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TRENDS IN SUMMER PHOSPHORUS, CHLOROPHYLL, AND WATER CLARITY IN THE YAHARA LAKES, 1976-1988

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Lakes Mendota, Monona, Waubesa, and Kegonsa, collectively called the Yahara lakes, are located near Madison in southern Wisconsin (Fig. 1). Algal blooms in the lakes are a continuing concern, particularly during summers when blue-green algae are dense. Besides causing objectionable "green" water, the blue-green algae can form noxious surface scums that accumulate and decompose along downwind shorelines. Algal blooms also decrease light penetration, thereby restricting the growth of macrophytes important as fish habitat.

My objective in this article is to present trends in the summer levels of phosphorus (P), chlorophyll-*a* (Chl-*a*), and water clarity in the Yahara lakes from 1976-88. These 3 interrelated parameters are indices of lake trophic state (degree of fertility). In the Yahara lakes, algal blooms are symptoms of lake eutrophication accelerated by excessive loadings of phosphorus and other nutrients that have been entering the lakes since the late 1800s. A more complete treatment of this subject will be presented in detailed technical reports in preparation.

Methods

Data used in this report were collected by the Bureau of Research as part of our long-term research study of the 4 lakes. Lake sampling was conducted at the deep-hole location in each lake. Water samples for both total P and dissolved reactive P (TP and DRP) were collected at 0 meters and for Chl-*a* at 0-2 m. The P analyses were performed at the Delafield Research Laboratory in 1976-79 and the State Lab of Hygiene in 1980-88 using prescribed U.S. Environmental Protection Agency (EPA) methods. Chl-*a* analyses were conducted at field headquarters using EPA's trichromatic technique. Water clarity was measured by recording the depth of disappearance/reappearance of a 20 cm black and white Secchi disk lowered into the water. The "summer" sampling period was defined as 30 June to 1 September, but it included sampling dates

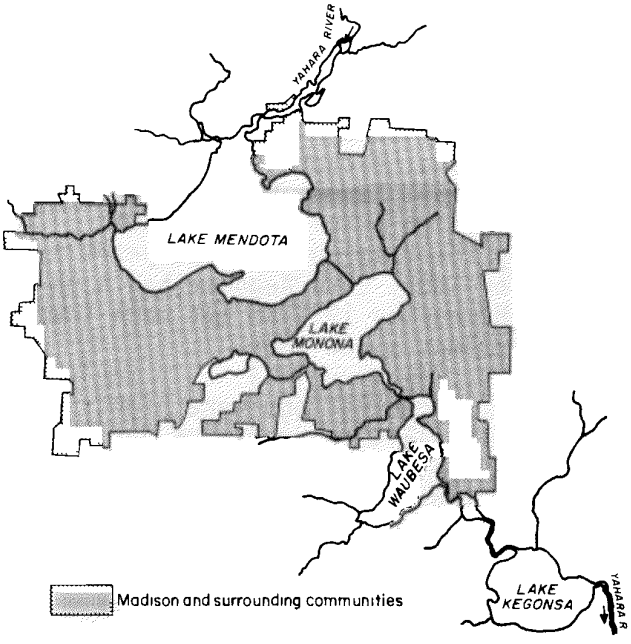

FIGURE 1. Location of the Yahara lakes.

either before or after that period when the entire top 6 m of lake water were warmer than 22 C. Lake Mendota had generally 4-5 summer sampling dates for most years, except 1977 (2), 1978 (3), 1982 (3), and 1987 (13). Lake Monona had 4-6 summer sampling dates except in 1977 (2) and 1987 (9). Lakes Waubesa and Kegonsa had 3 or more sampling dates in all summers except 1977 (1), 1978 (2), and 1985-86 (2). Kegonsa was sampled twice in 1979 and 1983.

Phosphorus Trends

Phosphorus is generally the nutrient causing lake eutrophication. Surface water concentrations of DRP are an indicator of the P supplies for algal growth during summer months. When DRP is below analytical detection (<0.004 mg P/L), P may be growth-limiting to algae. When DRP is higher, P is generally not growth-limiting. The excess DRP may actually promote luxury P consumption by the algae. TP concentrations in the lake surface waters generally correspond to the overall amount of P that has been taken up by algae (particulate P) plus the P that is dissolved and potentially available for algal growth.

Summer DRP concentrations in Lake Mendota generally were very low during 1976-88, with concentrations well above analytical detection only in 1977 and part of 1985 (Fig. 2). Similar DRP trends were found in Lake Monona, except that DRP was much higher in 1985. Summer DRP in Waubesa was relatively high prior to 1982, but generally lower in more recent years except for 1985. Lake Kegonsa had high summer DRP during 1976-84 but much lower concentrations since then.

Summer TP concentrations were highly variable in all 4 Yahara lakes during 1976-88 (Fig. 2). Median TP concentrations were relatively similar in Mendota and Monona, higher in Waubesa, and the highest in Kegonsa, particularly during the late 1970s. However, all 4 lakes have experienced a general decline in TP from the late 1970s to 1988. Although TP increased noticeably in Mendota and Monona in 1985, TP was the lowest in all 4 lakes in 1988.

Chlorophyll-a Trends

Chl-*a*, the primary photosynthetic pigment, is a direct measure of algal biomass. Three major inferences can be made from the Chl-*a* data about summer algal blooms in the Yahara lakes: (1) phytoplankton biomass levels were highly variable each summer; (2) median summer biomass levels were relatively similar in Mendota and Monona, higher in Waubesa, and highest in Kegonsa; and (3) median summer biomass levels have generally dropped since 1976 (Fig. 2).

Water Clarity Trends

Secchi disk transparency readings represent an easily understood measure of the water clarity of the Yahara lakes, or how "green" the lakes are perceived. Secchi readings <1.0 m can be classified as "very poor," 1.0-1.5 m as "poor," 1.5-2.0 m as "fair," 2.0-3.0 m as "good," and >3.0 m as "very good" (Lillie and Mason 1983). Variability in the summer readings adds subjectivity and imprecision to any classification system.

The water clarity of the 4 Yahara lakes has varied between lakes and has changed over time in each lake since 1976 (Fig. 2). Summer Secchi readings in Mendota during 1976-84 were 1-2 m, and averaged about 1.5 m, except in 1983 when they were >2 m. In 1985 when P concentrations were higher and the algal blooms were more intense than in other years, Secchi readings averaged about 1 m. However, water clarity in Mendota has improved since then with the majority of readings in the 2-3 m range in 1986-87. In 1988, the deepest summer Secchi readings (>4 m) in the Yahara lakes were recorded in Mendota during July.

Water clarity trends in Monona have been similar to those in Mendota, but some differences are noteworthy. Secchi disk readings for Monona were occasionally >2 m for a number of years between 1976-84, but median summer readings were 1.0-1.5 m in 1976-79 and 1981. However, median readings were substantially better in 1980, 1982-84, and 1987-88. Waubesa water clarity was generally very poor during 1976-80, with most readings <1 m.

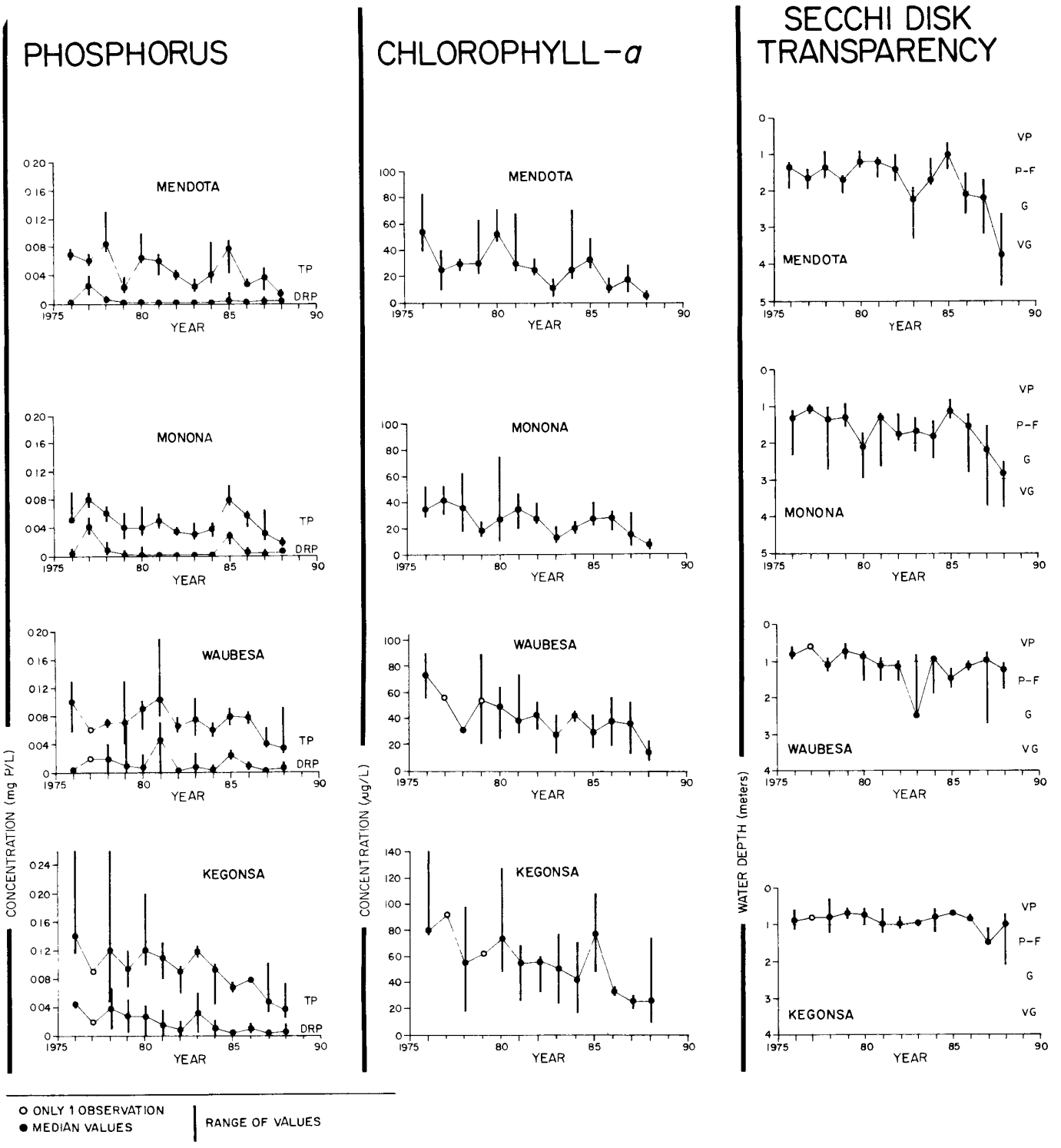

FIGURE 2. Trends in summer phosphorus (total phosphorus and dissolved reactive phosphorus), chlorophyll-a, and Secchi disk transparency for the Yahara lakes, 1976-88. For Secchi disk transparency, VP=very poor, P=poor, F=fair, G=good, and VG=very good.

Water clarity has increased somewhat since then. Summer Secchi readings in Kegonsa were consistently <1 m during 1976-86. A slight improvement was observed in 1987-88.

Summary and Conclusions

The P, Chl-*a*, and Secchi transparency data all indicate that the summer water quality of the 4 Yahara lakes is getting better. However, algal blooms in Waubesa and Kegonsa still produce poor water clarity. Water clarity in Mendota and Monona in the past 2-3 summers has been good, particularly in 1988.

In a previous *Findings* (No. 11, April 1988) I summarized other data indicating that P has been decreasing in all 4 Yahara lakes since the late 1970s and concluded that this trend corresponded to lower than normal spring runoff in most years during 1977-88. Since sewage diversion in 1971, the majority of Mendota's P loading comes from runoff. Monona, Waubesa, and Kegonsa also receive urban and rural runoff, but most of their P loading comes from the Yahara River, which discharges from each upstream lake in the chain. Coupled with reduced river flow because of less runoff, the lower P concentrations in each upstream lake have caused less P loading to downstream lakes. P levels have dropped and water quality improvements have occurred. In Waubesa and Kegonsa, the P loading reductions have resulted in summer DRP concentrations becoming close to analytical detection in recent years, an indication that P is becoming growth-limiting to the summer algae.

Further decreases in P loadings to all the Yahara lakes should result in less severe summer algal blooms. However, if runoff were substantially greater in future years, then P loadings will increase and a reversal to the recent water quality improvements may occur. Watershed management practices can prevent part of these loading increases from occurring and may decrease P loadings even further during periods of low to normal runoff.

Literature Cited

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