The Fish Community of Lake Ellis Simon, North Carolina

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Abstract: We sampled the fish community of 607-ha Lake Ellis Simon (Lake Ellis), North Carolina, from 1980 to 1983 with 6 types of gear. Several currently used fishery indices were calculated from the data and the values evaluated for classification of the fish community of Lake Ellis Simon. More of the 21 species recorded from the lake were taken by electrofishing and rotenone (18 and 17, respectively) than by the other methods. Electrofishing provided the largest catch per unit of effort. Standing crop estimates based on rotenone sampling were 51 kg/ha in 1981 and 78.7 kg/ha in 1983. About 91% of the biomass in the rotenone samples was contributed by 8 species: yellow bullhead (*Ictalurus natalis*), lake chubsucker (*Erimyzon sucetta*), yellow perch (*Perca flavescens*), bluespotted sunfish (*Enneacanthus gloriosus*), warmouth (*Lepomis gulosus*), chain pickerel (*Esox niger*), redfin pickerel (*Esox americanus americanus*), and largemouth bass (*Micropterus salmoides*). Biomass of piscivorous fish species (primarily largemouth bass) represented 52.5% of the total. The F/C values of rotenone collections in 1981 and 1983 were 3.4 and 0.39 and Y/C values were 0.47 and 0.08. AP/P values of rotenone collections ranged from 1.2 to 20.1 in 1981 and from 0.5 to 12.1 in 1983. In the 1981 and 1983 rotenone collections 63.2% and 85.6% of the fish were classed as harvestable (A_t value). These and other indices (PSD, RSD_{15}, YAR and W_r) reflected the relatively high predator biomass.

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Indices describing freshwater fish communities and their potentials for supporting sport fisheries are based on trophic level biomass estimates and relationships within and between species, determined by numbers, lengths, and physical condition of fish. For the most part, indices were developed from pond systems that differ significantly from large reservoirs and lakes (Carline et al. 1984). Swingle (1950) provided indices that are still frequently used by fishery managers in the

southeastern U.S. These include F/C, weight of forage species (F) divided by weight of piscivorous species (C); Y/C, weight of forage fish (Y) small enough to be eaten by the average size predator, divided by the total weight of piscivores (C); and A_t (percentage of weight of larger fish in a population). Jenkins and Morais (1976), using cove rotenone sample data from large reservoirs, developed an available prey-predator model (AP/P) that describes the cumulative weight of "prey" species that can be eaten by the cumulative weight of predator fish as determined by an equivalence scale, based on largemouth bass length classes.

In addition to biomass indices, Swingle (1956) also described "balanced" communities on the basis of numbers and condition of small and intermediate sized fish caught with seines. Indices of proportional stock density (PSD) and relative stock density (RSD), which are based on the percentages of numbers of fish of selected lengths in populations, were developed by Anderson (1976) and Wege and Anderson (1978). Swingle and Swingle (1967) suggested a standard length-weight relationship for largemouth bass based on the relative condition factor (K_r) developed by LeCren (1951). Wege and Anderson (1978) provided a standard to be used for relative weight (W_r) comparisons of largemouth bass populations. An index to reproductive success of largemouth bass (YAR, number of young $\leq$15 cm divided by the number of adults $\geq$30 cm) was described by Reynolds and Babb (1978).

Such indices may improve the understanding of fish communities and provide managers a means of evaluating fisheries with a minimum of manpower. However, due to a lack of comparable data sets, variable opinions as to what constitutes desirable populations, and problems associated with collection methods, evaluations of the indices are scarce.

The objectives of our study were to determine if several current indices, developed for farm pond communities, would also represent the multi-species fish community of Lake Ellis Simon (Lake Ellis).

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Methods

Lake Ellis Simon is a 607-ha impoundment in the Croatan National Forest, North Carolina; the maximum depth is 1 m except in canals (which are 1-2 m deep). Submerged and emergent aquatic vegetation, including various tree species, cover 70% to 80% of the area (Roe 1981). Secchi disk visibility was typically to the sand or silt bottom except during periods of heavy precipitation, when waters stained

with tannic acid entered the lake. Alkalinity ranged from 4.5 to 9.5 ppm and pH from 4.5 to 5.5 in the samples taken monthly from May 1979 to April 1980.

Six collection methods were used: electrofishing, rotenone, experimental gill nets, fyke nets, wire traps, and small mesh seines. A Smith-Root Type VI electroshocker was operated for 1.5 hours at several dispersed shoreline locations during daylight on 23 July 1980. Rotenone was used on 21–24 July 1981 and 1–2 August 1983 in 8 0.04-ha areas with depths of 60–90 cm. The areas selected were the same in both years and included vegetated or nonvegetated areas with sand or silt substrates. They were enclosed with block netting before the rotenone was applied. Five experimental gill nets, 30.5 m long, 1.6 m deep, each consisting of 4 panels of net with meshes of 1.9, 2.5, 3.8, 5.1 cm (bar measure) were set in open water between stands of emergent vegetation for a total of 462 hours of effort in July 1980. Nine fyke nets (2.5-cm bar mesh) 8.3 m long, 1.4 m in diameter, and with 9.2-m wings were set in July 1980 for a total of 238 hours. Three wire traps constructed of 2.5-cm mesh poultry wire, 1.2 m long and about 60 cm in diameter, with single funnels, were also set in July 1980 (total of 244 hours of fishing effort). Additionally, 10 efforts with a 20-m long, 1.4-m deep seine with 1.2 cm mesh were conducted. Creel and fishing pressure surveys were conducted either by the investigators or the camp members. Total lengths, weights, and scale samples of fish caught by sportsmen were collected in April of 1979 and 1983. The data from each collection method were developed, when suitable, into the previously mentioned indices for analysis.

Results and Discussion

The species, numbers, and lengths of fish collected by the different methods varied widely. Catch per unit of effort was lowest (0.02 kg/hour) in wire traps. Fyke nets and gill nets were more effective, capturing 0.14 kg/hour and 0.36 kg/hour respectively. Electrofishing was the most efficient (Table 1).

Warmouth, lake chubsuckers, largemouth bass, and yellow bullheads were (in descending order) the most abundant of the species caught in 1.5 hours daylight electrofishing. On a weight basis, largemouth bass (8.0 kg), warmouth (2.9 kg), yellow bullheads (2.8 kg), bowfins (*Amia calva*) (2.4 kg), and lake chubsuckers (1.9 kg) were the major species. Total weight of fish collected by electrofishing was 20.3 kg.

Rotenone sampling required approximately 6 to 8 man-days each year, but this method collected more fish and more small fish than any other method. The shallow, clear water permitted recovery of virtually all the fish and adjustments were not made for unrecovered losses (Grinstead et al. 1976). In 1981, the bluespotted sunfish was the most abundant species in the rotenone collections, and the lake chubsucker, yellow perch, swamp darter (*Etheostoma fusiforme*), and swamp fish (*Chologaster cornuta*) ranked next. Composition of the 16.8 kg total biomass, in descending order, included yellow perch, largemouth bass, warmouth, lake chub-

Table 1. Number (*N*) and weight (kg) of fish caught and catch per hour of effort by sample method, Lake Ellis Simon, North Carolina. (Dash indicates weight was not determined.)

	Wiretrap		Fyke net		Gill net		Electroshocking		Rotenone 1981		Rotenone 1983	
Species	*N*	Kg	*N*	Kg	*N*	Kg	*N*	Kg	*N*	Kg	*N*	Kg
Bowfin *Amia calva*					7	16.25	3	2.43			1	2.02
American eel *Anguilla rostrata*							5	.56			1	.005
Eastern mudminnow *Umbra pygmaea*							1	—	1	.002	1	.001
Redfin pickerel *Esox americanus*							1	—	3	.02	2	.05
Chain pickerel *Esox niger*					2	1.39	2	.12	29	1.33	32	2.20
Golden shiner *Notemigonus crysoleucas*					8	.71	1	.03				
Lake chubsucker *Erimyzon sucetta*			49	11.97	60	22.76	27	1.90	140	1.76	252	1.02
Yellow bullhead *Ictalurus natalis*	6	1.91	13	4.35	347	95.24	17	2.79	50	1.24	65	1.93
Brown bullhead *Ictalurus nebulosus*			5	1.10	4	2.25						
Swampfish *Chologaster cornuta*							3	—	70	.03	55	.01

Pirate perch *Aphredoderus sayanus*							1	—	1	.001	14	.02
Mosquitofish *Gambusia affinis*							2	—	11	0.01	3	—
Mud sunfish[a] *Acantharcus pomotis*												
Flier *Centrarchus macropterus*					1	.13	3	.15				
Bluespotted sunfish *Enneacanthus gloriosus*							10	—	1,990	1.64	1,675	0.72
Warmouth *Lepomis gulosus*	6	.44	69	6.30	20	1.98	29	2.94	60	2.11	73	1.88
Bluegill *Lepomis macrochirus*	13	1.10	24	5.05	1	.34	9	1.31	2	.50	1	0.34
Redear sunfish *Lepomis microlophus*									1	.34	1	0.43
Largemouth bass *Micropterus salmoides*	1	.26	4	3.12	29	12.92	19	7.94	27	2.48	26	14.04
Swamp darter *Etheostoma fusiforme*							2	—	92	.03	139	0.02
Yellow perch *Perca flavescens*			3	.26	74	11.31	1	0.10	95	5.31	32	0.80
Total weight	26	3.71	167	32.15	553	165.28	136	20.27	2,561	16.79	2,370	25.49
Catch/hour		.02		.14		.36		13.51				

[a]Collected with rotenone in canal (not part of structured samples)

suckers, bluespotted sunfish, and others (3.8 kg). The estimated standing crop of fish was 50.9 kg/ha. In 1983, bluespotted sunfish and lake chubsuckers were again the most abundant species, followed by swamp darters and warmouth. Largemouth bass composed 14 kg of the total of 25.5 kg collected. Chain pickerel (2.2 kg), one bowfin (2.0 kg), and warmouth (1.9 kg) were next in terms of declining biomass. Estimated standing crop in 1983 was 79.9 kg/ha. Variations between the 0.04-ha rotenone samples were large for species, numbers, and weights of fish collected. Total weights ranged from 0.64 kg to 3.10 kg in the 1981 samples and 0.07 kg to 14.99 kg in 1983. The total weight difference, 16.8 kg and 25.5 kg in 1981 and 1983 respectively, could be due to sample variation rather than between year differences of standing crop.

Evaluations of fishery indices on the basis of data collected by the various methods were affected by catch per unit effort, species representation, and information about smaller fish. Data on catches from wire traps and fyke nets were considered of no value for evaluations of the indices. Efforts with the seine were also ineffective because fish escaped due to water clarity or to the interference of mats of vegetation. Creel and gill net collections were of limited value because they included no small fish. Collections made by electrofishing and with rotenone were the most useful.

Forage/carnivorous (F/C) values (calculated from the collections in gill nets and by electrofishing) were 4.4 and 0.93, respectively; values from rotenone collections were 3.4 in 1981 and 0.39 in 1983. Thus, the gill net data (though they did not include the smallest fish) and the 1981 rotenone data indicated that F/C values were within the optimum range (3.0–6.0) suggested by Swingle (1950). However, the F/C values for electrofishing and 1983 rotenone samples were below the optimum range and indicated that predators were overcrowded.

Young/carnivorous (Y/C) values were 0.62 from the electrofishing and 0.47 and 0.08 from the 1981 and 1983 rotenone samples, respectively. Thus the electrofishing results and 1981 rotenone values were within the Y/C "balanced range" (0.2–4.8), though they were lower than the optimum range of 1.0–3.0. The 1983 Y/C value was indicative of a marginally overcrowded piscivorous population (Swingle 1950).

Jenkins and Morais (1976) considered a 1:1 or higher ratio for the available prey/predator (AP/P) index to be desirable for August collections, since their ratio suggested that the weight of prey available to predators was adequate through fall and winter, and thus the predators would probably be in good condition for the following spring. In Lake Ellis Simon rotenone samples, the ratio exceeded 1:1 for all predator size classes in 1981 and for all except the three largest predator size classes (56, 58, and 61 cm) in 1983. Sample AP/P ratios obtained from rotenone collections were generally higher in 1983 than in 1981 (Table 2). In both years the ratios for the smallest size classes of predators were higher than those reported in the literature for reservoirs. This observation suggested that a large forage base was available and did not indicate a large biomass of predators (Table 2). These results may reflect the ease of recovering small fish at Lake Ellis Simon, as contrasted to

Table 2. Index values for sample methods and years at Lake Ellis Simon. (N indicates the data were not suitable for developing the index.)

Sample method and year		Biomass indices				Numerical indices			Relative weight
		F/C	Y/C	A_t	AP/P	PSD	RSD_{15}	YAR	(W/W_s)
Rotenone	1981	3.38	0.47	63.2	2.5–20.1	33.3	N	8.5	0.7–1.1
	1983	0.39	0.08	85.6	0.5–12.1	25.0	20.8	3.6	0.7–1.0
Electroshocker	1980	0.93	0.62	59.3	0.1–1.4	27.7	27.3	1.6	0.9–1.6
Gill net	1980	4.41	N	N	N	28.6	7.14	N	0.8–1.2
Creel	1979	N	N	N	N	N	N	N	0.7–1.1
	1983	N	N	N	N	N	N	N	0.7–1.3
Satisfactory range		1.4–10.0	0.5–4.8	40–85	1:1	40–70	10–25	1–10	1
Optimum range		3.0–6.0	1.0–3.0	60–85					

recovery in cove rotenone samples of larger reservoirs, or to the dense vegetation making small fish less available as prey. Based on the 1980 electrofishing collections, the indices were consistently lower than 1 : 1 for smaller size classes of largemouth bass but consistently exceeded 1 : 1 for bass longer than 41 cm. This difference may have reflected electrofishing selectively for larger fish.

The Total Availability (A_t) index (percentage of the total weight of a population composed of fish of harvestable size (Swingle 1950)) ranges from 33% to 90% in balanced populations and 60% to 85% is considered in the desirable range. Values >80% indicate populations containing a large and efficient predatory population. The index calculated from electrofishing data was 59.3, within the balanced range. Values for the 1981 and 1983 rotenone collections were 63.2 and 85.6, respectively, and thus were in the desirable range in 1981 but indicated overcrowding of predatory species in 1983.

Wege and Anderson (1978) suggested the length-weight relationship equation $\log_{10} W_g = -5.316 + 3.191 \log_{10} TL_{mm}$ as a "standard" for largemouth bass >152 mm. If largemouth bass of given lengths weigh less than those calculated from the "standard," the authors indicated the biomass of available prey is smaller than desirable. A similar standard was provided by Swingle and Swingle (1967), but they noted that a single equation may not accurately represent the length-weight relationships of both small and larger largemouth bass.

The W_r or relative weight index (Wege and Anderson 1978) of largemouth bass collected with rotenone at Lake Ellis Simon was generally lower than the suggested 95% favorable range for smaller largemouth bass and higher than 100% for larger largemouth bass. Comparisons of these fish with the suggested standards of Swingle and Swingle (1967) and Wege and Anderson (1978) indicated that the condition of smaller largemouth bass of the population was relatively poor. Data for largemouth bass <20 mm long were not considered suitable for examining this relationship.

Indices of population composition based on numbers and lengths of fish include the seine methods of Swingle (1950) and proportional and relative stock density indices of Anderson (1976). Because seine collections were not representative, as explained above, we used rotenone data to develop the Swingle numerical evaluations. The results met the Swingle criteria for a population crowded with piscivorous fish and in a precarious balance. Four factors contributed to this conclusion: young largemouth bass were present; no small or intermediate-sized bluegills were collected; few adult bluegills were caught; and there was an abundant number of species that compete with bluegills.

Proportional Stock Density (PSD) of largemouth bass is defined as the number of "quality-size" fish in a sample divided by the number of "stock-size" fish × 100 (Anderson 1976). "Stock" and "quality" sizes are defined as those ≥20 cm and ≥30 cm respectively. Because of the low standing crop of fish at Lake Ellis Simon, in contrast to the crops in more fertile ponds and reservoirs, the numbers of largemouth bass in the samples did not satisfy the recommended requirements for computing the PSD index (Anderson and Gutreuter 1983). The creel information was

reported on a voluntary basis and thus fishermen catches were not used as a source of information.

Relative Stock Density (Wege and Anderson 1978), defined as the number of largemouth bass >38 cm long in a sample, divided by the number >20 cm long × 100, was also affected by low numbers of largemouth bass in the collections. No largemouth bass >38 cm long were collected in the 1981 rotenone samples. However, gill net data indicated an index value of 7%, below the 10%–25% desirable range. The electrofishing and the 1983 rotenone results provided 27% and 21% values, respectively, and were within or near the desirable range. In addition to small numbers of largemouth bass collected, factors that may affect PSD or RSD values and their interpretation are annual variations in recruitment, nutrient input, water levels, and size of impoundment (Carline et al. 1984).

Schools of small largemouth bass were observed during each study year and satisfactory recruitment was indicated by the YAR indexes determined from the electrofishing and rotenone samples. The acceptable range is regarded as being between 1 and 10 (Reynolds and Babb 1978). The YAR values for the electrofishing and the 1981 and 1983 rotenone data were 1.7, 8.5, and 3.6, respectively. Creel and gill net data were not suitable for developing this index.

In summary, the standing crop of Lake Ellis Simon, as compared with crops reported for many midwestern and southern ponds and reservoirs, was relatively low. Even though low, it provided a good fishery for largemouth bass for about 25 fishermen. Similar waters constitute an appreciable portion of the aquatic resources of Atlantic coast states, but little effort has been made toward describing their populations. Even less has been accomplished toward developing strategies for managing their fisheries. We demonstrated that, in an instance of a relatively high population of piscivorous fish, some of the available indices to fish populations were useful for depicting the fish population of this low-productive lake.

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