Zooplankton, Fish and Sport Fishing Quality Among Four Alabama and Georgia Reservoirs of Varying Trophic Status

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Zooplankton, Fish and Sport Fishing Quality Among Four Alabama and Georgia Reservoirs of Varying Trophic Status

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ABSTRACT

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Four mainstream river impoundments located in Alabama and Georgia were examined in 1989 and 1990 to determine the response of zooplankton and fish to trophic gradient. Mean chlorophyll *a* concentrations ranged from 2 μg/L in the mesotrophic lake to 34 μg/L in the highly eutrophic lake. Two of the lakes were moderately eutrophic with mean chlorophyll *a* concentrations of 13 and 15 μg/L. Rotifer and total zooplankton densities increased with increasing trophic status, but crustacean zooplankton densities and biomass did not. Estimates of fish abundance and biomass were positively related to trophic state. Forage fish community structure in the mesotrophic lake was numerically comprised of lepomid sunfish (47%), cyprinid minnows (20%) and shad (*Dorosoma*) (13%), but shad comprised 45% to 53% of the fish community in the eutrophic lakes. Black bass (*Micropterus* spp.) growth rates were similar in all lakes, however crappie (*Pomoxis* spp.) grew faster in the more eutrophic reservoirs. Fishing effort adjusted for lake size was positively related to trophic gradient. Total weight and number of fish harvested was highest in the most eutrophic lake, but highest harvest per unit effort occurred in the mesotrophic lake. Generally, larger fish were caught in the eutrophic lakes than in the mesotrophic lake, and angler-caught black bass size was similar among the three eutrophic lakes. Trophic gradient was not related to angler perception of fishing success nor to where anglers chose to hold their fishing tournaments. Reservoirs with mean growing-season (May-September) chlorophyll *a* concentrations between 10 and 15 μg/L may provide black bass and crappie fisheries that are similar to those fisheries of more productive lakes.

Key Words: trophic gradient, tropic status, fish, zooplankton, sport fishery, reservoir, lake, fertility, nutrient limitation, retention time.

Most limnologists and fishery biologists agree that increases in lake fertility will result in higher fish biomass and sportfish harvest (O'Brien 1990). Scientists have developed indices and empirical models to predict fish biomass or yield in natural lakes and reservoirs (reviewed by Carline 1986). It is not clear, however, whether increasing levels of algal biomass will produce better quality sport fisheries in warmwater systems. Kautz (1980) found sportfish biomass was highest in mesotrophic-eutrophic Florida lakes and commercial (primarily catfish, Ictaluridae) and rough fish biomass peaked in hypereutrophic lakes. Total phosphorus was positively correlated to total fish and sportfish biomass in southern Appalachian reservoirs (Yurk and Ney 1989). In midwestern lakes and reservoirs, sportfish harvest increased linearly with chlorophyll *a* concentrations (Jones and Hoyer 1982). Conversely, a reduction in total phosphorus was not related to a decline in sportfish biomass, but was associated with a decline in fish growth rates in Smith Mountain Lake, Virginia (Ney et al. 1990). Reduction in phosphorus input and subsequent decline in primary productivity, due in part to wastewater treatment, led to improvement of water quality in Lake Mead (Nevada), but adversely affected the $100 million sport fishery (Axler et al. 1988). Jenkins (1982) reported reservoir sportfish biomass reached an asymptote at higher trophic states as indicated by the morphoedaphic index (MEI; total dissolved solids/mean depth).

However, the MEI only explained 21% of the variation in sportfish biomass.

The relationship between water quality and fish production, and public expectations for cleaner water can pose conflicts (Ney et al. 1990) that will require a greater understanding of these interactions in large river impoundments. Regulatory enforcement to halt or reverse eutrophication raises the question of what water quality standards are required to adequately protect all uses of the resource. Although compromise will likely be necessary among lake users, managers should be prepared to propose standards and predict impacts of nutrient reduction on water clarity, fish community structure, sportfish abundance, and fishing quality. Therefore, additional information is needed to assess nutrient reduction programs.

From April 1989 through September 1991, we examined four large reservoirs located in Alabama and Georgia that encompassed the trophic status range of large Alabama lakes (Bayne et al. 1989). The objectives of the study were to: 1) define limnological conditions and trophic status of each lake, 2) describe the relationships among zooplankton and fish communities to lake trophic gradient, and 3) document effects of trophic gradient on sportfish growth, yields, and angler perceptions.

Materials and Methods

Study Areas

The four mainstream impoundments were located within a 161 km radius in east Alabama and west Georgia. Physical characteristics of the four lakes varied considerably (Table 1), but autochthonous production was dominated by phytoplankton (few macrophytes) and fish assemblages were similar in all lakes.

Limnological Studies

Reservoirs were sampled near the dam forebay and at a mid-reservoir location during the growing seasons (May-September) of 1989 and 1990. Water quality analyses followed procedures recommended by U.S. EPA (1974) or APHA et al. (1985). Secchi disk visibility measurements were made *in situ* at each station, monthly. All other analyses were conducted on duplicate composite water samples collected once a month at each station from the euphotic zone. The composite sample was collected by raising and lowering a submersible pump and hose throughout the euphotic zone. Analyses included turbidity, specific conductance, total alkalinity, pH, ammonia nitrogen, orthophosphate, total phosphorus and total organic carbon.

Water subsamples for phytoplankton analysis were taken from each euphotic zone composite sample collected at each sampling location once each month. Organisms were identified to genus and species when possible (diatoms to order) and enumerated (APHA et al. 1985). Chlorophyll *a* was measured to estimate algal biomass using the trichromatic method (APHA et al. 1985).

Zooplankton samples were collected at both locations in each reservoir by raising and lowering a submersible pump and hose throughout the water column until 40 L (80 L in Lake Martin) of water had been filtered through a 53 μm-mesh plankton net (Lind 1979). Duplicate littoral and limnetic samples were collected monthly between May 1989 and March 1990, twice monthly from April through June 1990, and monthly July through August 1990. Organisms were identified to genus (copepods to suborder) and species when possible and counted (Weber 1973). For each sample, 10 (when present) representative crustaceans (cladocerans and copepods) of each taxon were measured with the aid of an ocular micrometer. When more than 10 crustaceans were present, organisms to be measured were chosen randomly. These measurements were used to compute organism volume and estimate biomass (Dumont et al. 1975, Bottrell et al. 1976, Pace and Orcutt 1981, Rosen 1981).

Fish Community Structure and Growth

In October and November 1989 and in March and April 1991, electrofishing was conducted on each reservoir to assess nearshore fish community composition and black bass (*Micropterus* spp.) growth rates. Electrofishing was conducted using a direct-current 5000 watt Smith-Root Type VI boat at six randomly chosen stations each month for a total of 23 or 24 stations per reservoir. At each station, all fish were collected for a 20-min period. Crappie

Table 1. Characteristics of four Alabama reservoirs included in this study. SLD = Shoreline development index.

Impoundment	River	Yr impounded	Surface Area (ha)	(Volume (ha-mx1000)	$\bar{Z}$ (m)	Zmax (m)	SLD	Retention[1] (days)
Martin	Tallapoosa	1926	15,850	203	13.0	47.0	24	190
Eufaula	Chattahoochee	1963	18,300	115	6.3	29.0	21	59
Jones Bluff	Alabama	1973	5,060	30	8.8	18.3	24	5
Weiss	Coosa	1961	12,200	34	3.1	19.0	18	18

[1]Represents long-term historic values.

(*Pomoxis* spp.) populations were assessed in the fall of 1989 and 1990 in lakes Weiss, Martin and Jones Bluff using trapnets. Twenty trapnets were set on each lake in October and November, checked, and all fish removed after 24 hrs and checked again and retrieved after 48 hrs.

Captured fish were weighed to the nearest gram and measured to the nearest mm in total length (TL). Otoliths were removed from all crappie and black bass to determine growth rates. Otolith preparation, measurements to annuli, and estimation of back calculated lengths followed Hoyer et al. (1985) and Maceina and Betsill (1987). Within each reservoir, black crappie (*P. nigromaculatus*) and white crappie (*P. annularis*) growth rates were similar. Therefore, these species were pooled to analyze growth differences among lakes. The nearshore fish community was analyzed from electrofishing data by examination of catch/hr and percent composition for both numbers and weight.

Fishing Quality

On Jones Bluff, Martin, and Weiss reservoirs, a stratified, nonuniform probability, roving creel survey (Malvestuto et al. 1978) was conducted in spring (March-May) 1990. Because the reservoirs were too large to conduct a roving creel survey in 1 day, lakes Jones Bluff, Martin, and Weiss were divided into 3, 8, and 5 spatial sampling units, respectively. Anglers were asked a series of questions including effort expended, targeted species, number caught, and number released. From lengths of fish caught by anglers, weight of harvested fish was estimated (Swingle and Shell 1971). Estimates of fishing effort, and harvest rates were expanded to monthly totals (Malvestuto et al. 1978). Attitude questions were summarized using percentages derived directly from interview data. We assumed that this creel survey was indicative of steady-state trophic conditions on these reservoirs.

Bass angling clubs report data gathered during club-sponsored tournaments held on Alabama lakes to the Alabama Department of Conservation and Natural Resources. For each tournament, total fishing effort (hrs), number of fish caught at weigh-in, total weight, number of black bass ≥2.27 kg that were caught, and the number of anglers catching at least one black bass >304 mm TL were recorded for tournaments conducted on these reservoirs between 1986 and 1990.

Statistical Analysis

For limnological and fishery data collected over time from permanent stations, a split-plot, repeated-measures analysis of variance (Steel and Torrie 1960) and least squares mean separation tests were used to test for differences among mean values. One-way analysis of variance and least squares means were used for data collected from random fishery sampling and from bass tournaments to examine for reservoir differences. Where comparisons were made between two means, a t-test was employed.

Results and Discussion

Limnology

Mean monthly retention time (mean volume/ mean daily discharge) between May and September was different ($P < 0.05$) in each of the lakes. Greatest retention was in Lake Martin and lowest was in Jones Bluff (Table 2). Due to greater precipitation and runoff in 1989 compared to 1990, retention time significantly ($P < 0.01$) increased in 1990 in all four reservoirs.

Edaphic factors of the four drainage basins varied considerably as evidenced by the variation in specific conductance among the four lakes (Table 2). The Tallapoosa (Lake Martin) and Chattahoochee (Lake Eufaula) rivers originate in the Mountains and Piedmont provinces of north Georgia and these waters are generally soft and low in mineral content. The Coosa (Weiss Lake) and Alabama (Jones Bluff Lake) rivers drain basins with soils containing greater quantities of calcium and magnesium salts. These waters are better buffered and naturally contain higher mineral and nutrient content (Lineback 1973).

Water quality data revealed a strong trophic state gradient among the four lakes. Specific conductance and total phosphorus concentrations varied significantly ($P < 0.05$) among lakes during both growing seasons (Table 2). Lake Martin had the lowest mineral and nutrient content followed, in order, by lakes Eufaula, Jones Bluff and Weiss. Mean total phosphorus concentrations in Weiss Lake (>100 μg/L) were high enough to produce hypereutrophic conditions were it not for the fact that the lake was shown to be nitrogen limited in a separate, 1991 study (Schultz, U.S. EPA, pers. commun.).

Phytoplankton community response to the nutrient conditions of the four lakes was evident. The highest Secchi visibility (313 cm) and lowest chlorophyll *a* concentrations (2.4 μg/L) were measured in mesotrophic Lake Martin (Table 2). Conversely, the lowest Secchi visibility (73 cm) and highest chlorophyll *a* concentrations (34.2 μg/L) were in Weiss Lake. Lakes Jones Bluff and Eufaula had Secchi visibility (101 and 140 cm, respectively) and chlorophyll *a* values (13.0 and 15.4 μg/L, respectively) that were intermediate between Lake Martin and Weiss Lake and were similar to each other (Table 2). Chlorophyll *a* concentrations for both years were used to calculate the Carlson trophic state index (TSI) for each lake (Carlson 1977). Lake Martin (TSI 39) was midrange mesotrophic, lakes Jones Bluff and Eufaula (TSIs of 55 and 57, respectively) were

Table 2. Mean (min. and max.) of limnological variables during the 1989 and 1990 growing seasons (May-September) in lakes Martin, Jones Bluff, Eufaula, and Weiss. Means subtended by like letters were not significantly (P > 0.05) different (within yr comparison, only).

		Lake			
Variable	Yr	Martin	Jones Bluff	Eufaula	Weiss
Retention (days)	1989	198 A	6 D	55 B	17 C
	1990	478 A	14 D	78 B	28 C
Specific conductance (μmhos/cm)	1989	39 (34-43) A	101 (90-120) C	73 (59-87) B	142 (102-180) D
	1990	35 (30-43) A	121 (89-143) C	74 (53-97) B	132 (81-173) D
Total P (μg/L)	1989	10 (3-17) A	68 (39-98) C	44 (19-79) B	104 (67-193) D
	1990	14 (9-30) A	51 (40-80) C	37 (22-57) B	100 (66-138) D
Secchi depth (cm)	1989	341 (193-485) A	93 (58-122) C	130 (54-183) B	68 (39-105) D
	1990	285 (181-427) A	109 (74-140) C	149 (90-222) B	78 (65-103) C
Chlorophyll *a* (μg/L)	1989	2.1 (0-4) A	10.7 (5-26) B	17.9 (11-24) C	27.3 (9-43) D
	1990	2.7 (1-5) A	15.3 (12-19) B	12.9 (2-19) B	41.1 (24-76) C
Total organic carbon (mg/L)	1989	9.2 (5-17) A	9.5 (5-16) AB	11.0 (6-19) BC	11.9 (8-21) C
	1990	3.4 (2-11) A	4.5 (3-10) A	4.6 (3-12) A	4.1 (3-5) A
Turbidity (JTU)	1989	1.8 (1.4-7) A	11.5 (6-21) BC	6.8 (2-27) AB	15.3 (6-37) C
	1990	2.1 (0.5-5) A	5.4 (2-10) C	3.7 (1-10) B	9.2 (5-16) D

moderately eutrophic and Lake Weiss (TSI 65) was highly eutrophic. On average, algal biomass in lakes Jones Bluff and Eufaula was over twice that found in Lake Martin but about one-half that measured in Weiss Lake.

In lakes Martin and Eufaula, which displayed longer retention times, increases in chlorophyll *a* concentrations were not observed between 1989 and 1990 (Table 2). However, variation in retention times of less than 30 days appeared related to algal biomass changes in lakes Weiss and Jones Bluff. Longer retention times in 1990 were positively associated with greater chlorophyll *a* concentrations in these two reservoirs. This pattern is in agreement with Soballe and Kimmel (1987) who found that retention times less than 75 days were too short to allow full biotic expression of nutrients.

Phytoplankton densities ranged between 3000 and 8000 organisms per mL in lakes Jones Bluff, Eufaula, and Weiss. Phytoplankton were less abundant in Lake Martin, seldom exceeding densities of 2000 organisms per mL. Green algae (Chlorophyta) were numerically dominant in all lakes on most occasions followed by yellow-green algae (Chrysophyta) comprised mostly of diatoms. Weiss Lake frequently had higher densities of blue-green (Cyanobacteria) algae than the other three lakes.

Within years, the lakes had similar concentrations of total organic carbon (TOC), but between years TOC measured in 1989 was over twice as high as concentrations for 1990 (Table 2). Dissolved organic carbon normally comprises most (5-10 times) of the TOC and much of it originates on the watershed (Wetzel 1983). Higher runoff that occurred in 1989 apparently increased the movement of organic carbon from basin watersheds into all the lakes. The increased allochthonous carbon input during high rainfall/runoff events (1989) could partially offset the loss of algal biomass (chlorophyll *a*) that occurred as a result of higher abiogenic turbidity in reservoirs with short hydraulic retention times (Table 2).

Zooplankton response to the trophic gradient among the four lakes was mixed. Rotifer and total zooplankton densities were generally higher in the three eutrophic lakes compared to Lake Martin. However, crustacean zooplankton, an important fish food, did not follow this trend (Figs. 1 and 2). In the fall/winter (November-March) period, Lake Martin maintained as high or higher ($P < 0.05$) crustacean zooplankton densities and biomasses as the three eutrophic lakes (Figs. 1 and 2). During the spring (April-June) zooplankton pulse, Lake Martin maintained as high or higher crustacean zooplankton biomass as the three eutrophic lakes with the exception of samples collected near the dam in Lake Eufaula (Fig. 2). Springtime crustacean zooplankton densities in Lake Martin were significantly ($P < 0.05$) lower than densities in lakes Weiss and Eufaula (Fig. 1), but the average size of Lake Martin organisms was larger because cladocerans and adult copepods were more numerous in Lake Martin. During summer (July-October) there were no significant ($P < 0.05$) differences in crustacean zooplankton densities or biomasses among the four lakes (Figs. 1 and 2). In Lake Martin, the persistence of higher crustacean biomass from winter into early spring might provide a source of food for fish fry spawned in early spring (March-April) that is not available in the other three

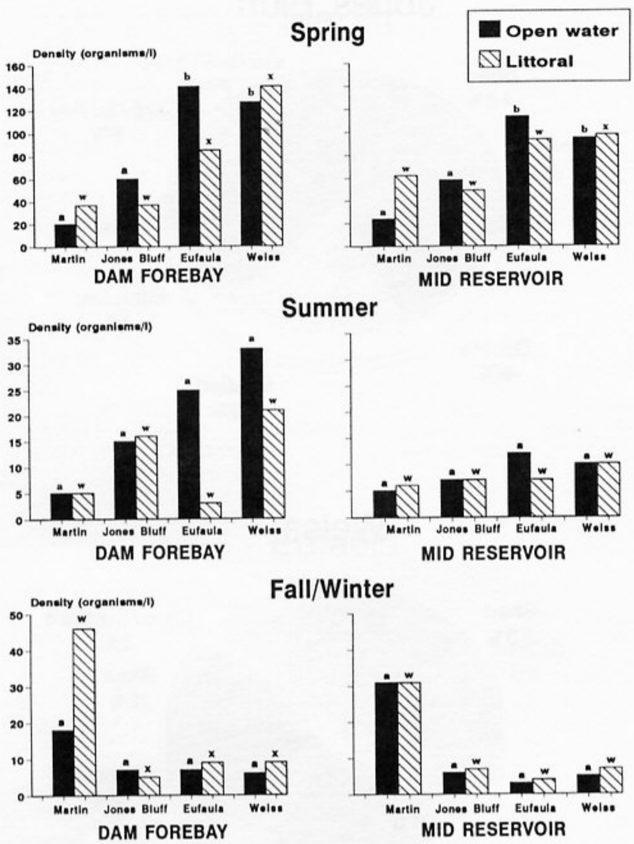

Figure 1.—Seasonal mean crustacean zooplankton densities at all sampling locations in lakes Martin, Jones Bluff, Eufaula, and Weiss during the spring, summer and fall/winter sampling periods. Means (bars) surmounted by like letters were not significantly ($P > 0.05$) different. Comparisons possible within a sampling zone (open water or littoral) only.

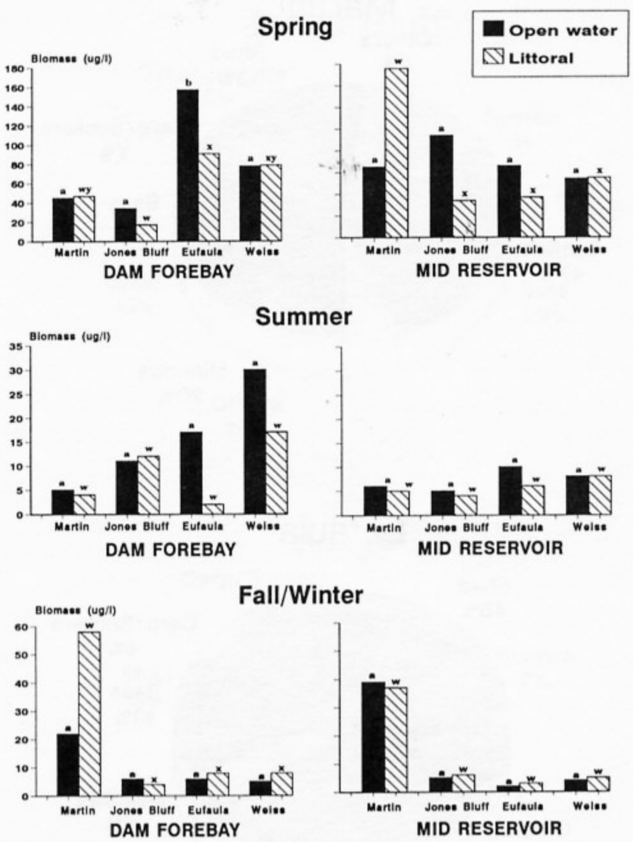

Figure 2.—Seasonal mean crustacean zooplankton biomass at all sampling locations in lakes Martin, Jones Bluff, Eufaula, and Weiss during the spring, summer, and fall/winter sampling periods. Means (bars) surmounted by like letters were not significantly ($P > 0.05$) different. Comparisons possible within a sampling zone (open water or littoral) only.

eutrophic lakes. This could help ensure more consistent annual fish recruitment, and at least partially offset the lack of primary and secondary productivity of this mesotrophic lake.

A difference in mean algal biomass from 2 μg/L chlorophyll *a* (Lake Martin) to 34 μg/L chlorophyll *a* (Lake Weiss) did not result in a clear increase in crustacean zooplankton biomass. Threadfin and gizzard shad (*Dorosoma petenense* and *D. cepedianum*), that were more abundant in the eutrophic lakes (Fig. 3), undoubtedly consumed large quantities of crustacean zooplankton. Predation by young-of-year gizzard shad on zooplankton can virtually eliminate crustacean zooplankton (DeVries and Stein 1992). However, failure of the zooplankton to positively respond to the trophic gradient among the four lakes may have been influenced also by a decline in efficiency of energy transfer that occurs in lakes of higher trophic status. In controlled studies in the absence of shad, the ratio of herbivorous zooplankton production to primary production has been shown to decline as nutrient enrichment of experimental ponds increased (Pederson et al. 1976, Bayne et al. 1992). Apparently, nutrient enrichment beyond certain limits does not enhance herbivore production, but rather shifts the food web toward a bacteria/detritus base favoring rotifers rather than copepods and cladocerans (Gannon and Stemberger 1978, Bays and Crisman 1983, Blancher 1984). This is, in part, a result of the response of the phytoplankton community to nutrient enrichment. Moderate nutrient limitation usually favors smaller and sometimes motile phytoplankters (Porter 1977, Wetzel 1983) that have higher turnover rates (Wetzel 1983) and are favored food items of herbivorous zooplankters (McCauley and Kalff 1981, Elser and Goldman 1991). Nutrient enrichment into the eutrophic range favors larger phytoplankters, frequently composed of gelatinous green as well as colonial and filamentous blue-green algae (Porter 1973). These phytoplankters are less edible by herbivorous zooplankton (Porter 1977) but are consumed by the filter-feeding adult gizzard shad (Drenner et al. 1984). Even though some of these net phytoplankters are not digestible by gizzard shad (Smith 1962), nutrient enrichment of lakes enhances

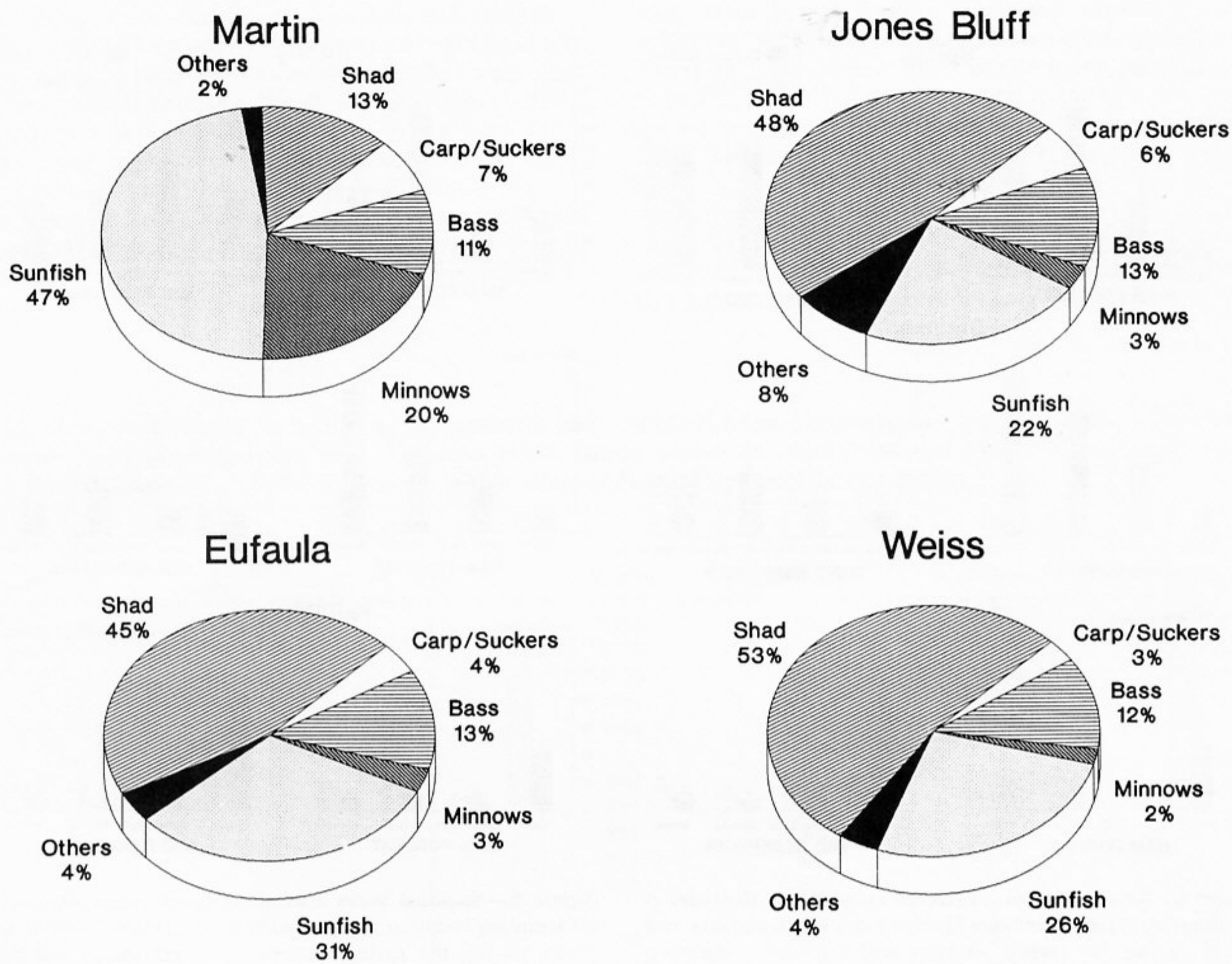

Figure 3.—Percent composition by number of various fish groups from lakes Martin, Jones Bluff, Eufaula, and Weiss. Fish were collected using electrofishing gear in fall 1989 and spring 1991.

the transfer of phytoplankton primary production directly to adult shad rather than to herbivorous zooplankton. Centrarchid sportfish fry dependent upon crustacean zooplankton as a food supply would be adversely affected in the more eutrophic lakes containing gizzard shad (Ali and Bayne 1985, DeVries and Stein 1992).

Fish Community Structure

Assessment of fish community structure using electrofishing gear indicated mesotrophic Lake Martin was unique compared to the other three eutrophic reservoirs. Lowest catch rates by weight were observed in Lake Martin (Table 3). Catch rates of fish by number and weight were highest in lakes Weiss and Eufaula, with Jones Bluff intermediate between these lakes and Lake Martin. Percent composition by number indicated black bass populations were similar among lakes and ranged from 11 to 13%, but weight composition was lowest in Lake Martin and highest in Weiss Lake (Figs. 3 and 4). Threadfin and gizzard shad numerically comprised 45-53% of the total number of fish caught in lakes Eufaula, Weiss, and Jones Bluff compared to 13% in Lake

Table 3. Mean catch of fish/hr using electrofishing from four Alabama lakes. Fish were collected in fall 1989 and spring 1991. Mean values in rows followed by the same letter are not significantly (P > 0.05) different.

	Lake			
Taxa	**Martin**	**Jones Bluff**	**Eufaula**	**Weiss**
Bluegill	65[ab]	34[b]	55[ab]	74[a]
Sunfish (*Lepomis*)	76[a]	44[b]	81[ab]	85[a]
Largemouth bass	8[b]	23[a]	33[a]	35[a]
Black bass (largemouth and spotted)	19[b]	25[b]	35[a]	40[a]
Gizzard shad	13[b]	66[a]	42[a]	66[a]
Threadfin shad	8[c]	31[bc]	75[ab]	110[a]
Total n/hr	161[b]	199[ab]	263[a]	335[a]
Fish kg/hr	25[c]	34[b]	43[a]	43[a]

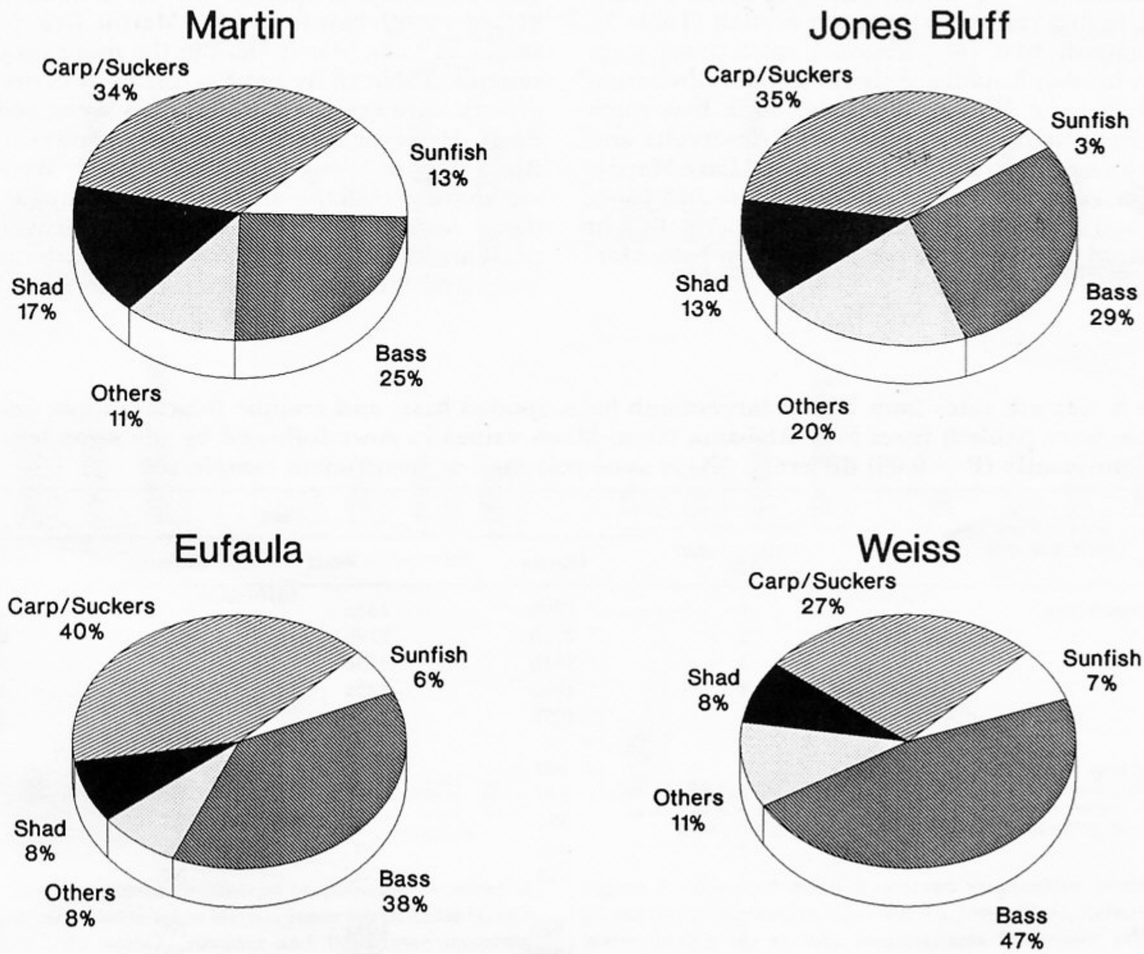

Figure 4.—Percent composition by weight of various fish groups from lakes Martin, Jones Bluff, Eufaula, and Weiss. Fish were collected using electrofishing gear in fall 1989 and spring 1991.

Martin. Although shad comprised only a small numeric proportion of the fish community in Lake Martin, these fish accounted for 17% of fish biomass compared to 8-13% in the other lakes (Fig. 4). In Lake Martin, 73% of gizzard shad were greater than 250 mm TL compared to 2-18% in the other lakes. Percent composition by number and weight of lepomid sunfish was highest in Lake Martin. Small cyprinid minnows numerically comprised 20% of the fish community in Lake Martin. These fish were a negligible component of the fish community in lakes Eufaula, Weiss, and Jones Bluff. Thus, numerically in Lake Martin, the forage-fish community was predominantly composed of lepomid sunfish and minnows compared to other lakes which were dominated by shad.

Gizzard shad catch rates ranged from 42 to 66 fish/hr in the eutrophic reservoirs compared to 13/hr in Lake Martin (Table 3). Threadfin shad abundance was also an order of magnitude higher in Weiss Lake compared to Lake Martin. In Weiss Lake, threadfin shad abundance was similar to Lake Eufaula, but was greater than in Jones Bluff Lake. Total catch per effort of bluegill and all sunfish was higher in Weiss Lake compared to Jones Bluff, but other distinct statistically significant trends in sunfish abundance among reservoirs were not evident (Table 3). Largemouth bass (*M. salmoides*) catch rates were higher in lakes Eufaula, Weiss, and Jones Bluff compared to Lake Martin. Similarly, black bass catch rates were highest in the eutrophic reservoirs and were twice as high in Weiss Lake than in Lake Martin. Crappie catch was higher in lakes Weiss and Jones Bluff and averaged 7.2 and 8.1 crappie per net-night compared to 1.6 crappie per net-night in Lake Martin.

We recognize that electrofishing constrained our sampling to shallow littoral regions in each reservoir. This technique is size and species selective, but we believe that the relative magnitude of the differences we detected among the reservoirs was real. For example, percent composition by weight for black bass ranged from 25 to 47% which is high, but these species are littoral and were targeted for collection for growth analysis.

Growth Rates of Black Bass and Crappie

During the first 3 yrs of life, growth rates of largemouth bass were greater in Lake Eufaula than in the other three reservoirs (Table 4). By age 5, largemouth bass size was similar among the three eutrophic lakes, but Lake Martin largemouth bass were significantly ($P < 0.05$) smaller than Lake Eufaula bass at age 5. Spotted bass (*M. punctulatus*) were relatively abundant in Lake Martin and for the first 2 yrs they grew more slowly than largemouth bass. After age 2, spotted bass were similar in size to largemouth bass from Lake Martin. Crappie grew slower in Lake Martin than in the more productive systems (Table 4). By age-3 no differences in crappie growth were evident between lakes Weiss and Jones Bluff. However, age-4 crappie were larger in Jones Bluff than in Weiss Lake even though Weiss Lake was more productive and contained a greater abundance of threadfin shad, a prey item usually positively associated with faster crappie growth rates (DeVries and Stein 1990). Differences in growth rates

Table 4. Growth rates (mm TL) of largemouth bass, spotted bass, and crappie (black crappie and white crappie were pooled) from four Alabama lakes. Mean values in rows followed by the same letter were not significantly ($P > 0.05$) different. NC is none collected or insufficient sample size.

		Lake			
Species	Age	Martin	Jones Bluff	Eufaula	Weiss
Largemouth bass	1	179b	188a	197a	172b
	2	273b	279b	302a	275b
	3	331b	335b	353a	335b
	4	402a	395a	397a	405a
	5	407b	457ab	475a	444ab
Spotted bass	1	160	NC	NC	NC
	2	246	NC	NC	NC
	3	331	NC	NC	NC
	4	392	NC	NC	NC
	5	415	NC	NC	NC
Crappie	1	92b	104a	NC	109a
	2	182b	184b	NC	198a
	3	204b	260a	NC	264a
	4	NC	310a	NC	292b

between lakes Jones Bluff and Weiss did not seem related to density-dependent factors because trap net catch rates were similar between lakes.

Fishing Quality

Total fishing effort, adjusted for lake size, varied according to trophic status during March and May 1990 (Table 5). Lowest effort (9 hrs/ha) was exerted on Lake Martin while about three times more angling effort was exerted on Weiss Lake (28 hrs/ha). Total weight and number of fish harvested, adjusted for area, were lowest in Jones Bluff Lake and highest in Weiss Lake. Total harvest per unit of effort for both numbers (number/hr) and weight (kg/hr) was highest in Lake Martin and lowest in Jones Bluff Lake. The higher harvest rate in Lake Martin resulted, in part, because a greater proportion of anglers kept their fish in this lake. About 60% of black bass caught in Lake Martin were retained by anglers, while in lakes Weiss and Jones Bluff about 70% of bass were released (Table 5). Highest and lowest crappie catch rates were observed in Lake Martin and Weiss Lake, respectively. Only 19% of fishing effort targeted crappie in Lake Martin compared to 41-49% in lakes Weiss and Jones Bluff, respectively. Thus, fishing effort for crappie was low in Lake Martin, but those fisherman seeking these fish had relatively good success. Angler-rated fishing success was similar among the three lakes and was not related to trophic gradient (Table 5).

Table 5. Summary statistics for the 1990 creel survey conducted on three Alabama lakes. Creels were conducted from March to May.

Parameter	Lake		
	Martin	Jones Bluff	Weiss
Effort			
Total hrs	151,900	72,600	343,000
Hrs/ha	9	15	28
Harvest			
Total wgt (kg)	27,500	8,000	42,400
Total N[1]	88,900	24,100	124,800
Kg/ha	1.7	1.6	3.5
N/ha	5.6	4.8	10.0
Kg/hr	0.17	0.13	0.15
N/hr	0.52	0.38	0.42
Black bass			
Total n/hr	0.43	0.37	0.63
Harvest n/hr	0.26	0.11	0.22
Crappie			
N/hr	1.23	0.93	0.66
Harvest n/hr	0.90	0.54	0.30
Targeted effort (%)			
Bass	57	34	43
Crappie	19	49	41
Fishing Success and Quality (%)			
Poor	60	62	67
Fair-good	38	37	30
Excellent	2	1	3

[1]N=Number of fish harvested.

Larger crappie and black bass were harvested by anglers in the more eutrophic reservoir. For example, 9% of harvested crappie were less than 20 cm TL in Lake Martin compared to 5 and 1% in Jones Bluff and Weiss lakes, respectively. Weiss Lake had a minimum length limit of 25 cm, and this undoubtedly influenced the size of crappie retained by anglers in this lake. In Lake Martin, 26% of black bass harvested were less than 30 cm TL compared to 14 and 7% in lakes Jones Bluff and Weiss, respectively. These differences in bass size were due, in part, to the large percentage of spotted bass found in Lake Martin. Spotted bass grew slower than largemouth bass during the first 2 yrs of life.

Tournament data indicated the quality of black bass fishing was different in reservoirs of varying trophic state as smaller bass were caught by anglers in Lake Martin compared to other lakes (Table 6). These differences in mean weight may be, in part, attributable to trophic state and production of prey fish, but probably were also influenced by genetic composition of the resident largemouth bass population. In southern latitudes, Florida largemouth bass growth was greater than northern largemouth bass (Bottroff and Lembeck 1978, Maceina et al. 1988). Highest mean weight was in Lake Eufaula, where largemouth bass contained nearly equal proportions of northern and Florida largemouth bass influence (Philipp et al. 1983). However, largemouth bass in Jones Bluff expressed little Florida largemouth bass influence (4%; Maceina, unpubl. data) compared to Lake Martin (16%; Norgren et al. 1986), yet average weight of black bass in eutrophic Jones Bluff was greater than in Lake Martin. The amount of effort to catch a memorable bass (>2.27 kg which is >50 cm TL) was greatest in Lake Martin and lowest in Lake Eufaula, with Weiss Lake and Jones Bluff intermediate between these two lakes (Table 6). Effort to catch a memorable bass was negatively correlated ($r=-0.93$; $P < 0.10$) to largemouth bass length at age 5, suggesting growth rate influenced catch of larger bass.

Catch per effort for bass of minimum size (≥304 mm TL) was higher in lakes Eufaula and Weiss than in Martin and Jones Bluff (Table 6). In Weiss Lake, which demonstrated the highest trophic state, percent success of weighing in at least one black bass >304 mm TL was significantly ($P < 0.05$) greater compared to the other three lakes (Table 6). Greatest fishing effort (adjusted for area) was exerted on Lake Eufaula and lowest on lakes Martin and Weiss for fishing clubs reporting their data. Based on these statistics, tournament effort was not related to trophic state (Table 6).

Trophic State—Sportfish Relationship

Equations of Jenkins (1982) were used to predict reservoir sportfish and total fish biomass from the MEI (Ryder 1965). To compute MEI values for these four reservoirs, we multiplied specific conductance by 0.65 (APHA et al. 1985) and divided this value by the mean depth (m). Trends observed among the four reservoirs were analogous to fish data gathered during this study (Table 7). The estimate of total fish biomass was three times greater in Weiss Lake than in Lake Martin, with lakes Eufaula and Jones Bluff intermediate between these two systems. Although a three-fold difference in MEI values was computed among Lakes Eufaula, Jones Bluff, and Weiss, these equations predicted sportfish standing crop was only one-third higher in Weiss Lake. These equations also predicted greater efficiency of sportfish production in mesotrophic Lake Martin as 39% of total fish standing crop was composed of sportfish compared to 25% in Weiss Lake. Our findings from these predictive equations were consonant with findings of Kautz (1980); a greater percentage of sportfish comprising the entire fish community was found in meso-eutrophic lakes.

Weiss Lake maintained mean chlorophyll *a* concentrations an order of magnitude higher than those encountered in Lake Martin and yet estimated fish biomass and yield were only two times higher in Weiss Lake. Greater trophic efficiency in Lake Martin, however, did not compensate for lower algal biomass, and fish production was less than in eutrophic waterbodies. Lakes Eufaula and Jones Bluff, with mean chlorophyll *a* concentration (13-15 µg/L) about one-half that of Weiss Lake (34 µg/L) produced fish and supported a black bass and crappie fishery similar to or superior to Weiss Lake. Although our data set is limited to four reservoirs, we tentatively propose Alabama lakes with mean growing season chlorophyll *a* concentrations between 10 and 15 µg/L may support quality black bass and crappie fisheries that are similar to more productive waterbodies. Thus improvement of water quality from near hypereutrophic condition to a moderately eutrophic state may not be detrimental to these sport fisheries.

Table 6. Black bass tournament statistics among four Alabama lakes. Data were collected from 1987 to 1990. When appropriate, mean values followed by the same letter were not significantly ($P > 0.05$) different.

	Lake			
Parameter	**Martin**	**Jones Bluff**	**Eufaula**	**Weiss**
Catch-per-effort (N/hr)	0.25b	0.22b	0.29a	0.30a
Mean weight (kg)	0.62c	0.72b	0.82a	0.71b
Effort (hrs) to catch black bass >2.27 kg	418c	253b	107a	189b
Angler success (%) (at least one fish caught)	73b	71b	75b	82a
Effort (hrs/ha/yr)	0.3	0.5	1.2	0.3

Table 7. Predicted sportfish biomass (SFB) and total fish biomass (TFB) among four Alabama reservoirs derived from the morphoedaphic index (MEI) and the regression equations computed by Jenkins[1] (1982).

	Lake			
Variable	**Martin**	**Jones Bluff**	**Eufaula**	**Weiss**
MEI	1.85	8.20	7.63	28.73
Sportfish biomass (kg/ha)	36	51	50	68
Total fish biomass (kg/ha)	93	164	160	268
Ratio sportfish: total fish	0.39	0.31	0.31	0.25

[1]Equations from Jenkins (1982):
$\log_{10}SFB = 1.498 + 0.677(\log_{10}MEI) - 0.233(\log_{10}MEI^2)$
$\log_{10}TFB = 1.862 + 0.796(\log_{10}MEI) - 0.204(\log_{10}MEI^2)$

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