United States
Environmental Protection
Agency

Environmental Monitoring Systems
Laboratory
Las Vegas NV 89114

Research and Development

EPA-600/S3-81-001 Feb. 1981

EPA

Project Summary

Modifications of Models Predicting Trophic State of Lakes: Adjustment of Models to Account for the Biological Manifestations of Nutrients

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The strong relationship between total phosphorus and phytoplankton biomass in lakes has been clearly confirmed by researchers. What is now needed to predict algal biomass for making better management decisions for individual lakes is a quantitative understanding of the range in biomass (as measured by chlorophyll *a*) per unit of phosphorus. This range extends over several orders of magnitude.

To determine the environmental factors affecting the response of phytoplankton chlorophyll *a* to total phosphorus concentration, collected data from 757 U.S. lakes were analyzed showing that light attenuation from interferences not related to chlorophyll *a* can dramatically affect the quantity of phytoplankton biomass in many U.S. lakes. The ratio of biologically available phosphorus to nitrogen is, in some cases, an important factor in determining the amount of chlorophyll *a* produced per unit of phosphorus present.

This report presents methods to modify nutrient ambient- and loading-models that predict the trophic state of lakes to:

1. **change the trophic classification based on an ambient total phosphorus level to one based on the biological manifestation of nutrients as measured by chlorophyll *a*,**
2. **allow determination of the critical levels of phosphorus that will result in unacceptable levels of chlorophyll *a*, and**
3. **account for the unique characteristics of a lake that affect the amount of chlorophyll *a* produced per unit of phosphorus.**

If chlorophyll *a* is used as the trophic classification criterion rather than total phosphorus, many U.S. lakes would be classified lower, i.e., less eutrophic.

This Project Summary was developed by EPA's Environmental Monitoring Systems Laboratory, Las Vegas, NV, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Phosphorus supply is considered to be the primary determinant of algal community biomass and production in most temperate zone lakes.

Researchers clearly confirm the strong correlation between total phosphorus and phytoplankton biomass (as measured by chlorophyll *a*). What is presently needed to predict algal biomass for management decisions on individual lakes is a quantitative understanding of the range in biomass (chlorophyll *a*) per unit of phosphorus; this range extends over orders of magnitude.

Existing models predict ambient total phosphorus lake concentration from tributary phosphorus loading data. These and similar models are widely used to indicate the degree of eutrophy of lakes and to evaluate the environmental effects of ambient phosphorus levels in lakes and, accordingly, to make decisions about lake management. For example, they can be used to manipulate ambient total phosphorus concentration to produce a desired environmental effect. All these models use levels of 10 and 20 micrograms per liter of ambient phosphorus concentrations to divide lakes into three standard trophic classifications—oligotrophic, mesotrophic, and eutrophic—on the assumption that the relationship of phytoplankton biomass to phosphorus is the same for all lakes.

However, the use and incorporation of phosphorus into phytoplankton biomass varies significantly from lake to lake. The efficiency of use of phosphorus is largely dependent on the availability of light, sufficient supply of other nutrients, and biological availability of the various phosphorus species.

The use of these models to predict phytoplankton biomass from actual or potential phosphorus concentrations in individual bodies of water could lead to faulty management decisions if the factors affecting the use of phosphorus are not taken into consideration. This study evaluates the factors affecting the relationship of phytoplankton biomass to phosphorus levels and shows how to modify models predicting the trophic state of lakes to take these factors into account. The data base used to evaluate the factors was derived from data collected in the National Eutrophication Survey during the spring, summer and fall of 1972 through 1975, and involved 757 of the lakes surveyed throughout the 48 conterminous States.

Conclusions

Previous workers have established a strong relationship between CHLA (a measure of phytoplankton biomass) and total phosphorus in lakes. They report an extremely high log-log product moment correlation coefficient ranging from 0.85 to 0.98 between chlorophyll *a* and total phosphorus in lakes. The implication of these findings is that phosphorus is the element that controls algal biomass. However, we believe that the relationship between chlorophyll *a* and total phosphorus described by these workers represents the situation under nearly ideal conditions, i.e., without major interferences.

In this study of 757 U.S. lakes, a log-log product moment correlation coefficient of only 0.60 was found between chlorophyll *a* and total phosphorus, and the response ratio (i.e., the amount of chlorophyll *a* produced per unit of total phosphorus) was found to vary greatly. It therefore appeared that many U.S. lakes do not reach maximum production of chlorophyll *a* because of interference factors.

Interference factors that may prevent phytoplankton chlorophyll *a* from achieving maximum theoretical concentrations based upon ambient total phosphorus levels in a lake include availability of light, limitation of growth factors other than total phosphorus components, domination of the aquatic flora by vascular plants rather than phytoplankton, short hydraulic retention time, and the presence of toxic substances. We found that light attenuation from non-chlorophyll *a* related interferences can dramatically affect the quantity of phytoplankton biomass present in lakes In some cases the ratio of biologically available phosphorus to nitrogen is an important factor in determining the amount of chlorophyll *a* produced per unit of total phosphorus, while temperature is not an important factor.

Most of the trophic classification schemes for lakes use nutrient levels rather than the biological manifestation of nutrients as measured by chlorophyll *a* as the basis of classification. When classified on the basis of chlorophyll *a* rather than total phosphorus, 25 percent of the 757 lakes used in the study were classified lower, i.e., less eutrophic. If, in fact, the large population of lakes used in this study is representative of conditions throughout the U.S., and if the manifestations of nutrients rather than their absolute concentrations are the primary criteria for beneficial water use, many communities could be spared the burden of costly nutrient-removal programs suggested by phosphorus-based trophic classifications.

This study developed methods to modify loading and ambient models that predict the trophic state of lakes to (1) change the trophic classification based on an ambient total phosphorus level to one based on the biological manifestation of nutrients measured by chlorophyll *a*; (2) determine the critical levels of total phosphorus which will result in an unacceptable level of chlorophyll *a* so that the level of total phosphorus can be manipulated to achieve the desired use of a given waterbody; and (3) account for the unique characteristics of a lake that affect the amount of chlorophyll *a* produced per unit of total phosphorus.

Recommendations

The commonly used ambient and loading models predict the trophic state of a lake from total phosphorus levels and assume that all lakes will respond in the same manner to a given ambient total phosphorus concentration. Because non-chlorophyll *a* light interferences and other interferences in many U.S. lakes significantly decrease the amount of chlorphyll *a* produced per unit of total phosphorus, and since excessive algal growth or other manifestations of nutrients are more important from a water quality standpoint than a trophic classification based on an arbitrary ambient total phosphorus level, we recommend that ambient and loading models predicting trophic state be adjusted to account for the amount of chlorophyll *a* produced per unit of total phosphorus in a lake.

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The complete report, entitled "Modifications of Models Predicting Trophic State of Lakes: Adjustment of Models to Account for the Biological Manifestations of Nutrients," (Order No. PB 81-144 362; Cost: $6.50, subject to change) will be available only from:

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★ U.S. GOVERNMENT PRINTING OFFICE: 1981 -757-064/0258

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