

## POPULATION, COMMUNITY, AND ECOSYSTEM VARIATES AS ECOLOGICAL INDICATORS: PHYTOPLANKTON RESPONSES TO WHOLE-LAKE ENRICHMENT

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*Abstract.* We quantified the reliability of phytoplankton population, community, and ecosystem variates as indicators of whole-lake enrichment. Variates with high sensitivity to perturbation and low background variability were assumed to be more reliable indicators than variates with low sensitivity or high variability. Our data set included weekly data in four lakes (three manipulated and one reference) during two pretreatment summers and two summers of enrichment. We determined background variability by evaluating change in each variate from year to year in the reference lake throughout the experiment and in each manipulated lake during the pretreatment period. We evaluated sensitivity to enrichment using the frequency of departure from expected conditions for each variate during the period of experimental enrichment. Using this information, we then (1) tested the expectation that species populations are more reliable indicators of perturbation than ecosystem variates (biomass, chlorophyll, and primary productivity), and (2) evaluated whether community variates (genera, taxonomic divisions, allometric variates, and community diversity) were reliable indicators of enrichment.

Contrary to expectations from other perturbations, phytoplankton species populations were less reliable indicators of enrichment than community and ecosystem variates. Chlorophyll, species diversity, and species evenness were the most reliable indicators of enrichment: each changed significantly only during the first year of enrichment and only in the three enriched lakes. Simultaneous changes in multiple taxonomic divisions also signaled enrichment very reliably. In contrast, the frequency of significant changes in species populations differed little between the reference lake and the enriched lakes, even after experimental enrichment. Changes in species were difficult to detect reliably due to high background variability in all four lakes: most taxa were not present often enough during a single year to assess reliably whether they had increased or decreased compared to the previous years. Genera and allometric variates were also unreliable indicators due to high variability and moderate sensitivity, respectively. Reliable indicators of phytoplankton responses to enrichment were very different from reliable indicators of animal responses to toxic stressors, suggesting that it may be difficult to make generalizations regarding the use of population, community, and ecosystem variates as indicators of a wide array of perturbations.

*Key words:* diversity; dynamic linear model; ecological indicators; natural variability; nutrient enrichment; perturbation; phytoplankton; taxonomy; whole-lake experiments.