Transport Dynamics of Floc in Ridge and Slough Vegetation Communities: A Laboratory Flume Experiment and Numerical Study

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The ridge and slough landscape is a topographically and vegetationally heterogeneous, patterned region of the Everglades that is valued for its relatively high species diversity. Landscape patterning and heterogeneity have diminished rapidly over the past century, with degradation predominantly taking the form of loss of sloughs. The entrainment of detrital floc within sloughs and deposition of that floc on *Cladium* ridges is a leading hypothesis for the maintenance of lateral ridge stability.

In this study we undertook a series of laboratory experiments to parameterize a numerical model of floc transport in the ridge and slough landscape. An advection-dispersion equation for floc requires knowledge of the distribution of floc settling velocities, particle sizes, aggregation/disaggregation rates in different flow conditions, and entrainment fluxes over a range of bed shear stresses. We collected floc from sites within the best-preserved part of the ridge and slough landscape and performed experiments in a racetrack flume, rotating annular flume, and settling column within days of collection.

Though settling velocity and aggregate size distributions differed between floc from two slough sites with differences in periphyton abundance, these differences were small compared to differences in floc characteristics between the organic Everglades floc and the less organic floc populations in rivers, lakes, and estuaries. Everglades floc settled more slowly and had higher porosity but was also entrained at a threshold bed shear stress (1.0×10^{-2} Pa) an order of magnitude lower than the critical shear stress for entrainment of other floc populations. Unlike many other aquatic environments, floc disaggregation in the Everglades was not significant over the appropriate velocity/shear range. However, particle aggregation became significant at high flow speeds (7.5 cm s^{-1}) and continued via differential settling as the flow speed declined. Thus, from the rising limb to the falling limb of a flow velocity time-series, particle aggregation was hysteretic. Entrainment flux was also hysteretic: floc entrainment was higher on the falling limb of a velocity time-series than on the rising limb, due to resuspension.

Results from the racetrack flume entrainment experiment were coupled to a Reynolds-averaged Navier-Stokes simulation of velocity profiles and bed shear stresses to predict the hydrologic conditions that would induce redistribution of material from sloughs to ridges. Drag coefficients for ridge and slough vegetation communities were calibrated from field and laboratory experiments, and representative vegetation architecture profiles were computed from a statistical analysis on a database of Everglades clip plots. Inputs to the simulation were surface water stage, water surface slope, and vegetation community architecture, and the output was a one-dimensional vertical velocity profile, computed under assumed steady, uniform conditions. The velocity profile was used to compute the depth-averaged drag force from vegetation resistance and bed shear stress.

Simulation results suggested that in slough communities with abundant *Eleocharis*, present-day surface-water slopes are lower than the minimum slopes needed to entrain sediment from within sloughs. Bed shear stress was more sensitive to surface-water slope than water surface level, so raising mean water levels in *Eleocharis* sloughs would not induce floc entrainment, unless the elevated water levels were accompanied by a substantial increase in water surface slopes. However, in deepwater slough communities with less abundant *Eleocharis*, sediment entrainment occurs within sloughs at the present mean water surface slope of 3×10^{-5} for surface-water levels of at least 80 cm. In contrast, at equivalent surface-water depths, entrainment of floc within ridges begins at a water surface slope of 1×10^{-4}; larger water surface slopes are required for floc entrainment at shallower water depths. Predicted bed sediment entrainment thresholds in *Eleocharis* sloughs were validated by elevated flow experiments in a field flume.

Overall, key findings of this study relevant to restoration efforts were:

- The critical bed shear stress threshold for floc entrainment in the Everglades is 1.0×10^{-2} Pa, with the greatest increase in entrainment flux occurring between this threshold and bed shear stresses of 2.0×10^{-2} Pa. Depth-averaged velocities at which these bed shear stresses are obtained vary with vegetation community, flow depth, and water surface slope.
- Under current water surface slopes in the Everglades, floc entrainment by flow will never occur in densely vegetated *Eleocharis* sloughs and will rarely occur in sparser deep-water sloughs. However, redistribution of sediment from sloughs to ridges by flow can be restored by a combination of reducing *Eleocharis* abundance and releasing pulses of water from impounded areas that temporarily increase water surface slope. Above surface-water depths of approximately 45 cm, bed shear stresses vary little with water level but are highly sensitive to water surface slope. For all surface-water depths, bed shear stresses are highly sensitive to vegetation frontal area.
- The duration of flow conditions that induce sediment transport to an extent significant for landscape evolution is on the order of weeks. At a bed shear stress of 2.0×10^{-2} Pa, two weeks of flows that induce sediment transport will result in an annual scour rate in sloughs equivalent to the spatially averaged rate of peat accumulation throughout the ridge and slough landscape.

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