Population and biomass estimates of fishes in Lake Wingra. No. 93 1976

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Madison, Wisconsin: Wisconsin Department of Natural Resources, 1976

POPULATION and BIOMASS ESTIMATES of FISHES in LAKE WINGRA

Technical Bulletin No. 93
Wisconsin Department of Natural Resources
1976

Cover Photo:
A winter fyke net catch on Lake Wingra.

ABSTRACT

Between spring 1972 and spring 1974, the fish population of Lake Wingra in Dane County was studied as part of an ecosystem analysis of the lake drainage basin being conducted for the International Biological Program. Objectives of the study were to estimate numbers and biomass of the principal fish species in Lake Wingra and to estimate changes in numbers and biomass resulting from death and reproduction.

The average standing crop of fish over 75 mm in length was found to be about 494 kg/ha. Most of this consisted of panfish, with about 75 percent of the biomass being made up by bluegill. Total biomass and species composition varied due to fluctuations in the reproductive success of the different species. From 1972 to 1974, the biomass of bluegill over 75 mm varied from 140 to 500 kg/ha, while numbers of bluegill over two years old varied from 7,000 to 25,000/ha. The bluegill population was dominated by a very large 1971 year class, with very little recruitment in 1972 or 1973. Other species showed similar variations in abundance.

POPULATION AND BIOMASS ESTIMATES OF FISHES IN LAKE WINGRA

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Technical Bulletin No. 93
Wisconsin Department of Natural Resources
Box 7921
Madison, Wisconsin 53707
1976

2100—3i—60151-76

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INTRODUCTION

The fish population of Lake Wingra, Dane County, Wisconsin, was studied as part of the ecosystem analysis of the lake drainage basin conducted by the Eastern Deciduous Forest Biome investigation for the International Biological Program. My major objective was to estimate numbers and biomass of the principal fish species in Lake Wingra and changes in numbers and biomass resulting from death and reproduction. Magnuson and Kitchell (1971) studied the energy flux and movement of nutrient materials within and between fishes. The present work was intended to define and quantify the population within which these processes occur. Fish populations were sampled between spring 1972 and spring 1974. The scope and organization of the Lake Wingra study have been described by Adams et al. (1972). The lake itself and its situation were reviewed by Baumann et al. (1974).

Lake Wingra has an area of 134 ha, a depth seldom greater than 3.5 m, and very heavy growth of submerged vegetation in the littoral zone (Fig. 1). The principal fish species studied were bluegill *(Lepomis macrochirus),* pumpkinseed *(L. gibbosus),* white crappie *(Pomoxis annularis),* black crappie *(P. nigromaculatus),* and yellow bass *(Morone mississippiensis).* Bullheads *(Ictalurus* spp.), yellow perch *(Perca flavescens),* largemouth bass *(Micropterus salmoides),* green sunfish *(Lepomis cyanellus),* northern pike *(Esox lucius.),* carp *(Cyprinus carpio),* and golden shiners *(Notemigonus crysoleucas)* were also present, but small sample sizes precluded reliable estimation of numbers and biomass. Brook silverside *(Labidesthes sicculus)* and minnows *(Notropis* spp.) were present but not estimated. Specimens of bowfin *(Amia calva),* longnose gar *(Lepisosteus osseus),* white sucker *(Catostomus commersoni),* rock bass *(Ambloplites rupestris),* and walleye *(Stizostedion vitreum)* were taken only occasionally.

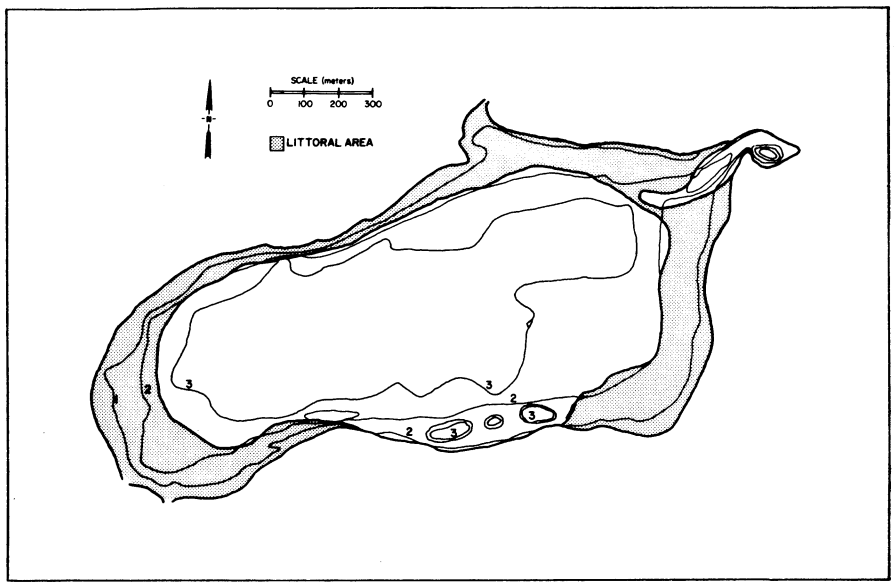
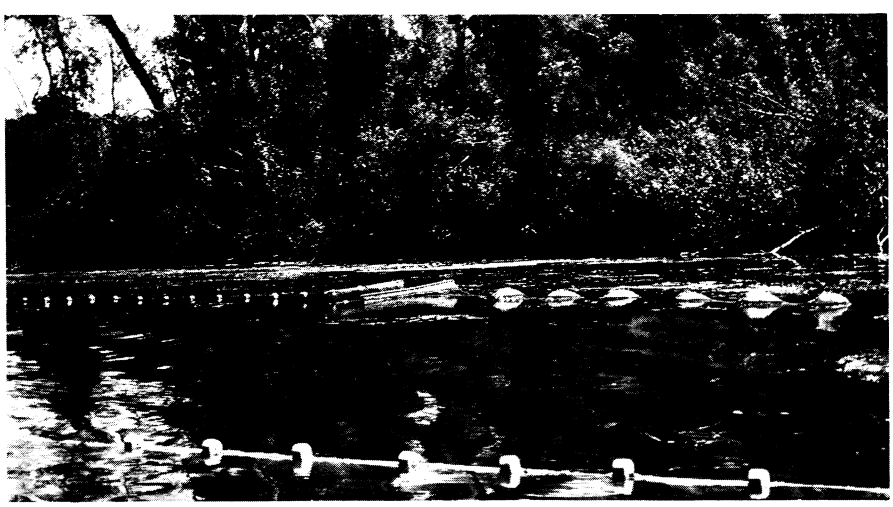


FIGURE 1. Lake Wingra, showing depth contours (meters) and the heavily vegetated (littoral) area.

MATERIALS AND METHODS



A fyke net set inside a quadrat in Lake Wingra.

POPULATION ESTIMATES

Fish were captured with fyke nets, an electroshocker or a trawl. The fyke nets were of 9-mm bar mesh with 0.9-m hoops, usually set near shore with a 15-m lead running to the shore. A few were set further out in pairs with a single lead between, and on occasion, some were set under the ice. This was the only method used for winter samples. Small fyke nets of 5-mm bobbinet with 0.3-m hoops (Beard and Priegel 1975) were set in shallow water near shore to capture young fish.

Electrofishing was done with a pulsed DC electroshocker as described by Baumann and Kitchell (1972).

The trawl was a 4.5-m shrimp try-net equipped with otter-boards, set to fish on the bottom. It covered a strip 2.5 m wide and was towed at a speed of 95 m/min.

Fish, over 75 mm in length captured by these methods, were marked for population estimate by clipping a part of one fin, usually a lobe of the caudal. These marks were not intended to be permanent, but only to last through a recovery period of a few weeks. However, some marks did persist until the next marking period, requiring the use of a different mark for each estimate. After marking, fish were held in floating live-boxes of 5-mm bobbinet, 1 x 2 x ½ m until the end of the day when all dead and apparently dying fish were removed before release. During 3 of the 6 marking periods, samples were held one night in the same live-boxes to estimate delayed marking mortality. Marked fish were not individually measured, but were recorded by species and predetermined size groups. Periodically, samples consisting of the complete catch of a unit, e.g., a trawl haul or fyke net, were measured to determine length distribution of the population

Population estimates were calculated from the recapture of marked fish, by the Bailey modification of the Petersen formula. Estimates were made in the spring of 1972, 1973, and 1974 and in the fall of 1972 and 1973.

Another population estimate was attempted in the summer of 1973 by the use of quadrats in the littoral zone and measured trawl hauls in the limnetic zone. Measured quadrats of about .25 ha in the littoral zone were enclosed by a 5-mm seine and the number of entrapped fish was estimated by a mark-recapture procedure similar to that used for the entire lake. Fyke nets were set within the enclosure, and in some cases the shocker was brought in for the final capture. In the enclosure, captures were made daily and the population was estimated by the Schnabel formula (Ricker 1958).

A series of measured trawl hauls was made at this time to estimate the population of the limnetic zone.

GROWTH DETERMINATION

Scales were taken from samples stratified by fish length for growth studies, and in some cases these fish were individually weighed on a dietetic scale to the nearest gram. Fish scales were pressed on acetate strips and read for age and growth determination with a microprojector at a magnification of 48 x. The relation between fish length and scale measurement was linear, so lengths of fish at the time of annulus formation were calculated from scale measurements using method II described by Ricker (1968).

Length-weight curves were calculated as regressions of the natural log of weight (g) on natural log of total length (mm). Biomass estimates were calculated from the length distribution of each age group at the time of estimate, as the sum of the weights of all fish in each 5-mm size class.

EGG COUNTS

Fish sampled for egg counts were taken into the laboratory and weighed on a Mettler balance. Ovaries were weighed and preserved in modified Gilson's fluid as described by Ricker (1968). They were subsequently air dried and divided into sub-samples by weight. Egg counts of the sub-samples were expanded by direct proportion to estimate total egg production.

RESULTS

POPULATION AND BIOMASS

More than 240,000 fish were captured in Lake Wingra by all methods during the 6 sampling periods between spring 1972 and spring 1974. About 80 percent of these were bluegill. Numbers and species composition are listed in Table 1.

Length distribution of the more common species collected in the spring showed three distinct size classes (Fig. 2). Scale analysis confirmed that these were fish of age I, II, and III and over. During their third summer, age II fish grew into the next size range, and by fall were not distinguishable by size from those of age III and over. Estimates of numbers were made by these size classes. Since fish of less than two summers could not survive the marking process, only two sizes were estimated at each time, those of two summers, considered juvenile, and those of 3 or more, considered adult.

Since ages of fish are conventionally reported by calendar years, a juvenile (2 summers) would be age I in the fall and age II the following spring. An age II fish in the fall would have 3 summers' growth and be included with the adults.

Samples of fish of these sizes held in live-boxes after marking suffered an average 20 percent overnight mortality. This figure was relatively consistent between species and between years (Table 2). Accordingly, the number of marked fish was reduced by 20 percent in calculating population estimates (Table 3).

Estimates made by the Petersen method are seldom extremely accurate, the precision depending on the number of marked individuals recaptured. All numbers in Table 3 have been rounded to 2 significant figures, and 95 percent confidence limits have been appended as an index of

TABLE 1. Total catch from Lake Wingra, 1972-74*

Species and Size	Catch: Spring 1972	Fall 1972	Spring 1973	Summer 1973	Fall 1973	Spring 1974	Total	Percent of Total
Bluegill								79.7
Adult	4,834	13,899	32,374	10,403	46,022	49,797	157,329	
Juvenile	6,238	12,084	15,998	1,119	255	198	35,892	
Pumpkinseed								7.2
Adult	804	1,080	7,203	1,040	988	3,191	14,305	
Juvenile	444	450	1,060	907	102	239	3,202	
Yellow bass								6.7
Adult	1,317	804	3,755	217	722	9,092	15,907	
Juvenile	64	----	133	11	13	5	226	
White crappie								3.4
Adult	1,502	363	3,021	543	283	1,800	7,512	
Juvenile	642	----	44	----	31	57	774	
Black crappie								1.6
Adult	242	185	2,171	48	99	938	3,683	
Juvenile	----	----	11	17	31	117	176	
Yellow perch								0.8
All	144	130	897	99	99	451	1,820	
Carp								0.1
All	43	27	37	17	8	32	164	
Bullhead**								0.4
All	131	104	380	63	67	162	907	
Largemouth bass								0.1
All	143	83	----	81	18	27	352	
Northern pike								----
All	----	9	31	1	3	23	68	
Miscellaneous***								----
All	----	----	----	----	----	----	23	
TOTALS	16,549	29,218	67,115	14,566	48,714	66,129	242,318	100

*Includes all fishes except minnows and silversides.
**Includes all species of bullheads.
***Includes bowfin, white sucker, walleye, rock bass, muskellunge and longnose gar.

TABLE 2. Overnight mortality of marked fish in Lake Wingra, 1973-74.

Date	Species	No. of Samples	No. of Fish	Avg. % Mortality
Spring 1973	Bluegill	24	1,600	20
Fall 1973	Bluegill	7	270	21
	Pumpkinseed	6	78	20
	Yellow Bass	5	23	23
Spring 1974	Bluegill	6	320	16
	Yellow bass	6	150	20
	White crappie	4	37	15
	Black crappie	5	27	10

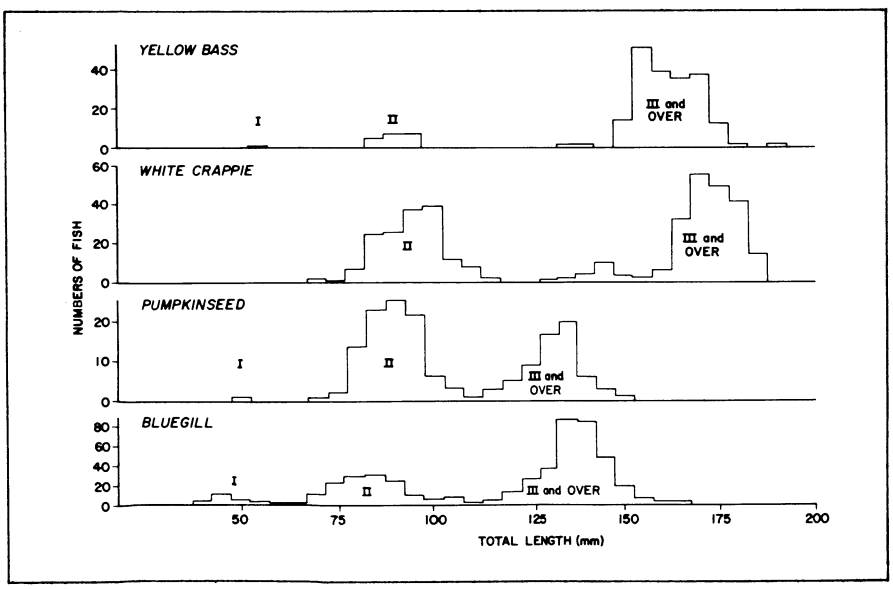


FIGURE 2. Length distribution of the most abundant fishes in Lake Wingra, spring 1972.

the possible variation from the point estimate. All estimates that could be calculated are presented, even though a few are obviously inconsistent with the rest.

Bluegill was the most abundant species, making up about 87 percent of the total number of fish in the most complete estimate (May 1973). Successive estimates (Table 4) demonstrate a change in age structure which may be part of a cycle. A moderate population of about a million adult and 2-year-old fish in the spring of 1972 was suddenly expanded by a huge 1971 year class which could not be measured at that time. The first estimate of this year class, in October 1972, was 2.5 million, so it is safe to assume that there were four to five million in the spring. Since then, this year class has made up the bulk of the bluegill population, reaching adult size in the fall of 1973. The 1972 and 1973 year classes were insignificant and do not appear in any population estimate.

Bluegill also made up most of the weight of fish in Lake Wingra, reaching a maximum of about 500 kg/ha in fall 1972 and spring 1973. They made up 75 percent of the estimated total biomass of the five principal species in May 1973 (Table 5).

Numerically, the bluegill population must have reached a maximum in the summer of 1971 with the hatching of the new year class, declining steadily thereafter. Biomass, on the other hand, would have been near a minimum in May 1972. The four to five million yearling assumed to have been present in the spring of 1972 would add only about 70 kg/hectare, for a total estimate of about 200 kg/hectare of bluegill. This increased over the summer to about 500 kg/hectare, individual growth outweighing numerical loss. After May 1973, losses by mortality exceeded gain by growth, and total biomass declined (Fig. 3). Since there was little recruitment in 1972 or 1973, one may speculate that the bluegill biomass would continue to decline until the occurrence of another large year class.

Other species were more diffcult to estimate, due to low recapture, especially in the fall. Such estimates as could be made of the other common species—pumpkinseed, yellow bass, black crappie and white crappie—were mostly less than 10 percent of the number of bluegill

TABLE 3. Estimated populations (in thousands) of the principal species of fish in Lake Wingra, 1972-74.

Date	Species	Size	Estimate	95% Confidence Limits
May 1972	Bluegill	Juvenile*	650	220 — 1,100
		Adult	280	100 — 450
	Pumpkinseed	Juvenile	22**	0.3 — 44
		Adult	16	4 — 27
	White crappie	Adult	31	6 — 56
Oct. 1972	Bluegill	Juvenile	2,500	940 — 4,200
		Adult	930	600 — 1,300
	Pumpkinseed	Adult	30**	0.5 — 60
	Yellow bass	Adult	20**	2 — 38
May 1973	Bluegill	Juvenile	2,200	1,200 — 3,200
		Adult	970	830 — 1,100
	Pumpkinseed	Juvenile	47**	0.4 — 93
		Adult	32	28 — 37
	Yellow bass	Adult	230	97 — 360
	White crappie	Adult	120	49 — 180
	Black crappie	Adult	36	19 — 53
	Yellow perch	All	2.5	1.4 — 3.7
	Golden shiner	Adult	7.3	2.8 — 12
	Bullhead (All sp.)	Adult	4.1	1.3 — 6.8
Oct. 1973	Bluegill	Adult	2,400	1,700 — 3,100
	Pumpkinseed	Adult	21	5 — 37
May 1974	Bluegill	Adult	1,600	1,400 — 1,800
	Pumpkinseed	Adult	45	30 — 60
	White crappie	Adult	43	20 — 64
	Yellow bass	Adult	730	400 — 1,000
	Yellow perch	All	5.1	1.7 — 8.5

*Juvenile fish are those less than three summers of age.
**Estimate based on 5 or less recaptures.

TABLE 4. Estimates (in thousands) of bluegill and pumpkinseed populations by year class in Lake Wingra, 1972-74.

Species and Year Class	Estimated Number of Fish (x 1,000)				
	May 1972	Oct. 1972	May 1973	Oct. 1973	May 1974
Bluegill					
1969 + older	280				
1970	650				
1970 + older	930	930	970		
1971		2,500	2,200		
1971 + older		3,400	3,200	2,400	1,600
Pumpkinseed					
1969 + older	16				
1970	22				
1970 + older	38	30	32		
1971		----	47		
1971 + older			79	21	45

TABLE 5. Estimated biomass (kg/ha) of principal fish species in Lake Wingra, 1972-74.

Species	Size	Biomass in kg/ha				
		May 1972	Oct. 1972	May 1973*	Oct. 1973	May 1974
Bluegill	Juvenile	51	192	201		
	Adult	87	328	302	365	396
Pumpkinseed	Juvenile	3	----	4		
	Adult	6	10	10	4	11
White crappie	Adult	12	----	56	----	13
Black crappie	Adult			20		
Yellow bass	Adult		7	75		184

*Total biomass for all 5 species was 668 kg/ha.

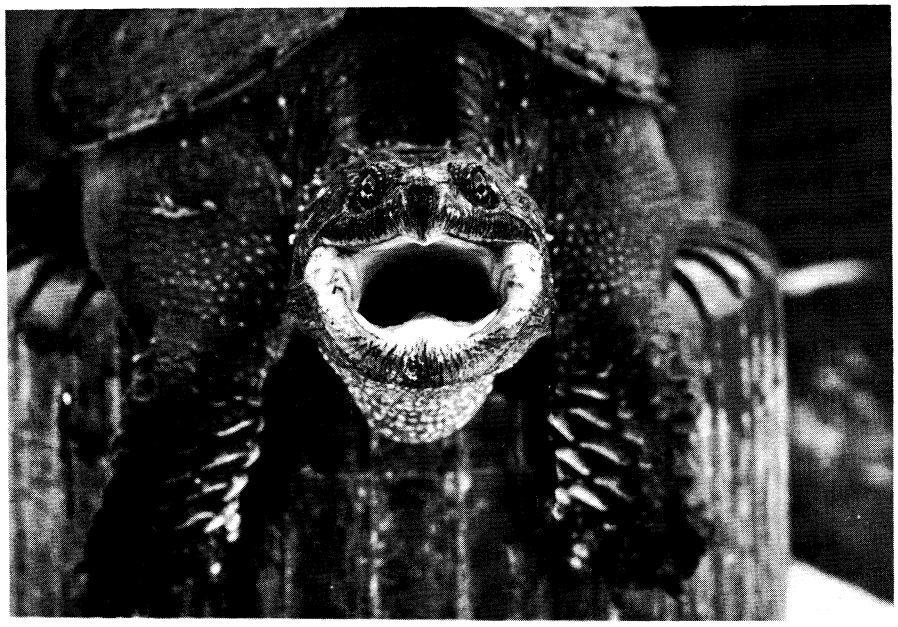
(Table 3). One exception was the estimate of 730,000 yellow bass in May 1974, almost half the number of bluegill. This could be an overestimate; however, it coincides with a substantial increase in the percentage of yellow bass in the entire catch (Table 1).

Carp, northern pike, and largemouth bass were present in the lake and were sometimes taken by our gear, but never in sufficient numbers to permit an estimate. These species together made up 0.25 percent of all fish taken in the study (Table 1).

Fall efforts in 1972 and 1973 produced mainly estimates of bluegill and pumpkinseed. Spring estimates were more successful, but here also certain species could not be estimated in some years. Spring estimates are lacking for yellow bass in 1972 and black crappie in 1972 and 1974. The latter are relatively unimportant species in Lake Wingra, making up only 1 to 3 percent of the total spring catch each year, and 3 percent of the biomass in 1973. Fluctuations of this species would have relatively little effect on the total biomass.

Yellow bass contributed 11 and 30 percent, respectively, to the estimated total spring biomass in 1973 and 1974. In 1972, their percentage of the total catch (Table 1) was between that of the other two years. Assuming that biomass was the same, we estimate the 1972 population of yellow bass at about 20 percent of the total or about 35-40 kg/ha. Further allowance of about 2 percent for the two missing estimates of black crappie biomass yields estimates for the spring of 3 years of 200,668, and 615 kg/ha, respectively, of fish over 75 mm in length, with an average of about 494 kg/ha. The great difference between 1972 and the other two years is due to growth of young bluegills. As noted above, the tremendous number of bluegill yearling present in 1971 could not have added more than 70 kg/ha to that year's estimate.

Fluctuations in the abundance of any species are usual in inland lakes as the result of variable reproductive success. Comparisons of single estimates of individual lakes may have little significance. It is more appropriate to compare the average estimate for Lake Wingra (494 kg/ha) with averages obtained by other investigations.



Occupational hazard.

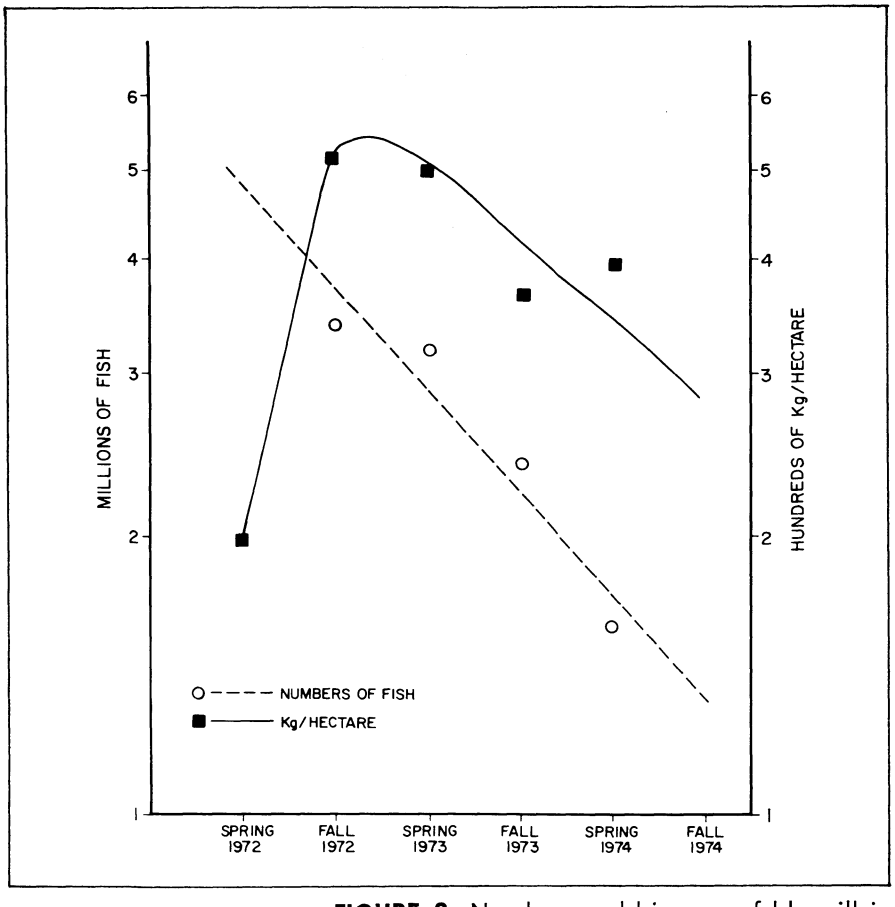


FIGURE 3. Numbers and biomass of bluegill in Lake Wingra, spring 1972-fall 1974.

Threinen and Helm (1952) considered a standing crop of about 325 lb/acre (350 kg/ha), exclusive of rough fish, to be average for southern Wisconsin. Moyle et al. (1950) estimated the average population of 68 game fish lakes in southern Minnesota at about 110 lb/acre (120 kg/ha), with a maximum of 444 lb/acre (490 kg/ha). Schneider (1973), in a study of 64 Michigan lakes, found that the highest standing crops occurred in those dominated by slow-growing bluegill, as is Lake Wingra. His average estimate for 12 such lakes in the lower peninsula was 182 lb/acre (200 kg/ha) with a maximum of 305 lb/acre (335 kg/ha.)

The estimate of 494 kg/ha for Lake Wingra is thus well above average for this region, but is not unreasonable in view of the highly eutrophic nature of the lake. Brynildson (1955) recovered 400 lbs/acre (440 kg/ha), mostly bluegill, from a small lake in Dane County and felt that the recovery was incomplete.

In the alternative estimate by quadrat and trawl in the summer of 1973, the density of bluegill and pumpkinseed in the littoral zone was estimated at 18,000 and 2,000 fish per hectare, respectively. Juvenile (from the 1971 year class) and older fish were counted together, since by the end of the summer they were indistinguishable by size. If the littoral zone is regarded as the 50-ha vegetated area defined by Adams et al. (1972), the littoral population of bluegill and pumpkinseed is estimated at 900,000 and 100,000 respectively.

Measured trawl hauls made in the summer of 1973 yielded 1,000 bluegill and 56 pumpkinseed per hectare covered, but the efficiency of the trawl is not known. The previous spring, when marked bluegill were present at an overall density of 122 per hectare, extensive trawling yielded 12.6 per hectare. If distribution was uniform throughout the lake, at this time the efficiency of the trawl was 10 percent, and the density of bluegill in the summer can be estimated at 10,000 per hectare or 840,000 in the limnetic zone. The total estimate by this method is thus 1,700,000 bluegill for the entire lake, about 70 percent of the fall estimate by the Petersen method. The latter must be considered more probable, since it involves fewer variables.

The total estimate for pumpkinseed was 124,000, 57 percent above the spring estimate. The alternative method does no more than confirm the order of magnitude of the Petersen estimates.

GROWTH

The growth rate of bluegill in Lake Wingra, for the first three years of life, was comparable to the statewide averages for Minnestoa (Minn. Conserv. Dep. 1952) and Michigan (Beckman 1949) and slower than the average for southern Wisconsin (Druckenmiller 1972) (Fig. 4). After the third summer, growth was quite slow, and after age IV many ages could not be assessed with confidence because of slow growth and consequent crowding of the annuli.

The ratio of weight to length of 1,134 bluegill weighed in 1972 and 1973, ranging from 57 to 170 mm in total length, was described by the formula:

$$\text{Log } W = 3.062 \text{ Log } L - 4.8904$$

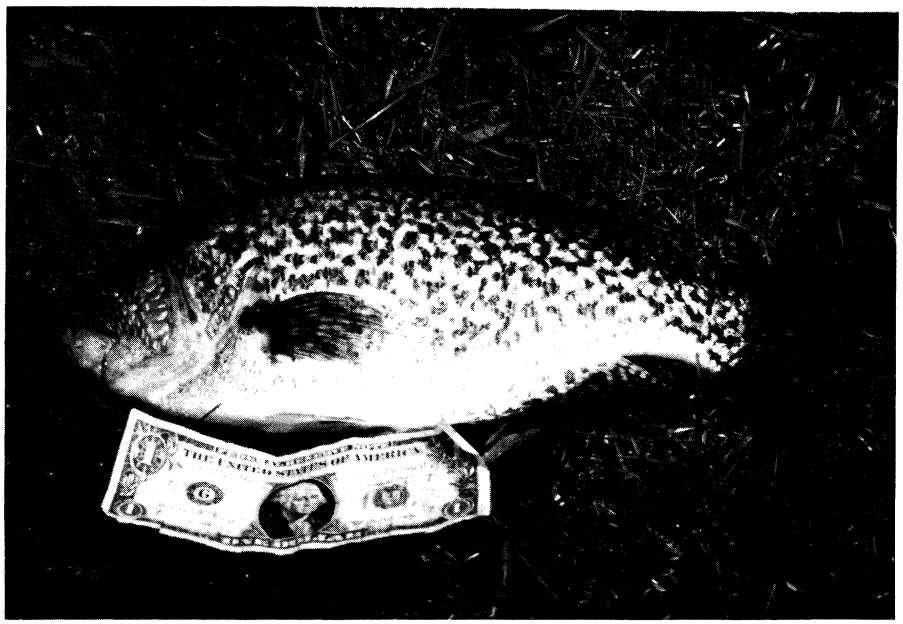
Where Log W is the weight in grams and Log L is the total length in millimeters. There was no significant difference between the two years. This represents a condition slightly lower than the average for Michigan (Beckman 1948) and notably lower than that for southern Wisconsin (Mackenthun 1948).

Pumpkinseed, white crappie, and yellow bass showed similar growth characteristics, exhibiting typical growth for the first three years, slowing abruptly after the third (Table 6). Their condition was also generally lower than that cited for various waters of the north central states by Carlander (1950).

Black crappie were a notable exception, growing at about the usual rate for this region for four years. After four years they grew faster than those reported from other waters of this region, though their condition was somewhat lower than average.

FECUNDITY

Bluegill, pumpkinseed, yellow bass, white crappie, and black crappie began spawning in May and continued



The biggest crappie in Lake Wingra.

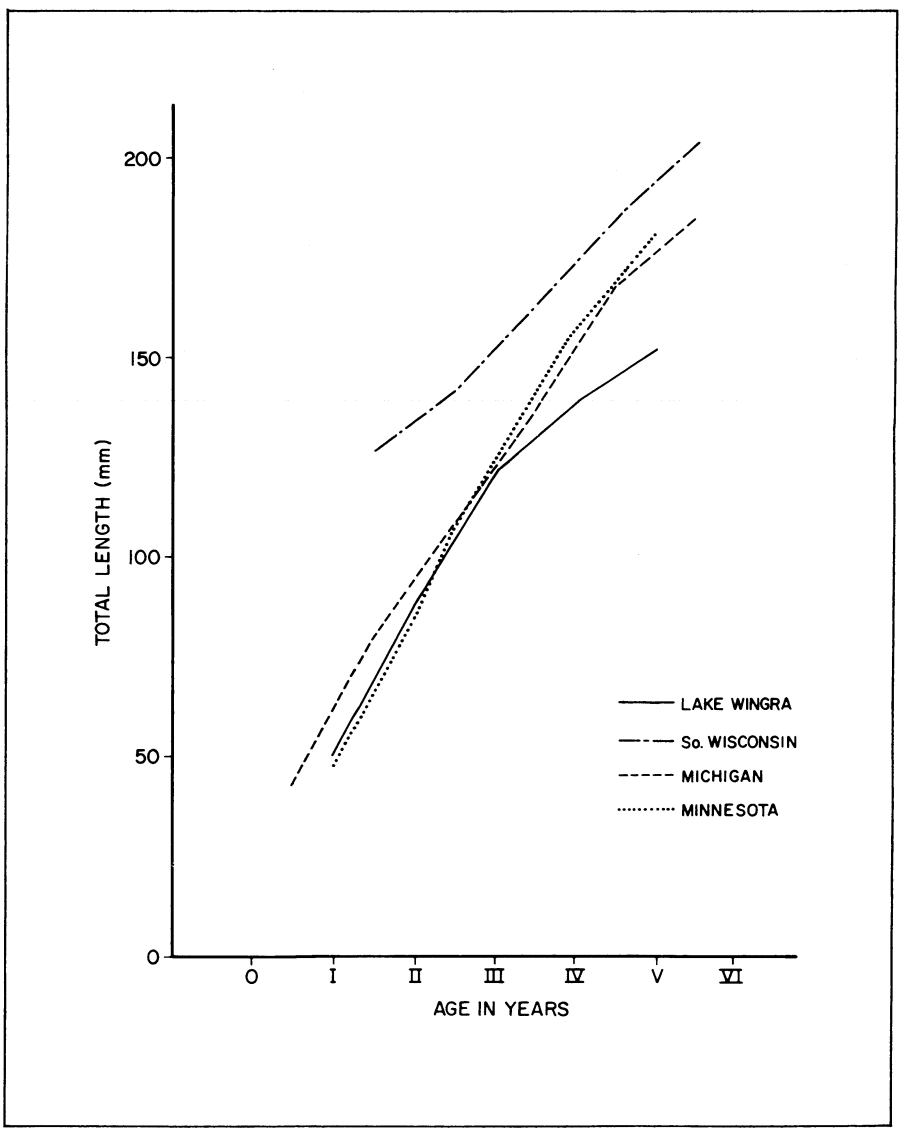


FIGURE 4. Growth rate of bluegill in Lake Wingra compared with that in other waters.

well into the summer. A few spawning bluegill were found in early August. Estimated egg counts on two different dates are shown in Table 7. The consistently lower count on the later date indicates that individual fish continued to spawn over an extended period. Thus the earlier figure is a better estimate of the total egg production. Even this figure is probably low, since most of these fish were completely ripe at capture, and may have already deposited some of their eggs. If one half of the adult bluegill in 1972 were females, the total estimated egg production in that year is 700,000,000.

TABLE 6. Growth of Lake Wingra fishes, 1972-73.

Species	Number (All Ages)	Average Calculated Total Length in mm at Annulus Formation						
		I	II	III	IV	V	VI	VII
Bluegill	1,134	50	88	122	139	152	-----	-----
Pumpkinseed	438	48	87	120	134	137	-----	-----
White crappie	382	92	140	165	175	179	-----	-----
Black crappie	259	73	133	170	202	267	296	352
Yellow bass	282	97	136	153	159	-----	-----	-----
Largemouth bass	40	96	166	208	251	293	-----	-----
Yellow perch	51	109	145	170	192	-----	-----	-----

TABLE 7. Egg production of Lake Wingra fishes, 1972.

Species	Date	Number of fish	Total Length (mm)		Number of eggs per fish		
			Mean	Range	Mean	Minimum	Maximum
Bluegill	May 25	16	134	122-144	4,800	2,900	8,000
	June 29	5	140	132-144	2,900	1,900	4,600
Pumpkinseed	May 31	3	129	112-141	5,800	4,100	7,000
	June 29	6	130	119-135	4,500	2,400	6,700
White crappie	May 25	35	171	159-187	12,000	6,200	24,000
	June 29	10	170	163-176	3,300	300	5,100
Black crappie	May 25	6	172	163-180	11,400	7,900	19,100
	June 29	1	157	----	4,700	----	----
Yellow bass	May 25	7	156	148-168	19,300	14,300	39,400
	June 29	4	153	152-154	10,200	6,800	13,900

SUMMARY

Lake Wingra is a very productive lake, with an average standing crop of about 494 kg/ha of fish over 75 mm in length. Most of this consists of panfishes, and about 75 percent of the biomass is made up by bluegill. Total biomass and species composition vary due to fluctuations in reproductive success of the various species. During the period of study, the biomass of bluegill over 75 mm varied from 140 to 500 kg/ha while numbers of bluegill over two years old varied from 7,000 to 25,000 per hectare. The bluegill population was dominated by a very large 1971 year class with very little recruitment in 1972 or 1973. Other species showed similar variations in abundance.

Individuals of all the more common species except black crappie grew at a typical rate for the first three years and very slowly thereafter. The ratio of weight to length of all specias was somewhat lower than average for waters of this area.

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ACKNOWLEDGMENTS

Support for the studies reported here was supplied by the Eastern Deciduous Forest Biome Project, U.S. IBP, funded by the National Science Foundation under Interagency Agreement AG-199, BMS69-01147 A09 with the Energy Research and Development Administration—Oak Ridge National Laboratory. Contribution No. 258.

Thanks are due to Dr. John Magnuson and Dr. James Kitchell of the University of Wisconsin-Madison Laboratory of Limnology and Mr. Lyle Christenson of the DNR Bureau of Research for assisting in planning and conducting the research and review of the manuscript. James Holzer, Thomas Kuczynski, Theodore Amman, Thomas Waters, and Douglas Stamm assisted with the field and laboratory work and Peter Weiler with the data processing. Egg counts were made by Theodore Amman.

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