60 Years of Change in Flow and Ecology in the Dam-Regulated Colorado River in Glen and Grand Canyons, Arizona

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In this talk we present three topics related to the consequences of modification of Glen Canyon Dam hydropower production to reduce sandbar erosion in Glen and Grand Canyons in the Colorado River Ecosystem (CRE). We first describe the transition in flow patterns from pre-dam time, to the hydropeaking period from 1964-1991, and the modified low fluctuating flow (MLFF) period from 1992-present. Construction of the dam initiated colonization of the river benthos (channel floor) by a dense bed of the green alga, *Cladophora glomerata* in the Glen Canyon reach upstream from Lees Ferry. Epiphytic (attached) algae, particularly diatoms, provided food for a simple array of aquatic macroinvertebrates that, in turn, provided food of rainbow trout. Increased stability of discharge under MLFFs has resulted in a poorly recognized gradual, but dramatic change from *Cladophora* dominance to a mix of several macrophytes, which now vary seasonally in dominance and by late summer develop into profuse stands. These newly colonizing macrophytes host a diverse array - perhaps as many as 300 – species of epiphytic algae, half of which are new to the CRE and most of which have an uncertain role in the food web. In addition, the proliferation of non-native New Zealand mudsnail and quagga mussel in these novel conditions is likely to further destabilize the aquatic food web. As a consequence of enormous seasonal productivity of macrophytes in the Glen Canyon reach, dieback in winter generates large quantities of decomposing organic matter and creates widespread anoxic conditions that destabilize and reduce primary BMI production. These anoxic conditions could be mitigated by higher flows, cooler water temperature, and increased dissolved oxygen concentration, but these conditions presently strongly influence the potential for food web stability and wintertime productivity.

To better understand the effects of flow variation, water quality, and benthic habitat availability we conducted detailed sampling and experimental studies at the mouth of Tapeats Creek. Water quality, temperature, and flow stability patterns in Tapeats Creek are remarkably similar to that in the mainstream. Our studies there revealed that Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly; collectively EPT) populations are abundant in the creek above the influence of dam operations and in the downstream mouth area, but decline to zero in the mainstream. The primary difference between creek and mainstream habitats was the abundance of sand in the mainstream, which covered interstitial space and generated embeddedness. To test the role of embeddedness further, we placed experimental baskets of cobbles in the creek and mainstream and subjected them to daily flow fluctuations of 0.5 m. After three weeks we found that colonization in the creek and adjacent mainstream was roughly equivalent, indicating that embeddedness, rather than flow fluctuations or water quality was the factor responsible for the absence of EPT in the mainstream. From these measurements and experiments, we conclude that the river cannot be simultaneously managed for both sand and EPT. Collectively, these studies illuminate the influences of flow regulation on the river's aquatic food web, and indicate that further changes are likely under climate change-driven reductions in discharge and increasing water temperature.