures in deep water are approaching this threshold in July in Island Park Reservoir, meaning Kokanee salmon are likely utilizing thermal refugia found in spring-fed inflows.

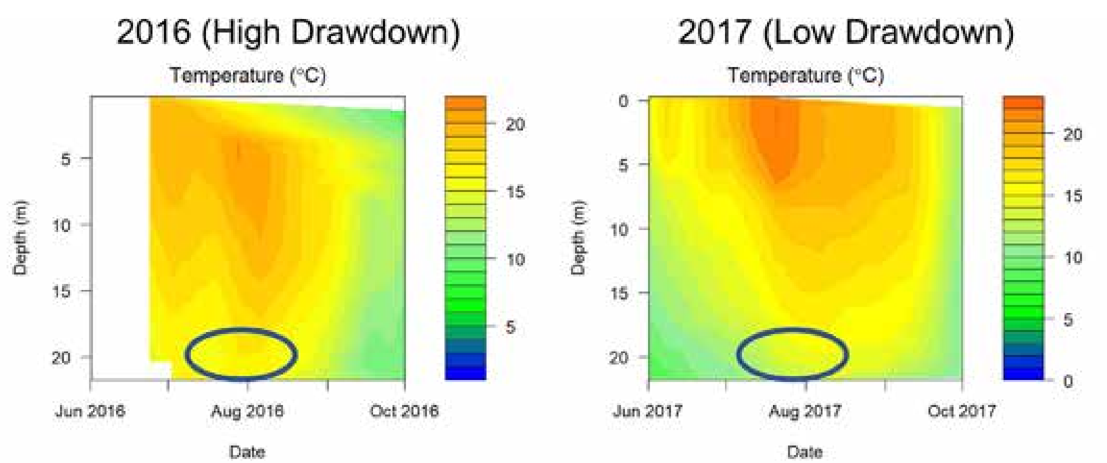

Figure 3. Isopleth-contour plot showing water temperature depth profiles through time over the course of high (2016) and low (2017) drawdown years at the Island Park Reservoir dam, the deepest point in the reservoir. Temperatures over 17°C (yellow/orange) are stressful for Kokanee salmon, and temperatures over 20°C (orange/red) are lethal. Water temperatures in the upper layer of Island Park Reservoir are too high for Kokanee regardless of drawdown amount, but water temperatures near the bottom of the reservoir appear to be affected by drawdown. A low-drawdown year occurred in 2017, and water temperatures at the bottom of the reservoir remain below 17 °C, while 2016 was a high-drawdown year and water temperatures at the bottom of the reservoir exceed 17 °C in July and early August (blue ovals for emphasis).

juvenile fish in ever-shrinking "pools" of localized cool, well-oxygenated water. As these "pools" shrink, juvenile fish may become concentrated and susceptible to predation from adult trout and birds, and adult fish likely compete for food and space.

Based on data analysis of Kokanee salmon run-returns, we found that the number of Kokanee salmon running out of Island Park Reservoir to spawn in a given year is tightly and negatively related to drawdown of Island Park Reservoir in the two years previous (Figure 4). A close relationship between drawdown and Kokanee run-returns indicates to us that increased drawdown destroys critical juvenile fish refugia, reducing recruitment. The loss of migratory Kokanee salmon due to drawdown may also decouple nutrient cycling between Island Park Reservoir and its tributaries (Figure 5). Current research efforts at the Henry's Fork Foundation are focused on quantifying the amount of habitat in Island Park Reservoir given drawdown, and the extent to which kokanee salmon contribute to nutrient cycling and productivity in the Henry's Fork system.

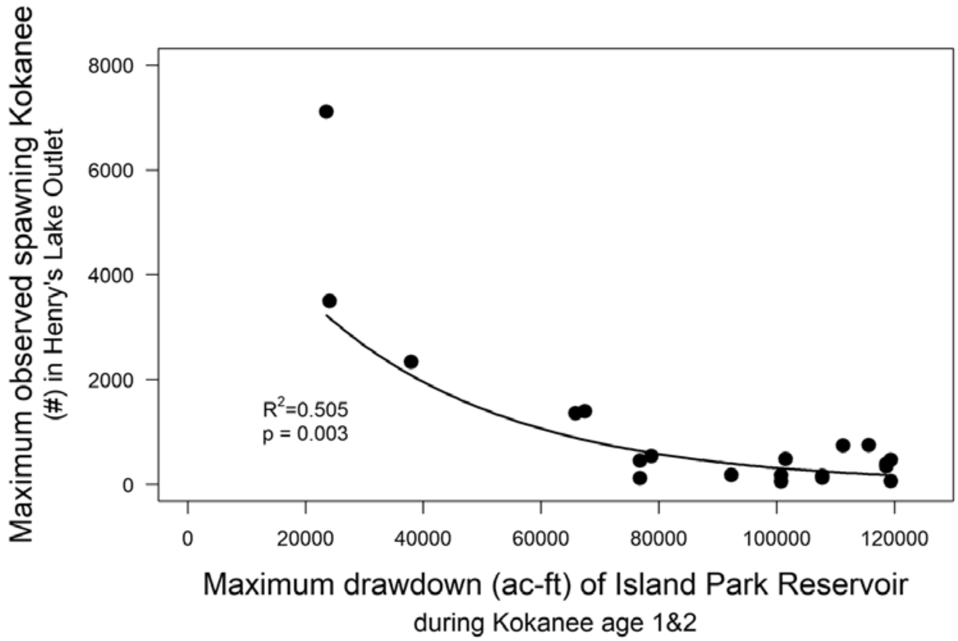

Figure 4. The y axis represents the maximum number of Kokanee salmon found in a tributary stream upstream from Island Park Reservoir in each year of record. These Kokanee salmon are age-3 spawning fish that will die at the end of their spawning run. These age-3 fish lived the entirety of the previous two years in Island Park Reservoir. The x-axis shows the maximum drawdown in Island Park Reservoir during those previous two years of Kokanee juvenile development. Thus, we found that high drawdown during years 1 and 2 of Kokanee life may destroy thermal refugia (see Figures 2 and 3) and result in lower recruitment and future low run-returns.

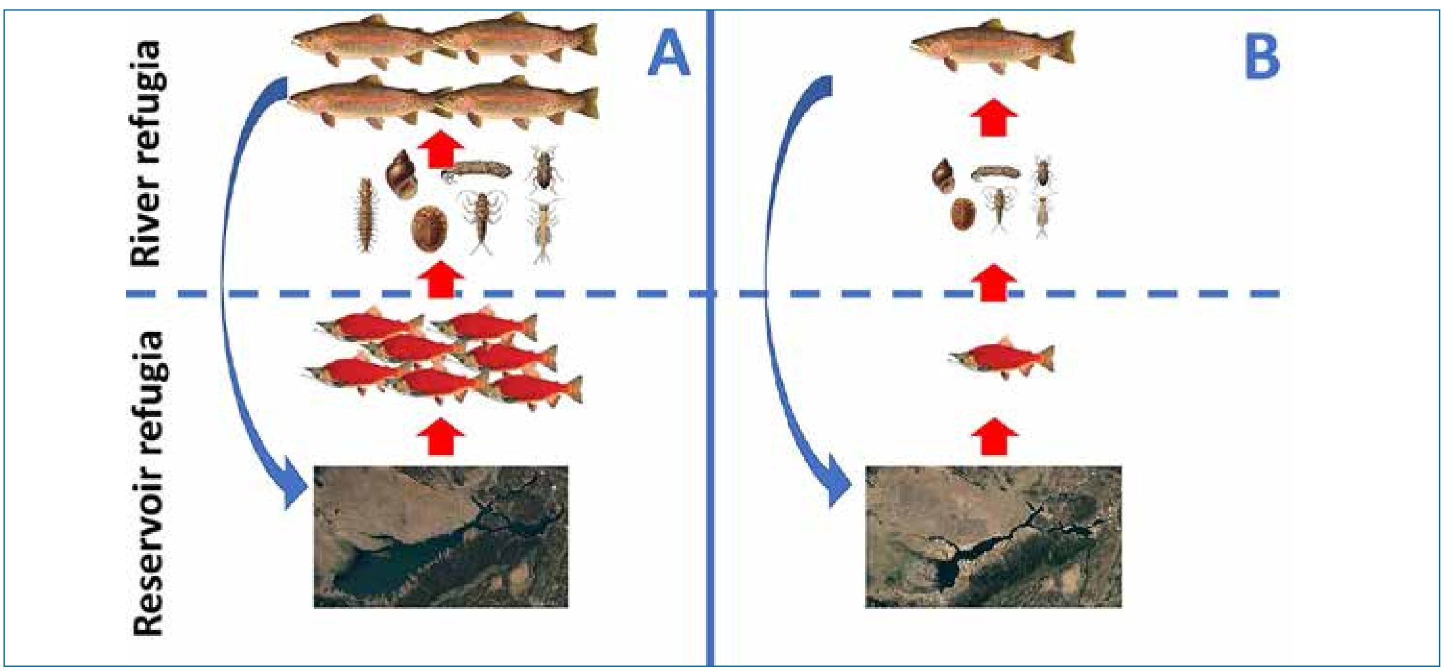

Figure 5.: Hypothesis showing how in-reservoir refugia, Kokanee salmon populations, and Upper Henry's Fork river habitat refugia quality could be linked. Panel A describes hypothesized conditions at low drawdown, whereas panel B describes hypothesized conditions at high drawdown. Better physical and biological reservoir conditions brought about by lower drawdown lead to larger migratory spawning runs of Kokanee into the Upper Henry's Fork, which lead to more nutrients in the Upper Henry's Fork, which makes more food available for fish, which improves refuge habitat for other sport fish, such as rainbow trout, when thermal refugia is needed during stressful summertime conditions. Rainbow trout can freely move between river refugia and reservoir habitat, and so the availability and quality of river refugia may create a more robust, resilient reservoir fishery.

Results from our research are already in use; fisheries and agricultural interests are exploring collaborative programs to improve irrigation management and reduce irrigation water delivery and resulting drawdown at Island Park Reservoir. The Henry's Fork Foundation is attempting to increase fish populations and fish habitat through a unique mechanism: utilizing small-scale, on-farm collaborative programs to increase precision of irrigation management, thereby reducing the need for irrigation water delivery and resultant drawdown at Island Park Reservoir (Figure 6).

The HFF aims to protect the fishery and aesthetic qualities of Island Park Reservoir and the Henry's Fork River by utilizing a portfolio of data-driven, collaborative conservation projects to reduce annual drawdown to no more than 60,000 acre-feet out of 135,000 acre feet, a number shown to be beneficial to downstream water quality and fisheries (Van Kirk 1996). This data- and research-driven strategy for conservation may provide a model for other rivers and reservoirs throughout the western U.S. as climate change intensifies drought and increases pressure on water supplies to meet the needs of a growing population, agriculture, and recreational and ecological needs.

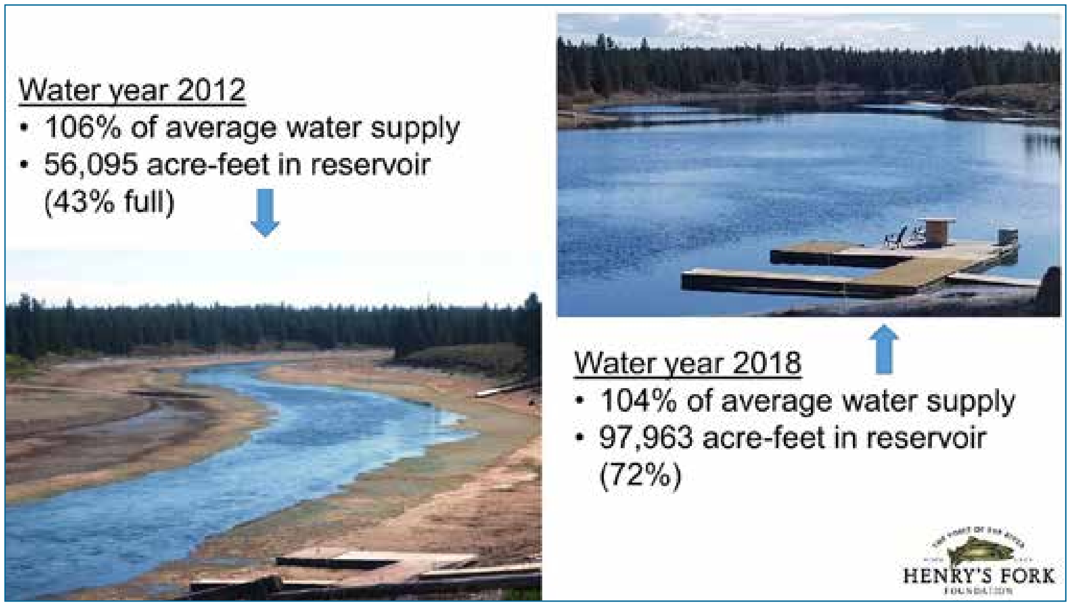

Figure 6. Figure showing the cumulative impact of precision management, which reduces drawdown even in years with remarkably similar water supply. Understanding the fish habitat effect of this reduced drawdown will be critical for optimizing management and quantifying the benefits of precision management.

Literature cited

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