Hyporheic anoxia in the tailwaters reach and its impacts on river ecosystem ecology

Abstract

Glen Canyon Dam has greatly influenced the ecosystem characteristics of the Colorado River in Glen and Grand Canyons. Some of the changes are easy to see (e.g., predictable stage changes in the river), while others are far less noticeable. One of the phenomena occurring in the Glen Canyon reach is the development of hyporheic anoxia (HA) (soils on the riverbed with little to no oxygen), which turns the sand into a black sludge. Anoxia is a common characteristic of many wetlands and other stagnant water bodies but has not been recorded to any great extent in flowing rivers. Our goals with this project are to (1) determine the extent of HA in the Glen Canyon reach, Lake Powell, and just below Lees Ferry; (2) figure out what is causing HA to form; and (3) quantify the effects of HA on the invertebrate organisms that would typically be found living in the hyporheic zone.

To gain a better understanding of the extent of HA, we surveyed and mapped the soils in Lake Powell (just above the dam), the Glen Canyon reach of the river (from the dam to Lees Ferry), and below the Paria River confluence. The greatest concentration and volume of HA is found in the 15-mile Glen Canyon reach. HA is found in Lake Powell and below the Paria confluence (the first stretch of river with significant turbidity), but to a much lesser extent. HA was most commonly found in areas with slow-moving water (i.e., eddies) that contained dense stands of submerged aquatic vegetation (such as *Chara* algae and *Zanichellia* pondweed), which indicate this anoxia is most likely the result of vegetation whose growth is not light-limited by turbidity (suspended sediment) that is dying back and decaying in place rather than being transported downstream by swift currents.

We completed lab and field experiments to determine how quickly HA develops and what conditions are necessary for its formation. For this objective, we attempted to “create” HA by adding *Chara* algae and by altering the temperature of the water and aeration of the soil. In a completely controlled setting, HA developed within 10 days and only in the presence of *Chara* algae, providing further evidence that this process is driven by decaying vegetation. Warmer water and lack of aeration also caused an increase in HA development over the 10-day experiment.

Finally, to resolve any effects the anoxic soil has on the riverine organisms, we exposed macroinvertebrates to HA and recorded percent mortality. The results were mixed and depended strongly on the organism. Hardier macroinvertebrates, such as amphipods (scuds) and dragonfly larvae did not experience any negative effects over the 10-day experiment. However, mayfly larvae (which are typically more sensitive and often used as bioindicators of water quality) experienced over 95% mortality when exposed to HA.

Our results show that the development of HA occurs in clear, slow-moving water where submerged aquatic vegetation is not light-limited and is not transported downstream following die-back. The input of tributary sediments and swiftly-flowing water beyond the Glen Canyon tailwaters appears to limit HA development. However, with the prospect of climate change leading to a drier climate in the West (and, in turn, lower tributary flows), this phenomenon could potentially move downstream into Grand Canyon. Further investigation into other tailwaters may help clarify the hyporheic anoxia development process and its effects.