Jack McLaren

Student Corner

Reservoir profiles uncover mechanism behind warming waters in the Henry's Fork

Introduction: Study Location

Island Park Reservoir (IPR) serves as an irrigation storage reservoir on the Henry's Fork of the Snake River in southeastern Idaho (Figure 1). It is a relatively shallow reservoir with a 1.67×10^8 m^3 (135,205 acre-foot) capacity and a mean depth of just over 5 m (16 ft.). IPR's exclusive purpose is irrigation storage; the patterns of water storage and release are driven by need to supply valuable downstream agriculture during the summer irrigation season.

Like other large irrigation storage reservoirs in the western U.S., IPR releases water into its tailwater from the deepest part of the reservoir, cooling and moderating river water temperature to the benefit of cold-water sport fish (Olden and Naiman 2010) (Figure 2). In part because of consistent water supply and moderated water temperatures, IPR's tailwater, the Henry's Fork River, supports a world-class fishery known for its excellent macroinvertebrate hatches and large population of fast-growing and hard-fighting rainbow trout (*Oncorhynchus mykiss*). The fishery attracts fly-fishermen from around the world, adding $29 million and 851 jobs to the local economy (Loomis 2006).

The Henry's Fork Foundation (HFF) is a conservation organization focused on

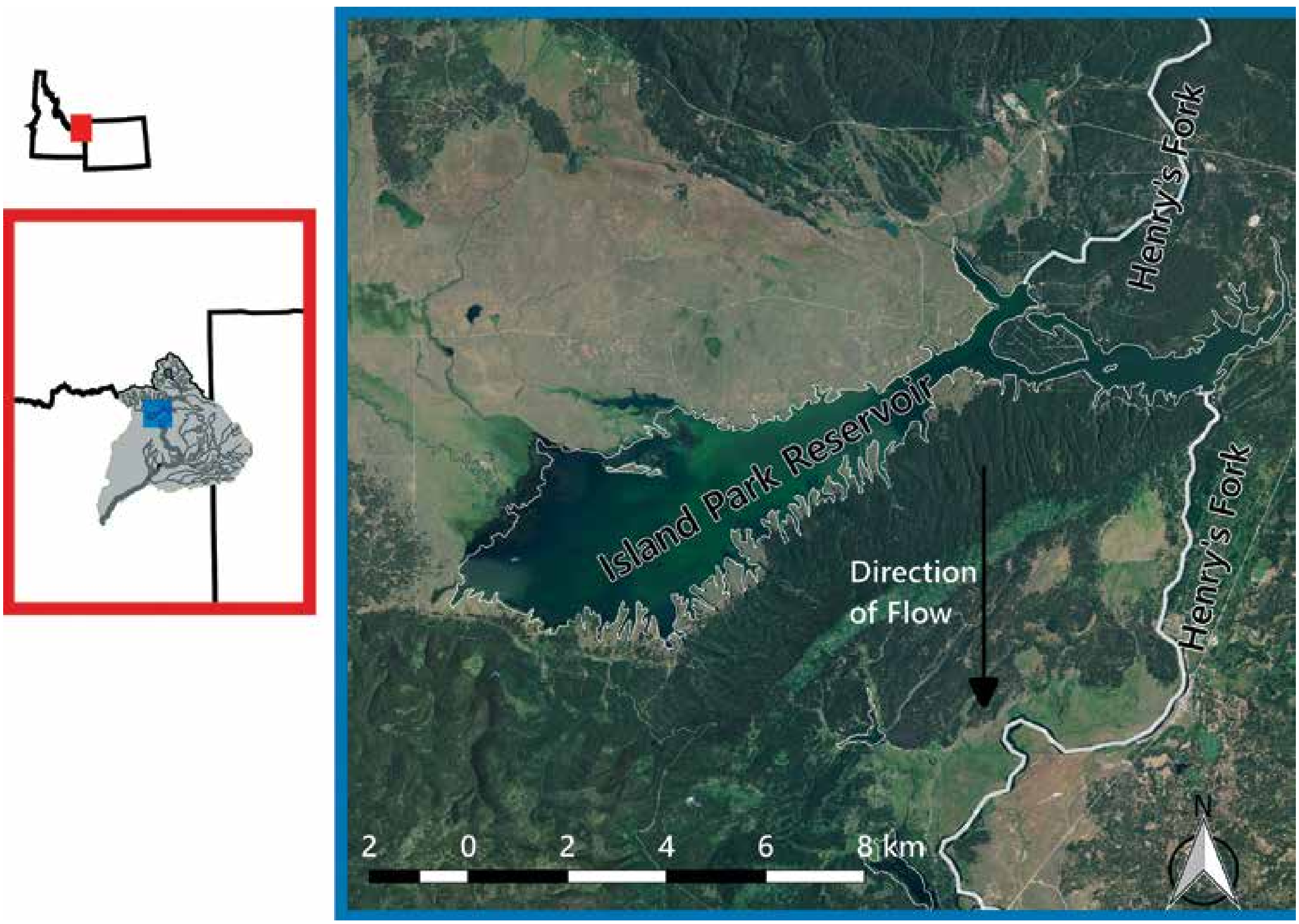

Figure 1. Aerial imagery showing Island Park Reservoir within the Henry's Fork watershed in Idaho and Wyoming (USDA 2011).

Figure 2. Island Park Dam (background) and the Henry's Fork River (foreground), showing the USBR hypolimnetic outlet on the lower-left part of the dam. Picture was taken on July 22, 2015, during peak irrigation delivery.

wild trout protection in the Henry's Fork basin. Because water temperature controls fish and macroinvertebrate growth and development, the Henry's Fork Foundation's science program monitors river water temperatures using a network of water-quality monitoring sondes. HFF's sonde data indicates a larger-than-expected between-year variation in water temperature over the last 20 years immediately below IPR (Figure 3). If reservoirs are supposed to moderate water temperatures, why do water temperatures in the Henry's Fork vary so much?

To understand the reason behind water temperature variation downstream of IPR, I developed my thesis in conjunction with Dr. Todd Royer at Indiana University's School of Public and Environmental Affairs and Dr. Rob Van Kirk with the HFF. My thesis seeks to understand the drivers of water temperature variation in IPR's tailwater. One potential driver is limnological processes within the reservoir. By

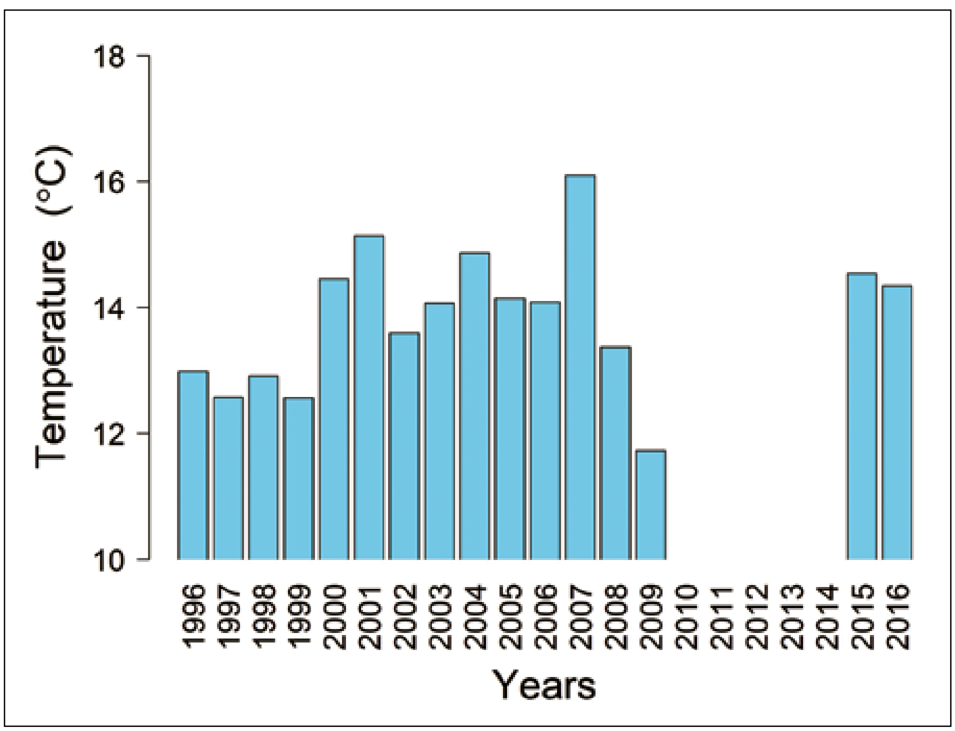

Figure 3. Averaged May to August water temperatures (°C) from 1996 to 2016 in the Henry's Fork River immediately below Island Park Reservoir, ID.

collecting weekly reservoir temperature profiles during the drought year of 2016, I hope to determine the mechanisms for higher water temperature in the Henry's Fork River.

Methods

Water temperature data for the Henry's Fork immediately downstream of IPR for 1996-2009 were collected by Fall River Rural Electric Cooperative, which operates a hydropower plant on the IPR dam. The hydropower facility does not control reservoir outflow but rather generates electricity from the flow released for irrigation storage and delivery. As a condition of operating the hydropower plant, Fall River Rural Electric Cooperative is required to monitor water quality in the Henry's Fork. Water temperatures were recorded hourly approximately 200 m downstream of IPR dam at a US Geological Survey (USGS) stream gauge site (Figure 4). In 2015 and 2016, water temperature data was recorded every 15 minutes with data loggers provided by the HFF.

For my research, I recorded reservoir profiles weekly using an EXO-II sonde (Xylem Incorporated, Yellow Springs, OH) beginning June 15, 2016 at the US Bureau of Reclamation gates, which at 21 m is the deepest location in the reservoir. This sampling location is where outflow not passed through the power plant leaves IPR (Figure 4).

Results

Temporal progression of water temperature downstream of the dam reflects evolution of temperature gradients in the reservoir (Figure 5A-H). The profile taken on June 15 was similar to what is expected in an average dimictic lake: a thermally stratified water column with warm epilimnetic water at about 20 °C above a layer of hypolimnetic water around 10 °C (Figure 5B). As the summer progressed and outflow increased to meet downstream irrigation demand, the hypolimnion was quickly depleted. By July 1 temperatures at the deepest point in IPR increased to 16°C as warm epilimnetic water replaced cold hypolimnetic water that had passed through the IPR outflow (Figure 5D). The result was a 7 °C increase in water temperature in the tailwater in less than three weeks (Figure 5A). A decrease in water temperature in mid-July (Figure 5A) was caused by a week of cool, wet weather that increased cool-water inflow to the reservoir, temporarily reestablishing the hypolimnion (Figure 5F). This bank of cool water was quickly used up as warm temperatures and high irrigation delivery continued in late July and early August, resulting in a return to high temperatures (Figure 5A).

Figure 4. Sampling locations for reservoir profiles (designated as IPR Gates) and data logger temperature monitoring in Island Park Reservoirs tailwater on the Henry's Fork River (USDA 2011).

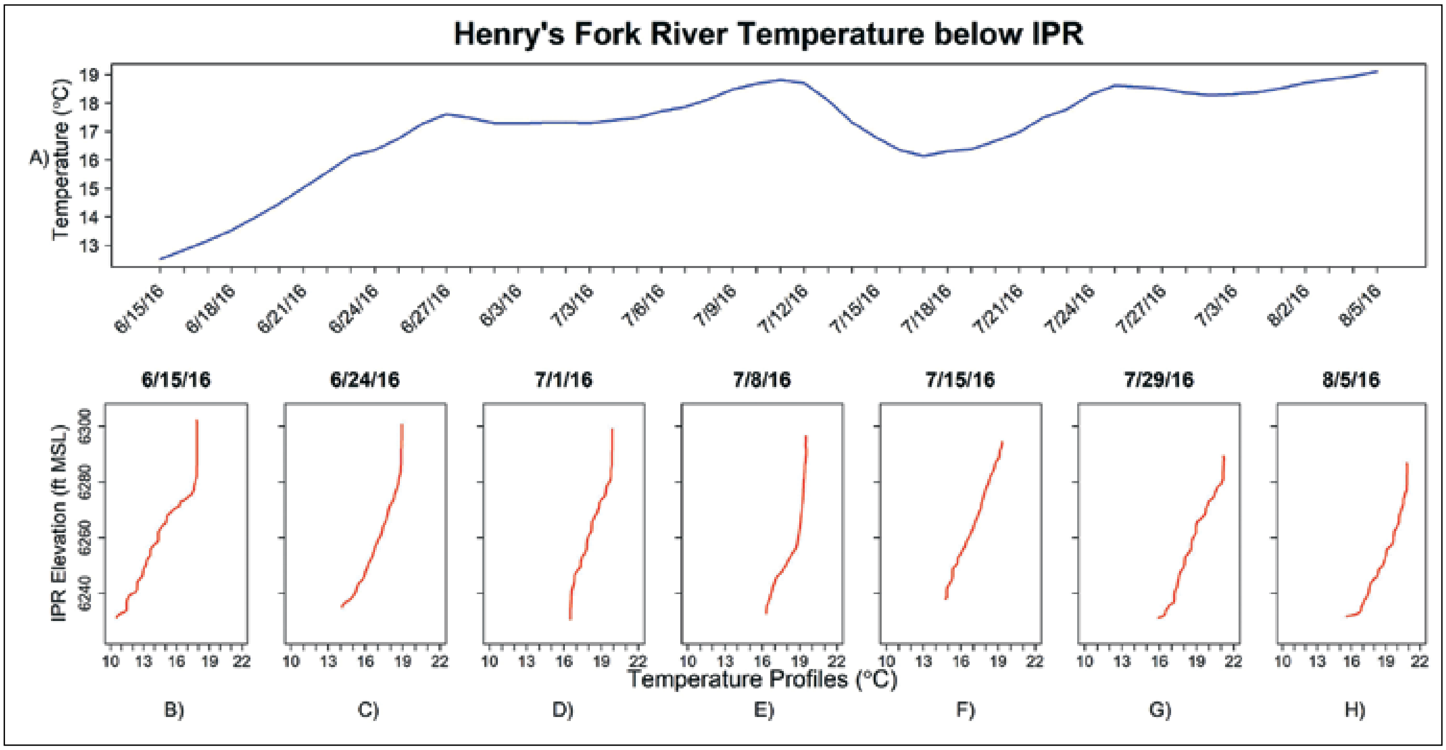

Figure 5. 5A shows water temperature (°C) trends collected in the Henry's Fork River from June 15 to August 5, 2016. 5B-H show water temperature profiles collected at IPR Gates. Note in figures 5B-H the top of each profile starts at a lower elevation as the summer progresses, reflecting reservoir draft

Discussion

My research to date indicates that drought-induced water shortage may change the expected water temperature regime in IPR and similar reservoirs, resulting in higher-than-expected water temperatures downstream. 2016 was a severe drought year; low snowpack and low summertime precipitation result in low natural flow (Figure 6), necessitating high delivery of storage water from IPR relative to inflow. As a result, IPR was drafted much lower than the median (Figure 7). The high draft appears to have released all available hypolimnetic water, resulting in the release of epilimnetic water, resulting in higher river water temperatures.

Water shortages in the West are predicted to become more severe due to climate change (Woodhouse et al. 2016). Creative management may be needed to preserve water quality for sport fishing while simultaneously providing the allotted water for irrigators. A first step towards developing creative management solutions involves finding which climactic and hydrologic factors predict tailwater temperatures. During the 2017 field season, I am developing a bathymetric map for IPR. With a depth-volume curve developed from this bathymetric map coupled with temperature monitoring and hydrologic data, I plan to develop an accurate heat model for IPR. Knowing how heat – and therefore water temperature – flows through IPR, we could alter the timing and amounts of

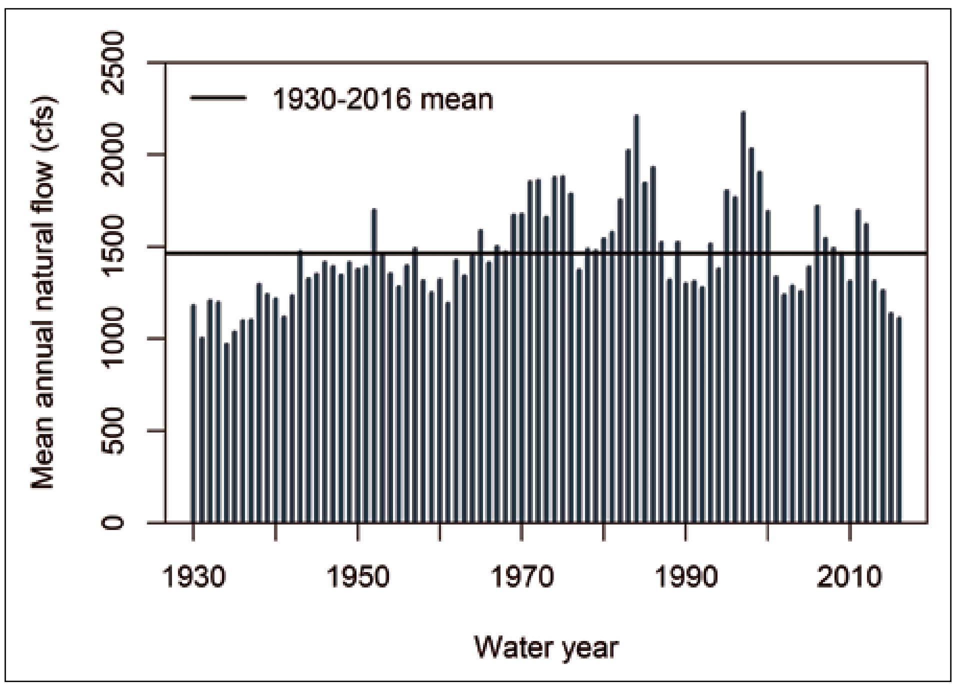

Figure 6. Mean yearly watershed yield, a measure of natural flow, for the entire Upper Henry's Fork watershed from 1930 to 2016. Note 2016 is well below the 1930-2016 mean, and is the lowest since the severe drought of the dust bowl years in the mid-1930s

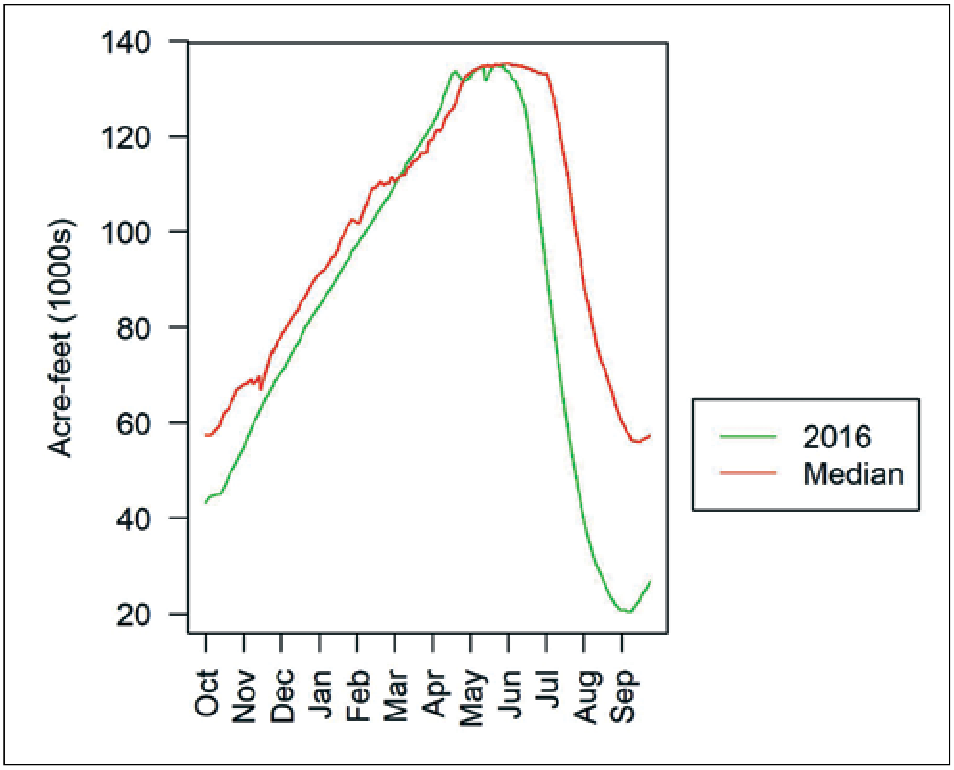

Figure 7. Island Park Reservoir volume comparison between the 2016 water year and median of 1939-2016.

releases to simultaneously meet irrigators' needs while keeping water temperatures in the optimal range for trout and macroinvertebrate growth and survival.

Other more dramatic examples of creative management could include infrastructure changes. A selective withdrawal system, which is a movable outflow gate that can withdraw water from any vertical point in the reservoir, would allow managers to manipulate water temperature in the river below the dam. The system could be used to draw epilimnetic water in the spring and early summer when epilimnetic water temperatures are cool, reducing hypolimnetic releases early in the year and preserving cool water for later in the summer. Another infrastructure change could include increasing the size of IPR by raising the height of the dam, storing more water to benefit irrigators while increasing the volume of the hypolimnion as a side benefit.

Short of infrastructure improvements, a new water market system in Idaho could allow the HFF to pay irrigators to use less water during the irrigation season. The saved water would no longer need to be withdrawn from IPR in the summer, reducing usage of the hypolimnion and keeping water temperatures cooler in the Henry's Fork River. These and other creative solutions will be needed both at IPR and across the West to mitigate the impact of climate-change-driven drought and preserve water supply, quality, and sustain fish populations.

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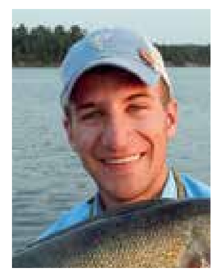

Jack McLaren is a Master in Environmental Science-Master in Public Affairs student at Indiana University's School of Public and Environmental Affairs advised by Dr. Todd Royer. His research interests involve how limnology and climate influence water quality in the Upper Henry's Fork River system in Island Park, Idaho.

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