Geophysical Research Abstracts
Vol. 13, EGU2011-5445-1, 2011
EGU General Assembly 2011

Experimental Flows from Glen Canyon Dam Reveal Surprises for Adaptive Resource Management of the Colorado River in Grand Canyon, USA

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Glen Canyon Dam (GCD) was constructed to store water in Lake Powell, the second largest reservoir in the United States and produces valuable electrical energy through hydropeaking as a secondary project purpose. Following dam closure in 1963, a series of short-duration high flows from the dam in 1965 scoured the river channel and transformed the 25 km long tailwater reach from a sand-bed to a gravel-bed river in a few months. Channel cleaning promoted efficient hydropeaking operations from 1966 onward and also created downstream habitat for a high quality recreational rainbow trout fishery. In 1967, the humpback chub (Gila cypha), an endemic fish of the Colorado River, was listed by the U.S. Fish and Wildlife Service as an endangered species, owing to declining populations that were attributed to the combined effects of water development and the introduction of nonnative fishes. The new recreational trout fishery was sustained through annual stocking until limits imposed on daily hydropeaking in the 1990s, intended to mitigate sandbar erosion in Grand Canyon, created conditions that resulted in a self-sustaining trout population. The trout population continued to expand through the late 1990s and then declined steeply through 2006. Besides the humpback chub and the rainbow trout fishery, resources of concern to river managers include sandbars, riparian vegetation and sensitive cultural sites along the river.

Despite limits on hydropeaking, sandbar erosion in the Colorado River below GCD continues. Since 1995, three artificial flood experiments have been released from the dam to determine whether the remaining sand supplies from two major tributaries below the tailwater reach (∼6-16 percent of the pre-dam sand supply) are sufficient to rebuild and maintain sandbars. The artificial floods have rebuilt sandbars, but clear water releases associated with water transfers and hydropeaking have eroded new deposits following each test in less than a year. Researchers hypothesize that sandbars might be rebuilt and maintained more effectively if short-duration floods are repeated more frequently after tributaries sand deliveries to the river (perhaps annually). Planning for such a test started in 2010, and it may begin in 2011. Although the outcome of such a sediment experiment is highly uncertain, these floods might also sustain previously measured trout and food web responses in the tailwater reach. Biotic responses from the last flood in March 2008 showed that the 2.5 day long high flow initially reduced aquatic food production in the tailwater, but then production of certain drift-prone taxa, known to be valuable as food to trout, increased. Data collected after the 2008 flood also showed trout production below the dam increased from two to about five-fold during the two years following the spring flood. Survival of trout fry apparently increased in response to habitat improvement and availability of higher-quality drifting food items. The 2010, data indicate that trout production returned to lower levels measured in 2006-7. Trout movement downstream to Grand Canyon is a threat to humpback chub because of their documented predation of juvenile chub and competition for limited food and habitat. Adult chub found near the Little Colorado River confluence reach of Grand Canyon (∼100 km below the tailwater reach) have increased by 50 percent since 2001, perhaps at least partly in response to experimental nonnative fish removal there in 2003-6. The 2009 rainbow trout data from Grand Canyon show a 3,800 percent increase in their abundance compared with 2006, when nonnative fish removal ended with most of this increase measured after the spring 2008 flood. Experimental release of more frequent artificial floods following tributary sand inputs to rebuild sandbars might achieve sediment management objectives. However, if frequent floods are tested, then careful monitoring of rainbow trout and food web responses is needed to determine whether altered flood timing can also limit trout production. If the biotic response is sustained regardless of flood timing, then increased trout abundance and downstream movement to Grand Canyon might limit or even reverse the recent recovery of this unique native fish.