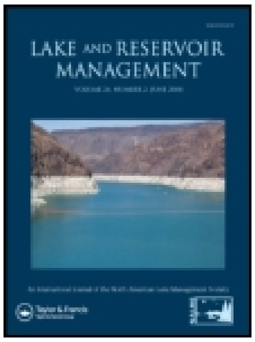

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ASSESSING THE TROPHIC STATUS OF LAKES WITH AQUATIC MACROPHYTES

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ABSTRACT

We propose that as a first approach the trophic status of natural and artificial lakes having growths of aquatic macrophytes may be assessed by using the total nutrient concentration in the water column (nutrients contained in the macrophytes plus those in the water) in conjunction with existing classification systems. We developed our approach because current approaches for assessing the trophic status of lakes do not adequately classify lakes dominated by aquatic macrophytes. This occurs because conventional sampling and trophic state assessment emphasize conditions in the water and do not consider the nutrients, plant biomass, or organic production associated with macrophytes. Relationships between aquatic macrophytes and other trophic indicators are discussed because changes in macrophyte abundance influence the structural and functional characteristics of lakes. These changes alter perceptions of water quality and overall lake quality.

INTRODUCTION

Aquatic macrophytes are found in nearly all of the world's lakes. In many, these plants contribute significantly to nutrient cycling and primary productivity (cf. Wetzel, 1975; Ewel and Fontaine, 1983; Shireman et al. 1982). Studies of macrophytes have also shown that these plants can influence the structure and function of other biotic communities within a lake (Shireman et al. 1982). Yet with the exception of the Lake Evaluation Index (Porcella et al. 1979), existing lake classification systems use only classical indicators such as open-water nutrient concentrations, algal biomass expressed as chlorophyll *a*, and water transparency as measured by using a Secchi disk to assess lake trophic status (e.g., Likens, 1975; Carlson, 1977; Forsberg and Ryding, 1980; Kratzer and Brezonik, 1981).

Even the Lake Evaluation Index, which includes a term for macrophyte coverage, gives no consideration to the nutrients, plant biomass, or organic production associated with macrophytes. Thus, large errors in trophic state assessment can occur when classifying macrophyte-dominated lakes. For example, in Lake Baldwin (Fla.), Secchi disk transparencies were greater than 5 m, total phosphorus concentrations averaged 11 mg/m^3, and chlorophyll *a* concentrations were less than 3 mg/m^3 when extensive growths (156 g dry wt/m^2) of hydrilla (*Hydrilla verticillata*) covered 80 percent of the lake bottom (Canfield et al. 1983a).

If only the open water nutrient and algal biomass values were considered, Lake Baldwin would be classified as oligotrophic (e.g., Forsberg and Ryding, 1980) and given a low trophic state index (TSI) value. Yet, the quantity of macrophytes clearly indicates the lake is eutrophic. Current trophic classification approaches classified Lake Baldwin as eutrophic only after submersed macrophytes were removed by grass carp (*Ctenopharyngodon idella*) and the ecological structure of the lake changed (macrophytes to phytoplankton); Secchi disk transparencies decreased to less than 2 m, total phosphorus concentrations averaged 30 mg/m^3, and chlorophyll *a* concentrations averaged 20 mg/m^3 (Canfield et al. 1983a).

The case of Lake Baldwin raised the question of how we should assess the trophic status of lakes if the simple trophic standards of total phosphorus, total nitrogen, chlorophyll *a*, and Secchi disk transparency are unreliable trophic indicators in lakes having extensive growths of aquatic macrophytes. In this paper, we review our efforts to resolve this problem. We discuss our recent proposal (Canfield et al. 1983b) that as a preliminary approach the trophic status of lakes having growths of aquatic macrophytes may be assessed by adding the nutrients in the macrophytes to the nutrients in the water and then using the potential water column nutrient concentration in conjunction with existing classification systems (e.g., Carlson, 1977) to classify the lake. We also discuss an empirical multivariate regression equation (Canfield et al. 1984) describing the influence of nutrient (total phosphorus and total nitrogen) concentrations and macrophyte abundance (expressed as a percent of a lake's total volume infested) on planktonic chlorophyll *a* concentrations. Finally, we discuss problems that occur when the trophic state concept and trophic state index values are used to communicate lake quality.

TROPHIC STATE AND AQUATIC MACROPHYTES

The concept of trophic state has been reviewed and discussed many times (Hutchinson, 1969; Rodhe, 1969; Carlson, 1979; Shapiro, 1979). However, as noted by Carlson (1979) the meaning of the concept is still not generally agreed upon because of its two basic aspects: Some limnologists define trophic state based on the supply of nutrients entering a lake or the in-lake nutrient concentration whereas others prefer to define trophic state based on the biology of the lake (e.g., primary production or chlorophyll *a* concentration). Hutchinson (1969), however, suggested that we should not think of oligotrophic or eutrophic water types, but of lakes and their drainage basins as forming oligotrophic or eutrophic systems. He further suggested that trophic determinations should be based on the total potential concentration of nutrients since at any given time a low concentration in the water may result because part of the lake's nutrient supply is tied up elsewhere in the system (e.g., sediments or the bodies of organisms like macrophytes).

Although this approach would be difficult to implement due to problems associated with measuring nutrients in all components of the system, we concluded a modification of this approach might provide a reasonable first approximation of the trophic status of lakes having extensive growths of aquatic macrophytes. We hypothesized that as a preliminary approach, trophic determinations could be based on a potential water column nutrient concentration which would be determined by adding the nutrients in the macrophytes to the nutrients in the water. This approach is consistent with Hutchinson's (1969) suggestion and it is consistent with methods that use in-lake nutrient concentrations determined by nutrient loading, hydrology, and lake morphometry as a major component of trophic state assessment (Dillion, 1975; Vollenweider, 1968, 1975, 1976; Canfield and Bachmann, 1981).

To test our hypothesis, we sampled six Florida lakes covering a range of limnological characteristics (Table 1) during September and October 1981 (the period of peak macrophyte abundance) to determine the nutrient content of the water and the biomass and nutrient content of the submersed aquatic macrophytes. We used these data to estimate the total potential phosphorus content of the water column (WCP values). Phosphorus was emphasized as the criterion for trophic state assessment because phosphorus is often the limiting nutrient in lakes and these Florida lakes had nitrogen to phosphorus ratios greater than 10 (Table 1). Nitrogen, however, could be used for nitrogen-limited lakes (see Kratzer and Brezonik, 1981). Details of the procedure are given in Canfield et al. (1983b).

Total submersed macrophyte biomass in the study lakes ranged from 18,100 kg dry wt in Lake Kerr to 2,170,000 kg dry wt in Lake Lochloosa (Table 2). The WCP values were 1.2 to 26 times the measured open-water concentrations with 20 to 96 percent of the phosphorus associated with submersed macrophytes (Table 2). We found the effect of macrophytes on WCP values depends on the quantity of macrophytes relative to the total lake volume. For example, Lake Fairview has extensive growths (49 g dry wt/m^3) of submersed macrophytes. Based on our measured open-water total phosphorus concentrations (10 mg/m^3) and conventional criteria (Likens, 1975; Forsberg and Ryding, 1980) we would classify Lake Fairview as oligotrophic. The calculated Carlson (1977) TSI value would be 37.

Table 1.—Average chemical conditions for the surface waters of six Florida lakes between September 1979 and August 1980 (Canfield, 1981).

Lake	pH	Total Alkalinity (mg/l as $CaCO_3$)	Specific Conductance (µmhos/cm at 25°C)	Total P (mg/m^3)	Total N (mg/m^3)	Chlorophyll *a* (mg/m^3)	Secchi Depth (m)
Down	6.5	3	208	8	310	1.0	6.2
Fairview	8.0	52	173	15	450	2.5	4.8
Kerr	6.1	3	105	13	220	1.5	3.3
Lochloosa	7.4	23	77	36	1200	32	0.7
Okahumpka	8.3	50	177	14	880	5	1.2^A
Stella	7.0	16	239	13	460	3	4.1

^{A}Secchi depth represents bottom readings

Table 2.—Comparison of TSMB, total submersed macrophyte biomass; TSMP, total submersed macrophyte phosphorus; SA, surface area; V, volume; TP, measured total phosphorus concentration; WCP, potential water column phosphorus assuming 100 percent release of phosphorus from the macrophytes; and TSMB•V^{-1}, macrophyte concentration measured in six Florida lakes during September-October 1981. Numbers in parentheses for TSMB are 95 percent confidence interval. For other variables, numbers represent empirical 95 percent confidence intervals calculated assuming all errors are associated with measurements of TSMB (from Canfield et al. 1983b).

Variable	Lake					
	Kerr	Down	Stella	Lochloosa	Fairview	Okahumpka
TSMB (kg dry wt)	18,100 (±6,100)	82,800 (±17,700)	139,000 (±30,000)	2,170,000 (±530,000)	211,000 (±48,500)	500,000 (±118,000)
TSMP (kg)	65 (±22)	132 (±28)	180 (±39)	5,640 (±1,380)	300 (±69)	1,050 (±250)
SA (ha)	1,130	360	123	2,190	114	208
V (m^3)	42,000,000	12,000,000	4,300,000	46,000,000	4,300,000	2,600,000
TP (mg•m^{-3})	8	9	12	25	10	16
WCP (mg•m^{-3})	9.6 (±0.5)	20 (±2)	54 (±9)	148 (±30)	80 (±16)	420 (±96)
TSMB•V^{-1} (g dry wt•m^{-3})	0.4 (±0.2)	7 (±1)	32 (±7)	47 (±12)	49 (±11)	192 (±46)

Using the calculated WCP value (80 mg/m^3), however, the Carlson TSI value would be 67 and the lake would be classified as eutrophic, which is similar to other lakes located in the same physiographic region (Canfield, 1981). In contrast, macrophyte abundance in Lake Kerr is negligible relative to the total lake volume (0.4 g dry wt/m^3). The WCP value was only 1.6 mg/m^3 higher than the measured total phosphorus concentration of 8 mg/m^3 (Table 3). Thus, the nutrients contained in the macrophytes would not affect the trophic classification of the lake.

To determine if our approach provides reasonable estimates of open-water phosphorus concentrations in lakes where macrophyte abundance is low, we compared our predicted WCP value with the measured open-water phosphorus concentration in Lake Baldwin, Fla., where submersed macrophytes were removed by grass carp (*Ctenopharyngodon idella*). In 1978, Lake Baldwin supported approximately 100,000 kg dry wt of hydrilla which contained 140 kg of phosphorus (Shireman and Maceina, 1981; Canfield et al. 1983a). Open-water phosphorus values averaged 11 mg/m^3. We calculated a WCP value for Lake Baldwin of 52 mg/m^3. After hydrilla was eliminated by the grass carp, the open-water phosphorus concentration in the lake averaged 30 mg/m^3, substantially lower than our initial calculated WCP value. However, we did not account for the phosphorus (72 kg) retained by the grass carp (Canfield et al. 1983a). If the phosphorus consumed by the grass carp is subtracted from that contained in the macrophytes, Lake Baldwin's WCP value would be 31 mg/m^3 which agrees with the measured phosphorus concentration. We also found that our calculated WCP values for our six study lakes were comparable to open-water phosphorus concentrations measured in phytoplankton dominated lakes located in the same physiographic region (Canfield et al. 1983b).

Although using WCP values for trophic assessment presents some potential problems, including the fact that estimating WCP values is a relatively labor intensive process that is inconsistent with current approaches to trophic state classification that require minimal data (Carlson, 1977; Kratzer and Brezonik, 1981; Osgood, 1982), we believe our approach reduces the danger of incorrectly assessing trophic status for macrophyte-dominated lakes (see Canfield et al. 1983b). This is especially important because regulatory and management decisions are often made using open-water nutrient, chlorophyll *a*, and Secchi disk transparency data obtained from limnological surveys. Values for WCP may also prove useful in predicting the impact of changes in macrophyte abundance on limnological characteristics when the nutrient supply to the lake remains unchanged. Currently, there are no accepted methods for evaluating how open-water nutrient concentrations, chlorophyll *a* values, and Secchi transparencies will change with partial to complete removal of macrophyte biomass by natural factors or management practices (harvesting, herbicides, or herbivores).

At this time, however, we cannot provide definitive criteria for when WCP values should be considered in trophic state assessment. We suggest that the importance of using WCP values to evaluate the trophic status of lakes having aquatic macrophytes is directly related to the macrophyte abundance per volume of lake or epilimnion (our lakes were not thermally stratified). Our analysis indicates that macrophytes have little effect on trophic state assessment when $<$ 25 percent of the phosphorus in the water column is associated with macrophytes and the mean macrophyte concentration in the lake is less than 1 g dry wt/m^3 (Canfield et al. 1983b). Until more lakes are sampled to provide such criteria, we believe that decisions to use WCP values should be made on the basis of the extent of macrophyte coverage (% of surface area) in relation to lake volume. For large deep lakes with small littoral areas, the effect of macrophytes on lake trophic state assessment will be negligible. Our approach, however, is likely to be most useful when classifying shallow macrophyte-dominated lakes.

RELATIONS BETWEEN MACROPHYTE AND OTHER TROPHIC INDICATORS

Studies of lakes having a wide range of limnological conditions and located in different geographical areas have demonstrated a strong relation between total phosphorus and nitrogen concentrations and chlorophyll *a* concentrations (Sakamoto, 1966; Smith, 1982;

Table 3.—Chlorophyll *a* concentrations (mg/m^3, predicted by use of Eq. 4) in five hypothetical cases which depict different combinations of total phosphorus (TP), total nitrogen (TN), and percent of the total lake volume infested with macrophytes (PVI). Values in parentheses are Secchi disk transparences (m) predicted using the Secchi-chlorophyll relationships of Jones and Bachmann (1978). Table is from Canfield et al. 1984.

	Hypothetical Case				
PVI	1	2	3	4	5
TP =	10	20	40	80	160
(%)					
TN =	200	400	800	1600	3200
0	3.5 (3.2)	8.7 (2.0)	21 (1.2)	53 (.7)	129 (.4)
10	3.1 (3.4)	7.8 (2.1)	19 (1.3)	47 (.8)	115 (.5)
20	2.8 (3.6)	6.9 (2.2)	17 (1.4)	42 (.8)	102 (.5)
30	2.5 (3.9)	6.2 (2.4)	15 (1.5)	37 (.9)	91 (.5)
40	2.2 (4.1)	5.5 (2.5)	13 (1.6)	33 (.9)	81 (.6)
50	2.0 (4.4)	4.9 (2.7)	12 (1.6)	30 (1.0)	72 (.6)
60	1.8 (4.6)	4.4 (2.8)	11 (1.7)	26 (1.1)	65 (.7)
70	1.6 (4.9)	3.9 (3.0)	10 (1.8)	23 (1.2)	58 (.7)
80	1.4 (5.3)	3.5 (3.2)	8.5 (2.0)	21 (1.2)	51 (.7)
90	1.3 (5.5)	3.1 (3.4)	7.6 (2.1)	19 (1.3)	46 (.8)
100	1.1 (6.0)	2.8 (3.6)	6.8 (2.2)	17 (1.4)	41 (.8)

Canfield, 1983). Other studies have shown a significant hyperbolic relation between water transparency and algal biomass (Bachmann and Jones, 1974; Dillon and Rigler, 1975; Canfield and Hodgson, 1983). From these studies, simple quantitative empirical models have been developed to describe these relations (Jones and Bachmann, 1976, 1978; Smith, 1982; Canfield, 1983; Canfield and Hodgson, 1983).

Despite these research efforts, however, relations between macrophytes and other trophic indicators such as planktonic chlorophyll *a* concentrations remain poorly defined. Although it is generally recognized that macrophytes, especially submersed macrophytes, can inhibit the development of phytoplankton (Hasler and Jones, 1949; Hogetsu et al. 1960; Goulder, 1969), existing macrophyte studies have provided no quantitative information on how different levels of macrophyte abundance influence planktonic chlorophyll *a* concentrations in lakes. This lack of quantitative information has contributed to the problems associated with classifying the trophic status of macrophyte-dominated lakes.

Our initial efforts to quantify relationships between macrophytes and other trophic indicators centered on two whole-lake manipulations (Lake Baldwin and Lake Pearl, Fla.) where herbicides and grass carp were used to reduce macrophyte abundance. Details of these studies are given in Canfield et al. (1983a, 1984) and Shireman et al. (1983). In both studies, we found no relation between macrophyte coverage and total phosphorus, total nitrogen, Secchi disk, or chlorophyll *a* values. This agrees with the findings of Huber et al. (1982) for chlorophyll *a* concentrations. We found, however, that over time chlorophyll *a* concentrations (CHLA) were inversely related to the percentage of the lake's total volume infested with macrophytes (PVI) (Fig. 1). For Lake Pearl, the correlation between CHLA and PVI was -0.63 ($P < 0.001$).

To test the hypothesis that variations in the percent of a lake's total volume infested with macrophytes could be a component of the variance in nutrient-chlorophyll regressions (Canfield, 1983), we sampled 32 Florida lakes to determine total phosphorus (TP), total nitrogen (TN), chlorophyll *a* (CHLA), and PVI levels. Details are given in Canfield et al. (1984). Using the TP, TN, CHLA, and PVI data, we developed regression models to determine if the addition of a term for PVI could improve the predictive ability of nutrient-chlorophyll models. Although limited, our sampling included a wide range of limnological conditions. Concentrations of TP ranged from 0.6 to 159 mg/m^3 and TN concentrations ranged from 65 to 6,020 mg/m^3. Values of CHLA ranged from 0.5 to 174 mg/m^3 and PVI levels ranged from 0 to 95 percent. Regression models for our data set were:

$$\log \mathrm{CHLA} = -0.40 + 1.09 \log \mathrm{TP} \qquad R^2 = 0.73 \quad (1)$$

$$\log \mathrm{CHLA} = -2.24 + 1.16 \log \mathrm{TN} \qquad R^2 = 0.78 \quad (2)$$

$$\log \mathrm{CHLA} = -1.65 + 0.51 \log \mathrm{TP} + 0.73 \log \mathrm{TN} \qquad R^2 = 0.82 \quad (3)$$

$$\log \mathrm{CHLA} = -2.08 + 0.28 \log \mathrm{TP} + 1.02 \log \mathrm{TN} - 0.005\,\mathrm{PVI} \qquad R^2 = 0.86 \quad (4)$$

By incorporating a PVI term (Eq. 4), we found that an additional 4 percent of the variance in our chlorophyll data was accounted for. Regression coefficients for TP and TN in Eq. 4 were also similar to those reported by Canfield (1983). Although small, the 4 percent increase in R^2 was significant and suggested, similar to the findings at Lake Pearl and Lake Baldwin, that the percent of a lake's total volume infested with aquatic macrophytes significantly influences planktonic chlorophyll concentrations in lakes.

Our regression equation (Eq. 4) suggests the potential impact of macrophytes on chlorophyll yields in lakes varies with trophic state. To assess the possible impact of different levels of macrophyte abundance in lakes ranging from oligotrophic to eutrophic, we used Eq. 4 to predict CHLA values for five different combinations of TP and TN values (assuming phosphorus limitation and a TN:TP = 20:1) given PVI values ranging from 0 to 100 percent (Table 3). For a nutrient-poor lake such as Case 1 (Table 3), the expected reduction in CHLA with increasing macrophyte abundance is small even if macrophytes could occupy 100 percent of the lake volume. Major changes in Secchi disk transparencies, however, could occur if major changes in PVI occurred. In Case 2 and 3 (Table 3), a large increase in macrophyte abundance could substantially reduce chlorophyll yields and change the trophic classification of a lake. It is also likely that improvements in water transparency would be noted by the public as PVI values increase and chlorophyll values decrease. For nutrient-rich lakes (Case 4 and 5), the change in CHLA would be large but even at a PVI of 100 percent there would be sufficient chlorophyll to classify a lake as eutrophic and to maintain reduced water transparency.

We are not certain of the causative mechanisms of the inverse relationship between chlorophyll *a* concentrations and the percent of a lake's total volume infested with aquatic macrophytes. Several factors, however, are probably involved, including: (1) release and uptake of nutrients by macrophytes and their associated epiphyton; (2) reduction in nutrient cycling because macrophytes reduce wind mixing and the resuspension of nutrients from the bottom sediments; and (3) increased sedimentation of plankton algae resulting from a reduction in water turbulence by macrophytes. Whatever the mechanisms may be, our analysis suggests that the percent of the lake's total volume infested with aquatic macrophytes may be a useful empirical measure that can be used to assess the impact of aquatic macrophytes on lake chloro-

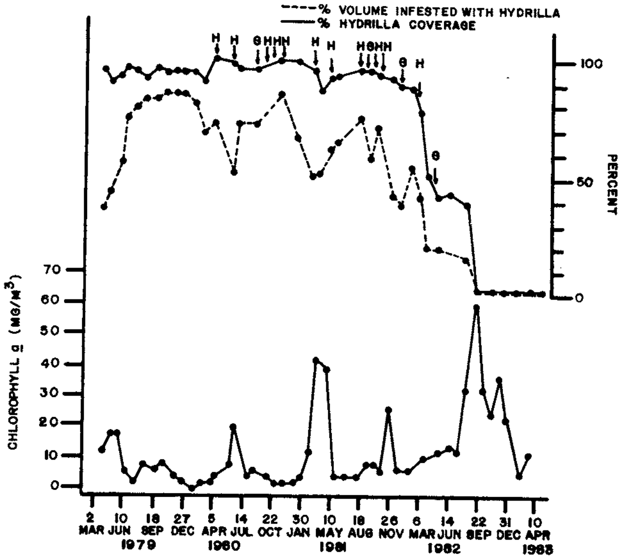

Figure 1.—Changes in chlorophyll *a* concentrations, macrophyte (hydrilla) coverage, and the percent of the lake's total volume infested measured in Lake Pearl, Fla. H = a herbicide treatment and G = a grass carp stocking.

phyll levels. Our sampling, however, has been limited and further testing is needed to test the applicability of our results to other Florida lakes and to lakes located in other geographical regions.

CLASSIFICATION OF LAKES

In the United States, Section 314 of the Water Pollution Control Act requires all States to classify lakes according to trophic state. This classification process is intended to help prioritize lakes for possible restoration and protection. Consequently, lake classification has become an integral part of the overall U.S. strategy for developing lake management programs. Various trophic state indices have, therefore, been developed to evaluate trophic status and rank lakes according to their overall quality. As noted by Carlson (1980) these indices by one method or another attach a label or a number to the lake. However, two practical problems are associated with the use of indices: (1) the various trophic indices do not always classify lakes similarly, and (2) implicit with the use of the indices is the assumption that eutrophic (high TSI) lakes are of poorer quality than oligotrophic (low TSI) lakes.

The problem of different trophic state indices ranking lakes differently seems to be especially serious when classifying macrophyte-dominated lakes. For example, Huber et al. (1982) classified 573 Florida lakes using chlorophyll *a*, Secchi disk, total phosphorus, and total nitrogen data. In their classification, Lake Fairview (Table 2) ranked among the 50 least eutrophic lakes in the State. Using our calculated WCP value (80 mg/m^3) which considers macrophytes, Lake Fairview would be ranked among the 100 most eutrophic lakes. Recently, Myers and Edmiston (1983) of the Florida Department of Environmental Regulation ranked Lake Fairview among the top 50 lakes in Florida in need of restoration. These differences in trophic ranking, however, need not be a problem if considered in the proper context. Differences among the different trophic indices can be used to demonstrate basic differences in the ecological structure and function of lakes (Carlson, 1980).

Over the last few decades, a management ethic has emerged that nutrient loadings to lakes should not be increased and that lakes should not be eutrophic. Eutrophication has often become synonymous with anthropogenic pollution. Vollenweider (1968, 1976) has used terms such as dangerous, nonacceptable, or excessive to describe nutrient loading rates that result in eutrophic lakes. Many water quality experts, especially limnologists, correlate the quality of a lake with characteristics that are typical of oligotrophic lakes (see Fusilier, 1982). Thus eutrophic lakes or lakes with high TSI values are commonly considered of poorer quality than are clear, unproductive waters.

Although controlling eutrophication is a worthy goal, especially where water is used for multiple purposes, scientists and natural resource management agencies must explicitly define their management criteria when presenting various nutrient control strategies. As noted by Bachmann (1980), the high algal levels associated with eutrophic lakes can increase the amount of treatment needed if the lake water is to be used for water supply. Some algae can contribute to taste and odors in the water. For recreational purposes, clear waters are generally more appealing for swimming and aesthetically pleasing, but eutrophic waters are commonly used.

From a fisheries standpoint the choice between oligotrophic and eutrophic waters is less defined (Bachmann, 1980). In northern areas, oligotrophic waters generally support the highly prized salmonid fisheries, but the overall productivity of these waters is low and sportfish harvest is low. Within limits, increases in nutrient inputs can increase total fish yield (Oglesby, 1977; Jones and Lee, 1982). For warmwater fisheries, the productivity of a lake can be increased well above the level that causes a decline in coldwater fisheries. Recently, Jones and Hoyer (1982) showed that warmwater sportfish harvest is directly correlated with planktonic chlorophyll *a* concentrations. Although there is most likely a level of productivity beyond which warmwater fishery yield is diminished (e.g., where oxygen depletions occur), it is obvious that eutrophication can benefit the yield of sportfishes from lakes and reservoirs. For this reason, it is inappropriate to assume that a lake with a eutrophic classification or a high trophic state index value is a poor quality lake for all human uses.

In the future, we can expect continued population growth, and with it, increased development within lake watersheds. Thus, environmental changes within lakes will be inevitable. Even remote lakes will be affected by increased anthropogenic activities. We, however, have the ability to either minimize changes or to exploit them to our benefit, but we must develop workable lake management plans that have definable criteria.

We must recognize that lakes in various geographical regions have different limnological potentials based on regional geology (Deevey, 1940; Moyle, 1956; Jones and Bachmann, 1978; Canfield, 1981). Within a given geographical region, lake morphometry and hydrology will affect the trophic status of individual lakes and reservoirs (Vollenweider, 1968, 1976; Canfield and Bachmann, 1981). Thus, our lake management goals must be realistic in their expectations. Many shallow lakes in fertile areas are naturally productive and no reasonable amount of management will make them oligotrophic.

We must also define aquatic environmental quality in terms of "for what" and "for whom" (see Harvey, 1976). The trophic state concept has proven useful in limnological investigations, but continued reliance on the concept or trophic state indices as a management tool without defining management criteria will do little to improve our capabilities to manage lakes.

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