CHANGES IN THE FISH COMMUNITY OF LAKE CARL BLACKWELL, OKLAHOMA (1967-77) AND A TEST OF THE REPRODUCTIVE GUILD CONCEPT

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Numerical density, biomass density, and diversity of fishes in coves of Lake Carl Blackwell were estimated in 7 years during the period 1967-77. Among fishes within the same reproductive guild, some exhibited similar trends in abundance but others did not. Some species in different reproductive guilds showed similar trends in abundance. Densities of fishes within the following groups were positively correlated with each other: (a) green sunfish (*Lepomis cyanellus*), longear sunfish (*Lepomis megalotis*), flathead catfish (*Pylodictis olivaris*), and white crappie (*Pomoxis annularis*); (b) gizzard shad (*Dorosoma cepedianum*), orangespotted sunfish (*Lepomis humilis*), black bullhead (*Ictalurus melas*), and largemouth bass (*Micropterus salmoides*); and (c) freshwater drum (*Aplodinotus grunniens*), river carpsucker (*Carpiodes carpio*), and white bass (*Morone chrysops*).

INTRODUCTION

The effect of reservoir water management on the abundance of fishes has been the topic of numerous investigations. Reservoir water regimens affect the fish community directly by influencing reproductive success (1, 2) and indirectly by altering plankton abundance (3, 4), benthos abundance (5, 6, 7, 8), and the establishment of aquatic macrophytes (9, 10).

Typically investigations into the factors governing density and biomass of fishes have focused on individual species. With the increasing interest in applying ecosystem modeling techniques to reservoir management, the need for a more meaningful ecological classification of fishes has become apparent. Preliminary attempts to develop reservoir ecosystem models have involved a functional classification based on food habits (11, 12, 13). The weakness here was the inability to accurately model recruitment. For instance, by maintaining a constant water level during the simulation of a reservoir cove ecosystem, Patten (13) concluded that the fish compartments appeared to be insensitive to water level variations. However, the marked effect of water level variations on recruitment of reservoir fishes has been documented in many reservoirs (14, 15, 16, 17).

Balon (18) has proposed an ecological classification scheme that is based on the reproductive strategies of fishes. Fishes are grouped into guilds based on breeding behavior and the character of their predominant spawning grounds, as well as on the morphology of embryonic and larval respiratory organs and pigments, and behavior of embryos and larvae. Balon hypothesized that, since the density of fishes is typically determined during these early stages, classification by reproductive guild may prove to be more meaningful than classification by feeding strategies. If the reproductive guild concept is valid, fishes within the same guild should exhibit similar trends in abundance. The objective of this study was to examine the changes in the structure of the fish community of Lake Carl Blackwell to see if fishes in the same reproductive guild do indeed exhibit similar trends in abundance.

STUDY AREA

Lake Carl Blackwell is a 1400-hectare impoundment located in Payne County in north central Oklahoma that has been subject to large fluctuations in water level since its impoundment in 1938 (Fig. 1). During years of declining water levels, terrestrial vegetation developed along the exposed shoreline and in years of rising water levels this vegetation was inundated. Declining water levels, unstable bottom sediments, and wave action probably in-

*Cooperators are the Oklahoma Department of Wildlife Conservation, the Oklahoma State University, and the U. S. Fish and Wildlife Service.

hibit the development of aquatic macrophytes in the littoral zone.

METHODS AND MATERIALS

Estimates of fish standing crops in coves were made by personnel of the Oklahoma Cooperative Fishery Research Unit in July and October 1967 and July and September 1971 (19) and during the second week of August for 1973-77. In 1967 and 1971 two coves were sampled — one in the northeast arm of the lake, and the other on the north shore of the lake; in 1973 two of the three coves sampled were in the northeast arm of the lake and the other cove was in a southern arm; and each year in 1974-77, the same two adjacent coves in the northeast arm of the lake were sampled.

Coves were mapped to determine area and volume. The mouth of the cove was blocked with a net (6.4 mm square mesh) and a 5% solution of rotenone was applied at a concentration of 2-3 mg/*l*. Fish were collected for a 3-day period, identified, and weighed. The numbers of dead fish of each species recovered were divided by the area of the cove to obtain numerical densities. Biomass densities were obtained by multiplying numerical densities by the mean weight of individuals of each species. Estimates were not expanded on the basis of percent recovery since percent recovery was not determined each year. In years when fish were marked and released before rotenone was applied, the recovery of marked fish ranged from 44 to 70%.

Diversity of the fish communities was measured by the Shannon-Weaver index:

$$\bar{d} = \sum_{i=1}^{s} p_i \log_2 p_i$$

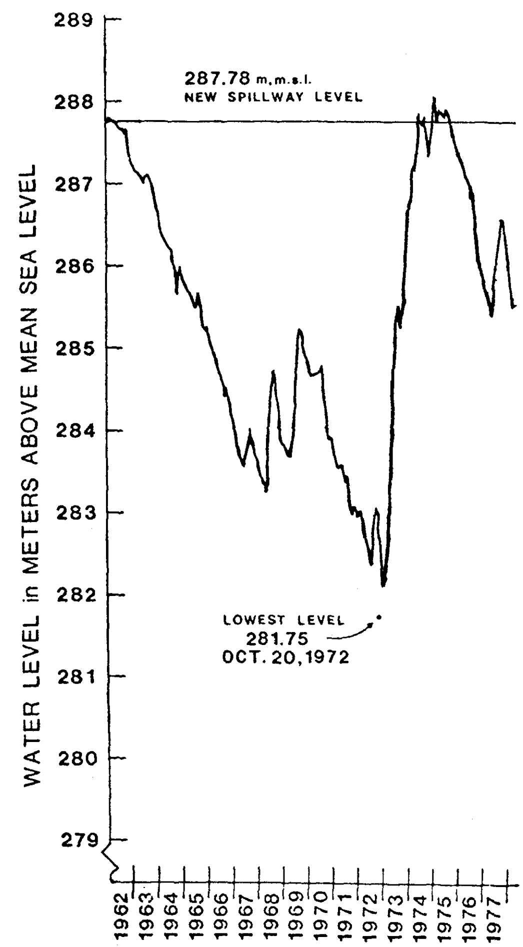

FIGURE 1. Fluctuations in the water surface elevation of Lake Carl Blackwell, 1962-1977.

where p_i is the proportion of fish (as either individuals or biomass) in the *i*th species and *s* is the total number of species (20, 21).

Correlation coefficients were computed between the numerical densities of all possible combinations of species, and between diversity ($\bar{d}$) calculated from numerical units and the numerical densities of each species.

RESULTS

The nest-spawning lithophil guild of Balon (18) contains the greatest number of fish species (six) from Lake Carl Blackwell (Table 1); other guilds are represented by only one to three species.

Twenty species were collected from the coves, of which 13 were collected in all seven years (Tables 2 and 3). Gizzard shad made up the greatest proportion of the fish community in both numbers and biomass in almost every year. Abundance of all fish species varied from year to year as did the total fish standing crop (Tables 2 and 3; Fig. 2). Total fish standing crop increased markedly after 1973, from an average of 156 kg/hectare for 1967 and 1971, to an average of 387 kg/hectare for 1974 through 1977. Several species (notably gizzard shad and orangespotted sunfish) produced a large year class in 1973 as evidenced by the increase in numerical density, and decrease in mean weight per individual (Fig. 2).

Diversity as calculated from numerical units declined from 1967 to 1973, and then increased through 1977. Diversity as calculated from biomass units was higher than diversity calculated from numerical units in all years except 1975, when the gizzard shad reached its highest biomass (Fig. 3). Diversity for all years averaged 2.01 and 2.57, respectively, based on numerical and biomass units. Diversity calculated from numerical units was positively correlated with numerical densities of white crappie (r = 0.77; P = 0.04), green sunfish (r = 0.75; P = 0.05), and channel catfish (r = 0.77; P = 0.04).

The matrix of correlation coefficients (Table 4) indicated which fish species exhibited similar trends in abundance. Three lithophils (longear sunfish, green sunfish, and flathead catfish) had similar trends in abundance.

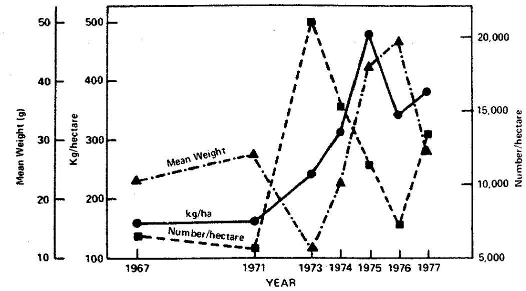

FIGURE 2. Mean weight per individual (g), biomass per hectare (kg/ha), and numbers per hectare (no/ha) of all fishes recovered in cove rotenone samples from Lake Carl Blackwell.

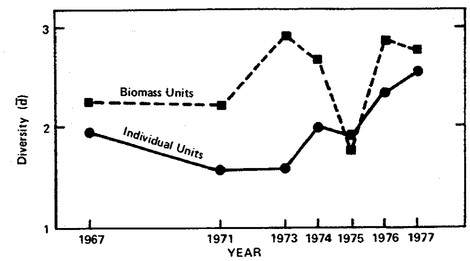

FIGURE 3. Diversity ($\bar{d}$) of fishes recovered in cove rotenone samples from Lake Carl Blackwell.

DISCUSSION

The hypothesis examined here is that fishes which use similar reproductive strategies to exploit the same resources should exhibit similar trends in abundance. These

TABLE 1. *Reproductive guilds of fishes of Lake Carl Blackwell.*

Reproductive guilds[a]	Species: Common name	Species: Scientific name
A. Nonguarders		
A.1 Open substrate spawners		
Pelagophils	Freshwater drum	*Aplodinotus grunniens*
Litho-pelagophil	Gizzard shad	*Dorosoma cepedianum*
Phytolithophil	White bass	*Morone chrysops*
Phytophil	Carp	*Cyprinus carpio*
	Golden shiner	*Notemigonus chrysoleucas*
Psammophil	River carpsucker	*Carpiodes carpio*
B. Guarders		
B.1 Substratum choosers		
Phytophil	White crappie	*Pomoxis annularis*
B.2 Nest spawners		
Lithophils	Bluegill	*Lepomis macrochirus*
	Longear sunfish	*Lepomis megalotis*
	Orangespotted sunfish	*Lepomis humilis*
	Green sunfish	*Lepomis cyanellus*
	Flathead catfish	*Pylodictis olivaris*
	Black bullhead	*Ictalurus melas*
Phytophils	Largemouth bass	*Micropterus salmoides*
	Black crappie	*Pomoxis nigromaculatus*
	Redear sunfish	*Lepomis microlophus*
Speleophils	Channel catfish	*Ictalurus punctatus*
	Minnows	*Pimephales* spp.
C. Bearers		
C.2 Internal bearers		
C.2.3 Viviparous	Mosquitofish	*Gambusia affinis*

[a]from Balon (18).

data on the changes in the abundance of fishes of Lake Carl Blackwell show that, among fish species within the same reproductive guild, some exhibited similar trends in abundance but others did not. Also, some fishes in different reproductive guilds showed similar trends in abundance.

Among the nest-spawning lithophils, the longear sunfish, green sunfish, and flathead catfish showed similar trends in abundance. Two other nest-spawning lithophils, orangespotted sunfish and black bullhead, also showed similar trends in abundance, but the abundance of neither was correlated

TABLE 2. *Number of fish per hectare (no/ha) recovered in cove rotenone samples from Lake Carl Blackwell.* (T = trace, <0.05%)[a]

Species	1967 no/ha	%	1971 no/ha	%	1973 no/ha	%	1974 no/ha	%	1975 no/ha	%	1976 no/ha	%	1977 no/ha	%
Gizzard shad	4,448	67.7	4,126	71.7	15,929	74.4	7,074	46.8	5,730	49.3	2,571	35.0	5,768	42.6
Bluegill	328	5.0	127	2.2	1,634	7.6	5,266	34.8	3,932	33.8	2,599	35.0	2,081	15.4
White crappie	377	5.7	110	1.9	503	2.4	374	2.5	336	2.9	480	6.5	1,071	7.9
Longear sunfish	256	3.9	39	.7	445	2.1	833	5.5	645	5.5	237	3.2	1,092	8.1
Freshwater drum	428	6.5	845	14.7	225	1.0	217	1.4	139	1.2	431	5.8	641	4.7
Orangespotted sunfish	330	5.0	34	.6	1,137	5.3	157	1.0	26	.2	118	1.6	170	1.3
Green sunfish	90	1.4	60	1.0	616	2.9	669	4.4	332	2.9	586	7.9	1,805	13.3
Largemouth bass	87	1.3	17	.3	451	2.1	319	2.1	293	2.5	121	1.6	203	1.5
Channel catfish	71	1.0	59	1.0	54	.3	55	.4	142	1.2	110	1.5	185	1.4
Carp	45	.7	146	2.5	130	.6	29	.2	4	T	83	1.1	181	1.3
River carpsucker	7	.1	136	2.4	39	.2	23	.2	9	.1	62	.8	51	.4
White bass	22	.3	36	.6									20	.2
Flathead catfish	3	T	4	.1	31	.2	40	.3	31	.3	22	.3	64	.5
Pimephales spp.	40	.6	14	.2	37	.2	4	T	4	T	1	T	45	.3
Black bullhead	1	T			107	.5	13	.1	3	T	3	T	9	.1
Others[b]	34	.5			63	.3	53	.4	8	.1	4	T	164	1.2
Total	6,567		5,753		21,401		15,126		11,634		7,428		13,548	
Diversity (d)	1.91		1.57		1.58		2.00		1.92		2.45		2.66	

[a]Data for 1967, weighted average for two samples on 17 July and 23 October (Johnson, 19); for 1971, weighted average for four samples on 30 July, 11 August, 25 August, and 13 September (Johnson, 19); for 1973, weighted average for three samples taken during the second week of August; and for 1974-77, weighted average for two samples taken during the second week of August.

[b]Others included red shiner, *Notropis lutrensi* (1967, 1973, 1977); golden shiner (1973, 1974, 1975, 1976); mosquitofish (1973, 1974, 1976, 1977); redear sunfish (1974); and black crappie (1973, 1974, 1975).

with the abundance of other lithophils. There were, however, no significant correlations between the abundance of bluegills and other lithophils. It is possible that not all members of the nest-spawning lithophil guild are similarly affected by the same factors. Furthermore, some factors may be common to members of different guilds.

If fishes with similar trends in abundance were combined, they would form three groups: (a) green sunfish, longear sunfish, flathead catfish, and white crappie; (b) gizzard shad, orangespotted sunfish,

TABLE 3. *Biomass of fish per hectare (kg/ha) recovered in cove rotenone samples from Lake Carl Blackwell.* (T = trace; <0.05 kg/ha)[a]

Species	1967 kg/ha	%	1971 kg/ha	%	1973 kg/ha	%	1974 kg/ha	%	1975 kg/ha	%	1976 kg/ha	%	1977 kg/ha	%
Gizzard shad	75.9	50.3	68.3	42.6	70.6	29.4	143.3	43.4	322.5	66.0	87.5	25.3	63.9	16.7
Bluegill	3.7	2.5	1.7	1.0	15.9	6.6	53.5	16.2	74.9	15.3	47.6	13.8	38.1	9.9
White crappie	10.7	7.1	4.1	2.5	11.8	4.9	25.1	7.6	14.4	2.9	11.8	3.4	27.2	7.1
Longear sunfish	3.1	2.1	1.1	0.7	5.2	2.2	11.4	3.5	7.4	1.5	5.3	1.5	6.5	1.7
Freshwater drum	15.0	10.0	13.5	8.4	8.4	3.5	15.7	4.7	9.7	2.0	31.2	9.0	35.2	9.2
Orangespotted sunfish	1.2	0.8	0.2	0.1	2.9	1.2	1.2	0.4	0.1	0.0	0.6	0.2	0.6	0.2
Green sunfish	1.2	0.8	0.9	0.6	20.8	8.7	11.6	3.5	4.8	1.0	7.5	2.2	7.5	1.9
Largemouth bass	8.4	5.6	3.9	2.5	6.6	2.7	24.3	7.3	16.2	3.3	5.8	1.7	19.6	5.1
Channel catfish	4.4	2.9	3.4	2.1	5.5	2.3	10.1	3.1	26.4	5.4	21.1	6.1	17.4	4.5
Carp	25.2	16.7	37.4	23.3	64.7	27.0	16.4	5.0	3.8	0.8	78.6	22.8	138.2	35.9
River carpsucker	0.5	0.3	24.6	15.3	18.9	7.9	10.8	3.3	5.7	1.2	44.7	13.0	27.2	7.1
White bass	1.4	0.9	0.9	0.6									0.2	0.1
Flathead catfish	0.1	0.0	0.2	0.1	7.1	3.0	3.8	1.2	2.6	0.5	3.0	0.9	2.3	0.6
Pimephales spp.	T	0.0	T	0.0	0.1	0.0	T	0.0	T	0.0	T	0.0	T	0.0
Black bullhead					0.7	0.3	1.1	0.3	0.2	0.0	0.7	0.2	1.3	0.3
Others[b]	T	0.0			0.8	0.3	1.1	0.7	0.1	0.0	T	0.0	0.1	0.0
Total	150.9		160.3		240.1		330.2		488.8		345.5		385.3	
Diversity (d)	2.37		2.34		2.94		2.76		1.80		2.90		2.87	

[a]Data from 1967, weighted average for two samples on 17 July and 23 October (Johnson, 19); for 1971, weighted average for four samples on 30 July, 11 August, 25 August, and 13 September (Johnson, 19); for 1973, weighted average for three samples taken during the second week of August; and for 1974-77, weighted average for two samples taken during the second week of August.

[b]Others included red shiner (1967, 1973, 1977), golden shiner (1973, 1974, 1975, 1976), mosquitofish (1973, 1974, 1976, 1977), redear sunfish (1974), and black crappie (1973, 1974, 1975).

TABLE 4. *Correlation coefficients between the abundance of fishes recovered in cove rotenone samples from Lake Carl Blackwell, 1967-77.*

Species	Gizzard shad	Bluegill	White crappie	Longear sunfish	Freshwater drum	Orangespotted sunfish	Green sunfish	Largemouth bass	Channel catfish	Carp	River carpsucker	White bass	Flathead catfish	*Pimephales* spp.	Black bullhead
Gizzard shad	1.00	.05	.12	.18	—.44	.91[a]	.12	.84[b]	—.32	.19	—.21	—.38	.25	.38	.97[a]
Bluegill		1.00	.09	.61	—.68	—.22	.25	.56	.17	—.55	—.48	—.76[b]	.55	—.57	—.06
White crappie			1.00	.74	.07	.13	.95[a]	.23	.72	.49	—.24	—.10	.82[b]	.57	.11
Longear sunfish				1.00	—.30	—.05	.82[b]	.51	.59	.04	—.46	—.32	.94[a]	.21	.03
Freshwater drum					1.00	—.34	.10	—.77[b]	.10	.72	.82[b]	.89[a]	—.20	.25	—.37
Orangespotted sunfish						1.00	.04	.64	—.39	.25	—.20	—.29	.04	.52	.96[a]
Green sunfish							1.00	.28	.69	.52	—.09	—.12	.92[a]	.40	.09
Largemouth bass								1.00	—.05	—.16	—.53	—.75	.53	.07	.75[b]
Channel catfish									1.00	.19	—.16	—.03	.64	.15	—.35
Carp										1.00	.65	.51	.26	.55	.27
River carpsucker											1.00	.62	—.27	—.13	—.12
White bass												1.00	—.36	.39	—.38
Flathead catfish													1.00	.19	.16
Pimephales spp.														1.00	.37
Black bullhead															1.00

[a] = significant at $P < .01$
[b] = significant at $P < .05$

black bullhead, and largemouth bass; and (c) freshwater drum, river carpsucker, and white bass. Although some of these groups contain members of the same reproductive guilds, the correspondence with the guild is not close enough to support the application of the reproductive guild concept for modeling communities of fishes in this reservoir. However, the close correlations within these groups may indicate that either similar factors influence fishes of the same group, or the different factors which influence fishes of the same group are themselves correlated.

A possible explanation for the lack of correspondence of the three groups distinguished in this study with reproductive guilds could be that short-term population trends are determined by random environmental factors. Fishes that showed similar short-term trends in abundance may be similarly affected by these random environmental factors. This explanation is supported by the predominance of significant positive correlations over significant negative correlations in Table 4 (12 vs. 2). The dramatic changes in density (Fig. 2) may be related to water level changes (Fig. 1) and the concomitant changes in habitat and biota. Diversity also increased as total fish density increased and increases in diversity were correlated with increased densities of white crappie, green sunfish, and channel catfish. Average diversities and the variation in diversity were comparable to those reported by Wilhm (21) for rotenone sampling of Oklahoma reservoirs.

If niche breadth is a function of population density as suggested by Vandermeer (22), fish species will fit more distinctly into reproductive guilds at low densities than at high densities; at the higher densities, reproductive strategies and breeding grounds of fish species may encompass more than one reproductive guild. For specific predictions of short-term changes in abundance, the grouping of reservoir fish species into reproductive guilds may not be advantageous. The reproductive guild concept has, however, been applied with success to long-term population changes (23, 24) and further tests on long-term population trends in other reservoirs would be informative.

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