The Mechanics of Diurnal Thermal Stratification in River Pools: Implications for Water Management and Species Conservation

Todd H. Buxton[1], Yong Lai[2], Nicholas A. Som[3], Eric Peterson[1], and Ben Abban[2]

[1]US Bureau of Reclamation Mid-Pacific Region
[2]US Bureau of Reclamation Denver Federal Center
[3]Arcata Fish and Wildlife Office

July 6, 2022

Abstract

We examined conditions that form or prevent thermal stratification in river pools using field measurements and statistical and three-dimensional (3D) computational fluid dynamics (CFD) modeling. Our motivation is to identify variables that control stratification for exploitation to enhance or prevent thermal gradients as needed to benefit species in rivers. One study pool (UT) is above water storage reservoirs and receives natural flows, and the other pool (PT) is regulated and receives unnaturally high, cold water in summer on the Trinity River, California. Thermal stratification formed in UT pool in spring at a critical flow of 1.01 m ^{3}/s, peaked at 8.1 °C in summer, and exhibited diurnal formation and destruction under sub-critical flows until fall. At PT pool, the 14.2 m ^{3}/s baseflow caused mixing that prevented stratification and formed a spatially homogenous thermal environment. Statistical modeling indicated the daily range in air and inlet water temperature at UT pool best correlated with the occurrence and strength of stratification but were progressively irrelevant as flows increased above the critical value. The 3D CFD model was verified by predicting the observed critical flow and dynamics of stratification at UT pool and isohytes observed at PT pool. The 3D model was then used to explore the thermal stratification process. Results confirmed low flows are the main variable for stratification to form, and the daily range in inlet water temperature drives the strength of the thermal gradient. The model estimated a critical discharge at PT pool of 2.0 m ^{3}/s, twice that for UT pool owing to its 2.6-times larger area, suggesting critical flows scale with pool size. Results show that releasing critical and lower flows in summer on regulated streams may conserve water and provide thermal gradients that benefit poikilothermic species; alternately, higher than critical flows can prevent stratification where needed to improve water quality.

Hosted file

`Diurnal Thermal Stratification in River Pools (6-28-22).docx` available at https://authorea.com/users/493651/articles/575998-the-mechanics-of-diurnal-thermal-stratification-in-river-pools-implications-for-water-management-and-species-conservation

Hosted file

`Diurnal Thermal Stratification in River Pools (Figures).docx` available at https://authorea.com/users/493651/articles/575998-the-mechanics-of-diurnal-thermal-stratification-in-river-pools-implications-for-water-management-and-species-conservation