World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:18, No:05, 2024

Parallel Opportunity for Water Conservation and Habitat Formation on Regulated Streams through Formation of Thermal Stratification in River Pools

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Abstract : Temperature management in regulated rivers can involve significant expenditures of water to meet the cold-water requirements of species in summer. For this purpose, flows released from Lewiston Dam on the Trinity River in Northern California are 12.7 cms with temperatures around 11oC in July through September to provide adult spring Chinook cold water to hold in deep pools and mature until spawning in fall. The releases are more than double the flow and 10oC colder temperatures than the natural conditions before the dam was built. The high, cold releases provide springers the habitat they require but may suppress the stream food base and limit future populations of salmon by reducing the juvenile fish size and survival to adults via the positive relationship between the two. Field and modeling research was undertaken to explore whether lowering summer releases from Lewiston Dam may promote thermal stratification in river pools so that both the cold-water needs of adult salmon and warmer water requirements of other organisms in the stream biome may be met. For this investigation, a three-dimensional (3D) computational fluid dynamics (CFD) model was developed and validated with field measurements in two deep pools on the Trinity River. Modeling and field observations were then used to identify the flows and temperatures that may form and maintain thermal stratification under different meteorologic conditions. Under low flows, a pool was found to be well mixed and thermally homogenous until temperatures began to stratify shortly after sunrise. Stratification then strengthened through the day until shading from trees and mountains cooled the inlet flow and decayed the thermal gradient, which collapsed shortly before sunset and returned the pool to a well-mixed state. This diurnal process of stratification formation and destruction was closely predicted by the 3D CFD model. Both the model and field observations indicate that thermal stratification maintained the coldest temperatures of the day at ≥2m depth in a pool and provided water that was around 8oC warmer in the upper 2m of the pool. Results further indicate that the stratified pool under low flows provided almost the same daily average temperatures as when flows were an order of magnitude higher and stratification was prevented, indicating significant water savings may be realized in regulated streams while also providing a diversity in water temperatures the ecosystem requires. With confidence in the 3D CFD model, the model is now being applied to a dozen pools in the Trinity River to understand how pool bathymetry influences thermal stratification under variable flows and diurnal temperature variations. This knowledge will be used to expand the results to 52 pools in a 64 km reach below Lewiston Dam that meet the depth criteria (≥2 m) for spring Chinook holding. From this, rating curves will be developed to relate discharge to the volume of pool habitat that provides springers the temperature (<15.6oC daily average), velocity (0.15 to 0.4 m/s) and depths that accommodate the escapement target for spring Chinook (6,000 adults) under maximum fish densities measured in other streams (3.1 m3/fish) during the holding time of year (May through August). Flow releases that meet these goals will be evaluated for water savings relative to the current flow regime and their influence on indicator species, including the Foothill Yellow-Legged Frog, and aspects of the stream biome that support salmon populations, including macroinvertebrate production and juvenile Chinook growth rates.

Keywords : 3D CFD modeling, flow regulation, thermal stratification, chinook salmon, foothill yellow-legged frogs, water managment
Conference Title : ICER 2024 : International Conference on Ecological Restoration
Conference Location : Vancouver, Canada
Conference Dates : May 20-21, 2024