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Compatibility between Water Clarity and Quality Black Bass and Crappie Fisheries in Alabama

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Abstract.—The reversal of cultural eutrophication of reservoirs can be deleterious to warmwater sport fisheries because it can reduce fish production and biomass. However, this process has resulted in greater water transparency and improved aesthetics for nonangling recreational users. In Alabama, we found angler catch rates of black bass *Micropterus* spp. and crappie *Pomoxis* spp. did not vary between oligomesotrophic (chlorophyll $a \leq 7$ mg/m^3) and eutrophic (chlorophyll $a \geq 8$ mg/m^3) reservoirs. However, the mean weight of angler-caught black bass and catch rates of memorable-size black bass ($\geq$2.27 kg) were higher in eutrophic than in oligomesotrophic reservoirs. Consonant with these observations, crappie and black bass growth and condition were usually greater in eutrophic reservoirs. However, within the range of eutrophic reservoirs, sport fishery and population characteristics did not change with higher chlorophyll-*a* concentrations. Based on empirical relations in 32 major impoundments in Alabama, chlorophyll-*a* concentrations greater than 15 mg/m^3 would generally result in water transparencies less than 120 cm, which may be less appealing to nonangling reservoir users. We propose that in southern U.S. reservoirs, reductions in chlorophyll-*a* concentrations to 10–15 mg/m^3 will not necessarily be detrimental to black bass and crappie fisheries, and will likely improve water clarity.

The reversal of eutrophication and improvement of water clarity in reservoirs can be deleterious to warmwater sport fisheries (Axler et al. 1988; Yurk and Ney 1989; Ney et al. 1990; Ney 1996, this volume) as reductions in fish biomass and production can occur. However, this process has resulted in greater water transparency and can increase satisfaction among nonangling reservoir users (Smeltzer and Heiskary 1990). Although the quantity of phytoplankton is inversely related to water transparency in reservoirs, nonalgal suspended particulate matter is also an important factor regulating water clarity in these systems (Canfield and Bachmann 1981; Hoyer and Jones 1983; Soballe and Kimmel 1987). Phosphorus and nitrogen are positive correlates of phytoplankton in reservoirs and natural lakes (Soballe and Kimmel 1987), and are usually considered the primary nutrients limiting algal production. Thus, reduction of anthropogenic nutrient loading by control of point or nonpoint sources, or by construction of an upstream reservoir that traps phosphorus, can result in a decline in primary production. Consequently, a reduction in predatory sport fish can occur by limiting production at the bottom of the trophic web (McQueen et al. 1986).

Oglesby (1977) and Jones and Hoyer (1982) found that algal production was positively correlated to fish yields in natural lakes and reservoirs. Axler et al. (1988) attributed the decline in the US$100 million per year fisheries for largemouth bass *Micropterus salmoides* and striped bass *Morone saxatilis* in Lake Mead, Nevada–Arizona, to advanced nutrient removal in wastewater and the construction of Lake Powell upstream. To increase phytoplankton production and improve fishing in Lake Mead, 202 t of liquid ammonium polyphosphate were applied to one arm of the reservoir in 1987, resulting in only a short-term increase in algal production (Axler et al. 1988). Thus, costs were incurred to reduce and subsequently add nutrients

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TABLE 1.—Summary statistics used to assess crappie and black bass in Alabama reservoirs.

Variable	Mean	Range	SD	N
Angler catch rate of crappie (N/h)	1.09	0.10–2.91	0.70	23
Angler harvest rate of crappie (N/h)	0.64	0.09–1.27	0.35	20
Angler catch of black bass (N/hr)	0.24	0.12–0.31	0.04	27
Average total length (TL) of crappie harvested by anglers (mm)	265	234–292	17	19
Average weight of angler-caught black bass (kg)	0.71	0.57–0.82	0.06	27
Angler effort to catch black bass ≥2.27 kg (h)	356	136–1,298	277	28
Time for crappie to reach 229 mm TL (years)	2.30	1.57–3.01	0.39	32
Time for crappie to reach 254 mm TL (years)	2.81	2.00–4.04	0.48	31
Time for largemouth bass to reach 304 mm TL (years)	2.47	1.89–3.21	0.31	32
Time for largemouth bass to reach 381 mm TL (years)	3.79	3.15–4.89	0.40	31
Time for largemouth bass to reach 508 mm TL (years)	7.45	6.52–10.21	0.67	28
Time for spotted bass to reach 304 mm TL (years)	2.61	2.25–2.97	0.22	11
Time for spotted bass to reach 432 mm TL (years)	5.20	4.32–6.97	0.75	11
Relative weight (W_r) for stock-size black crappie	88	79–102	7	15
W_r for quality-size black crappie	89	80–104	8	11
W_r for preferred-size black crappie	93	81–103	8	7
W_r for stock-size white crappie	89	81–98	6	19
W_r for quality-size white crappie	93	81–105	7	19
W_r for preferred-size white crappie	95	86–115	8	14
W_r for stock-size largemouth bass	90	80–102	7	32
W_r for quality-size largemouth bass	93	81–108	8	32
W_r for preferred-size largemouth bass	95	83–112	8	31
W_r for stock-size spotted bass	88	77–97	8	11
W_r for quality-size spotted bass	90	77–102	9	11
W_r for preferred-size spotted bass	91	75–108	10	11

sured. Differences in year-class strength caused large variation in crappie catch rates and average lengths of harvested crappies from year to year; multiple observations for these variables were therefore made at each reservoir and compared with a single mean for chlorophyll *a*, a figure derived from annual means for each reservoir sampled. To assess harvest success, only reservoirs with no length limits were used, and the daily bag limit was consistent among reservoirs.

Black bass catch rates were obtained from a database compiled from reports provided between 1986 and 1992 by tournament anglers at 27 reservoirs where 304-mm TL limits were imposed (Hendricks et al. 1995). Catch statistics for black bass were summed and pooled for the entire sample period representing 2,183 tournaments and 596,407 h of angling (Table 1). Also, mean weight and the angler effort to catch a large (≥2.27 kg) black bass were determined for all reservoirs. Angler effort to catch a large black bass was computed for an additional reservoir that had a 406-mm TL limit on black bass. These black bass fisheries included largemouth bass and spotted bass *M. punctulatus*, except for two fisheries in the Tennessee River that also included smallmouth bass *M. dolomieu*.

From 1990 to 1992 in October and November, 5,451 black crappie *P. nigromaculatus* and white crappie *P. annularis* were collected in Indiana trap nets (20 × 0.91 m, 13-mm stretch mesh). Age-1 and older largemouth bass (N = 5,997) and spotted bass (N = 2,449) were collected with electrofishing gear from 15 March to 15 May between 1989 and 1993. Crappies and black bass were measured for total length (mm) and weight (g). Sagittal otoliths were removed and aged according to procedures described by Maceina and Betsill (1987) and Hoyer et al. (1985). Mean lengths at age and von Bertalanffy (1938) growth parameters were estimated in 9 reservoirs for black crappie, 8 for white crappie, 31 for largemouth bass, and 11 for spotted bass. For crappies, we used von Bertalanffy growth models to estimate the time (years) to reach Alabama's current legal minimum size (229 mm TL) and preferred size (254 mm TL; Table 1). Differences in growth rates were not evident between crappie species within reservoirs (Black 1994), hence growth rates were pooled for both species when reservoir-wide comparisons were made. Similarly for largemouth bass, we computed the time needed to reach quality (304 mm), preferred (381 mm), and memorable (508 mm) total lengths, and for spotted bass, the time to reach the minimum tournament size (304 mm) and memorable (432 mm) total length (Table 1).

Body condition for black crappie and white crappie was computed from the relative weight (W_r) equations of Neumann and Murphy (1991). Largemouth bass W_r was computed from the equation published by Anderson and Gutreuter (1983). For

TABLE 2.—Summar
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Variable
Surface area (ha)
Mean depth (m)
Secchi disk transparency
Chlorophyll *a* (mg/m³)
Retention time (d)
Total phosphorus (mg/m
Total nitrogen (mg/m³)
Total suspended solids (mg/L)

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TABLE 2.—Summary statistics for annual mean values for limnological variables in Alabama reservoirs.

Variable	Mean	Range	SD	N
Surface area (ha)	6,709	443–27,976	7,195	32
Mean depth (m)	7.2	1.6–20.0	4.0	32
Secchi disk transparency (cm)	164	50–467	100	32
Chlorophyll *a* (mg/m^3)	10	2–27	6	32
Retention time (d)	56	1–435	96	32
Total phosphorus (mg/m^3)	36	5–90	23	19
Total nitrogen (mg/m^3)	610	290–1,860	370	18
Total suspended solids (mg/L)	6.9	0.6–20.5	5.3	31

spotted bass, W_r was computed from the standard weight (W_s) equation (C. Guy, Kansas Cooperative Fish and Wildlife Research Unit, unpublished analysis): $\log_{10} W_s = -5.358 + 3.201(\log_{10}\text{TL})$. Relative weights were computed according to structural length groups (Table 1) described by Anderson and Gutreuter (1983). Higher W_r values are generally associated with better physiological condition in fish.

For each reservoir and year, we determined mean monthly (April–September) values for Secchi disk transparency, chlorophyll *a*, total suspended solids, total phosphorus, and total nitrogen, and described relationships among these variables using correlation and regression analyses. In addition, mean monthly retention time (volume/discharge) was computed to determine its influence on chlorophyll-*a* concentrations. Because crappie and black bass are long-lived (7–10 years), their response to water quality would accumulate over the long term. Thus, a mean of average annual chlorophyll-*a* concentration values was computed for each reservoir to compare to fish data. Also, means of annual mean values for the other limnological variables defined earlier were computed to characterize limnological variation among Alabama reservoirs.

Results

Water Quality Relationships in Alabama

Water quality among the major impoundments in Alabama was diverse (Table 2). Water clarity ranged from poor to excellent (0.5–4.7 m). Trophic state varied from oligotrophic to eutrophic, and total phosphorus and total nitrogen varied according to trophic state. Retention time varied over two orders of magnitude.

Higher chlorophyll-*a* concentrations or algal biomass were associated with reduced water clarity for 292 monthly means. A nonlinear inverse relationship (Figure 2) was evident between Secchi disk transparency (SDT, cm) and chlorophyll-*a* concentrations (CHLA, mg/m^3);

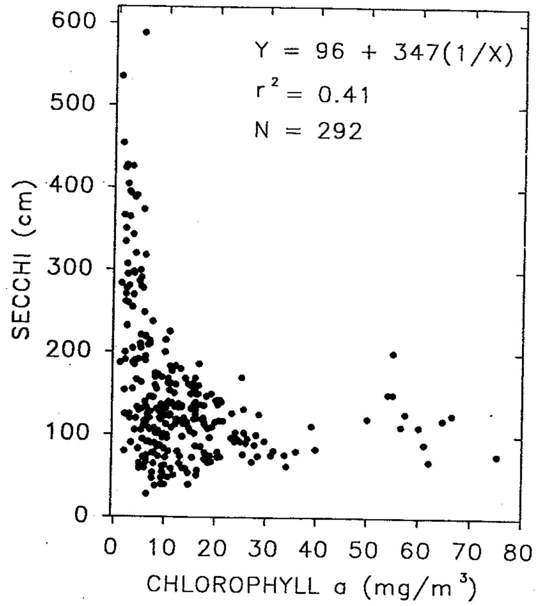

FIGURE 2.—The relationship between mean monthly values for Secchi disk transparency (Y) and chlorophyll *a* (X) in Alabama reservoirs.

$$\text{SDT} = 96 + 347(1/\text{CHLA}). \qquad (1)$$

Chlorophyll *a* explained 41% ($r^2 = 0.41$) of the variation in Secchi disk transparency. Log$_{10}$-transformed values for total suspended solids (TSS) were also negatively correlated ($r = -0.74, P < 0.01; N = 234$) to Secchi disk transparency for mean monthly data. The multiple regression equation was:

$$\text{SDT} = 256 + 151(1/\text{CHLA}) - 171(\log_{10}\text{TSS}), \qquad (2)$$

and this equation explained 64% ($r^2 = 0.64$) of the variation in water clarity. Chlorophyll *a* and total suspended solids were positively correlated ($r = 0.42, P < 0.01; N = 227$) as phytoplankton algae comprised some of the particulate matter measured in total suspended solids. Thus, some multicollinearity occurred between the two independent variables in equation (2) (multicollinearity can mask the importance of a single independent variable). Nevertheless, total suspended solids explained an additional 23% of the variation in Secchi disk transparency above that of chlorophyll *a*. In addition to phytoplankton, total suspended solids include nonalgal particles and these were also associated with a decline in water clarity.

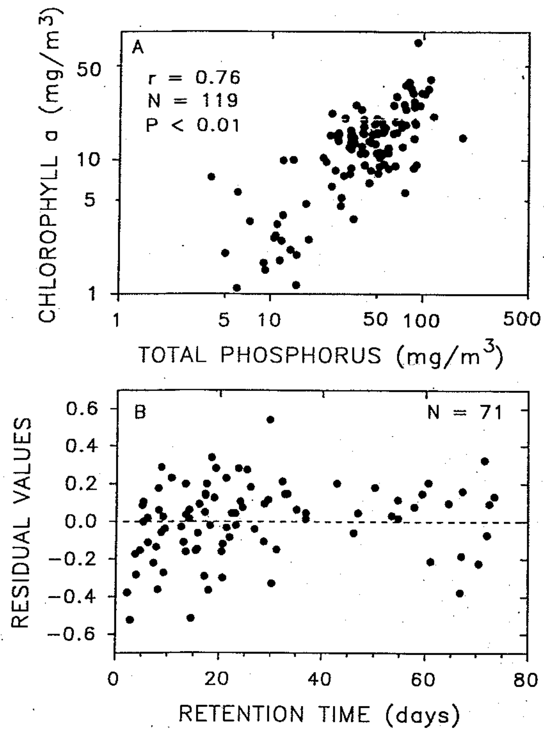

FIGURE 3.—Plot of the total phosphorus–chlorophyll-*a* relationship for mean monthly values (A). Residual values from the $\log_{10}$ chlorophyll *a*-to-$\log_{10}$ total phosphorus regression plotted against retention time for transitional (≤75 d retention time) reservoirs (B).

For a subset of 18 reservoirs that contained both total phosphorus and total nitrogen data were determined simultaneously, total phosphorus was a better correlate ($r = 0.71$, $P < 0.01$) of chlorophyll *a* than total nitrogen ($r = 0.18$, $P = 0.13$). For 118 mean monthly observations among a larger database of 19 reservoirs, total phosphorus (TP) explained 58% of the variation in chlorophyll-*a* concentrations (Figure 3a):

$$\log_{10}\text{CHLA} = -0.26 + 0.82(\log_{10}\text{TP}). \quad (3)$$

We examined chlorophyll-*a* relationships for transitional reservoirs, defined as reservoirs with a retention time (RET) of 75 d or less (Soballe and Kimmel 1987). In this smaller database, retention time and total phosphorus were positive and significant regressors ($P < 0.01$) of chlorophyll *a* ($R^2 = 0.50$):

$$\log_{10}\text{CHLA} = -0.27 + 0.70(\log_{10}\text{TP}) + 0.20(\log_{10}\text{RET}). \quad (4)$$

Retention explained an additional 7% of the variation in algal biomass after 43% of the variation in algal biomass was accounted for by total phosphorus.

For transitional reservoirs, a plot of residual values against retention time for chlorophyll *a* estimated from total phosphorus (from equation 3) indicated an inflection point at about 35 d, and a flattening of the relationship at longer retention times (Figure 3b). This analysis suggested that greater algal production for a given concentration of phosphorus could be expected at retention times of about 35 d or more given that nonalgal turbidity did not limit light and inhibit phytoplankton growth. In these transitional reservoirs, retention time was negatively correlated to total suspended solids ($r = -0.45$, $P < 0.01$), but not correlated to chlorophyll *a* ($r = 0.15$, $P = 0.14$) indicating that concentrations of nonalgal suspended particles were higher in faster flushing reservoirs. Retention time was a significant regressor of chlorophyll *a* in equation (4) only after the contribution of total phosphorus was accounted for.

Accounting for the effects of total phosphorus and retention time, mean depth (Z_x in m) was a significant negative regressor ($P < 0.01$) of chlorophyll *a* and adding this term to equation (4) we computed:

$$\log_{10}\text{CHLA} = 0.10 + 0.57(\log_{10}\text{TP}) + 0.22(\log_{10}\text{RET}) - 0.27(\log_{10}Z_x) \quad (5)$$

The coefficient of determination of equation (5) was 53%; thus, mean depth contributed an additional 3% to the total variation above that of total phosphorus and retention time. Although retention time and mean depth were weakly correlated ($r = -0.36$, $P < 0.01$), variance inflation factors and condition numbers were within acceptable ranges and multicollinearity was not too severe (Montgomery and Peck 1982). Thus, we conclude that for a given level of phosphorus in transitional reservoirs, algal biomass was lower in deeper, faster flushing reservoirs than in shallower reservoirs with longer retention time.

Water Quality–Sport Fishing Quality Interactions

Crappie catch and harvest rates averaged 1.05 and 0.60 fish/h in eutrophic reservoirs and were similar (*t*-test < 0.6, $P > 0.5$) to rates of 1.24 and 0.71 fish/h, respectively, in oligomesotrophic reservoirs. No relationships were evident between chlorophyll-*a* concentration and angler catch rates nor harvest rates of crappies (Figure 4). In addition, black bass catch rates were not correlated to chloby total phospho-

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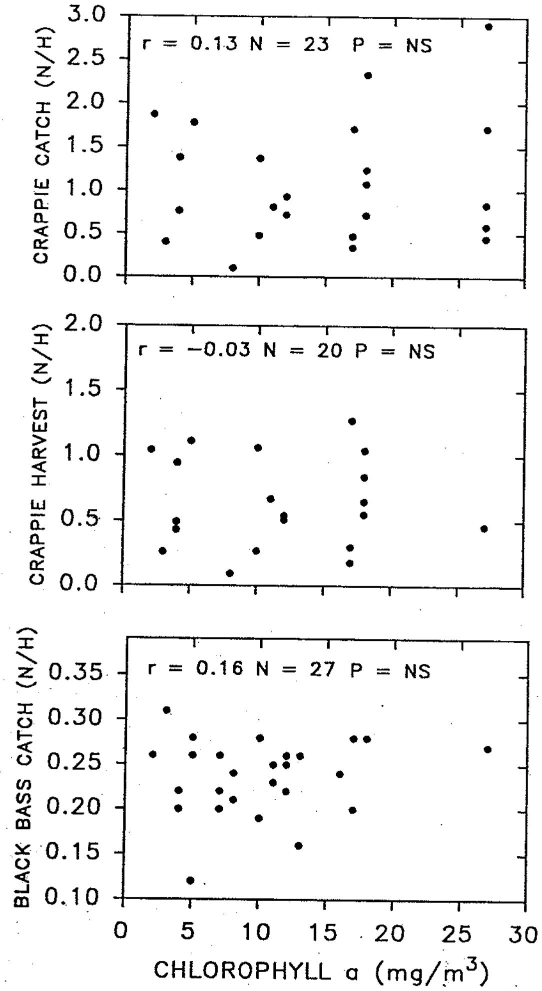

FIGURE 4.—Bivariate plots of crappie catch rates, crappie harvest rates, and black bass catch rates against mean of annual mean chlorophyll-*a* concentrations.

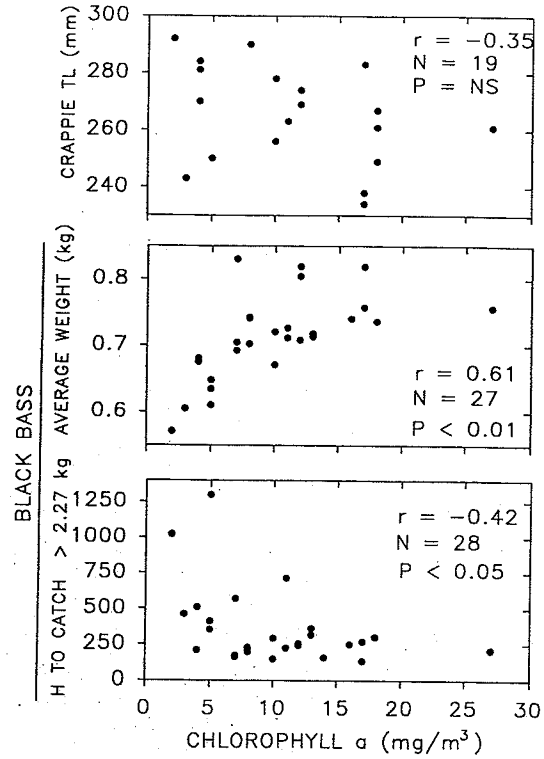

FIGURE 5.—Plots of total length of crappie (A) average weight (B) and the effort to catch (C) a black bass 2.27 kg or more by tournament anglers versus mean of annual mean chlorophyll-*a* concentrations.

rophyll *a* (Figure 4). Catch rates of black bass averaged 0.24 fish/h in eutrophic reservoirs and were similar (t-test = 0.41, $P > 0.5$) to the average 0.23 fish/h caught in oligomesotrophic reservoirs.

Size of crappies harvested by anglers was not related to chlorophyll-*a* concentrations ($r = -0.35$, $P > 0.10$; Figure 5a). Mean lengths of crappies harvested was 263 mm in eutrophic reservoirs and was similar ($t = -0.78$, $P = 0.4$) to 270 mm in oligomesotrophic reservoirs.

Although catch rates of black bass did not differ between trophic states of reservoirs, mean weights were higher and the amount of angler effort to catch a large (≥2.27 kg) black bass was less in eutrophic than in oligomesotrophic reservoirs. The mean weight of black bass longer than 304 mm TL caught in tournaments was 0.74 kg and was significantly greater (t-test = 3.03, $P < 0.01$) than 0.67 kg in oligomesotrophic reservoirs. Similarly, the amount of effort to catch a large black bass was 518 h in oligomesotrophic reservoirs, about twice as great ($t = 2.08$, $P = 0.05$) as 266 h required in eutrophic reservoirs. Mean weight of black bass caught and the amount of effort to catch a large black bass were correlated to chlorophyll *a* (Figure 5). However, in the eutrophic range, a flattening of these relationships were evident as chlorophyll *a* exceeded 8 mg/m³.

Crappie and Black Bass Growth and Condition

In eutrophic reservoirs, crappie reached 229 mm in 2.24 years and 254 mm in 2.73 years; these growing periods were significantly ($t > 2.5$, $P < 0.05$) less than the 2.73 years and 3.34 years for crappie to reach these same sizes, respectively, in oligomesotrophic reservoirs. However, faster crappie growth rates ($P > 0.5$) were not evident when chlorophyll-*a* levels were equal to or greater than 8 mg/m^3.

No relations were evident between W_r values for the three size groups of black crappie and chlorophyll *a* ($r = -0.04$–0.43, $P > 0.10$). Also, W_r values were similar between eutrophic and oligomesotrophic reservoirs. For white crappie, W_r for stock, quality, and preferred size groups increased over the entire range of chlorophyll-*a* levels ($r = 0.41$–0.75, $P < 0.10$).

The time for largemouth bass to reach 304, 381, and 508 mm TL was weakly, but negatively correlated to chlorophyll *a* (Figure 6), indicating faster growth occurred as trophic state increased. The time required for largemouth bass to reach 304, 381, and 508 mm TL was 2.37, 3.63, and 7.25 years, respectively, in eutrophic reservoirs which was less ($t = 1.67$–3.38, $P < 0.10$) than 2.63, 4.07, and 7.80 years, respectively, in oligomesotrophic reservoirs. Like for crappie, largemouth bass growth rates did not increase in eutrophic reservoirs at higher chlorophyll-*a* concentrations ($r = -0.18$–-0.22, $P > 0.4$). For the entire range of data, the asymptotic models did not significantly improve fit compared to the linear models.

Relative weights of three size groups of largemouth bass were better related than growth rates to chlorophyll-*a* concentrations (Figure 7). At chlorophyll-*a* concentrations greater than 7 mg/m^3, increases in condition were not evident for stock- and quality-size fish. Second-degree polynomial equation terms were significant ($P < 0.05$) for asymptotic relationships, but only for quality-size fish did the fit of W_r data improve significantly ($P < 0.10$) compared to the simple linear regression. Thus, higher chlorophyll-*a* concentrations within the eutrophic range did not confer higher W_r values. A weak correlation ($r = 0.43$, $P < 0.10$) was evident between W_r for preferred-size fish and chlorophyll *a* in eutrophic reservoirs.

Spotted bass grew faster and displayed better body condition in eutrophic than in oligomesotrophic reservoirs. Spotted bass reached 304 mm in 2.43 years in eutrophic reservoirs and 2.77 years in oligomesotrophic reservoirs ($t = 2.14$, $P < 0.10$); they reached 432 mm in 4.74 years in eutrophic reservoirs and 5.58 years in oligomesotrophic reservoirs ($t = 3.97$, $P < 0.01$). Relative weight values for stock-, quality-, and preferred-size groups were all higher ($t > 3.9$, $P < 0.01$) in eutrophic than in oligomesotrophic reservoirs. The relationship between increasing algal biomass and spotted bass

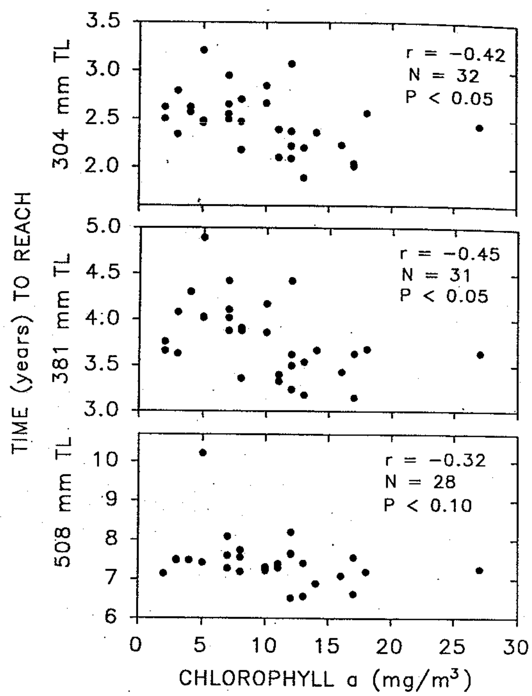

FIGURE 6.—Time in years for largemouth bass to obtain 304, 381, and 508 mm TL versus chlorophyll *a*.

growth and condition could not be adequately inferred because sample size was low (i.e., only 11 of the 32 major impoundments in Alabama contained substantial spotted bass fisheries and only 5 were in the eutrophic range).

Implications for Multiple Recreational Use

In Alabama, a reduction in chlorophyll *a* will increase the probability of greater water clarity and improve the aesthetic value among all recreational users. The National Academy of Sciences and National Academy of Engineering (1973) established a minimum criterion of 120 cm water clarity for safe swimming. If we assume that 120 cm visibility in the water is acceptable to most recreational users of Alabama reservoirs, then from predictive equation (1) this visibility equates to a chlorophyll-*a* concentration of 14 mg/m^3, which is still eutrophic. Attempts to reduce point or nonpoint nutrient sources will improve water clarity, if a nutrient–algal biomass relationship exists.

Algal biomass appeared as a slightly more important determinant of Secchi disk transparency in Alabama reservoirs compared to reservoirs located primarily throughout the southern and midwestern

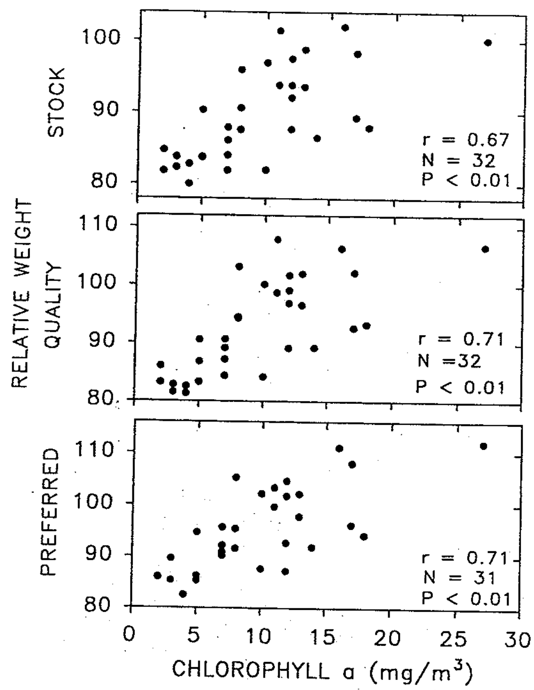

FIGURE 7.—Relative weight of stock, quality, and preferred sizes of largemouth bass versus chlorophyll *a*.

United States. In these regions, algal levels explained 12 to 42% of the variation in Secchi disk transparency (Canfield and Bachmann 1981; Hoyer and Jones 1983; Soballe and Kimmel 1987; Jones and Knowlton 1993) compared to 41% in Alabama. Much of Alabama is forested and agriculture is not as predominant as in the midwestern United States. Alluvial and clay soils are more common in these other regions, which likely results in waters with higher levels and persistence of nonalgal particulates.

The amount of chlorophyll-*a* variation explained by phosphorus in Alabama was similar to other regions. Total phosphorus accounted for 32 to 74% of the variation in chlorophyll *a* in other U.S. reservoirs (Canfield and Bachmann 1981; Hoyer and Jones 1983; Soballe and Kimmel 1987; Jones and Knowlton 1993) compared to 58% in Alabama. Poor fits to the chlorophyll *a*–phosphorus relationship in other regions were primarily due to high levels of inorganic suspended solids, which contained higher phosphorus concentrations but which also reduced water transparency, limiting the amount of light available for algal growth.

When allocating funds, reservoir managers need to consider retention time and nonalgal turbidity concentrations before embarking on any point or nonpoint nutrient reduction program. Our analyses indicated that a greater probability of reduction in algal biomass from nutrient control will occur in shallow reservoirs with retentions of 35 d or more than in deep, fast-flushing systems. Soballe and Kimmel (1987) also found total phosphorus, retention time, and mean depth explained about half the variation in chlorophyll-*a* concentrations in transitional reservoirs in the United States. Although empirically derived estimates of critical retention time for full algal production vary, previous reservoir investigations have consistently found this time was less than 60–100 d (reviewed by Soballe and Kimmel 1987). In fast-flushing reservoirs, the full production of phytoplankton algae is not realized because of time limitation. In addition, levels of nonalgal turbidity are likely higher in reservoirs with short-resident time, limiting light to algal production. Both these phenomena were indirectly observed in our analyses and in U.S. Army Corps of Engineers reservoirs in the southeastern United States (Kennedy and Gaugush 1988).

Variation in chlorophyll-*a* concentrations from low to highly eutrophic did not appear detrimental to quality crappie and black bass fisheries in Alabama. We found angler catch rates of crappie and black bass were similar for reservoirs ranging from oligomesotrophic to eutrophic. However, size of fish caught, growth rates, and condition were generally higher in eutrophic than in oligomesotrophic reservoirs. Thus, a reduction from eutrophic to oligomesotrophic will likely result in anglers catching smaller fish.

Increased biomass of plankton algae in reservoirs raises total fish standing stock via the planktivore (i.e., shad *Dorosoma* spp.) community, but the efficiency of transfer of this food (energy) source to piscivorous sport fish appears to decline in reservoirs of higher trophic status. In support of this, Yurk and Ney (1989) found that total phosphorus explained 84% of the variation in planktivore biomass, but explained only 51% of the piscivorous sport fish biomass in southern Appalachian reservoirs. In Smith Mountain Lake, Virginia, total phosphorus was positively correlated to biomass of gizzard shad *D. cepedianum*, but not to biomass of four piscivorous sport fish (Yurk and Ney 1989). Jenkins's (1982) parabolic plots of the morphoedaphic index (MEI) versus total fish and sport fish biomass showed decreasing efficiency of trophic transfer to sport fish as the percent composition of sport fish decline at higher MEI values. Increasing trophic state was associated with an increase in rough fish biomass (primarily gizzard shad), and a decline in sport fish abundance in Florida lakes (Kautz 1982).

Ney (1996) suggested that sport fish biomass would probably peak at total phosphorus concentrations of about 100 mg/m^3. Equation (3) suggests that about 50 mg/m^3 total phosphorus results in about 14 mg/m^3 chlorophyll-*a* concentration, which is at the low range of eutrophy. This level of algal biomass increases the probability of water clarity equal to or greater than 120 cm, but does not appear to sacrifice black bass and crappie fisheries in Alabama.

Contrary to our results, which indicated an asymptotic relationship between trophic state and crappie and black bass fisheries and population characteristics, other investigators have found fish yield and production increased linearly with algal biomass, primary production, total phosphorus, and the MEI (Melack 1976; Oglesby 1977; Matuszek 1978; Hanson and Leggett 1982; Jones and Hoyer 1982). However, our study was different because we examined only two major fish groups. Total recreational and commercial yield data were not collected in Alabama. Our data included only reservoirs, whereas lake data, reservoir data, or both were used in other studies. Trophic state response by fisheries for other species in Alabama may be different than for crappie and black bass fisheries.

Reservoir managers, limnologists, and fishery biologists should recognize and attempt to assess the impact of any planned oligotrophication project. Limnological investigations similar to the U.S. Environmental Protection Agency Diagnostic-Feasibility Studies should be conducted to determine factors that limit algal production in reservoirs. For example, nutrient reduction in fast-flushing reservoirs with high nonalgal turbidity may not result in greater water clarity, which is an important goal of any oligotrophication project. Currently, attempts are being made to reduce phosphorus loading in West Point Reservoir in Alabama–Georgia; the goal is to maintain an average chlorophyll-*a* concentration of 15–20 mg/m^3 (Bayne et al. 1994b). Based on our analyses, this level of algal biomass should continue to support desirable crappie and black bass fisheries. However, an extensive fishery for hybrid striped bass *Morone saxatilis* × *M. chrysops* exists and the impact of oligotrophication on this fishery is unknown, but shad populations are expected to decline. In Smith Mountain Lake, Virginia, management recommendations following oligotrophication included a reduction in the stocking rates of nonreproducing predatory game fish (striped bass and walleye *Stizostedion vitreum*; Ney et al. 1990). Thus, oligotrophication and subsequent reduction in prey fish may be detrimental to the success of stocking predator sport fish, other than crappie and black bass, and this impact should be assessed for each reservoir.

Our data indicated that reduction of chlorophyll-*a* concentrations in eutrophic reservoirs to 10–15 mg/m^3 will likely result in greater water clarity and improved aesthetics for other recreational users without adverse effects on quality black bass and crappie fisheries. If a shift in trophic state occurs from eutrophic to oligomesotrophic, catch rates of crappies and black bass will likely not change, but in some instances smaller and less robust fish will be caught, and the effort needed to catch a large-size black bass will increase. Thus, fisheries management approaches may need to be modified, and new expectations for the fishery should be communicated to the public.

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