Comparison of Creel and Physical/Chemical Parameters for Lake Norman, North Carolina, and Lake Wylie, North Carolina and South Carolina

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Abstract: From 1977 to 1983, non-uniform probability creel surveys were conducted on Lake Norman, North Carolina, and Lake Wylie, North Carolina and South Carolina, to estimate seasonal and annual creel parameters of pressure, success, harvest, and angler preference. Despite their geographical proximity on the Catawba River, mean annual pressure and harvest estimates on Lake Wylie were >3 times higher than respective estimates on Lake Norman. Catch rates for the 2 reservoirs were similar. Based on harvest, the Lake Norman sport fishery was a crappie and largemouth bass fishery, while the Lake Wylie fishery was a catfish, largemouth bass, and crappie fishery. The substantial productivity difference for these 2 edaphically similar reservoirs was attributed to certain physical/chemical characteristics of the reservoirs. Lake Wylie's much larger drainage area, smaller surface area, shallower basin morphometry, and shorter retention time resulted in higher annual nutrient loading and subsequent potential productivity. Sport fish harvest predictive models (morphoedaphic index and chlorophyll *a* index) were applied to both reservoirs and found to provide predictions within the range of natural variability. The author concludes that reservoir geographical proximity does not necessarily mean resource similarity. Consequently, broad management practices on a regional basis may not be optimal management policy. For proper resource management and utilization, reservoirs should be considered on a case by case basis. When manpower and budget constraints prohibit this, however, predictive models can be useful in considering reservoir differences based on physical and chemical parameter differences.

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Over the past 20 to 30 years, creel surveys have been conducted in the Southeast to meet a variety of objectives (Chance 1950, 1959; Fetterolf 1954; Carter 1957; Houser 1958; Stevens 1958, 1959; Byrd 1959; Lambou and

Stern 1959*a,* 1959*b*; Barkley 1960, etc.). In reviewing creel survey literature, Lambou concluded "There are as many different statistics collected, ways of calculating these statistics, and methods of reporting them as there are creel surveys" (unpubl. data, Recommended method of reporting creel survey data for reservoirs, prepared for the Res. Comm. South. Div. Am. Fish. Soc. 1961). Although survey design, data collection and interpretation, and presentation of data results may vary substantially, all surveys are directed toward 1 major objective: the evaluation of the sport fishery by examining its exploitation and utilization by the angling public. Creel surveys can provide managers and developers with timely feedback on major changes to the sport fishery, whether natural or man-induced. For this reason, Duke Power Company conducted creel surveys on Lake Norman, North Carolina, and Lake Wylie, North Carolina and South Carolina, as components of multi-disciplinary aquatic studies. These studies were implemented to establish baseline environmental data for detecting and assessing operational effects of McGuire Nuclear Station and Catawba Nuclear Station on aquatic biota in Lake Norman and Lake Wylie, respectively. Comparative operational data will be supplied by similar studies during commercial operation.

The creel surveys were originally conducted independently to assess the fishery within each reservoir. However, similar creel designs allowed for comparisons between the 2 reservoirs. Substantial differences in creel parameters for the 2 geographically promixate reservoirs raised many questions about relative productivities. The purpose of this paper is to present and compare the creel data and to discuss possible reasons for the productivity differences between the reservoirs.

In addition to the previously mentioned nuclear generating facilities under construction during the creel survey periods, an existing fossil-fired generating facility was operating on each of these reservoirs. Heated effluent discharge areas associated with steam electric generating facilities provide areas of seasonally high fish concentrations and resulting fishing pressure due to fish attraction to warm water (Siler 1975, Hogan 1977), current (Dupont 1976), and/or abundance of prey fish (Dryer and Benson 1957, Siler 1975, Hogan 1977). Although these areas represent a small proportion of the total reservoir area, they receive considerable seasonal fishing pressure. For the purposes of this paper, however, these discharge areas will not be discussed as such, as the objectives of this paper concern creel parameter comparisons between reservoirs rather than within reservoirs. The objectives of this paper are: 1) compare the lake-wide annual creel parameters of pressure, success, harvest, and angler preference for Lake Norman, North Carolina, and Lake Wylie, North Carolina and South Carolina, and 2) relate the relative productivity of the 2 reservoirs, as indicated by creel data, to selected physical/chemical parameters of the 2 reservoirs.

Study Areas

Lake Norman

Lake Norman, North Carolina, is a 13,156-ha (full pond) recreational, hydroelectric, and cooling water impoundment (Table 1) located on the Catawba River in the Piedmont region of North Carolina. Lake Norman reached full pond elevation (232 m m.s.l.) in 1963. The lake has been characterized as an oligo-mesotrophic reservoir (Weiss and Kuenzler 1976) excellent for water sports but of low fishing potential.

Three electric generating facilities are located on Lake Norman. Cowans Ford Hydroelectric Station is rated at 360 MW. Marshall Steam Station, a 1,900-MW fossil-fired facility is located approximately 13 km upstream of Cowans Ford Dam. McGuire Nuclear Station, a 2-unit, 2,360-MW facility is located just east of Cowans Ford Dam. This facility was still under construction and had not begun sustained operation during the creel study periods.

Lake Wylie

Lake Wylie, North Carolina and South Carolina, is a 4,912-ha recreational, hydroelectric, and cooling water impoundment (Table 1) located on the Catawba River approximately 16 km downstream of Lake Norman. Lake Wylie was impounded in 1904 and has a full pond elevation of 173.6 m (m.s.l.). Lake Wylie has been characterized as a eutrophic reservoir (U.S. Environ. Protection Agency 1975) with high levels of municipal, industrial, and agricultural nutrient input.

Three electric generating facilities are located on Lake Wylie. The Wylie Hydroelectric Station is rated at 54 MW. Plant Allen, a 1,140-MW fossil-fired facility, is located approximately 21 km upstream of the dam. Catawba Nuclear Station, a 2-unit, 2,290-MW facility, is presently under construction 5 km upstream of the Lake Wylie Dam. As with McGuire Nuclear Station on Lake Norman, Catawba Nuclear Station was not commercially operational during the study period.

Table 1. A comparison of physical and chemical parameters for Lake Norman, North Carolina, and Lake Wylie, North Carolina and South Carolina.

	Lake Norman	Lake Wylie
Use	Recreation, hydroelectric, cooling	Recreation, hydroelectric, cooling
Surface area	13,156 ha (full pond)	4,912 ha (full pond)
Drainage area	881 km^2	3,004 km^2
Mean depth	10.2 m (full pond)	6.9 m (full pond)
Age	21 years	59 years
Trophic status	Oligo-mesotrophic	Eutrophic
Retention time	207 days	32 days
Total dissolved solids	30 mg/liter	60 mg/liter
Annual net *P* loading	65,000 kg	247,000 kg
Mean summer chlorophyll *a*	4.2 mg/m^3	9.9 mg/m^3

Methods

A roving creel survey with non-uniform probability sampling (D. W. Hayne, unpubl. data, Notes on creel survey for Tenn. Coop. Fish. Unit, Tenn. Game Fish Comm. 1966; unpubl. data, N.C. State Univ. Inst. Statistics, 1976; Malvestuto et al. 1978) met study needs and manpower limitations. A major consideration, however, was the computation of catch per unit effort (CPUE) or success. An assumption had to be made that success estimates for incomplete fishing trips yielded an unbiased estimate of success for complete trips. Malvestuto et al. (1978) tested this assumption on West Point Reservoir, Alabama and Georgia, and concluded that, statistically, there was no significant correlation between fishing success and the amount of time spent fishing. Therefore, a roving creel survey employing non-uniform probability sampling was selected for sampling lakes Norman and Wylie.

Sampling of Lake Norman was conducted from December 1977 through November 1978 and from December 1981 through November 1982. Sampling of Lake Wylie was conducted from December 1979 through November 1980 and from December 1982 through November 1983. Both reservoirs were divided into zones based on projected areas of power plant operational effects, main drainage areas of the reservoirs, and/or transitional habitat boundaries (i.e., lotic habitat to lentic habitat). Lake Norman contained 6 zones; Lake Wylie contained 3 zones. Fishing pressure (angler-hours/ha/year), total pressure (angler-hours/year), success (kg/angler-hour), harvest (kg/ha/year), total harvest (kg/year), catch composition, and fisherman species preference were estimated seasonally (winter, December through February; spring, March through May; summer, June through August; and fall, September through November) for each zone and total lake.

Fishing pressure and distribution of sport fishermen were estimated from instantaneous counts of boat and bank/pier fishermen actively fishing. Counts were made during airplane/helicopter flights over Lake Norman and by boat on Lake Wylie. Boat counts, instead of aerial counts, were selected for Lake Wylie because of safety considerations concerning numerous power transmission line crossings and heavy air traffic from a large municipal airport. For Lake Norman, the entire lake was surveyed on each count day. For Lake Wylie, only 2 of the 3 zones were surveyed on each count day, since counts by boat took longer to complete. Counts on both reservoirs were completed within 4 hours of starting times. Malvestuto et al. (1978) found that progressive counts conducted within a 4-hour period provide similar results to preferred shorter count periods previously recommended (Neuhold and Lu 1957). For Lake Norman, 61 count days were sampled. For Lake Wylie, 38 count days were sampled. Counts on both reservoirs were seasonally allocated and initially, were proportional to historical car counts at Lake Norman access areas after corrections were made for heavy non-fishing activity during summer. For the second-year creels, count periods were seasonally allocated based on pressure estimates from the first-year studies. Approximately 5%, 56%, 27%, and 12% of the annual counts on both reservoirs were allocated to the winter, spring, summer, and fall, respectively. Within seasons, counts were further stratified among weekdays and weekend/holidays, based on historical fishing pressures of approximately 50% and 50%, respectively. All count days were randomly selected.

Flight times for the Lake Norman creel survey were also chosen randomly, with possible starting times for flights 1 hour after sunrise and the beginning of each consecutive two-hour period thereafter up to 2 hours before sunset. Fishermen interviews were conducted separately by boat. The creel clerk spent the entire workday (0900 hours–1700 hours) creeling 1 zone. A total of 190 interview days was allocated equally among seasons and zones. Within each zone, interview days were generally allocated equally among weekdays and weekend/holidays. The creel clerk systematically moved through the zone interviewing fishermen. If fishermen were too numerous to interview every fisherman, the clerk systematically skipped fishermen and interviewed every second, third, fourth, etc. depending on numbers present (Malvestuto et al. 1978). For each interview, the creel clerk sorted and weighed the catch by taxa. He also recorded the total number of fishermen in the party, the time spent fishing, the species fished for, and the type of fishermen (i.e., boat or bank/pier).

For the Lake Wylie creel survey, 2 zones were sampled each sampling trip. The sampling combinations of zones 1 and 2, zones 2 and 3, and zones 1 and 3 were randomly selected for each sampling trip. During the first count period of each trip (0800 hours to 1200 hours), the first of the 2 selected zones was sampled. During the second count period (1200 hours to 1600 hours), the remaining zone in the pair was sampled. The next time the same zonal combination occurred, the sampling order was reversed. During each count period, both fishermen counts and interviews were conducted. The creel clerk first made a complete circuit of the zone counting fishermen. Once counts with that zone were completed, the remainder of time was spent interviewing fishermen. Lake Wylie interviews were conducted as previously described for Lake Norman.

Total fishing pressure by season, zone, type of day (weekday and weekend/holiday), and type of fishing (boat and bank/pier) was independently estimated as the product of the average number of fishermen counted and the average seasonal day length in hours (Neuhold and Lu 1957, Lambou 1961, unpubl. data, N.C. State Univ. Inst. Statistics 1976). Total seasonal pressures for type of days and type of fishing were divided by the appropriate seasonal zonal areas to obtain areal pressure estimates (angler-hours/ha). All areas were adjusted based on the average lake level during that season. Pressures among seasons and zones were summed to obtain annual pressure estimates.

Fishing success or CPUE was estimated from fishermen interviews by the total ratio estimator method (Malvestuto 1983). Fishing success was expressed as the average catch (fish/angler-hour) per fishing party by taxa, season, zone, and type of fishing (boat and bank/pier). Fisherman success was based on all fishermen interviewed except those fishermen who caught but did not retain fish. Harvest was estimated by taxa, season, zone, and type of fishing (boat and bank/pier) as the product of success and pressure.

Fisherman preference was estimated for each taxon based on fishermen interviews. Preference was expressed as the percentage of total fishermen who were fishing for a particular taxon.

Results and Discussion

Mean annual creel parameters of pressure, success, and harvest varied substantially between Lake Norman and Lake Wylie (Table 2). Based on the 2 creel survey periods for each reservoir, Lake Wylie mean annual fishing pressure was more than 3 times higher than the Lake Norman mean fishing pressure. Mean success (kg/angler-hour) for the 2 reservoirs was essentially equal. Mean success, based on number of fish, followed the same trend with a success rate of 0.66 fish/angler-hour for both reservoirs. Similar to pressure, Lake Wylie mean harvest was also more than 3 times higher than the Lake Norman harvest. Lake Wylie harvest, based on number of fish, was slightly less than 3 times the Lake Norman mean harvest. Lake Wylie annual fishing pressure and harvest estimates were substantially higher than the national averages of a survey of 103 reservoirs (Jenkins and Morais 1971) (Table 3). Conversely, the national averages were substantially higher than the Lake Norman averages for pressure and harvest. Successes for both Lake Norman and Lake Wylie were lower than the national average.

A comparison of Lake Norman and Lake Wylie creel parameters to 4 southeastern reservoirs offered a more geographically representative comparison (Table 3). Lake Norman fishing pressure was lower, while Lake Wylie fishing pressure was higher than the average of 4 southeastern reservoirs (73.3 angler-hours/ha). The average successes for Lakes Norman and Wylie were similar to the average for the southeastern reservoirs (0.19 kg/angler-hour). Following the same trend as pressure, the average southeastern reservoir har-

Table 2. A comparison of creel parameters for Lake Norman, North Carolina, and Lake Wylie, North Carolina and South Carolina.

	Lake Norman			Lake Wylie		
	1977–78	1981–82	$\bar{X}$	1979–80	1982–83	$\bar{X}$
Pressure (hour/ha/year)	41.8	60.8	51.3	192.8	124.0	158.4
Success (kg/hour)	0.13	0.20	0.17	0.19	0.17	0.18
Success (*N*/hour)	0.46	0.85	0.66	0.64	0.67	0.66
Harvest (kg/ha/year)	5.3	12.5	8.9	35.6	20.6	28.1
Harvest (*N*/ha/year)	19.2	51.7	35.5	123.4	83.3	103.4

Table 3. Comparison of Lake Norman, North Carolina, and Lake Wylie, North Carolina and South Carolina, creel survey parameters with other southeastern reservoirs.

Reservoir	Year	Pressure (hour/ha/year)	Success (kg/hour)	Harvest (kg/ha/year)	Citation
National average		76.1	0.13	5.3	Current study
(103 reservoirs)			0.20	12.5	Current study
Cherokee, Tenn.	1972–73	59.8	0.19	35.6	Current study
Dale Hollow, Tenn.	1972–73	36.3	0.17	20.6	Current study
Sinclair, Ga.	1972–73	133.2	0.23	23.4	Campbell et al. 1977
Badin, N.C.	1972–73	63.8	0.16	8.0	Campbell et al. 1977
Wylie, N.C./S.C.	1980	192.8	0.18	8.6	Campbell et al. 1977
Wylie, N.C./S.C.	1983	124.0	0.18	5.3	Campbell et al. 1977
Norman, N.C.	1978	41.8	0.24	16.4	Jenkins and Morais 1971
Norman, N.C.	1982	60.8			

vest (11.3 kg/ha/yr) was slightly higher than Lake Norman harvest, but substantially less than Lake Wylie harvest.

One point to be considered is the issue of similar success for Lake Norman, Lake Wylie, and other southeastern reservoirs with substantially dissimilar pressures and harvests. A possible explanation for this occurrence has been offered by Campbell et al. (1977) and Siler et al. (in press). According to both investigators, it appears that fishermen tend to maximize their success by distributing their effort proportional to the abundance of fish. It further appears that fishermen will either shift their effort to other waters when a certain minimum success rate is reached or will simply quit fishing. Since harvest is the product of pressure and success, an argument could be made that if fishing pressure on Lake Norman were increased to the level of fishing pressure on Lake Wylie, equal harvests would result. This might be true if increasing fishing pressure had no effect on fishing success; however, within extremes (i.e., very high or very low pressure) fishing success should be inversely related to fishing pressure for a given body of water. In other words, the argument that increased pressure would result in a direct increase in harvest assumes that the 2 reservoirs have equal sport fish stocks and that Lake Norman is underfished, in which case, Lake Norman fishing success should be higher than that of Lake Wylie. In fact, the standing stocks of the 2 reservoirs are substantially different based on cove rotenone data (Table 4). Considering these data, it is felt that increased fishing pressure on Lake Norman would result in decreased success with little effect on harvest.

Success and distribution of harvest among the 4 major sport fish taxa common to both reservoirs (catfish, sunfish, largemouth bass, and crappie), varied for lakes Norman and Wylie (Table 5). Success for Lake Wylie catfish

Table 4. Comparison of cove rotenone standing stocks (kg/ha) for Lake Norman, North Carolina, and Lake Wylie, North Carolina and South Carolina. Numbers are annual lake means.

	Lake Norman[a]	Lake Wylie[b]
1978[c]	132.0	[d]
1979	126.7	479.1
1980[e]	137.6	429.6
1981	130.7	448.0
1982[c]	125.0	433.0
1983[e]	180.3	344.5
$\bar{X}$	138.7	426.8

[a] Based on 3 or 4 – 1.2 ha sampling locations.
[b] Based on 3 – 1.2 ha sampling locations.
[c] Lake Norman creel years.
[d] No sample taken.
[e] Lake Wylie creel years.

Table 5. Comparison of Lake Norman, North Carolina, and Lake Wylie, North Carolina and South Carolina, creel parameters for major sport fish. Numbers are means for the 2 surveys on each reservoir.

	Success (kg/hour)		Harvest (kg/ha)	
	Lake Norman	Lake Wylie	Lake Norman	Lake Wylie
Catfish	.01	.07	0.33	6.53
Sunfish	.01	.01	0.24	0.93
Largemouth bass	.04	.05	1.93	5.52
Crappie	.07	.03	3.78	4.36

was substantially higher than success for Lake Norman catfish. Conversely, Lake Norman fisherman success for crappie was more than 2 times greater than Lake Wylie success for crappie. Success for sunfish and largemouth bass was essentially the same for both reservoirs. Average successes from a national reservoir survey (Jenkins and Morais 1971) for catfish (0.02 kg/angler-hour) and crappie (0.08 kg/angler-hour) compared closely with respective Lake Norman successes, but were substantially lower for catfish and substantially higher for crappie than Lake Wylie successes. The national average largemouth bass catch rate (0.06 kg/angler-hour) was only slightly higher than the Lake Norman largemouth bass catch rate and comparable to the Lake Wylie largemouth bass catch rate.

Harvest estimates for all 4 sport fish taxa were higher for Lake Wylie than for Lake Norman and ranged from only slightly higher for crappie to approximately 19 times higher for catfish (Table 5). Crappie and largemouth bass comprised 91% of the Lake Norman sport fish harvest, with only minor contributions from catfish and sunfish. Lake Wylie sport fish harvest, on the other hand, was dominated by catfish, largemouth bass, and crappie. Again, sunfish were a minor component of the total sport fish harvest.

National harvests for catfish, largemouth bass, and crappie (1.9 kg/ha, 4.5 kg/ha, and 5.9 kg/ha, respectively) (Jenkins and Morais 1971) were substantially higher than respective Lake Norman harvests. For Lake Wylie, catfish harvest and largemouth bass harvest were higher than the national averages while crappie harvest was less than the national average.

Angler preference on the 2 reservoirs was a reflection of the respective species compositions of the two sport fisheries (Table 6). Lake Norman angler preference was highest for largemouth bass, crappie, and striped bass, while Lake Wylie preference was highest for largemouth bass, catfish, and crappie. Largemouth bass was the most fished for species on both reservoirs. Crappie were also highly fished for on both reservoirs, but were less fished for on Lake Wylie than catfish. Striped bass and crappie were about equally fished for by Lake Norman anglers. The low preference for striped bass on Lake Wylie is a result of their low abundance in Lake Wylie, which is neither stocked nor managed for striped bass.

Table 6. Angler preference (percent) on Lake Norman, North Carolina, and Lake Wylie, North Carolina and South Carolina. Percentages are based on the 2 creel survey periods combined for each reservoir.

Taxa	Lake Norman[1]	Lake Wylie[2]
Carp	1.0	0.4
Catfish	3.0	19.0
White bass	5.1	5.1
Striped bass	20.0	0.2
Sunfish	1.0	2.2
Largemouth bass	36.1	40.0
Crappie	20.9	15.7
No preference	12.9	17.5

[1] Based on 3,921 angler-party interviews.
[2] Based on 1,996 angler-party interviews.

The previously discussed creel parameters of annual harvests for Lake Norman and Lake Wylie indicate that Lake Wylie is a much more productive reservoir. Considering the proximity of these reservoirs and their resulting similar Piedmont geological and edaphic characteristics (igneous-metamorphic lithology) (Industrial Bio Test Laboratories, Inc. 1974), such large differences in productivity would not normally be expected. The relationships between reservoir harvest or yield and reservoir physical/chemical parameters have been recognized and investigated for years (Rawson 1952, 1955; Hayes 1957; Ryder 1965; Jenkins 1967; Jenkins and Morais 1971; Ryder et al. 1974; Ryder 1978). A comparison of the major physical/chemical parameters for Lake Norman and Lake Wylie indicates major differences in the 2 reservoirs (Table 1). Lake Wylie is about one third the size of Lake Norman but has almost 3.5 times the drainage area. Lake Wylie has a shallower mean depth than Lake Norman and is an older, more trophically-advanced reservoir. The retention time for Lake Wylie is about one sixth that for Lake Norman. Comparative physical parameters indicate 3 major characteristics of Lake Wylie that could account for its higher comparative productivity: 1) the much larger drainage area and smaller reservoir surface area, 2) the shallower basin morphometry, and 3) the much shorter retention time.

Each of these characteristics could substantially affect productivity. The drainage area basically determines the nutrient input into a system (Wetzel 1975). Total dissolved solid values for both reservoirs are low in comparison to a national average for 103 reservoirs (282 mg/liter) (Jenkins and Morais 1971), but are twice as high for Lake Wylie 60 mg/liter) as for Lake Norman (30 mg/liter). These low dissolved solid values are a reflection of the insoluble igneousmetamorphic lithology of the area which results in softer water (i.e., fewer dissolved minerals) (Industrial Bio Test Laboratories, Inc. 1974). Total hardness and alkalinity for both reservoirs typically range from 10 to 15 mg/liter $CaCO_3$ with average water pH of 6.5.

The annual total phosphorus loading values for Lake Norman and Lake Wylie (65,000 kg and 247,000 kg, respectively) (U.S. Environ. Protection Agency 1975) are in direct proportion to the comparative drainage areas (i.e., Lake Wylie has 3.5 times the drainage area of Lake Norman and 3.8 times the annual phosphorus loading of Lake Norman). It should be noted these values are actual annual phosphorus retention based on total phosphorus inflow and outflow for each reservoir. Placing these phosphorus values in perspective, annually, Lake Wylie retains approximately 50.3 kg P/ha compared to 4.9 kg P/ha for Lake Norman. Phosphorus is considered to be probably the least abundant nutritional component in reservoirs and the one whose deficiency most commonly limits reservoir productivity (Sawyer 1947, Hutchinson 1975, Wetzel 1975).

Because of the complexity of phosphorus cycling in reservoirs, it is difficult to determine how much of the total phosphorus in each reservoir is available for production. Readily available orthophosphate comprises only a small proportion of the total phosphorus in a system (Wetzel 1975). In natural waters, phosphorus is known to form complexes, chelates, and insoluble salts with a number of metal ions (Stumm and Morgan 1970). There is "an apparent net movement of phosphorus into the sediment in most lakes . . ." and ". . . the rapidity of processes regenerating the phosphorus to the water relate to an array of physical, chemical, and metabolic factors" (Wetzel 1975). Further complicating phosphorus availability in geographical locations characterized by clay soils, such as the Piedmont, the sorption of phosphates onto clay minerals by chemical bonding is a common occurrence (Fitzgerald 1970, Stumm and Morgan 1970, Edzwald et al. 1976). The complexity of phosphorus cycling in reservoirs is obvious, but based strictly on comparative annual total phosphorus loading, a reasonable assumption can be made that the much higher external annual phosphorus loading of Lake Wylie compared to Lake Norman is probably a major factor in its much higher productivity. This assumption is supported by Aggus and Lewis (1977) who inferred that in predator-stocking-evaluation reservoirs, total nutrient transport through a reservoir was apparently more important to fish production than the concentration of nutrients per unit volume. As nutrient flow-through increases, fish standing crops apparently increase.

The comparatively shallower basin morphometry of Lake Wylie is a second major factor contributing to Lake Wylie's high productivity. Hayes (1957) states that "shallow lakes are more productive than deeper ones because the most productive zone is that influenced by the sun's rays." Generally, as the mean depth of a reservoir decreases, productive littoral area increases. Shallow basin morphometry can be an advantage in terms of nutrients. Lake sediments have been found to contain much higher concentrations of phosphorus than the overlying water (Olsen 1958, 1964; Holden 1961; Hepher 1966). As previously mentioned, availability of phosphorus depends on a variety of conditions and variables, however, Zicker et al. (1956) stated that "the rate of phosphorus release from the sediments increases markedly and in fact about doubles if the sediments are disturbed by agitation from turbulence." In a shallow reservoir such as Lake Wylie, wind and resulting wave action may provide sufficient agitation to increase the release of sediment-bound phosphorus (Lee 1969). Jenkins (1967) and Jenkins and Morais (1971) found that reservoir area and mean depth exhibited a negative correlation with sport fish harvest. These findings are consistent with those for Lake Norman and Lake Wylie and support the contention that shallower basin morphometry contributes to the higher productivity of Lake Wylie.

Finally, shorter retention time is proposed as a contributing physical characteristic of Lake Wylie's higher productivity. Retention time reflects the flow-through rate of a reservoir. A portion of nutrient loss from the water column can be attributed to sedimentation (Hutchinson 1941, Lee 1969). "A large fraction of the organic matter synthesized sinks to the hypolimnion and is mineralized" (Wright 1961, 1967). Long retention times generally create nutrient sink conditions, where nutrients are sedimented to the reservoir bottom where they may or may not remain depending on the oxidation potential of the microzone (Wetzel 1975). Very short retention times, however, may adversely affect production by "washing out" or removing phytoplankton from the system before standing crops reach levels determined by nutrient limitations (Dickman 1969, Dillon 1975). Aggus and Lewis (1977) stated that mainstream reservoirs with high rates of flow-through (storage ratio <0.165) had higher mean total standing crops of fishes than reservoirs with low flow-through rates. The retention time of Lake Wylie (32 da) is apparently short enough to favor sustained suspension of nutrients due to a high flow-through rate (storage ratio of 0.102), while being long enough so that "washing out" of phytoplankton is apparently not productivity limiting. The much longer retention time of Lake Norman (207 da) results in a low flow-through rate (storage ratio of 0.566) and high sedimentation potential, less favorable to production (Aggus and Lewis 1977). The retention time of Lake Norman, combined with the larger reservoir surface area, greater mean depth, and lower nutrient loading, create conditions favorable for the sedimentation of nutrients. It is reasonable to assume, therefore, that higher nutrient loading and faster flow-through for Lake Wylie probably result in higher nutrient availability and resulting primary productivity. Mean summer chlorophyll *a* values for Lake Wylie (9.9 mg/m^3) and Lake Norman (4.2 mg/m^3) indicate that phytoplankton standing crops in Lake Wylie are over twice as high as those in Lake Norman. A positive direct relationship between phytoplankton standing crop and primary productivity and expected fish yield has been found by other investigators (Oglesby 1977, Jones and Hoyer 1981). Accordingly, higher phytoplankton standing crops in Lake Wylie would indicate potentially higher fish yields.

Creel harvest data indicated the substantial productivity differences between Lake Norman and Lake Wylie, while the major physical/chemical parameter comparisons provided some basis for correlating productivity with the aforementioned parameters. Logically then, the question arises, could certain nonfield predictive models based on such correlations yield predictions that are comparable to harvest estimates. Such a question was first addressed in the mid-1960s when Richard A. Ryder presented the popularized morphoedaphic index (MEI) (total dissolved solids in mg/liter divided by mean depth in meters) as an estimator of potential fish yield for Canadian Lakes (Ryder 1965). In recent years, the concept has been more specifically applied to the prediction of sport fish harvests and standing crops in temperate reservoirs (Jenkins 1982). The MEI has received much attention and has been extensively reviewed (Ryder et al. 1974), criticized (Youngs and Heimbuch 1982), and defended (Oglesby 1982). The MEI as outlined by Jenkins (1982) was applied to Lake Norman and Lake Wylie (Table 7). The MEI harvest prediction for Lake Norman was about 60% higher than the mean harvest estimated from the 2 Lake Norman creel surveys. On the other hand, the MEI harvest prediction for Lake Wylie was about 25% lower than the mean harvest estimated from the 2 creel surveys on Lake Wylie. Considering the substantial temporal variability in harvests within each reservoir (Table 7), however, the MEI predictions are fairly reasonable. The MEI can provide a quick, cost-effective means to predict the sport fish harvest or yield for a particular reservoir (Jenkins 1982). In situations where costly, detailed creel data are not available or necessary, the MEI can be an important management tool.

Not only have morphoedaphic characteristics been related to fish harvests, but measures of primary productivity have also been correlated to fish harvests. Oglesby (1977) developed an index to estimate harvest using chlorophyll *a* values in lakes, and Jones and Hoyer (1981) used mean summer

Table 7. Comparisons of Lake Norman, North Carolina, and Lake Wylie, North Carolina and South Carolina, estimated creel harvests to harvests predicted by the morphoedaphic index (MEI) and by mean summer chlorophyll *a*.

	Lake Norman			Lake Wylie		
	1977–78	1981–82	$\bar{X}$	1979–80	1982–83	$\bar{X}$
Estimated harvest by creel (kg/ha/year)	5.3	12.5	8.9	35.6	20.6	28.1
Predicted harvest by MEI (kg/ha/year)[a]			14.3			21.0
Predicted harvest by chlorophyll (kg/ha/year)[b]			9.5			24.9

[a] MEI = Total dissolved solids/mean depth (Ryder 1965).
[b] Yield = – 1.8 + 2.7 • mean summer chlorophyll *a* (Jones and Hoyer 1981).

chlorophyll *a* to estimate harvest in midwestern lakes and reservoirs. An application of this index to Lake Norman and Lake Wylie provided harvest predictions very close to estimated mean harvest for each reservoir (Table 7). Predicted harvest for Lake Norman was slightly higher than the creel estimate while predicted harvest for Lake Wylie was slightly less than the estimated creel harvest. This index can provide the manager with a cost effective method to obtain a quick prediction of expected fish harvest.

It is apparent from the studies of Lake Norman and Lake Wylie that broad management practices on a regional basis may not be optimal management policy. Assuming that geographical proximity results in resource similarity may lead to ineffective management practices. For proper resource management and utilization, reservoirs should be considered on a case-by-case basis. Manpower and budget constraints, however, may not allow this freedom. In such cases, previously mentioned predictive models can be useful in considering reservoir differences based on physical and chemical parameter differences.

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