Impacts of the zebra mussel (*Dreissena polymorpha*) on large lakes: influence of vertical turbulent mixing

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Abstract: Vertical mixing processes and thermal structure of large lakes can impact the biological processes both through vertical transport processes and the exponential decay of light with depth. I investigated the role of these issues in algal consumption, production and influence on oxygen dynamics.

The impact of a benthic filter feeder limited by physical transport of algae to the benthos.

Hydrodynamics strongly influence the role of benthic filter feeders in benthic-pelagic trophic coupling in large lakes. I used an Acoustic Doppler Profiler to investigate the hydrodynamics of a near shore region of the Lake Erie western basin and then incorporated the measured parameters in a numerical simulation to estimate the amount of phytoplankton biomass consumed by zebra mussel grazing in the benthos. I compared my modeled results with vertical profiles of algal abundance. Diel average eddy diffusivity estimates varied from $10^{-5}$ to $10^{-4}$ m$^2$s$^{-1}$ at my sample site location. Our simulations indicated that eddy diffusivities of this order of magnitude can result in extremely low algal biomass near the benthos, while the upper water column remains relatively unaffected. Discounting inputs, I estimated that between 8 and 49% of the algal biomass is consumed each day at our sample site. Measured vertical biomass profiles have a zone of algal depletion near the benthos, but little evidence of depletion near the surface. I found the daily flow of algal biomass into the benthos was strongly coupled with turbulent mixing, suggesting the flux of algal biomass into the benthos was small compared with previously published estimates.

Primary production and the vertical structure and transport of algae.

Vertical mixing can cause changes in exposure to incident radiation. The depth of the wind-mixed layer and diel thermoclines often determine the light climate of individual plankters, which, due to the random nature of turbulence can be different for plankters at the same depth. Time scales associated with photoresponse are often similar to various mixing time scales, on time scales of minutes to hours. I developed a method to estimate primary productivity considering the effects of vertical turbulent mixing. I used the indirect temperature gradient microstructure method for calculating energy dissipation, from which I obtained Lagrangian diffusivity estimates. I then applied measured photosynthetic parameters and a random walk simulation using the diffusivity estimates to predict the light climate of the phytoplankton and thus the primary productivity.

Oxygen depletion in the central basin of Lake Erie

Patterson et al. (1985) developed the last comprehensive oxygen budget for the Lake Erie central basin, finding that six factors influence the vertical oxygen budget in the central basin: 1) Vertical mixing; 2) exchange across the air-water interface; 3) photosynthesis; 4) community respiration; 5) sediment oxygen demand (benthic respiration); and 6) horizontal transport. Patterson et al. (1985) were able to predict oxygen changes in
oxygen profiles, estimate the relative importance of these factors under various environmental conditions, and determine that bottom mixing is the most important parameter in delaying the onset of anoxia in the hypolimnion. Since 1980, when this budget was tested, however, the trophic status of the lake has undergone profound changes, primarily due to the changing phosphorus loading and introduction of the exotic zebra mussel into the lake. Therefore, I tested the importance of hypolimnion thickness on two critical measures of dissolved oxygen. First, oxygen depletion, a measure of the total loss of oxygen in the hypolimnion over time (expressed per unit area) gives us an understanding of the biological oxygen demand of the hypolimnion. This demand is often dominated by the decomposition of algae from the epilimnion at the sediment-water interface. Thus there is a flux of oxygen into the bed. If the hypolimnion were thoroughly mixed, we would expect the oxygen depletion to be independent of hypolimnion depth. However, it is not well mixed and thus a strong oxygen gradient can develop, limiting the supply of oxygen to the bed. If this were true the differing mixing condition brought about by differing hypolimnion thickness would cause dependence between the thickness and oxygen depletion. I also tested the role of transport processes, across time and the variation with depth, in oxygen transport in the central basin. I investigate this using my oxygen budget at differing times of day and quantified the relative importance of different transport processes.