USING WATER QUALITY AND GIS TO EVALUATE LAKE TROUT HABITAT IN DEERFIELD RESERVOIR, SOUTH DAKOTA

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ABSTRACT

Lake trout prefer temperatures less the 19 °C and dissolved oxygen levels greater than 4 mg/l. Temperature and dissolved oxygen profiles were taken during the summer and fall of 2015 and were used with a recent map of Deerfield Reservoir to compute lake volumes. Adequate lake trout habitat existed throughout the study, but was markedly reduced in August and September when water volumes were 1.9×10^6 m^3 and 4.8×10^6 m^3, respectively.

Keywords

Water temperature, dissolved oxygen, critical habitat, lake trout, *Salvelinus namaycush*

INTRODUCTION

Salmonids, in general, can adapt to large changes in their environment (Carlson and Seamons 2008); however, water quality may negatively affect lake trout (*Salvelinus namaycush*) populations (Marsden et al. 1995). Dissolved oxygen levels less than 4.5 ppm have been found to retard developmental rates of embryos, resulting in lengthened hatching periods and delayed hatching and to cause total mortality at 10 °C or greater (Garside 1959). Maximum temperature tolerances for lake trout have been established at 23.5 °C (Gibson and Fry 1954). Plumb and Blanchfield (2009) suggested that the widely-used criteria of 8-12 °C greatly underestimated lake trout habitat and that combined criteria of temperatures at 15 °C or colder and dissolved oxygen >4 ppm matches more closely the preferred habitat of lake trout. A study on small lakes showed that lake trout can distribute in areas as warm as 20 °C (Sellers et al. 1998). In addition, lake trout may use groundwater refugia as habitat during warmer periods (Snucins and Gunn 1995).

The objective of our study was to determine the extent of critical habitat for lake trout in Deerfield Reservoir throughout the late summer and early fall in order to predict the success of a lake trout introduction. To accomplish this, we mapped the depth locations where temperatures <19 °C and dissolved oxygen >4ppm coincided. For this study, we used 19 °C as a temperature maximum as it was slightly more conservative than that reported by Sellers et al. (1998).

Deerfield Reservoir is a high altitude (5,906 msl) impoundment created in 1941 by damming Castle Creek approximately 30 km upstream from Pactola Reservoir. Located in the limestone region of the Black Hills in Pennington County, South Dakota, Deerfield Reservoir has a surface area of 176 ha (435 acres), a maximum depth of 28.3 m, a mean depth of 11 m and a watershed of approximately 24,605 ha (60,800 acres).

METHODS

A YSI Sonde unit, calibrated at the lake before each use, was used to measure temperature and dissolved oxygen from an anchored boat near the deepest portion of the lake. Temperature and dissolved oxygen were recorded at one meter intervals from the surface to the bottom of the lake. When a potential thermocline was encountered, temperatures at 0.5 m increments slightly above, in and below the thermocline were taken to improve precision. Data were collected once a month from July – October 2015.

From a recent map of Deerfield Lake (http://gfp.sd.gov/fishing-boating/tacklebox/lake-maps/docs/Deerfield.pdf), we used Inverse Distance Weighted (IDW) interpolation to develop a contour map from 21,318 depth points. This interpolation method has been used to produce acceptable results with similar data (Simpson and Wu 2014). Comparisons of accuracy for different interpolation methods have been examined and in many cases IDW has been found to be sufficiently accurate (Hengl 2007; Valley et al. 2005; Li and Heap 2008, 2011; Simpson and Wu 2014).

In our study, depth contours with barriers (slices) were developed within the Spatial Analysis extension in ArcGIS to create a digital bathymetric map of Deerfield Lake. This information was used in association with water quality data to locate depths of potential lake trout habitat. To do this we considered each of the depth contour slices to be a plane for further calculations. Volumes of water between planes were estimated based on frustum calculations. The equation used for determining frustum volumes was: $\frac{1}{3}H\,(A_1 + A_2 + \sqrt{A_1A_2})$, where H equals the height between the elevation contours, A_1 equals the area of one contour and A_2 equals the area of a second contour (Schneider 2000).

RESULTS

We found water temperatures within the critical parameters for lake trout survival at depths greater than 6.5, 7.5, 15 and 12 m in the months of July, August, September and October, respectively (Table 1, Figure 1). Similarly, critical dissolved oxygen levels were found at depths less than 15.5, 9.5, 8.5 and 12 m, respectively. The frustum volumes, ranged from 1.9×10^6 m^3 to over 14×10^6 m^3. The lowest volume of water adequate for lake trout survival was in August. By October the lake had cooled to the point that most of the lake was adequate for lake trout survival.

Table 1. Water depths where critical dissolved oxygen concentrations (4 gm/L) and water temperatures (19 °C) were observed at Deerfield Reservoir and their calculated frustum volumes between these depths.

Month	Water Temperature Min. Depth	Dissolved Oxygen Max. Depth	Water volume (m^3)
July	6.5 m	15.5 m	6,598,480
August	7.5 m	9.5 m	1,970,749
September	15.0 m	8.5 m	4,821,965
October	12.0 m	12.0 m	14,297,472

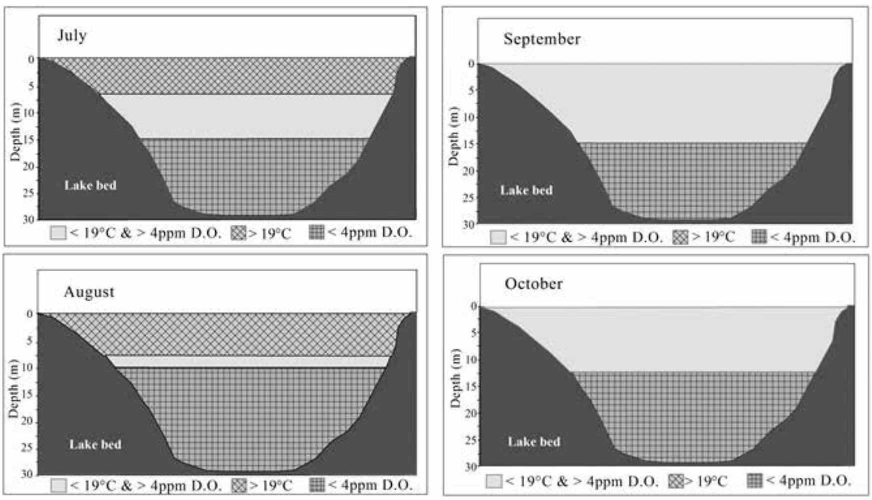

Figure 1. Temperature and dissolved oxygen profiles with critical habitat limits suitable for lake trout in Deerfield Reservoir, July – October 2015.

DISCUSSION

The use of a frustum to calculate the approximate volume of water has been used by others (Häkanson 1981; Taube 2000; Wetzel and Likens 2000). Although the method is seldom used in fisheries because few studies determine appropriate water quality parameters prior to the stocking of fish, it was used recently for the efficient culture of hybrid striped bass (female white bass *Morone chrysops* × male striped bass *M. saxatilis*) in a marine environment (Volkman et al. 2004).

Our study investigated the properties of oxygen and temperature over the course of one summer. It was assumed that this was a "typical" condition and could be used as the basis for further work on the long-term survival and behaviors of lake trout in Deerfield Reservoir. While there are limits and potential pitfalls to utilizing a single season of sampling, other studies employing a limited duration have been used to identify physical parameter influences in similar situations (Gunther et al 2007; Jacobson et al. 2010).

Lake trout typically are lacustrine in nature and are commonly found in the hypolimnion or metalimnion (Donald and Alger 1993; Mackenzie-Grieve and Post 2006). The preferred temperature for lake trout of 15 °C may not always provide the necessary relief for this temperature restricted species. Snucins and Gunn (1995) and Mackenzie-Grieve and Post (2006) found instances of lake trout searching out colder regions of lakes in order to survive the heat extremes of summer. Because of this, we used a temperature maximum of 19 °C based on studies of similar sized waters (Sellers et al. 1998). Throughout the summer and fall of 2015 there were suitable volumes of water in Deerfield Reservoir during the expected high temperature/low dissolved oxygen period. However, these water volumes were greatly diminished during August and September. These data show that there were preferred lake trout refugia, relative to oxygen and temperature, for the year-round survival of lake trout in Deerfield Reservoir. In addition, once salmonids become acclimated, they are able to survive temperatures beyond the thermal maximum (Cherry et al. 1977; Coutant 1977; Jobling 1981).

The actual determination of the number of lake trout that may be supported in Deerfield Reservoir was not investigated and is beyond the scope of this study. Results from this study indicate that, given time to adjust to the water temperature, lake trout will have cold water relief and may flourish in Deerfield Reservoir.

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