River plants may play major role in health of ocean coastal waters

January 29 2008

Recent research at MIT's Department of Civil and Environmental Engineering suggests how aquatic plants in rivers and streams may play a major role in the health of large areas of ocean coastal waters.

This work, which appeared in the Dec. 25 issue of the *Journal of Fluid Mechanics* (JFM), describes the physics of water flow around aquatic plants and demonstrates the importance of basic research to environmental engineering. This new understanding can be used to guide restoration work in rivers, wetlands and coastal zones by helping ecologists determine the vegetation patch length and planting density necessary to damp storm surge, lower nutrient levels, or promote sediment accumulation and make the new patch stable against erosion.

Professor Heidi Nepf is principle investigator on the research. Brian White, a former graduate student at MIT who is now an assistant professor at the University of North Carolina, is co-author with Nepf of the JFM paper. Marco Ghisalberti, a postdoctoral associate at the University of Western Australia, worked with Nepf on some aspects of this research when he was an MIT graduate student.

Traditionally people have removed vegetation growing along rivers to speed the passage of waters and prevent flooding. But in recent years that practice has changed. Ecologists now advocate replanting, because vegetation provides important habitat. In addition, aquatic plants and the microbial populations they support remove excess nutrients from the water. The removal of too many plants contributes to nutrient overload in rivers, which can subsequently lead to coastal dead zones—oxygen-deprived areas of coastal water where nothing can survive. One well-documented dead zone in the Gulf of Mexico, fed by nutrient pollution from the Mississippi River, grows to be as large as the state of New Jersey every summer.

Nepf's work—which describes how water flows into and through a plant canopy, and how long it remains within the canopy—can be used to find the right balance between canopy and flow in a river.

Vegetation generates resistance to flow, so the velocity within a canopy is much less than the velocity above it. This spatial gradient of velocity, or shear, produces a coherent swirl of water motion, called a vortex. Using scaled physical models, Nepf and Ghisalberti described the dynamic nature of these vortices and developed predictive models for canopy flushing that fit available field observations. The team showed that vortices control the flushing of canopies by controlling the exchange of fluid between the canopy and overflowing water. Similar vortices also form at the edge of a vegetated channel, setting the exchange between the channel and the vegetation.

The structure and density of the canopy controls the extent to which flow is reduced in the canopy and also the water-renewal time, which ranges from minutes to hours for typical submerged canopies. These timescales are comparable to those measured in much-studied underground hyporheic zones, suggesting that channel vegetation could play a role similar to these zones in nutrient retention. In dense canopies, the larger vortices cannot penetrate the full canopy height. Water renewal in the lower canopy is controlled by much smaller turbulence generated by individual stems and branches.

"We now understand more precisely how water moves through and around aquatic canopies, and know that the vortices control the water renewal and momentum exchange," said Nepf. "Knowing the timescale over which water is renewed in a bed, and knowing the degree to which currents are reduced within the beds help researchers determine how the size and shape of a canopy will impact stream restoration."

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Source: Massachusetts Institute of Technology

Citation: River plants may play major role in health of ocean coastal waters (2008, January 29) retrieved 18 April 2024 from https://phys.org/news/2008-01-river-major-role-health-ocean.html