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Application of Resource-Ratio Theory to Contaminant Transformation Phenomena in Natural Systems

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Resource-ratio theory is one of the major theoretical frameworks used in ecology to predict how competition for growth-limiting resources influences biological diversity and function within a biological community. This theory has been used to explain variations in the community structure and function of many environments, including species succession with terrestrial vascular plants; species succession and nitrogen fixation in freshwater lakes; and the microbial ecology of periodontal disease in humans. This presentation provides evidence that this general theory also can be used explain the affect of nutrient supply conditions on terrestrial and aquatic organic contaminant biodegradation.

The theory makes two major predictions about the relationship between contaminant degradation and nutrient supply conditions: 1) that changes in nutrient supply ratio conditions alter biodegradation rates (e.g. nitrogen:phosphorus (N:P) ratio for hydrocarbon degradation in soils or the carbon:P (C:P) ratio for herbicide degradation in aquatic systems), and that changes in the ratios result in consequential shifts in microbial community composition, and 2) that changes in the absolute nutrient supply levels, at constant supply ratios, alter the size of the biodegrading population, which also impacts degradation rates. The talk will first present previously reported results that how N and P supply conditions affect hydrocarbon degradation in soils (Smith et al., 1998; Graham et al., 1999). It was shown that hydrocarbon degradation rates were closely linked to the level of bio-available N and P within a system, although optimum nutrient supply conditions varied for the degradation of different classes of hydrocarbons.

The presentation will then show that resource-ratio theory also applies to the co-metabolic degradation of trace levels of herbicides in aquatic systems. We found that the transformation rate rate of alachlor, a common pre-emergence herbicide used throughout the world, increased significantly as C and P supply levels were increased. We had hypothesized that transformation rate should be linked with the absolute and relative C and P levels because autochthonous and allochthonous C is likely required as a co-substrate for the transformation of a herbicide like alachlor, and P is the usual the limiting-nutrient in aquatic ecosystems. We found that increases in transformation rate were correlated with the total microbial population size (a linear relationship), the size of the eukaryotic population (a linear relationship), and the size of the eubacterial population (a mixed-order relationship), as indicated by the levels of small sub-unit rRNA in the degradation system. Interestingly, the highest rates of transformation were seen in systems where the eubacterial population size was consistently larger than eukaryotic population size (that is primarily algae), suggesting that heterotrophic bacterial decomposition was primarily responsible for herbicide transformation. This suggests that microbial community composition, as well as microbial community size, impacted the co-metabolic degradation rates of alachlor, as would be predicted by resource-ratio theory. It is hoped that this paper will further encourage the application of resource-ratio theory to understanding the functional interactions and key activities of organisms in macroscopic and microscopic ecosystems.

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