Biogeochemical Transformations and Transport Related to Flow in the Ridge and Slough Landscape

***Gregory B. Noe**, Judson W. Harvey* and *Laurel G. Larsen*
National Research Program, U.S. Geological Survey, Reston, VA, USA

Sediment dynamics have important implications for phosphorus (P) biogeochemistry and transport in Everglades wetlands despite a clear water column. A synoptic survey including WCA-1, WCA-2A, WCA-3A, and ENP found that suspended sediment held 31% of total P while its concentration was low (1.5 mg L^{-1}) and particle size was small (9 µm) across Everglades peatlands. Total particulate P concentrations increased from 0.10 µmol L^{-1} to 0.31 µmol L^{-1} while the total particulate N:P ratio decreased along the P-enrichment gradient in WCA-2A. However, total suspended sediment concentrations were similar along the P enrichment gradient, resulting in a three-times greater density of P in suspended sediment at the most P-enriched site. These biogeochemical characteristics of suspended sediment suggest that it is more reactive with P enrichment.

Sequential chemical extraction of suspended particles identified that P fractionation differed with particle size. Fine suspended particles (<100 µm) were dominated by microbial P (65%) with little refractory organic P (2%), while coarse suspended particles (>100 µm) held proportionally less microbial (39%) and more refractory organic P (37%). The density of P in fine particles is ten fold higher than in coarse particles, so that total suspended particle P fractionation is largely microbial (62%) with little refractory organic P (6%). There is very little information on P speciation in Everglades floc. However, we sequentially extracted the surficial 2 cm of peat soils and found that 45% and 31% of total P were held in refractory organic P and microbial P, respectively. The size and chemical fractionation information suggest that the fine suspended and P-rich particles mostly consist of suspended bacteria.

Redistribution of sediment from low elevation sloughs to higher elevation ridges is a leading hypothesis for the formation and maintenance of the Everglades ridge and slough landscape pattern. We tested this hypothesis by measuring the concentration and characteristics of suspended sediment and its associated nutrients in adjacent ridge and slough plant communities that were located in a region of the Everglades with the best remnant ridge and slough pattern (central Water Conservation Area 3A). The concentrations and characteristics of suspended sediment and particulate nutrients over two wet seasons were the same in ridge and slough plant communities. Total suspended sediment mass concentrations were on average 0.94 mg L^{-1} over the duration of the study. Total particulate N and total particulate P concentrations were 4.2 and 0.10 µmol L^{-1}, respectively, on average. Fractionation of P in suspended sediment was also similar in the ridge and slough. Only the concentration of TDP significantly differed, with 8% more dissolved P in the surface water of the ridge.

Despite the low concentration of particulate P in both ridge and slough, 28% of all surface water P was associated with suspended sediment. In contrast, only 5.6% of surface water N was associated with suspended sediment, in part due to the relatively high average TDN concentrations (75 µmol L^{-1}) relative to TDP (0.29 µmol L^{-1}). The mass-weighted, N-weighted, and P-weighted geometric-mean size of particles decreased from 8.6, to 5.2, to 2.9 µm, respectively. The uniformity in suspended sediment concentrations and characteristics suggests that sediment redistribution between ridge and slough is currently rare in the Everglades.

However, the downstream fluxes of suspended sediment and nutrients were roughly 2x greater in the slough than the ridge, due entirely to the greater unit-width discharge in the slough.

Spatial and temporal variation in suspended sediment and particulate nutrient parameters were only slightly related to the observed slow sheetflow velocities, suggesting that the critical shear stress that causes entrainment is not commonly exceeded in the modern Everglades. Spikes of elevated suspended sediment abundance were observed following a hurricane, at night presumably due to bioturbation, and when waters depths were shallow. High resolution sampling using a LISST suspended sediment analyzer revealed strong diel fluctuations in the abundance of the smallest suspended sediment size class. The concentration of particles in the 1.4-2.7 μm size class, which includes the most abundant size class of particulate P, increased two to three orders of magnitude following sunrise and decreased to very low levels following sunset.

A field experiment with enhanced flow velocities in a deep water slough did not change P fractionation in suspended sediment. Volume concentrations ($\mu L\ L^{-1}$) and size of suspended sediment increased; however, total particulate P concentrations and the P fractionation of suspended particles was unvarying and largely microbial P with little refractory P. Thus, advection of labile particulate P increased greatly. Restoration actions intended to increase sheetflow velocity will also transport more labile P downstream with sediment. A better understanding of the sources, transport characteristics, and fate of suspended sediment is needed to improve water quality models and predict the effect of restoration actions on the transport of P.

Implications for restoration include:

- Suspended sediment holds an important proportion of surface water TP, in relatively labile forms, despite its low abundance.
- Concentrations and characteristics of suspended sediment and associated nutrients were similar in adjacent ridge and slough under the current hydrologic regime, suggesting that ridge and slough geomorphology is not currently sustainable.
- Higher discharge results in greater downstream transport of labile particulate P with sloughs transporting more material than ridges.
- Water quality models should consider the transport and fate of dissolved and particulate forms of P.
- Restoration of greater water flow through the Everglades will result in faster spread of the P hotspot in northern WCA-2A to down-gradient unenriched areas through increased transport of P both in the particulate form and in the dissolved form.

Contact Information: Gregory Noe, National Research Program, U.S. Geological Survey, Reston, VA 20192 USA, Phone: 703-648-5826, Fax: 703-648-5484, Email: gnoe@usgs.gov