IMPROVING COLD-WATER FISH HABITAT BELOW IMPOUNDMENTS USING MODIFIED DISCHARGE STRUCTURES

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Abstract. Impoundments commonly discharge water from lake (or pond) surfaces that are usually warmer than normal stream temperatures due to direct solar inputs. In Georgia, impoundment discharge temperatures commonly exceed 30ºC during the summer, which is generally harmful to sport and cold-water fisheries (including trout) that prefer temperatures below 20ºC. While benthic waters in most north Georgia impoundments maintain acceptable temperatures (i.e., $T < 20$ºC), low dissolved oxygen concentrations often found below the photic zone are deleterious to fish health and survival. This study examines the effects of impoundment water quality on stream water temperatures using a new technology that improves downstream water temperatures. This simple, easily installed addition to a conventional impoundment structure can be used to mitigate the thermal effects of lakes and ponds to promote cold-water fisheries.

INTRODUCTION

Impoundments, both large and small, affect downstream temperatures and water quality. Top-discharge structures release waters from the lake surface that are usually warmer and have more variable dissolved oxygen concentrations than influent streams, while bottom-discharge structures release water from near the lake bottom that are cooler and have lower dissolved oxygen concentrations (Ignatius and Rasmussen, 2015; 2016).

Higher temperatures near the lake surface result from increased solar absorption within the photic zone, while profundal waters maintain cooler waters due to shading from above. Diel fluctuation in dissolved oxygen concentrations also occurs in the photic zone due to photosynthesis, while deeper waters exhibit lower dissolved oxygen concentrations due to respiration. With sufficient nutrient loading, profundal water are often anoxic, leading to the accumulation of dissolved metals, such as iron, manganese, and mercury (Zeng et al., 2006).

Profiles of water temperature and dissolved oxygen concentrations for Fort Mountain Lake collected by the Georgia Department of Natural Resources in September 2015 are presented in Figure 1.

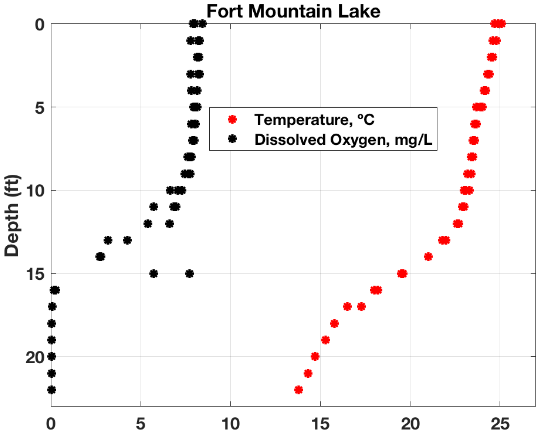

Figure 1. Water quality profile of Fort Mountain Lake in North Georgia (3 Sept 2015).

Note that water temperatures below 20ºC (preferred for cold-water fish) are present below a depth of fifteen feet, but that dissolved oxygen concentrations above 5 mg/L are only present above twelve feet. Thus, surface discharge impairs downstream fish habitat due to excessive heat, while bottom discharge impairs fish habitat due to poor water quality.

Figure 2 presents inflow and outflow water temperature data for Lake Marvin, in Northwest Georgia, provided by the Georgia Department of Natural Resources. Note how outflow water temperatures are substantially higher than inflow temperatures.

Managing downstream water quality can be improved using multi-stage discharge structures, which blends water from both the photic and profundal zones. Yet active monitoring and management of flow discharges from each zone is required to achieve downstream temperature and water quality goals.

OBJECTIVE

The research objective is to evaluate a method for improving water discharges below Georgia impoundments by releasing cold water ($T < 20$ºC) with high dissolved oxygen concentrations ($DO > 5$ mg/L) throughout the summer and fall. It is expected that improving water quality will expand cold-water habitat to more river-miles of streams, thus better supporting sport and non-sport fisheries.

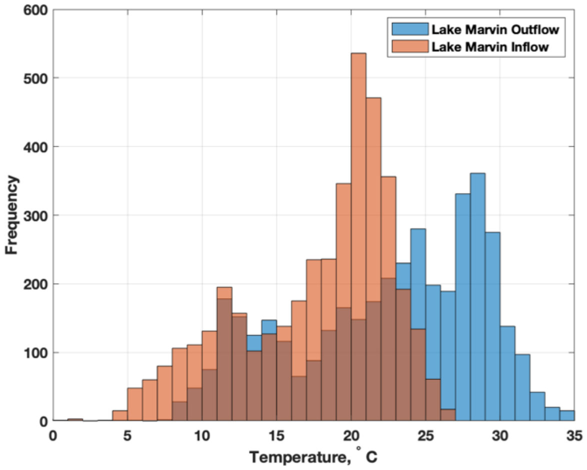

Figure 2. Lake Marvin inflow and outflow temperatures showing how outflow temperatures routinely exceed inflow temperatures.

Figure 3 presents our conceptual model of lake temperatures, where the cold-water pool with low oxygen content is limited to the deeper section of the lake, with warmer, oxygen-rich water above.

The proposed modification to existing impoundments is to install a passive structure that achieves the management goal of discharging cooler water from mid-depths within the impoundment.

The device that we are evaluating is manufactured by Storm Water Systems in Cleveland, GA (Figure 4). Rather than discharging warm water from the lake surface, this device collects cooler water from mid-levels within the lake. The device is placed over the impoundment discharge riser pipe and captures water from any depth. Water flows into the device from below, and then discharges through the existing riser.

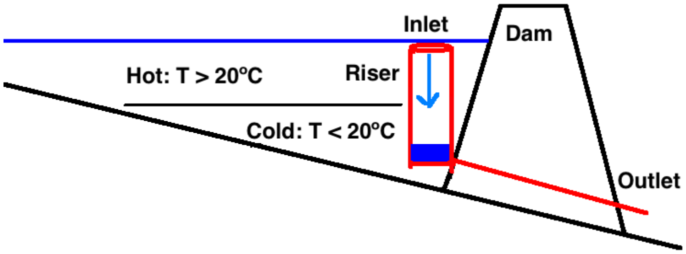

Figure 3. Conceptual model of lake with warmer, oxygen-rich water discharging from the surface layer through a riser pipe.

Figure 4. Impoundment outlet device that collects and discharges cooler, mid-depth lake water.

METHODOLOGY

A field experiment to evaluate the efficacy of this new technology. The study was conducted on Big Sister Pond (33.8885ºN, 83.3640ºW, 180 m amsl), located at Whitehall Forest (Figure 3**)**. Note that the pond investigated is the lowermost of three ponds, collectively called the Three Sisters. Both of the smaller sisters drain into the larger sister. The study site is the larger, most western pond.

The riser modification device measures 61 cm in diameter, with a length of 2.44 m. The device was installed in mid-September 2018, with continuous monitoring if pond inflow and outflow temperatures, as well as temperature profiles within the pond, using Hobo temperature probes (locations shown on Figure 5).

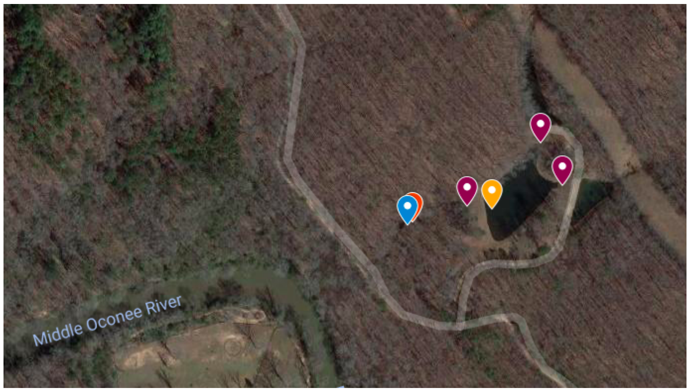

Figure 5. Google Map screenshot of Three Sisters Ponds at Whitehall Forest. The blue pin marks the location of a weir that is used to measure discharge. The orange pin marks the location of the weir inflow temperature. The orange pin marks the location where the temperature profile within the pond is measured. Violet pins mark where pond outflow temperatures are monitored.

RESULTS

Figure 6 presents surface and outlet temperatures for the Big Sister pond. Note that pond surface temperature always exceeds outlet temperature, which suggests that the device performs as expected. Collecting and discharging water from mid-depths shows that the substantial downstream cooling can be achieved, thus improving fish habitat.

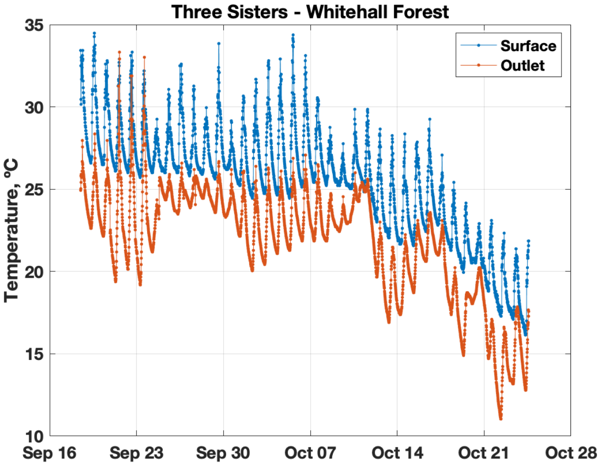

Figure 6. Time series of surface water and outflow temperatures for Big Sister Pond, Fall 2018.

DISCUSSION

To extrapolate to other impoundments, characterization data are required for each system. These data nclude lake inflows, outflow, thermal profiles, and bathymetry, which are used to estimate two components of the lake thermal budget:

- The total heat required to cool lake discharges to the target temperature:

$$J_1 = \rho\, C_p\, Q\, (T - T_o)$$

where ρ is the fluid density (g/L), C_p is the heat capacity (J/g/ºC), Q is the lake discharge (L/s), and T and T_o are the natural and target water temperatures, respectively.

- The total cold-water heat available within the lake for cooling:

$$J_2 = \rho\, C_p\, V\, (T_o - T)$$

where V is the volume of the cold-water pool.

Note that J_1 must be summed over the summer interval, and J_2 must be summed over all lake depths with temperatures below T_o. Also note that additional cooling is provided by the thermal mass of the sediments below the lake.

Figure 7 presents a bathymetric map for a small pond on the University of Georgia Main Campus. Note that most of the pond is shallow, which is where the warmest pool is located, and that only a small portion of the pond is sufficiently deep to support a cold-water pool.

Figure 8 presents the cold content of the Big Sister Pond at Whitehall Forest. Note that the greatest cold content lies at the mid-depth of the pond because the slightly warmer water at this depth is offset by the greater volume compared to deeper waters.

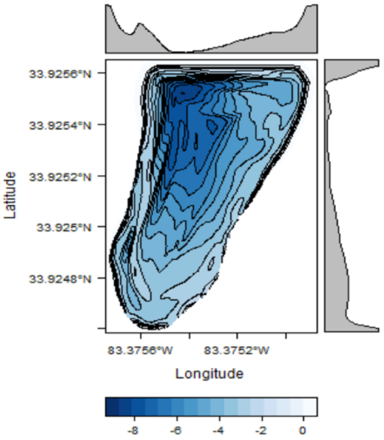

Figure 7. Bathymetric map of pond on UGAs Main Campus.

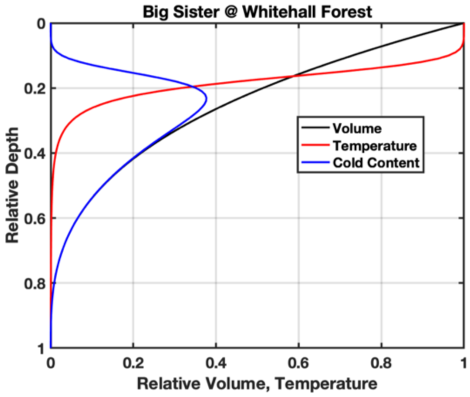

Figure 8. Volume of cold-water pool in Big Sister pond at Whitehall Forest.

CONCLUSIONS

Surface-discharge impoundments increase downstream water temperatures due to solar heating of the lake surface. Modifying the depth at which water is collected and discharge could improve stream habitat for fish that prefer cold water, such as trout. We examine an inexpensive, easily installed device for discharging cooler water from mid-depths of Big Sister Pond at Whitehall Forest near the University of Georgia Main Campus. Water ouflow temperatures are cooler than normal surface waters, thus demonstrating the utility of this modification.

Next steps include collecting water temperature data for Big Sister Pond for an entire summer to examine the effects of discharge modification. An additional effort will involve collecting bathymetric data for a variety of impoundments in North Georgia lakes that lie within the range where coldwater fisheries could be expanded. These bathymetric data will then be used to model how modifying existing discharge structures could be used to improve coldwater habitats, and then to prioritize impoundments for retrofitting.

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