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Effects of needle ice on peat erosion processes during overland flow events

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Freeze–thaw processes play a role in increasing erosion potential in upland peatlands, but their impact on overland flow hydraulics and fluvial erosion processes is not clearly established. We provide the first quantitative analysis demonstrating that needle ice production is a primary process contributing to upland peat erosion by enhancing peat erodibility during runoff events following thaw. To quantify the effects of needle ice processes on peat physical properties, overland flow hydraulics and erosion processes, physical overland flow simulation experiments were conducted on highly frost-susceptible blanket peat with and without needle ice processes. For each treatment, overland flow rates of 0.5, 1.0 and 2.0 L/min and slopes of 2.5° and 7.5° were applied. Peat erodibility, sediment concentration and sediment yield were significantly increased in treatments subjected to needle ice processes. Median peat losses were nearly six times higher in peat blocks subject to needle ice processes than in peat blocks not subject to needle ice processes. Needle ice processes decreased mean overland flow velocities by 32–44% via increased hydraulic roughness and changes to surface microtopographic features, with micro-rills and headcut development. Needle ice processes increased the hydrodynamic force of shear stress by 55–85%. Erosion rates under needle ice processes exhibited a significant linear relationship with stream power. Our findings indicate that models of overland flow-induced peat erosion would benefit from a winter component that properly accounts for the effects of needle ice processes on peat erodibility and erosion.