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Controls on suspended floc size, settling velocity, trapping and associated water clarity in partially-mixed estuaries: the role of organic versus inorganic content

Carl T. Friedrichs[1], Kelsey A. Fall[2], Grace M. Massey[3], and Lawrence P. Sanford[4]

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Abstract

Observations and analysis presented here suggest that properties of suspended particulate matter (SPM) in the water column of partially mixed estuaries, including floc size and settling velocity, are strongly related to the relative concentrations of inorganic versus organic matter in suspension. In regions with high inorganic SPM concentrations, addition of organic matter tends to increase the median size and settling velocity of flocs, removing both organic and inorganic SPM from the water column and enhancing water clarity relative to that in the absence of organics. In contrast, in regions with lower inorganic SPM concentration, suspended organic matter appears to decrease the median size and settling velocity of flocs, which keeps SPM in suspension and reduces water clarity relative to that seen in the absence of organics. Smaller particle sizes also have larger surface area to volume ratios, increasing light scattering and further degrading light penetration. The ecological and water quality ramifications with regards to light penetration and water clarity are significant.

Specific sections of moderate energy, partially-mixed estuaries tend to have enhanced fractions of inorganic versus organic matter in suspension in response to positive feedbacks driven by settling velocity and estuarine residual transport. In the upper water column, higher percent organic matter, smaller floc size, smaller settling velocity, and lower SPM concentration are favored. Conversely, in the lower water column, higher percent inorganic matter, larger floc size, larger settling velocity, and higher SPM concentration are favored. Interaction with two-layer transport patterns then promotes estuarine trapping of inorganic matter relative to organic matter. Estuarine residual transport further segregates organic and inorganic matter along the length of partially mixed estuaries, causing smaller, organic-rich, slowly settling flocs to make up a larger fraction of SPM in the lower estuary. In contrast, flocs in the upper estuary tend to be larger, dominantly inorganic, and have larger settling velocities.

In response to estuarine eutrophication (i.e., an increase in the rate of supply of organic matter), floc size and settling velocity are likely to evolve differently in distinct sections of partially mixed estuaries and differently in more turbid versus less turbid systems. In areas of relatively high inorganic sediment concentration, such as the upper estuary, organic matter and sediment will combine into larger, rapidly settling flocs, and more inorganic matter is likely to settle to the bed than in the absence of eutrophication. This may locally result in a net improvement in water clarity in the upper water column relative to less eutrophic conditions. When eutrophication occurs in the lower estuary, however, lower concentrations of inorganic sediment combined with increased organic matter will favor smaller, more slowly settling flocs. The net result will be more SPM in suspension and decreased water clarity. Because of these feedback mechanisms, it is also possible that partially mixed estuaries with relatively high inorganic SPM concentrations will see net improvement of upper water column clarity in response to eutrophication, while estuaries with low inorganic SPM concentrations will see marked degradation of water clarity.

This study synthesizes observations collected by the authors in three large, partially mixed estuaries located along the mid-Atlantic coast of the United States, specifically the Chesapeake Bay, the Potomac River, and the York River. Floc size distributions were determined via in situ laser diffraction and floc imaging, while organic and inorganic SPM concentrations were quantified by filtration of co-located water samples. Beam attenuation measured water clarity, and bulk floc density was estimated by dividing mass concentration by volume concentration. Floc settling velocity was estimated via a modified Stokes Law as a function of floc size and density. Size-specific floc settling velocity and bulk density were also estimated by settling camera image analysis where possible.

[1]Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, VA 23062, USA, Carl.Friedrichs@vims.edu
[2]Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, VA 23062, USA, kafall@vims.edu
[3]Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, VA 23062, USA, Grace.Massey@vims.edu
[4]University of Maryland Center for Environmental Science, Horn Point Lab, Cambridge, MD 21613, USA, lsanford@umces.edu