Indirect wave dissipation mechanism in submerged vegetation canopies with accompanying currents

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The wave dissipation process in mangroves and saltmarshes is a crucial aspect of their ecosystem service. These vegetation fields are often subjected to combined current-wave flows. The dissipation process is complex, and discrepancy exists in previous studies regarding the influence of the current direction on wave dissipation. We conducted flume experiments to mimic waves propagate through rigid vegetation with following and opposing currents. Synchronized velocity-force measurements were applied to directly derive vegetation drag coefficients and a generic drag coefficient relation for various flow conditions. Our experiments showed that opposing currents led to greater dissipation than following currents, especially in the submerged canopies, where additional dissipation above the canopy was induced indirectly by current-wave interaction. A two-layer analytical model for submerged canopies helps understand the indirect wave dissipation process: following currents reduce wave height via accelerated wave energy flux, but opposing currents can induce wave breaking leading to much greater dissipation. This current-induced breaking is similar to previous studies with elevated flume bottom, where confined opposing currents are forced to the upper layer of the water column and can easily trigger wave breaking. This indirect dissipation was generally neglected in previous studies, but we found it constitutes an essential part (up to 87%) of the vegetation-related dissipation. These indirect dissipation processes may occur in shallowly submerged mangrove forests. The present study may improve the understanding and prediction of wave dissipation in vegetated coastal wetlands.